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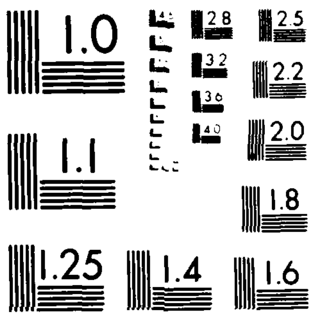

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RELATIONSHIP BETWEEN MANUFACTURING YIELDS AND FIELD FAILURE RATES OF ELECTRONIC EQUIPMENT

Eugene E. Jones
John M. Pearson

UNIVERSITY OF DAYTON
School of Engineering
Dayton, Ohio 45469

1 February 1983

Final Report for Phase I (30 Sep 1982 - 30 Nov 1982)

Distribution of this report is unlimited.

Prepared for:
AIR FORCE BUSINESS RESEARCH MANAGEMENT CENTER (AFBRMC)
Wright-Patterson Air Force Base, Ohio 45433

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. A128498
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Relationship Between Manufacturing Yields and Field Failure Rates of Electronic Equipment	5. TYPE OF REPORT & PERIOD COVERED Phase I - Final Report
	6. PERFORMING ORG. REPORT NUMBER UDR-TR-82-154
7. AUTHOR(s) Eugene E. Jones; John M. Pearson	8. CONTRACT OR GRANT NUMBER(s) F-33615-82-[redacted] 5097
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Dayton, School of Engineering (EMS), Dayton, OH 45469	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Business Research Management Center (AFBRMC), WPAFB, OH, 45433	12. REPORT DATE 1 February 1983
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

AFBRMC Project Manager for this research is Lt. Joseph Peck.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Reliability; Unit Failure Rate; Operational Failure Rate; Mean Time Between Failure (MTBF); Reliability Test Failure Rate; Unit Yield; Printed Circuit Boards (PCBs); Rework Rate

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research seeks to determine the degree of correlation between manufacturing yields and field failure rates (operational reliability) of electronic equipment. A designated set of line replaceable units (LRUs) within the avionic subsystems of the A-10A; F-4C/D/E; F-15C and F-16A/B is selected as pilot items in this study, with prime emphasis on the reliability of the printed circuit boards (PCBs) within these units. In Phase I, the data base needed to

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) measure this correlation is established. In Phase II, correlations among these data will be sought. Based on the significance of these correlations, recommendations will be formulated in Phase III to use these research results in Production Readiness Reviews (PRRs) and Risk Assessments for future acquitions of electronic equipment.

EXECUTIVE SUMMARY

The Air Force has experienced low operational reliability on numerous aircraft electronic units. Poor quality control by the unit manufacturers and/or the acceptance of low process yields are stated as the major contributors to this problem.

If this premise is true, the existence of a significant relationship between manufacturers' unit yields and the subsequent operational (field) failure rates for these units would provide a basis for revising current DoD policies and practices on acquisition of electronic units and the subsequent warranties of these units. This relationship could be used by the Air Force Systems Command (AFSC) in Production Readiness Reviews (PRRs) and Risk Assessments to estimate the potential effects of the unit on the future operational readiness of tactical aircraft systems.

The prime objective of this research is to determine the degree of correlation between manufacturing yields and the operational reliability of selected electronic units. In Phase I, the data base for a selected group of line replaceable units is established. In Phase II, the degree of correlation among these data will be assessed. Based on the degree of this correlation, guidelines to use this information in the Air Force Production Readiness Reviews (PRRs) will be developed in Phase III.

The completed events of Phase I demonstrate the limited availability of data to support the intended analyses of Phase II. There are ample data on operational reliability of the selected units over the time period of interest, but all units are not equally covered. Also, there is an imbalance of data on yield and rework in comparison to operational reliability data.

Section 1 of this report describes the problem and research objectives. A discussion of the objectives to concentrate on printed circuit boards within the pilot units is provided.

Section 2 provides definitions of key variables, gives the data gathering plan, the research data base, data sources and the key problems encountered in the data collection phase.

Section 3 gives a description of the data collected in the context of how these data will be used in the analyses of Phase II. Prime emphasis is devoted to a discussion of measurable parameters, such as failure rates and "mean time between failure" (MTBF) as the dominant variables reflecting operational reliability of a given unit. There are exceedingly wide variations in the computation and interpretation of these variables in both government and industry.

The opinions stated herein are those of the researchers and are not necessarily intended to reflect Air Force policies concerning the analysis of test and operational reliability data.

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SECTION 1-INTRODUCTION

1.1 PROBLEM STATEMENT

The Air Force has experienced low operational reliability on numerous aircraft electronic units. One premise is that a major contributor to this problem is poor quality control by the unit manufacturers and/or the acceptance of low process yields. The effect of this situation is the acceptance of unit process yields that decrease the probability that the average unit . will perform as expected.

If this premise is true, the existence of a significant relationship between manufacturers' unit yields and operational (field) failure rates would provide a basis for revising current DoD policies and practices on acquisition of electronic units and the subsequent warranties of these units. This relationship could be used by the Air Force Systems Command (AFSC) in Production Readiness Reviews (PRRs) and Risk Assessments to estimate the potential effects of the unit on future operational readiness capability of aircraft systems.

1.2 RESEARCH OBJECTIVES

The objectives of this research as stated in the Statement of Work are:

a. Phase I: Determine the availability of information and data on the manufacturing yields and operational reliability of a specific set of electronic units listed in Table 1;

b. Phase II: If the data are available, determine if there is a correlation between the manufacturing yield and operational reliability of these specific electronic units;

c. Phase III: If there is a significant correlation, determine what guidelines can be used to identify when process yields are "in control" and what manufacturing yield problems are likely to persist during the production and operation phases of these specific electronic units.

As an end product, this research will identify factors and affecting low operational reliability of selected electronic units and develop statistical indicators for use by AFSC during Production Readiness Reviews and Risk Assessments.

1.3 PHASE I REQUIREMENTS (WORK TASKS)

a. Determine the availability of information and data on the manufacturing yields of electronic Line Replaceable Units (LRUs) listed in Table 1, and their respective electronic Shop Replaceable Units (SRUs) for the period 1 January 1980 through 31 December 1981 (24 months).

b. Determine the availability of information and data on the operational reliability of the electronic LRUs in Table 1 and their respective electronic SRUs for the period 1 April 1980 through 31 March 1982 (24 months).

c. If the data mentioned in (a) and (b) are available, collect information for the periods specified and submit these data along with the draft Phase I final report.

This research executes Contract F-33615-82-R-5097 at the University of Dayton (UD) School of Engineering. This contract is sponsored by the Air Force Business Research Management Center (AFBRMC) at Wright Patterson AFB, Ohio, and the Air Force Project Manager for this effort is Lt. Joseph Peck.

1.4 CONCLUSIONS ON PHASE I DATA AVAILABILITY

1.4.1 Availability of Operational Reliability Data

On the basis of data and information collected in Phase I, sufficient time-related data (24 or more months) are available on the operational reliability of each one of the selected LRUs in Table 1 to support Phase II execution. The primary variables of interest are mean time between failure (MTBF), mean time between maintenance (MTBM), failures per unit period and unscheduled manhours expended for the related failures. Changes in the AFLC definition and computation of MTBF and MTBM have occurred within the time period of interest to this research and the effect of these changes are noted herein.

The singular source of extensive data on unit reliability is the Air Force Logistics Command (AFLC) D0-56 report maintained by AFLC/LOEP. Copies of the required operational reliability data for each LRU are available on ultrafiche at the University of Dayton.

TABLE 1

CONTROLLED COMPONENT DATA FOR RESEARCH ANALYSIS

ALC	Aircraft	Work Unit Code (WUC)	Description
Ogden	F-4C/D/E	513A0	Aural Tone Generator
	"	513H0	CADC 42400 227 1
	"	513U0	CADC
Sacramento	F-16A/B	51FA0	CADC
	"	65AA0	Rec/Transmitter
	"	74DA0	Inert Nav Univ
	F-15/C	51EA0	CADC
	"	63BA0	Control Panel
	"	65AA0	Rec/Transmitter
	"	65BH0	Processor, Radar Tgt
	"	74JC0	Processor, Sig Data
	"	74KC0	Processor, Sig Data
	"	76GF0	Rec/Transm OR 132
Warner-Robin	A-10A	52AA0	Computer
	"	52BB0	Computer, Beta Dot
	"	65AA0	Rec/Tr 1063AAPX101
	"	74CB0	Adapter Control
	"	76AR0	Comp, Sail Amp Det

1.4.2 Availability of LRU/SRU Rework Data

Data related to unscheduled manhours expended for base-level maintenance of all of the selected LRUs are included in the D0-56 B-05, B-06, B-22 , B-23, C-02 and C-03 reports, which are available on ultrafiche at the University of Dayton. However, within the AFLC D0-56 system, manhour data for the repair of SRUs at the AFLC depots cannot be directly linked to a specific Work Unit Code (WUC) or aircraft system. This problem can be solved as described in paragraph 2.5.3.

1.4.3 Availability of LRU/SRU Test/Yield Information

There are accessible, time sequenced data and information that can be used to compute manufacturing yields for eight (8) of the 18 selected LRUs/WUCs in Table 1 (mainly for the F-15 and F16). These data are derived from manufacturer's Reliability Qualification Testing (RQT) and Production Readiness Testing (PRT).

The required data for the F4 and A10 are spotty over the relevant time period due mainly to the maturity of the selected LRUs/WUCs. But the available data can be further augmented by extending the data collection to other electronic units for which sample test information and data have been routinely maintained (See paragraph 2.5.1).

Extending the test/yield data base to the printed circuit boards (PCBs) used to repair the selected LRUs in Table 1 represents a extended problem for several reasons. First, data from manufacturers' functional testing do not currently account for test failure statistics at the SRU/PCB level in a way that is upwards relatable to a specific LRU/WUC. Second, it is typical for two or more levels of manufacturer subcontracting to be involved in the design and supply of PCBs for major subsystems, such as the F-15 and F-16 avionics. Third, it is not unusual for equipment testing to greatly lag production and delivery.

Such factors may negate the use of PCB failure data from being linked "directly" to the operational reliability a specific LRU. Thus a working premise of this research is to first seek correlations between LRU test data and operational reliability, and then seek correlations between PCB yield and rework activity and unit test reliability. The objective of this research is accordingly partitioned into two interrelated parts.

1.5 PHASE I SUMMARY

There are sufficient data to support extension of this research to Phase II. The key limitation of these data is an imbalance of time-related data on operational reliability and rework actions in comparison to the amount of corresponding data about production and manufacturing yield of the selected units and/or the shop replaceable units used to repair these units (namely, PCBs).

This limitation can be resolved by expanding the population of selected LRUs. This expansion would also strengthen the statistical foundation of this study results, which are intended to apply to the general population of avionic units of tactical aircraft systems.

SECTION 2 - PHASE I DATA COLLECTION

2.1 RESEARCH DATA BASE STRUCTURE

The objective of this research is to determine if a significant relationship exists among three variables, unit field reliability, unit yields and rework activity related to printed circuit boards (PCBs) used to maintain selected avionic systems. In this section, parameter definitions and the data collection process needed to measure each of these variables are described.

The intent of this section is to assure that the data collection process is expressly directed towards the measurement of variables that have meaning in the AFSC/AFLC environment, and that these variables can be measured with the data available.

2.1.1 Definition of Unit Failure

The primary logistic event of interest to this research is a "unit failure". Typically, "failure" means that the item is incapable of performing its intended function. Varying degrees of this incapability are classified as "malfunctions". For this research, the accepted definition and usage of the term "unit failure" conforms with that used in the AFLC Maintenance Data Collection System, which is a function of the system of maintenance and action codes in Appendix IV.

2.1.2 Measures of Unit Field Reliability

The computed "mean time between failures" (MTBF) in the AFLC D0-56 (Product Performance System) B-05 report is the key variable that measures unit field reliability, although the credibility in this parameter as a sufficient measure of operational reliability is universally low. (The reason for this dilemma is explained in more detail in Section 3).

Another parameter is "mean time between maintenance" (MTBM), and due to the recent change in terminology within the D0-56 system, the computed values of MTBM are strongly correlated to the computed or estimated MTBF, as shown in Section 3.2.1.

2.1.3 Measures of Unit Yield

"First pass" unit yield is defined as the number of units passing functional testing on the first trial. In general, "functional testing" consists of operating the unit for a specified period of time equal to a percent (usually 10%) of its design MTBF. The data required for such computations are cumulative inventory and the number of units whose operating times to failure were less than the specified percentage.

The "desired" data to measure the yield variable are test data, where unit functional test failures are uniquely related to inventory changes for each production "lot". The data are derived from manufacturers Reliability Qualification and Acceptance Tests (RQAT) and/or Production Reliability Tests (PRT). Such test data exist and are available for some of the selected units, but are limited for other units for the time period of interest.

In terms of "available" data in the D0-56 B-05 report, the inventory of the higher assembly for each of the pilots units is available by month. Within D0-56, the closest category of unit data that relate to "premature" unit failures pertain to "inherent malfunctions". Therefore, the number of "inherent malfunctions per unit change in unit inventory" may be a computable measure of unit yield from the "operational" point of view.

2.1.4 Measures of Unit Rework

For printed circuit boards, "rework rate" is typically defined as the ratio of the number of first-time successfully tested boards to the total number of units tested. This definition applies mainly to a PCB manufacturing environment, but tends to be impractical as a useful measure of repair at the AFLC Air Logistics Centers (ALCs), since PCBs are treated as other reparable units to the degree that designs permit. "Manhours expended per PCB failure" appears to be a more functional measure of rework at the operational level.

Relevant data to determine the rework volume, or repair rate, of shop replaceable units (SRUs) are reflected in "unscheduled" manhours at base level, and "manhours" at depot level in the D0-56 B-06 and C-03 reports respectively. But the key problem as related to this research is establishing a unique linkage of manhour expenditure data for SRU repair at the depot to a specific work unit or LRU at base/field level (This issue is discussed further in Section 3.5.3).

2.2 PHASE I DATA GATHERING PLAN

The Phase I data collection plan was designed to use two separate sources to obtain the operational and production test and/or yield data for the set of pilot electronic units shown in Table 1. The primary source of operational reliability and rework (manhour) data is the AFLC DO-56 reports (B and C) generated from the AFM 66-1 data of the Air Force Maintenance Data Collection System (see samples of these reports in Appendix IV).

The primary sources of production reliability data are the manufacturers' continuing test data for selected units that are involved in Reliability Qualification Testings (RQT) and/or Production Reliability Testing (PRT). Other names for similar test are "All Equipment Production Reliability Test" (AEPRT) and Environmental Stress Screening (ESS). These test data are mandated by various MIL STDs and are routinely supplied to the government by unit manufacturers.

2.3 PRIME DATA SOURCES USED IN PHASE I

2.3.1 Manufacturers' Unit Test/Yield Data

Contacts with seven contractors/vendors of selected pilot units were established to obtain the required test and yield data for this research.

Teledyne produces the transponder receiver (APX 101, Work Unit 65AA0) used on the A-10, F-15 and F-16. A sample of the data provided by Teledyne is shown in Appendix II. Similar contacts were made with Honeywell Aerospace Defense Group (ADG) in Tampa, FL which makes a wide range of PCBs for a variety of military systems. Another Honeywell data source, is the Corporate Reliability Center for Electronic Components in Minneapolis.

Contact was made with Systems Research Laboratories (SRL) in Beavercreek, Ohio for data involving PCB yields during manufacturing. Similar contacts have been established with Opti-

Gauge Quality Circuits in Trotwood, Ohio and Texas Instruments in Dallas, Texas.

Mr. Jerry Edwards (ASD/TAEE) provided contractor-developed data on the reliability testing of five of the units used on the A10 and F15 (see Exhibits 1, 2 and 3). Mr. Edwards is a Reliability Engineer for the Tactical Systems Division (TA) and maintains a comprehensive collection of test and yield data related to this research. Captain Robert Russell, ASD/YPEC maintains the RQT and PRT test data bases for the F-16.

2.3.2 Operational Reliability and Rework Data

Computer data tapes were formally requested from AFLC (through AFBRMC) that generate the DO-56 reports for the time duration and applicable aircraft for the pilot set of electrical units specified in Table 1. Repair manhours for repair of each of the selected units are available on the DO-56 "B" and "C" reports, but as explained further in 2.5.3 below, these manhours cannot be uniquely retraced to the LRU from which the relevant PCB was removed.

Although these tapes were not received during Phase I, all of the relevant unit data on ultra-fiche were obtained from Mr. Neuman (AFLC/LOEP). Over 300 sets of ultrafiche (about 2800 pages of data) have been obtained for the DO-56 outputs for each of the pilot items, dating back to 1977 for the F-4 and A10 aircraft. The required data for all of the selected units were manually extracted using over 550 pages of these reports. Also, a monthly sequence of printouts, entitled "Selected Work Unit Maintenance Summaries" have been made available by AFLC on a continuing basis for each of the pilot WUCs in Table 1.

At WPAFB, the field reliability and rework data for PCBs at the PRAM PO were examined to give the researchers insight into the nature of actual PCB rework at the AFLC depots or manufacturers' facilities. Also, from DESC, an extensive set of failed printed circuit assemblies have been obtained that demonstrate the most typical failure modes of these assemblies (reference: Mr. Al Crockett, 513-296-6234).

At Warner Robins Air Logistics Center (WRALC), which is the depot for the maintenance of the APX 101 for the A10, the prime contact is a Maintenance Technician, Mr. H. C. Puckett, who is directly responsible for the maintenance actions on the circuit card assemblies related to the APX 101.

2.3.3 Other Sources of Data

An especially pertinent study, entitled "Failure Analysis of the 5900 Federal Stock Class" (AFIT SL Masters Thesis, 76-21) provides a classification of LRU failures as reported in a sample of over 320 "Quality Deficiency Reports" in FSC 5900 (Hardware-Electrical and Electronic) at the Defense Electronic Supply Center (DESC), Dayton, Ohio. This study concludes that over 53% of these failures could be attributed to "manufacturer or latent and/or random causes".

A study by George Kerns of Hughes Aircraft, entitled "Non-operational Failure Rates for Avionic Equipment" attributes over 20% of failures in avionic equipment to "non-operational" causes, which are causes not associated with the length of operating time of the equipment. The magnitude of these non-operating failures, Kern states, causes a bias in the computation of operational MTBF on the low side, so that the ratio of predicted to operational MTBF may range up to 20:1.

An overview of the "Production Verification Testing (PVT)" concept is presented in a brief paper by Capt. Keith Matthews. According to Matthews, PVT is intended to improved the probability of delivered systems meeting their design reliability. He also states that "...the relationship between testing and field reliability was not quantifiable". Mr. Paul Logus (ASD/AXP) was contacted on the application of documented results of PVT to this research.

A paper by Dillard and Frank of the DoD product Engineering Services Office (DPESO), entitled, "An Exploration of the Relationship Between Manufacturing Rework Events and Field Failure Rate" poses the hypothesis "...is there a relationship among product yield, unit complexity and operational reliability?" However, no formidable results supporting this hypothesis are provided in this paper. The key emphasis of this study is the repair of PCBs of varying degrees of complexity (which is measured in terms of board layers and density of discrete units thereon). The authors state that the Air Force 66-1 data system (that generates D0-56) is inadequate to support the data needed for the computation of MTBF of such units as PCBs.

MIL STDs 217, 781C and 756B were reviewed to assess test data requirements for electronic units and the requirements for manufacturers to continually supply unit test data to the government during the production of the unit. MIL-P-55110 provides a listing of certified manufacturers for printed circuits. MIL-P-13949 gives specifications for a wide variety of PCBs.

Data in the Government Industry Data Exchange Program (GIDEP) sources were reviewed for selective electronic unit reliability data. There are currently three sources of data on GIDEP at WPAFB: Bldg 22 (DTIC); AFIT(Mr. Rehg) and ASD/EN (Mr. Massey). The GIDEP data base (Failure Exchange) contains generic data on PCB's in a test environment, and some of the PCBs can be matched by stock number. Application for GIDEP membership at the University of Dayton has been made, so that future reliability data in each of the data bases can be obtained directly.

2.4. PRIMARY DATA COLLECTION PROBLEMS IN PHASE I

2.4.1 Operational Reliability Data on Computer Tape

Although extensive operational reliability data on ultrafiche were obtained from AFLC/LOEP on all of the selected units listed in Table 1, these data could not be obtained in computer readable format within the time limit of execution of Phase I.

Accordingly, all data used in this report had to be manually extracted from ultra-fiche. Nevertheless, the need for computer based data analysis is accented by the sheer volume of unit reliability data to be scanned to structure a solid data base to support the statistical analyses planned in Phase II.

2.4.2 Acquisition of Unit Yield Data

A sample of data obtained from TELEDYNE on production testing and reliability for three of the work unit codes is shown in Appendix II. Three other vendor/manufacturers contacted stated that such data in the detail desired for this research existed only at government sources, such as the Item or System Managers at the Air Logistics Centers (ALCs).

There are two key reasons for this apparent dilemma. First, some of the selected units (for the A10 and F4) in Table 1 are relatively "old" and during the pre-production testing stages, the contractor or manufacturer routinely turned over testing and reliability data for these units to the Air Force as specific requirements dictated by MIL STDs 217, 470, 781C and 780, etc., (which pertain to reliability qualification and production acceptance tests for electronic units).

Second, after the operational production of a unit begins, manufacturers tend to rely solely on AFLC-derived information (D0-56 reports) to assess the operational performance of a given unit, although there are explicit requirements (MIL STD 781C) that manufacturers maintain continual post-production test and reliability data for each unit. This requirement is particularly enforced if the item is government furnished equipment (GFE) or if the unit is involved in a "Quality Deficiency Report" (QDR) or an engineering change proposal (ECP).

However, continuous tracking of data on reliability and test/yield for a unit is usually done only if the unit is, or is expected to become, a "problem item" as evidenced by an increasing failure rate or its design complexity.

Nevertheless, the primary research problem in Phase I was locating "the" individual, such as an Item or Systems Manager or Equipment Specialist at the Air Logistics Centers (ALCs) having cognizance of specific data on a specific unit, since there is (or, at least appears to be) no formal requirement that these test data be kept at the ALC for continuous unit reliability assessment and/or verification as time evolves.

To help resolve this problem, backup sources for the manufacturers' reliability and test data for selected units at each of the System Program Offices at ASD for each aircraft (A10, F4, F15 and F16) had to be used. These sources were the reliability engineers for these systems, but the lists of units for which relevant test data is kept were limited, and did not cover all of the pilot items in Table 1.

2.5 NEED FOR ADDITIONAL DATA

In this section, a brief discussion is provided to establish the basis for an expanded research data base and the need to capture key operational influences of the pilot units through the use of additional measured parameters. Specifically, there is a need to restructure and increase the sample size of the pilot set of units to provide a more formidable basis for the mathematical conclusions to be derived in the Phase II analyses.

2.5.1 Need for Expanded Data Base

There are additional avionic units for which data are routinely maintained, which would be excellent candidates to be added to the pilot list for subsequent analyses in Phase II. For example, during the week of 19 November 1982, a "high level" Air Force (PACAF) request to AFLC was made to develop "logistical synopses" of approximately 50 electronic units (WUCs) that were labelled "war stoppers". In fact, the identical unit reliability histories as presented in Section 3 of this report will be needed for these designated units.

Also, there are several other operational variables, in addition to "mean time between failure" that can serve as auxillary factors that serve to link the SRU rework activities to operational reliability. The measurements for these parameters are included in the sample data base provided herein.

2.5.2 Revised Data Collection Strategy

For the pilot set of units in Table 1, the current strategy is to acquire time samples of manufacturers' test and rework data that relate to and/or influence the reliability of these units during the production and operational stages.

To complement this strategy, there is a need to select specific electronic units produced by a manufacturer, and then retrace the testing and operational reliability history of this unit across various applications in the Air Force.

This latter requirement looms more significant in view of the observation that almost all of the selected WUCs in the pilot set rank high on the list of "abort" generations for the respective systems as reflected in the DO-56 (B-06) report, suggesting that these items were most likely picked on the basis of known negative effect on the operational performance of the associated systems. In general, the "avionics" sub-system would be expected to cause more aborts due to its mission critical nature.

In either case, to avoid a built-in bias in the data base for this research, there is a need to obtain a relatively large sample of units and then stratify this sample according to some key functional factors, such as aircraft application; failure rates and intensity; overall MTBF range; avionics versus non-avionics; deployment location; unit inventory age; its involvement in ECPs; involvement in QDRs, or other factors that might affect the operational reliability of the unit. Another useful stratification of units might indicate whether the unit is manually accessed during normal operation, as through a control panel in cockpit avionics. Such data would provide a measure of the human interaction on failures of these units.

The rationale to support two key stratifications of data which are of prime interest to this research are discussed below. The intent of these stratifications is to capture data on unit application, maintenance and manufacturer influences that might affect the operational reliability of the unit.

2.5.2.1 <u>Influences of Aircraft Maintenance</u>

There are large "spot" variations in the failure rates and subsequent maintenance action taken for the same electronic unit used among different operational aircraft, or among aircraft of the same series which are deployed differently. This observation introduces the logistics and maintenance concepts employed among operational aircraft as prime influences on failures and resultant operational reliability.

To capture the effect of diverse maintenance influences, there is a need to stratify unit maintenance actions by aircraft, which are reflected in specific categories, such as "On-Equipment", "Shop", etc, and also by other codes, such as "How Malfunction", "When Discovered", and "Action Taken". This stratification is expected to isolate the effects of different maintenance actions and aircraft deployments on operational reliability of the selected units, as well as the "maintenance maturity" of a given aircraft system.

A preliminary stratification of this type is shown in Table 2, which gives a comparative display of the maintenance actions for the same unit used on different aircraft which have diverse missions. Note that the total number of maintenance actions for the LRU (65AA0) is not the sum of the maintenance actions for its associated SRUs. This is a quirk of the D0-56 system, which dually attributes maintenance actions and/or failure counts to both the SRU and the LRU for the same activity. (In Table 2 and for subsequent reference, the LRU designator always ends in a "0", as 65AA0. All associated SRUs have identical first four symbols but end with an alphabet, such as 65AAB, 65AAC, etc).

2.5.2.2 Stratification by Manufacturer/Vendor

The above-mentioned effects on unit reliability due to application supports the need to further stratify the operational data on selected electronic units manufactured by several vendors that have a common operational application. Such information would have keen relevance at the SRU/PCB level.

To test the feasibility of this type of stratification, stock numbers of each of the LRUs in Table 1 and the associated subassemblies (such as those shown in Table 2) used for base repair of these LRUs were interlinked to manufacturers' part numbers through the D0-46 system (Reference Mr. Gary Drexler, AFLC 257-3926). The stock numbers of the subassemblies were derived from the D0-56B B-05-WK-M17 Part III ("Parts

TABLE 2

MAINTENANCE ACTIONS BY AIRCRAFT AND WUC (65AA0)
A=ON-EQUIP ACTIONS; B=SHOP ACTIONS; C=PARTS REPLACED
DATA SOURCE: D0-56 B-05 REPORT (ENDING 8203)
THREE-MONTH WORK UNIT SUMMARY

	A-10A			F-16A			F-16B		
WUC	A	B	C	A	B	C	A	B	C
65AA0	455	449	214	75	142	125	26	45	51
65AAA	0	16	0	0	26	7	0	9	8
65AAB	0	39	2	0	7	0	0	1	0
65AAC				0	2	0			
65AAD	4	3	0	0	2	0			
65AAE	0	3	0	0	1	0	0	1	1
65AAF	0	27	2	0	18	18	0	7	0
65AAG	0	15	0		16	4			
65AAH	0	24	0		3	44			
65AAJ	-	-	-	0	1	0	0	1	0
65AAL	-	-	-	0	2	0	-	-	-
65AAM	0	2	0	-	-	-	0	0	1
65AAN	0	2	0	0	4	0	-	-	-
65AAP	0	1	0	0	0	1	0	1	1
65AAQ	0	2	0	0	8	1	0	8	4
65AAR	-	-	-	-	-	-	0	1	1
65AAS	-	-	-	0	3	0	-	-	-
65AAT	0	4	0	0	2	0	-	-	-
65AAU	0	3	0	-	-	-	-	-	-
65AAV	-	-	-	0	21	0	-	-	-
65AAW	0	1	0	-	-	-	-	-	-

Replaced") printout which gives a summary of maintenance action for selected WUCs.

The resultant output of the D0-46 System identifies each component by Federal Stock Class Manufacturers' (FSCM) code and noun (e.g., circuit card assembly). Since the input data are grouped by aircraft, the output stratification by aircraft and unit manufacturer can be accomplished. Given the FSCM, the identity of each manufacturer can be obtained from the H-4-1, 2 and 3 handbooks published by the Defense Logistics Systems Center (DLSC).

However, this stratification is a laborious procedure, since the FSC/Stock Number for each unit on the B-05 Part III report must be manually keypunched and re-entered into the D0-46 system. However this stratification also gives a measure of possible ambiguity in tracing an item through the AFLC data systems using FSC and NIIN (national item identification number) due to multiple unit stock numbers and multiple applications. Another method to achieve similar results at the LRU level involves the use of the AFLC K0-51 data system.

2.5.3 <u>Relating PCB Repair Data to Specific LRUs/WUCs</u>

In general, PCB's are not repairable at "base" or "field". These items are normally repaired at the AFLC depots and/or contractors facilities as detached units, or more infrequently, they are repaired as integral units in higher assemblies (LRUs) shipped from the field/base to the depot as NRTS (not reparable this station).

This situation causes a major problem in tracking the failures of PCBs through the AFLC D0-56 data system and subsequently linking these failures to an "end article" such as one of the pilot units (LRUs) in Table 1.

That is, since the PCBs are depot reparable, data concerning PCB repair will only appear in the "Off-Equipment" D0-56"C" report, instead of the "On-Equipment", D0-56"B" report. This means that within D0-56, "failure" data and subsequent rework activity on a PCB are not uniquely traceable to the end item (LRU/WUC) from which the PCB was removed upon malfunction or failure indications, since no identification with an aircraft or work unit code (WUC) appears in the D0-56"C" report.

This problem can be partially resolved by concurrently using both the D0-56"B" and the D0-56"C" reports for data on each of the work units of interest. The data on these two reports can be correlated to the Air Force base (location) of application for each work unit, hence to each relevant aircraft, and then to an LRU thereon.

The methodology mentioned in 2.5.2.2 involving the use of D0-46 and/or K0-51 can be used to further resolve this problem. For example, in the trial run mentioned above, which involved all of the pilot LRUs for the three month period ending April 30, 1982, approximately 82% of all parts replaced involved "circuit card assemblies" or PCBs. This percentage could be further stratified by aircraft to give manhour allocation by unit and weapon system which is missing in the direct use of D0-56.

The net effect of this problem is to increase the amount of data processing and analysis needed in Phase I that must be continued into Phase II. This requirement places prime emphasis on obtaining the data base for this research in computer readable format.

2.5.4 Measuring Other Key Operational Parameters

The intent of this research is to determine the "degree" of correlation among unit reliability, rework and yield, and there are several "intermediate" variables that contribute to this correlation that depend on operational data. Time trends in such measured parameters as (1) failures per maintenance action; (2) failures per unit inventory; (3) manhour allocation per unit failure, in addition to mean times between maintenance (MTBM) and failure (MTBF) illustrate some of the primary measured variables (i.e., available data) needed to link rework and yield data to operational reliability of the selected LRUs over time.

The data needed to quantify these additional parameters are included in the AFLC D0-56 B and C reports. These data are discussed in more detail in Section 3.

SECTION 3
DESCRIPTION AND EXPLANATION OF DATA AND INFORMATION COLLECTED IN PHASE I

3.1 DATA DESCRIPTION OVERVIEW

The objective of this section is to link the key parameters (available data) defined in Section 2 to the primary transformations (computational methods) on these data required to evolve a relationship among operational reliability of selected units (LRUs), unit yield and the degree of rework associated with the shop replaceable units used to repair these units. Emphases are placed on the different interpretations of similarly defined parameters and the different uses of the same data by manufacturers and the government.

The expressed intent of this section is to assure that the outcomes of this research can be replicated using different data.

3.2 DESCRIPTION OF OPERATIONAL RELIABILITY DATA

Due to the extensive volume of operational data reviewed in Phase I, only selected subsets are displayed in this section in the form of exhibits and graphs that illustrate each of the key parameters defined herein. Other parts of the research data base are shown in Appendix V. Also, there are several modes to display these data, which are the "time series" graphs where each data value is associated with the time of its occurrence; frequency distribution mode where each datum is detached from time, or the tabular form as used for bulk data displays in the appendices. Also "exhibits" are used to depict data in the format used by the source which illustrate the mode for assembling these data and how these data are used in actual operations.

In the sections below, descriptions of key parameters are made in the context of actual data used for their measurement.

3.2.1 Observations Concerning MTBF and MTBM

For both operational data generated in the Air Force and test data generated by manufacturers, the primary computed parameters are "mean time between failure" (MTBF) and its counterpart, "mean time between maintenance events" (MTBM).

However, the definition, computation and interpretation of these parameters vary widely between manufacturers' use and operational usage in the Air Force. These unresolved differences account for a major discontinuity in the use of unit test reliability data as a predictor of operational reliability (see reference by Kerns mentioned in Section 2.3.1).

Even within the Air Force, there has been a continuing problem with the definition and computation of both MTBF and MTBM from operational logistics data in the Air Force Maintenance Data System which generates DO-56. So, starting in January 1980, the term "MTBF" was completely dropped from AFLC data systems and replaced with MTBM (Type 1) to better reflect the operational measurement actually being computed. MTBM (Type 1) is denoted as "MTBM-1" and is computed as follows:

$$\text{MTBM-1} = \frac{(\text{A/C Operating Time})\text{X}(\text{Use Factor})\text{X}(\text{QPA})\text{X}(\text{Inv Ratio})}{\text{Quantity of Failures Observed}}$$

a. "A/C Operating Time" is a three month accumulation of flying hours;

b. "Use Factor" is the estimated ratio of the unit operating time to flying hours. Therefore, the product (Use Factor) X (A/C Operating Time) is an estimate of the "Unit Operating Time";

c. "QPA" denotes Quantity per Application and is the number of identical items reported under the same work unit code (WUC);

d. "Inv(entory) Ratio" is typically 1.0;

e. "Quantity of Failures" is a three-month accumulation of failures (as defined by selected maintenance codes. See Appendix IV).

The universal definition used to compute the "mean time between failure" (MTBF) is:

$$\text{MTBF} = \frac{\text{Unit Operating Time}}{\text{Quantity of Failures Observed}}$$

When QPA = Inv Ratio = 1, then MTBM-1 = MTBF, but only to the degree that the expression (Use Factor) X (A/C Operating Time) is an accurate estimate of Unit Operating Time. However, there are major deviations of this latter estimate which causes the wide variations in the computation, interpretation and comparison of operational MTBF (See RADC Report TR-76-366).

In general, the computed MTBM-1 is greater than or equal to the estimated operational MTBF as computed from AFLC DO-56 data. As with the MTBM-1 described above, MTBF can be computed for "spot" values of operating time and failures observed (say, over three months) or most often, MTBF is computed with cumulative values of these data derived over a long period of time.

In addition to MTBM-1, a new variable called MTBM-Total was defined in January 1980, which is computed exactly as MTBM-1 with the exception that the "total number of maintenance actions" for a given unit is substituted for the "quantity of failures observed". Thus MTBM-Total always equals or is less than MTBM-1. Succinctly stated, the intended equivalency of terms are:

Before Jan 1980	After Jan 1980
MTBF-----------	------->MTBM-1
MTBM------------	----->MTBM-Total

Since the Use Factor and Inv Ratio for all the pilot items in Table 1 are set to 1.0 (in the D056 B-06 Report), the primary distinguishing feature between the DO-56 computed MTBM (Tot) and MTBM-1 for these selected items is (or should be) the QPA, which suggests that time plots of the MTBM (Tot) and MTBM-1 will be highly correlated over time (which is actually the case with the data shown herein).

It should be specifically noted that the AFLC DO-56 system does not directly support the computation of operational "MTBF" that is equivalent to the computation used by manufacturers in the testing of units, since there is no measurement of the actual operating time of the specific unit and "failures" are defined differently. Moreover, it is estimated that about 20% of all unit failures can be attributed to non-operating causes (RADC Report TR 80-136), which if true, would tend cause a major distortion in the MTBF unit on the basis of "unit operating time".

But it has been observed that the D0-56 computed value of "operational" MTBF and/or MTBM-1 is roughly equivalent to one-half of the manufacturer's computed value of "test MTBF" for a given unit (See Figure 4, paragraph 3.2.4 and also RADC Report TR-76-366).

3.2.2 Analysis of MTBF/MTBM and MTBM-1/MTBM-Total Trends

A time series plot of the D0-56 computed MTBF (i.e., MTBM-1) for the LRU 65AA0 on the A10 (Figure 1) illustrates some of the most common features of similar plots for all of the other units, which are the widely varying cyclical patterns in all of these graphs. Also, nearly all of the similar graphs for the selected units show increasing trends in the MTBM-1 time graphs after the change in definition of MTBF/M occurred in January 1980. Of significance for the item shown is the continual and steady decrease in the computed operational values of MTBM-1, which might suggest that this item is "wearing out."

Quite possibly, the cyclic trends (from 6 to 8 months in length) in the MTBF/MTBM graphs are caused by the process used in D0-56 to compute MTBF and MTBM-1 which is the accumulation of data in three month intervals. In effect, the computation of the variables are "restarted" every three months. There are also large variations within each cycle, which could be a function of the procedure for collecting the AFM 66-1 data which causes "batching" of inputs into D0-56 computation system.

Without question, a longer smoothing (averaging) method with a time interval for data accumulation exceeding three months is needed for the MTBF/M computations, since the average variation in computed MTBF/M over a three-month period can exceed 300%. Such large variations account for the low credibility and continual misinterpretation of these computed variables for predictive or comparative purposes.

Figure 1

COMPUTED MTBF/MTBM-1 (WUC 65AA0, A-10A)

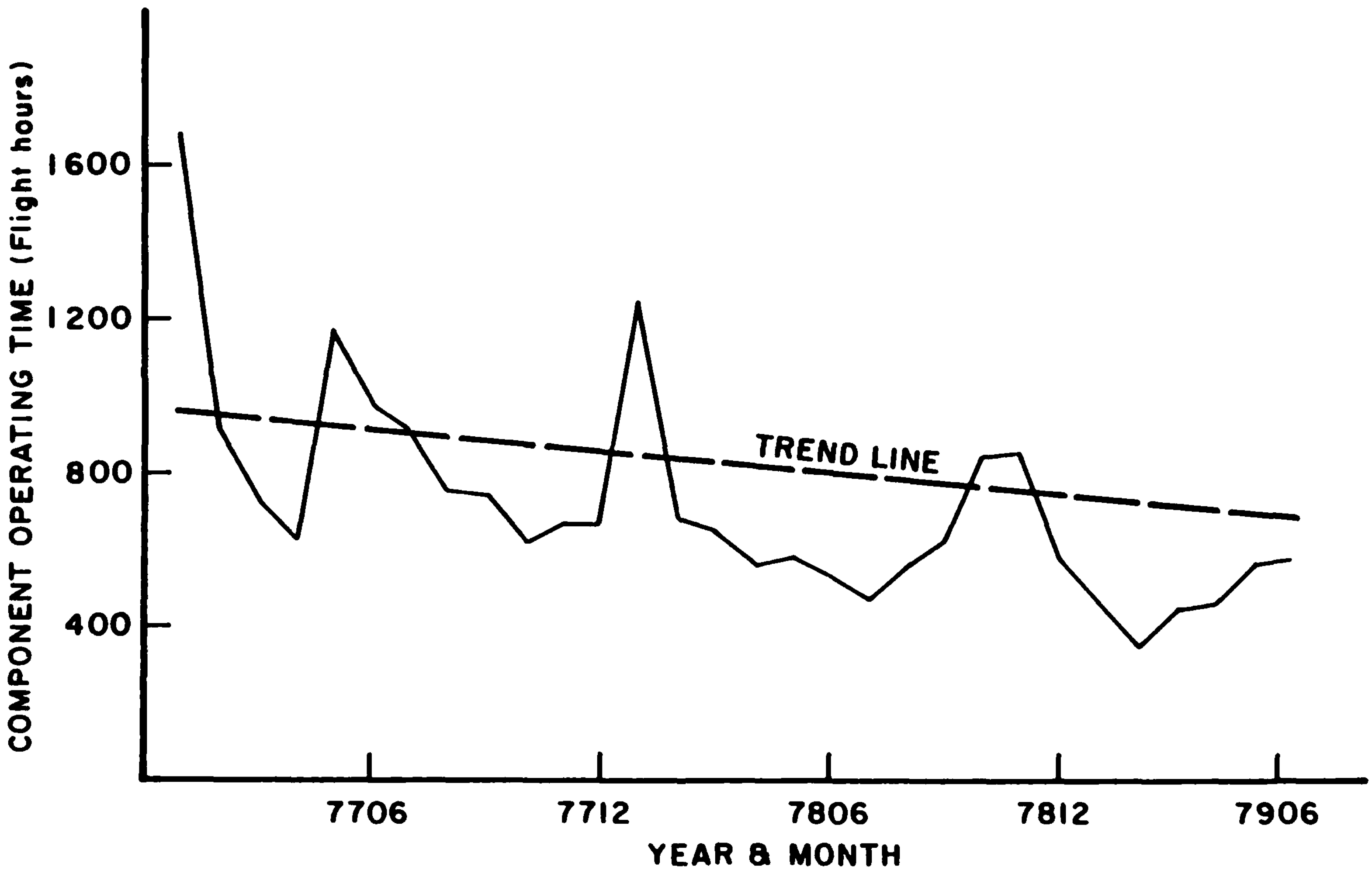
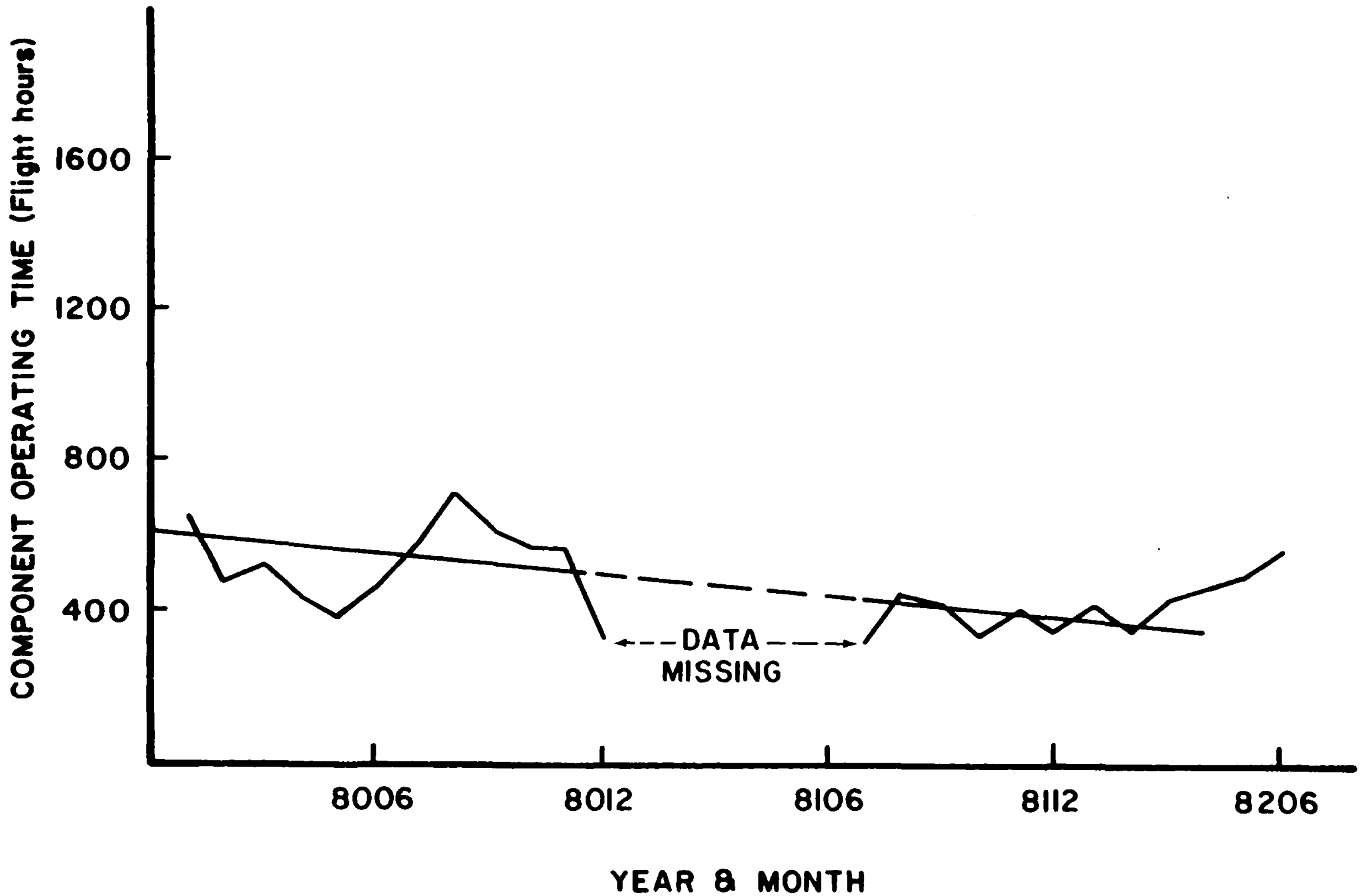


Figure 1 (Cont'd)

COMPUTED WTBF/MTBF-1 WUC 65AA0; A-10, (Cont'd)



There also appears to be influences in the MTBF/M computations due to changes in the inventory of the unit (or system inventory, as reflected on the D0-56 B-05 report). Spot decreases in inventory normally reflect increases in unit condemnations that in turn may affect the quantity of future procurements or influence reparable generation rates. But condemnations may be less frequent for the modular units in Table 1. Possibly, the computational methodology of D0-56 may affect this influence since newly procured units coming into the inventory may negate immediacy for reparable generations, which would cause distortions in the computed MTBM time graph.

3.2.3 Mission Influences on MTBF and MTBM Computations

The suspected relationship of unit yield, rework activity and operational reliability is affected by the aircraft system, its place of deployment and maintenance concepts. For example, Teledyne, who makes the APX-101 IFF transponder receiver concurrently used on the A10, F15, and F16, states that their data show a remarkably wide disparity of unit "failures" among these three aircraft (Reference: Mr. Leighty, Teledyne, Newbury Park, Calif Office).

The diverse missions of these aircraft are suggested as the cause of these differences. There are known differences in failure rates of the APX-101 used on the F-16 deployed in Germany (where the IFF is routinely used) versus the failure rate for F-16s employed stateside (where the IFF is rarely used and/or its use is not mission-critical).

These mission influences can be illustrated through the composite plots of the calculated MTBM-1 for the APX 101 (WUC 65AA0) for each of the three aircraft over the same time period as shown in Figures 2. In this plot, however, it is noticed that the linear trend of the MTBM-1 plots for each of the three aircraft is similar, although the spot variations among these graphs vary widely.

A similar plot showing MTBM-Total for the same aircraft and WUC is presented in Figure 3. The trend in both MTBM-1 and MTBM Total-plot are highly correlated as expected.

Figure 2

COMPUTED MTBF/MTBM-1 (WUC-65AA0)
(F-150; F-16A; F-16B)

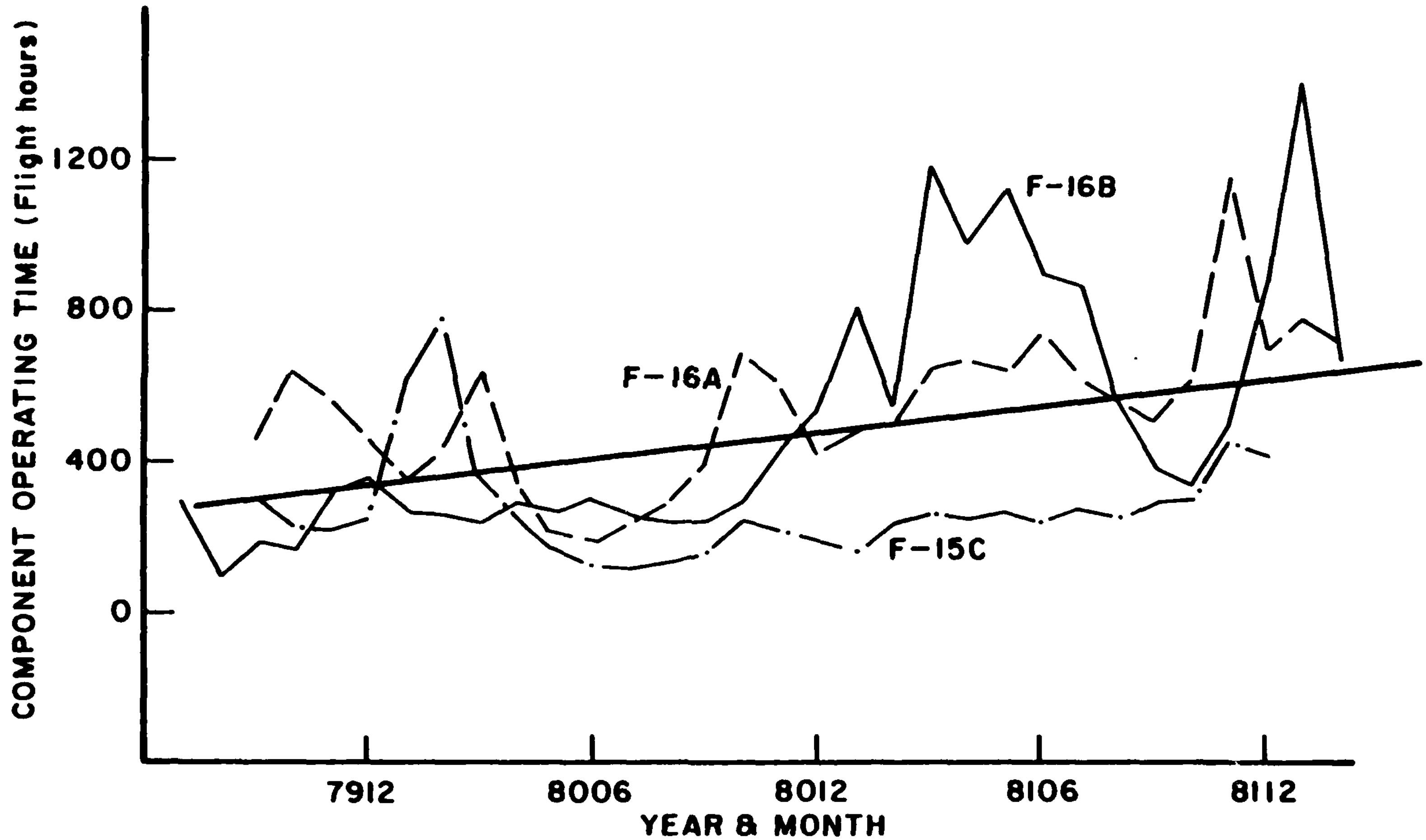
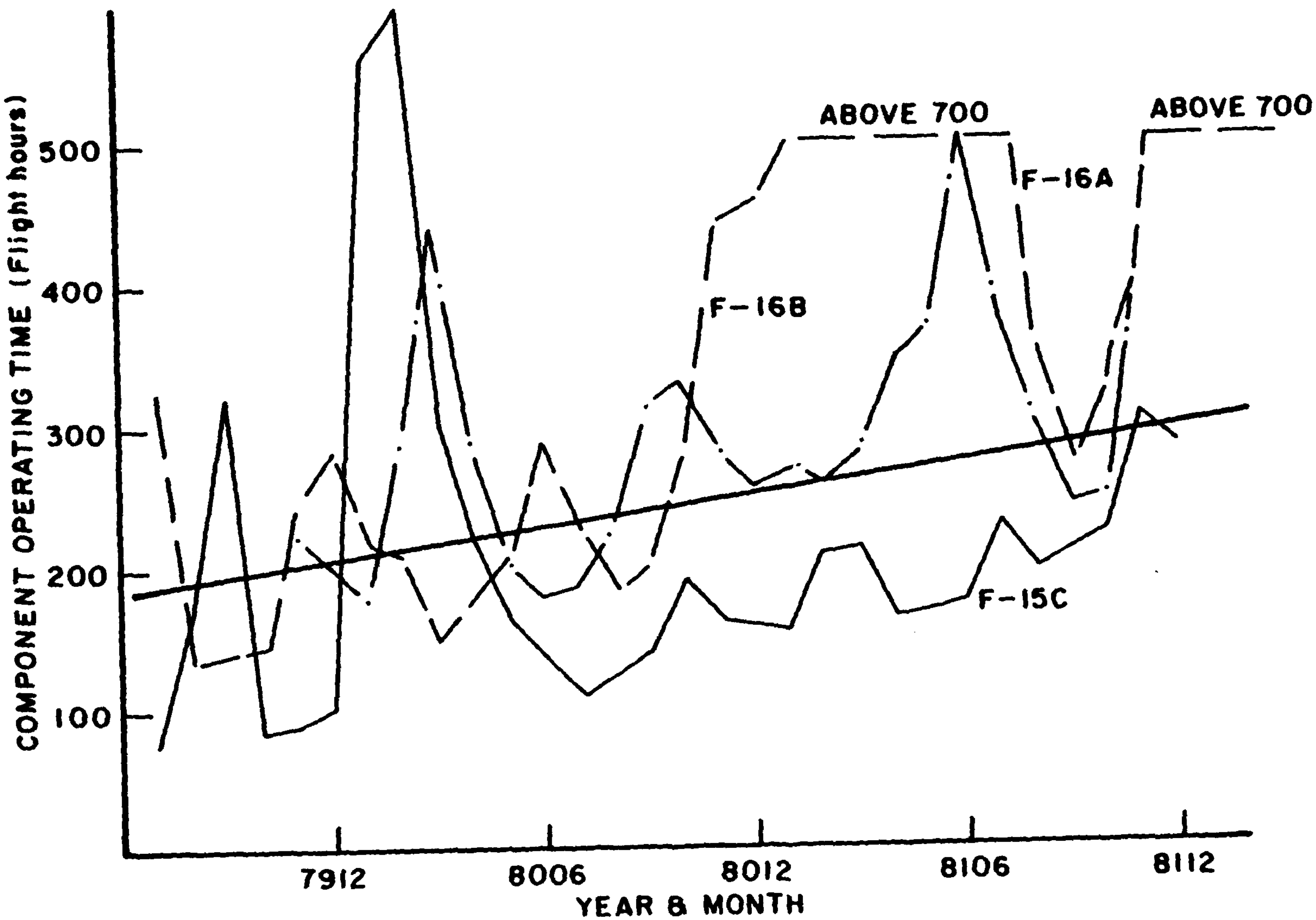


Figure 3
COMPUTED MTBM-T01 (WUC 65AA0)
(F-15C; F-16A; F-16B)



3.2.4 Comparison of Test and Operational Values of MTBF

The composite plots of MTBM-1 (which is proportional to MTBF) in Figure 2 suggest a possible method in which the "trend" of operational MTBF can be compared to "trend" of the MTBF computed from test lots of the same unit during the same period. This comparison directly impacts the objective of this research.

First, as noted, only the MTBM-1 computations for the newer model aircraft, F-15 and F-16, are included, to support the premise that the newly-tested units (Teledyne WUC 65AA0) may be more relevant to the future inventory of these aircraft than to the older F-4 and A-10.

In Figure 4, a Computed MTBM-1 Average for the aircraft shown is graphed as indicated. This trend line corresponds to the mathematical operation of averaging or smoothing the data shown in Figure 2.

The crosshatched area in Figure 4 shows the trend of test data from Teledyne: the solid plot in the crosshatched area is the computed MTBF from Teledyne (see Appendix II).

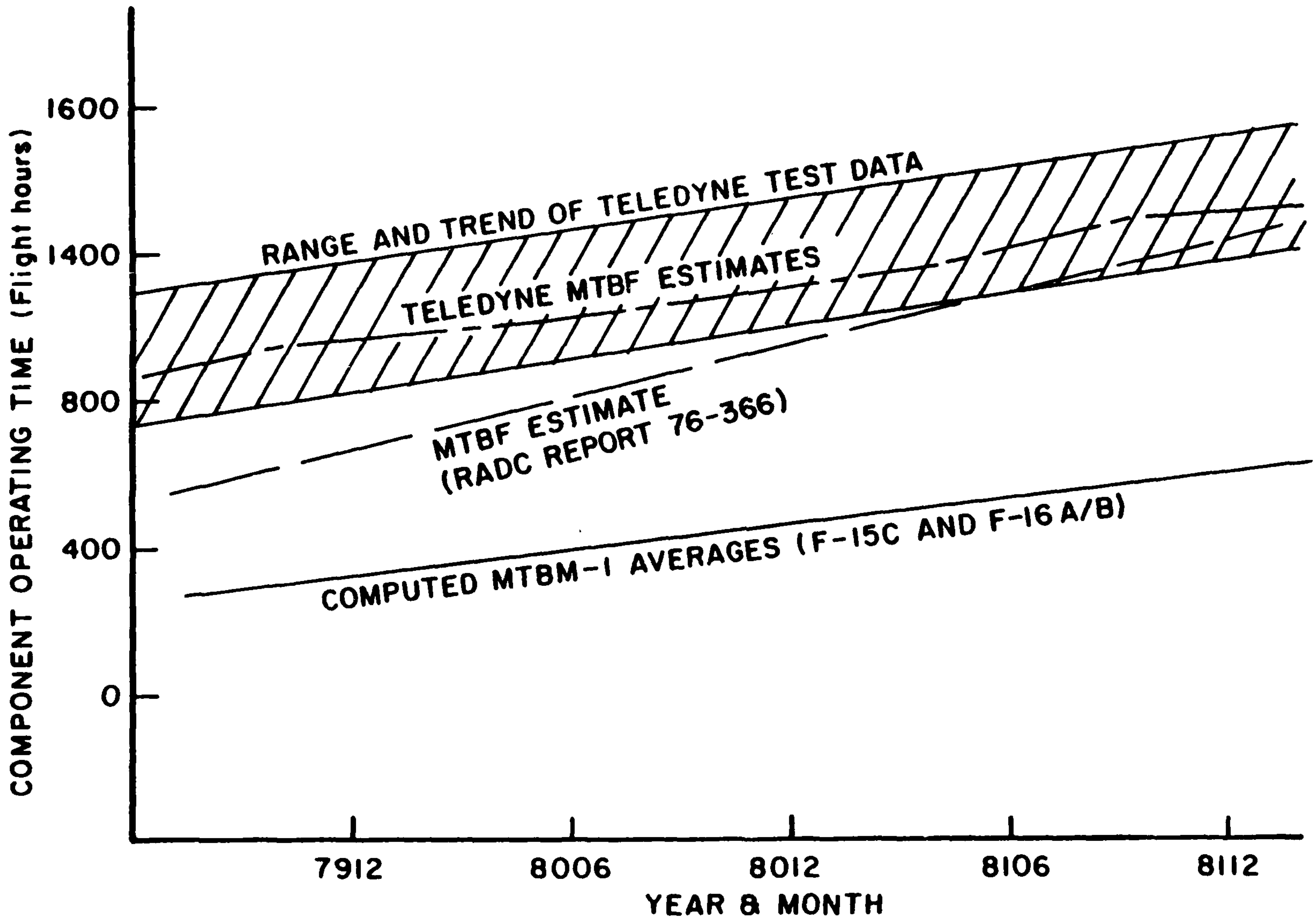
As illustrated in Figure 4, the slopes (linear trend) of the Computed MTBM-1 Average and the cumulative test MTBF values from Teledyne (solid line in crosshatched area) are nearly identical, although the numerical values of these curves differ widely for a given time period. This means that the time trend of the test and operational values of MTBM-1 are nearly equal and that the resultant equations for these lines differ by a constant value. Thus either variable could be used as a predictor of the other.

However, from the RADC Report 76-366, it is stated that the test MTBF and the computed operational MTBF typically differ by a factor of two. This premise is represented graphically by the line labelled "MTBF Estimate" in Figure 4. This line should approximate the Teledyne MTBF Estimates. In Figure 4, wide variations exist between these two estimates, although these estimates tend to converge as time increases.

Is it possible that this factor mentioned in the RADC

Figure 4

TEST VERSUS OPERATIONAL MTBM - I TREND



report may actually vary with time? To examine this premise, the ratio of the ordinate values of the line labelled "Computed MTBM-1 Averages" and the cumulative MTBF test values (solid curve in crosshatched area) is computed and plotted as a function of time in Figure 5. For these data, the resultant computed ratios range from four to slightly less than two over the time periods shown. The plotted curve in Figure 5 suggests that this ratio tends to stabilize as time increases.

The ratio plotted in Figure 5 is analogous to the K_3 factor used to convert unit "unit test operating time" to "flight hour equivalents" in the test data from ASD/TA (see Exhibit 1). Also this factor tends to be equivalent to the "Use Factor" described in paragraph 3.2.1. The typical range for this factor (as currently used) is about 1.5 to 2.7.

In further support of the above analysis, Exhibit 1 shows a plot of the composite operational MTBF of the avionic subsystem for the F-15, which encompasses each of the related units listed for the F-15C in Table 1. The key observation in this exhibit is that the average operational (computed) MTBF for the subsystem since 1976 is about half of the predicted MTBF (θ_0 = 9.7 hours). That is, the ratio of predicted to operational MTBF is a factor of two for the entire subsystem. The absence of a time-trend in this plot (since 1976) suggests that a constant value of two for this ratio might be applicable, as is represented schematically by the constant (no trend) line in Figure 5.

These results are tentative and cannot be generalized from this single example. They suggest a possible methodology, using factor and trend comparisons, could be devised to relate computed MTBM-1 (operational MTBF estimate) to the test values of MTBF computed by unit manufacturers over the same time periods.

However the foregoing analyses do not depict the cause and effect relationship of test MTBF to operational MTBF in future periods. The detection of such effects require more elaborate time series analysis methods to be employed in Phase II of this research.

Figure 5

RATIO OF TREND LINE VALUES FOR COMPUTED AND TEST MTBF

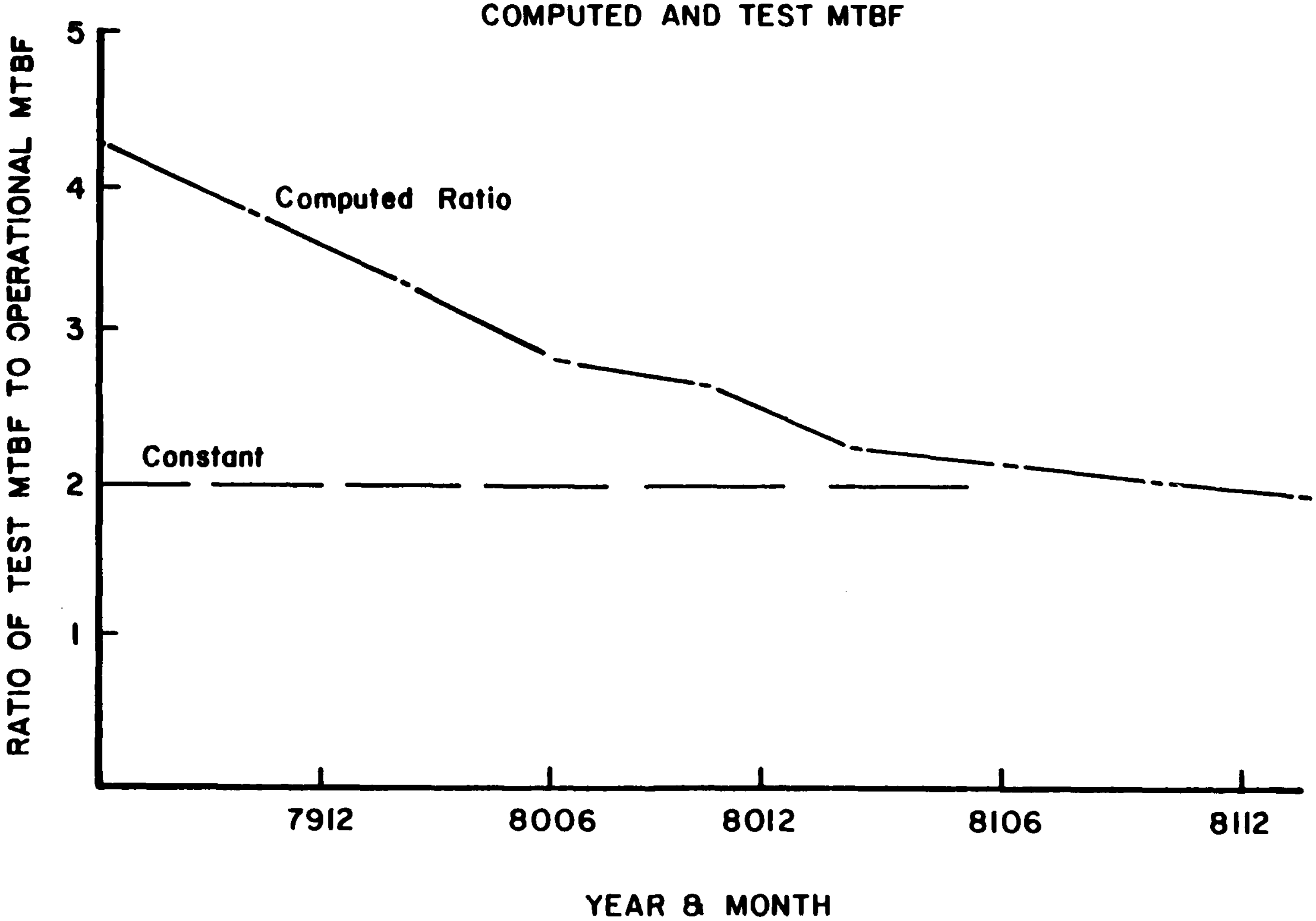
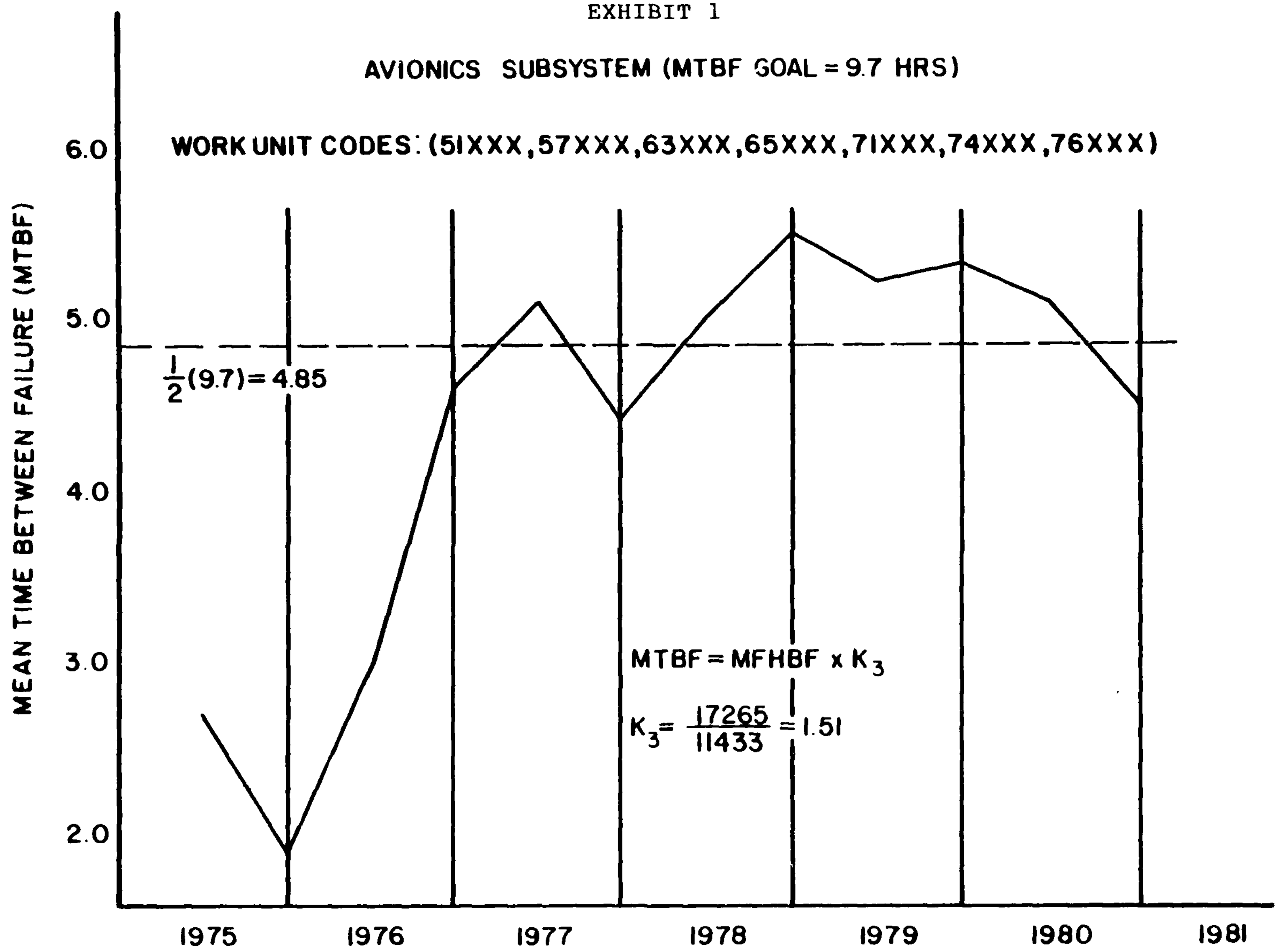


EXHIBIT 1

AVIONICS SUBSYSTEM (MTBF GOAL = 9.7 HRS)

WORK UNIT CODES: (51XXX, 57XXX, 63XXX, 65XXX, 71XXX, 74XXX, 76XXX)



3.3 MANUFACTURERS' UNIT YIELD/RELIABILITY DATA

3.3.1 Type of Yield Data Available

Exhibit 2 shows time-sequenced data that are uniquely appropriate to the primary objective of this research. Estimates of unit yield are computed for LRU 65AA0 on the basis of the number of units passing a preset number of failure-free (ff) test hours (here t_{ff} = 55 hours), which is usually set at about 10% of the specified MTBF in accordance with MIL STD 781C.

The "cumulative first pass yield" is computed by dividing the cumulative number of test unit failures by the cumulative number of units tested. This yield value is then used to estimate the operational MTBF, labelled O_{Yield}, for the selected unit using the exponential reliability model.

The "cumulative second pass yield" is derived by dividing the cumulative number of units with only one failure by the cumulative number of units having one or more failures (difference between units number tested and the number of units surviving without failures).

Of key significance in Exhibit 2 is the wide disparity between the value of the unit test operating hours (t_{ff} = 55 operating hours) and the predicted MTBF for the item (O_o = 1500 hours). However this criteria conforms to Mil STD 781C, which prorates the maximum acceptable failure rate over each delivered lot of units.

Note also the high stability of the computed values of first pass yield over the entire time period. This stability is in direct contrast to the wide variability of the MTBM-1 (Figure 1) estimates for the same unit over the same (and subsequent) time periods.

Exhibit 3 shows a typical test summary sheet for nine (9) production lots of the 63BXX subsystem, consisting of three test items per lot. The "desired" or predicted MTBF is O_o = 980 hours; the total test test time to failure is provided, and point estimates of the (laboratory) MTBF are computed.

The key feature of the test report in Exhibit 3 is the category labelled "Rel Fail" or Related Failures, since

EXHIBIT 2 *

AEPRT-New ICCP t_{ff} = 55hrs θ_0 = 1500 hrs

Month	Number Delivered (cum.)	Number Without Failure (cum.)	Cum First Pass Yields	$\hat{\theta}_{yield}$	Number with only one Failure (cum.)	Cum. Second Pass Yield	Total No. Of Failures ENV/ATP	Cum. Failures	Number Failures per LRU (cum.)	Op. Hours (cum.)	O_{time}
Jan-Mar '81	10(10)	5(5)	.50	79	2(2)	.40	10/1	11	1.1(1.1)	---	---
Apr '81	6(16)	1(6)	.38	56	4(6)	.60	6/1	18	1.2(1.1)	---	---
May '81	10(26)	5(11)	.42	64	4(10)	.67	3/3	24	0.6(0.9)	---	---
Jun '81	8(34)	2(13)	.38	57	2(12)	.57	8/6	38	1.8(1.1)	---	---
Jul '81	5(39)	1(14)	.36	54	1(13)	.52	9/7	54	3.2(1.4)	---	---
Aug '81	19(58)	9(23)	.40	60	3(16)	.46	12/10	76	1.2(1.3)	---	---
Sep '81	16(74)	9(32)	.43	66	4(20)	.48	12/3	91	0.9(1.2)	---	---
Oct '81	27(101)	16(48)	.48	7	6(26)	.49	15/8	114	0.9(1.1)	---	---
Nov '81	13(114)	3(51)	.45	68	4(30)	.48	17/8	139	1.9(1.2)	---	---
Dec '81	9(123)	6(57)	.46	72	3(33)	.50	1/2	142	0.3(1.2)	---	---
Jan '82	14(137)	8(65)	.47	74	1(34)	.47	12/5	159	1.2(1.2)	---	---
Feb '82	10(147)	4(69)	.47	74	4(38)	.49	6/3	168	0.9(1.1)	---	---
Mar '82	11(158)	5(74)	.47	74	2(40)	.48	9/2	179	1.0(1.1)	---	---
Apr '82	4(162)	2(76)	.47	74	0(40)	.47	2/2	183	1.0(1.1)	---	---
May '82	9(171)	6(82)	.48	75	2(42)	.47	3/1	167	.44(1.1)	---	---
Jun '82	11(182)	8(10)	.49	77	1(43)	.47	3/2	192	.45(1.1)	---	---
Jul '82	15(197)	10(100)	.51	82	1(44)	.45	17/1	210	1.2(1.1	---	---

*NOTE: The exhibits shown herin are re-typed versions of data supplied by appropriate agencies.

EXHIBIT 3

ICNICP

0_0 = 980 0_1 =   WUC = 63BXX   QPA = 1   CONTRACTOR: SCI

Type of Test	Lot S/N Range	S/N's Tested	Date Started	Date Completed	Total Test Time	Rel. Fail.	Total Fail.	Point Est. of MTBF	LCL 90%	Initial Approval	Final Report Approved
RQT for CNI Stn (A_0 = 100) SAIS			74/8/13	74/9/5	99	0		>99			75/3/10
RQT for ICNI Panels			74/3/6	74/10/8	4872	4		1218			75/10/7
<u>PRT</u>											
Lot 1	ICCP 40-114		75/6/20	75/9/22	3544	2		1772			76/8/19
Lot 2	ICCP 115-196		76/1/22	76/4/9	2864	1		2864			76/9/22
Lot 3	ICCP 197-267	3) 198,232,235	77/1/6	77/4/30	2843	1	1	2843			
Lot 4	ICCP 268-457	3) 265,331,332	77/7/22	78/1/30	3875	4	14	969	REJECT		
Lot 5	ICCP 349-417	3) 472,486,500	78/6/30	78/10/6	2868	1	3	2868	REJECT		
Lot 6	ICCP 526-597	3) 568,577,580	78/10/25	79/4/24	5577	5	12	1115			
Lot 7	ICCP 598-679	3) 641,647,661	79/6/27	79/12/29	4208	3	4	1403			
Lot 8	ICCP 680-748	3) 703,710,712	79/11/2	80/1/21	2170	0	1	>2170			
Lot 9	ICCP 749		80/3/19								
RLT for nu. ICCD	---	---	80/7/15	81/3/16	33392		42 (14	79.5 238.5)*		Info. only	

certain unit failures may be excluded from the computations by the manufacturer. It is this "failure count exclusion" issue that tends to undermine the credibility in "first pass yield" computation from the data provided by the manufacturer. At the most, this computation represents a "best case" estimate from the data provided. AEPRT (All Equipment Production Reliability Testing) was designed specifically to counteract this problem.

Also in Exhibit 3, the actual values of the test time for each item would be much more useful data than the aggregate values when the size of the test sample is so small. The most useful data would be the actual failure times for each of the item failures, regardless of cause (i.e., "related" and "unrelated" failures).

Exhibit 4 shows an actual "spot" sample of manufacturer-derived test and reliability data for several of the relevant units in Table 1 related to the F-15. These "typical" data were also provided by ASD/TA, and show some of the Work Unit Codes that extend below the subsystem level, which are 51EA0, 65AA0, 65BH0 listed in Table 1. Other system and subsystem level codes for the F15 relevant to this research include 52XXX, 74JXX and 74KXX as shown on this Exhibit.

Exhibit 4 is typical of the pre-selected sets of units whose test and production data are tracked over time based on criteria established early in the unit development phase.

3.3.2 Discussion of Test Procedures and Test Data

Although manufacturers' functional testings are witnessed by government personnel, the unit testing models and the resultant test data (reviewed by the researchers) appear exceedingly fragile and non-standard. Accordingly these test data are subject to wide variations in interpretations with correspondingly low credibility.

For example, in the unit test procedures reviewed, there are no explicit penalties associated with the failure of a test unit, since the test is simply repeated. That is, the primary objective (of the Air Force) is only to obtain a certain number of units that passes a given test. Thus a manufacturer

EXHIBIT 4

F-15 Subsystem Reliability for Selected Avionics Items

Equipment (WUC)	Cum Field MFHBF	Op. Hr. Flt. Hr.	Cum Field MTBF	RQT MTBF	Cum. Lab NTSF	MTB
1) EAIC (11PDO)	503	2.4	1207	1010	1260	1000
2) FDS (49AXX)	1234	1.5	1851	4340	2558	1500
3) ADI (51ADO)	660	5.7	3762	4512	2414	1500
4) ADC (51EAO)	480	2.3	1104	809	627	800
5) HSI (51NAO)	344	2.5	860	909	413	680
6) AFCS (52XXX)	157	2.3	361	708	555	415
7) SDRS (55BXX)	49	1.2	59	1789	2522	570
8) CC (57XXX)	180	2.4	432	1426	1243	1000
9) ICNICP (63BXX)	82	4.5	369	1218	1488	480
10) IFF (65AAO)	227	2.2	499	762	662	500
11) IRE (65BHO)	533	0.9	480	722	--	700
12) INS (71AXX)	71	1.5	106	--	--	200
13) ADF (71BXX)	2865	0.3	860	1434	2010	1000
14) ILS (71CAO)	1794	1.0	1794	1135	1184	1000
15) AHRS (71FXX)	148	2.3	340	933	603	750
16) LCG (74EBO)	350	1.6	560	1206	1193	1000
17) RADAR (74FXX)	16	1.5	24	38	58	60
18) VSD (74JXX)	137	1.8	247	569	290	500
19) HUD (74KXX)	67	1.7	100	236	--	350
20) ACS (75MXX)	264	(-)	396*	325	258	300
21) IBS (76CXX)	1370	(2.1)	3927	1060	2054	1000
22) TEWS,						
23) (ICC, RWR,						
24) EWWS)						

* Assumed Op Hr. to Flt Hr. ratio of 1.5.

producing a large volume of units (as PCBs) could substitute good units for failed ones and retain the failed units for inclusion in subsequent lots following rework actions thereon.

In effect, the in-depth analyses about "why" the unit test failure occurred are missing, which explains the absence of test data on unit failures during test below the LRU level.

3.4 DATA ON UNIT REWORK

3.4.1 Rework at the LRU Level

In all-modular LRUs such as WUC 65AA0, one would expect very high fault/failure isolation to the PCB (SRU) level, so that almost 100% of the base level "on equipment" repair actions should involve PCB replacements, with very few LRUs being NRTSed to the depot. Thus concurrent increases in item failures per unit inventory, number of NRTS and associated "unscheduled" manhours at base level should reflect changes in unit rework activity.

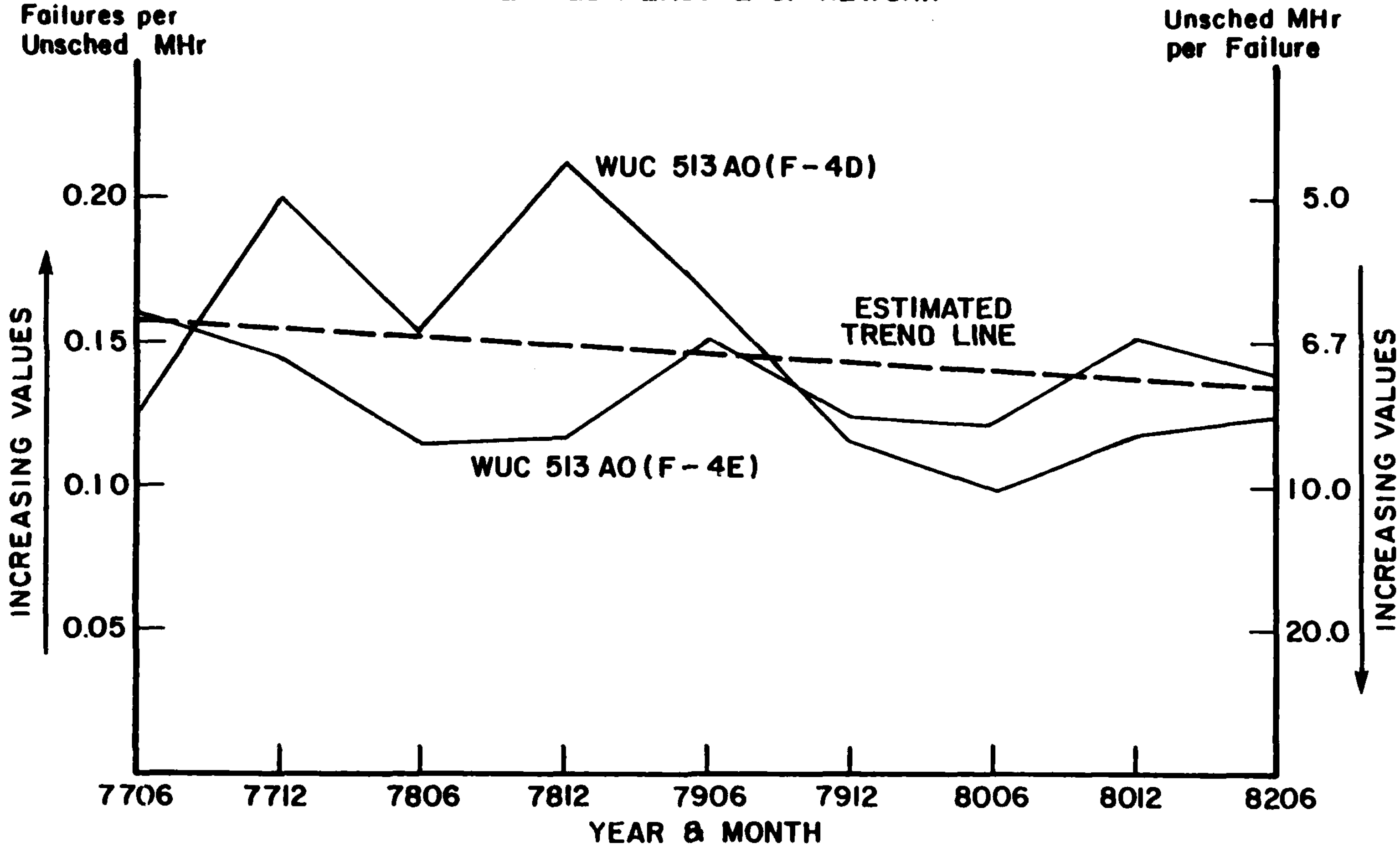
From the available data in the AFLC D0-56 system, a simple measure of rework volume may be the computed "failures per unscheduled manhour", or its inverse, "unscheduled manhours per failure". A composite plot of these computations is shown in Figure 6 for different aircraft applications of the same unit WUC 513A0.

In each case shown, the trend is towards increased manhours allocation per failure for each of the applications of this WUC/LRU. This rework might reflect the absence of the "maintenance learning curve" for the unit or the increasing fragility of the unit due to past rework actions (or possibly other factors).

Another potential measure of rework activity at the LRU level might be derived from the equations for MTBM (Tot) and MTBM-1. The reciprocal of each of these parameters is interpreted as a "rate" of occurrence of maintenance and failure events respectively. Thus the difference in the reciprocal of these two parameters can be interpreted as the rate of change in effectiveness of failure isolation and detection at the LRU

Figure 6

DERIVED MEASURE OF REWORK



level. This difference is expressable as a rate:

$$[1/\text{MTBM-Total}] - [1/\text{MTBM-1}] = \frac{\#\text{Maintenance Actions} - \#\text{Failures}}{K(\text{Operating Time})},$$

where K = (Use Factor)X(QPA)X(Inventory Ratio) and is typically equal to unity for the pilot units in Table 1.

From this formula, if the number of failures and maintenance actions are on a 1:1 basis (implying effective LRU fault diagnosis), this difference is zero. Conversely, as the number of maintenance actions exceeds the number of failures discovered (implying less effective fault diagnosis and/or rework increases), this difference increases accordingly. Thus it may be possible to link unit (LRU) rework activity directly to the computed operational parameters, MTBM-1 and MTBM-Total. Further development of this premise is scheduled in Phase II.

3.4.2 Rework at the SRU/PCB Level

As stated previously, there are no direct data linkages in the Air Force Maintenance Data System (D0-56) between the rework (manhour) data for an SRU/PCB and the specific unit or SRU from which the failed PCB is taken. But this problem may be partially resolved by data processing outside of the D0-56 system using the AFLC DO-46 and KO-51 data systems.

Nevertheless this linkage, or the absence thereof, requires further explanation for two major reasons. First, data on rework actions on PCBs by the manufacturer during reliability qualification testing (RQT) and/or production reliability testing (PRT) cannot be sufficiently distinguished in the resultant test reports. That is, there is no current requirement for these details to be included in the test data reports. Only during post-production test period is there isolation of data for unit failures at the SRU level, but these data are not currently required in the test reports; only "related failures" at the unit or LRU level are reported.

Second, it is noted that repair and rework actions on PCBs at the depots are a result of prior operational SRU failures, since for the highly-modular units as in Table 1, more than 80% of all failure are attributable to circuit card assemblies, which includes PCBs. In effect, there is a well-known and direct cause and effect relationship between PCB repair and unit failure due to the modular design of the unit. Also according to ASD/PRAM and DESC, PCB "failures" are most often credited to electrical connections on the board structure itself, as opposed to the failure of discrete units thereon. In this case, "rework" of the PCB is typically infeasible as a repair action.

Thus, as a tentative premise, it seems that repair and rework activities at the SRU/PCB level may tend only to reflect the consequence of past unit failures rather than be a predictor of future operational reliability of the associated LRU, since specific reliability problems at this level are continually assessed and subjected to "fixes" (as is the function of ASD/PRAM). If such problems are undetected, or otherwise masked and reliability improvements do not occur, data on PCB repair and rework actions would possess a greater predictive capability for subsequent LRU reliability.

The net effect of this situation is that the typical unit development and evolution tends to "decouple" the direct influence of PCB repair and rework from the operational reliability of the associated LRU. However, these effects are believed to be translated to other intermediate variables as discussed herein. This premise is tentative and will be further analyzed in the expanded data analyses to continue in Phase II.

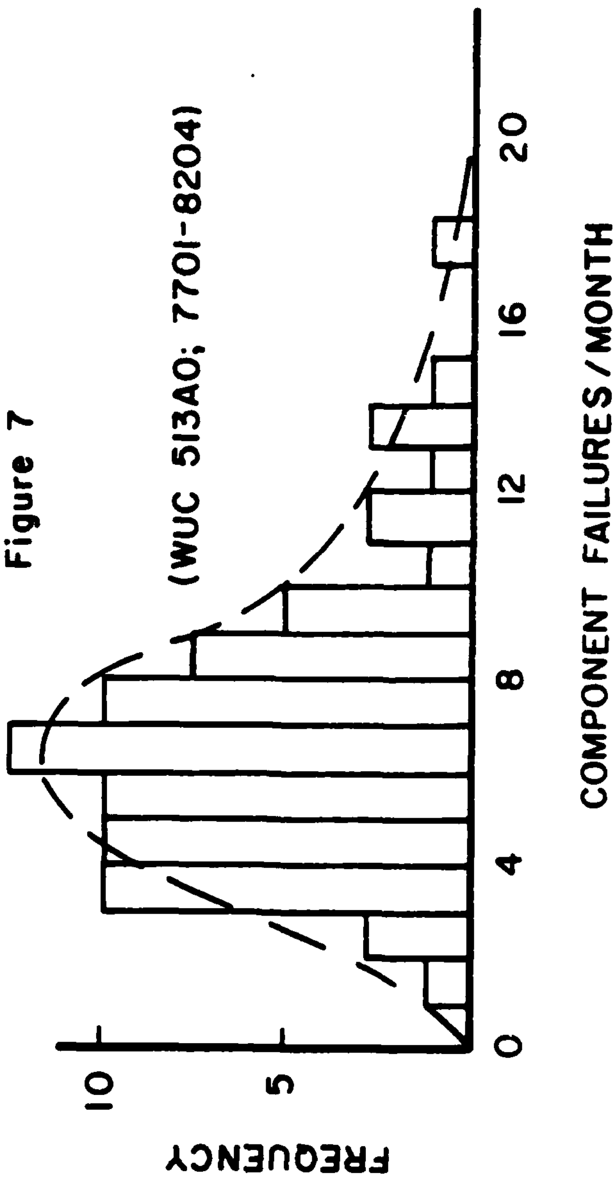
3.5 OTHER SUPPORTING DATA (UNIT FAILURE DISTRIBUTIONS)

Compilation of the extensive sets of data for each of the selected units is an excellent opportunity to develop statistical distributions for such parameters as failures per unit period, as illustrated in Figure 7. Data in this form could greatly augment the generalizations from this research if these distributions are well-defined and relatively stable (that is, the average number of events per randomly-chosen period is relative constant.

Unfortunately, such variables as the number of unit failures per time period depend on both flight activity and unit inven-

Figure 7

(WUC 513A0; 7701-8204)



tories which vary widely over time and are highly unstable due mainly to continual logistics influences that seek to decrease the failures for an unit. For example, Figure 7 shows the distribution of unit failures per month for WUC 513A0 over the time period indicated. The mean of this distribution continually shifts to the left, implying fewer failures per month are occurring as time passes.

The distribution in Figure 8 gives the failure distributions of WUC 513H0 (F-4) over two contigious time segments. The mean of these distributions has decreased drastically, again indicating fewer failures per period as time progresses.

For these same data, an alternative form for display is the time series mode as shown in Figure 9 for WUC 513U0 (F-4). The well-defined linear time trend of these data causes the instability in the mean of the frequency distributions discussed above.

However when the linear trend in Figure 9 is removed, a stable "normal" distribution results from the difference (residuals) in the trend line and the actual values as shown in Figure 10. This resultant distribution tends to be highly stable for each set of the above data, which suggests that "first order" time series methods may be much more powerful techniques for analysis of these data than the typically-used frequency distributions. Both time series and distributional data will be used in the analyses in Phase II as needed.

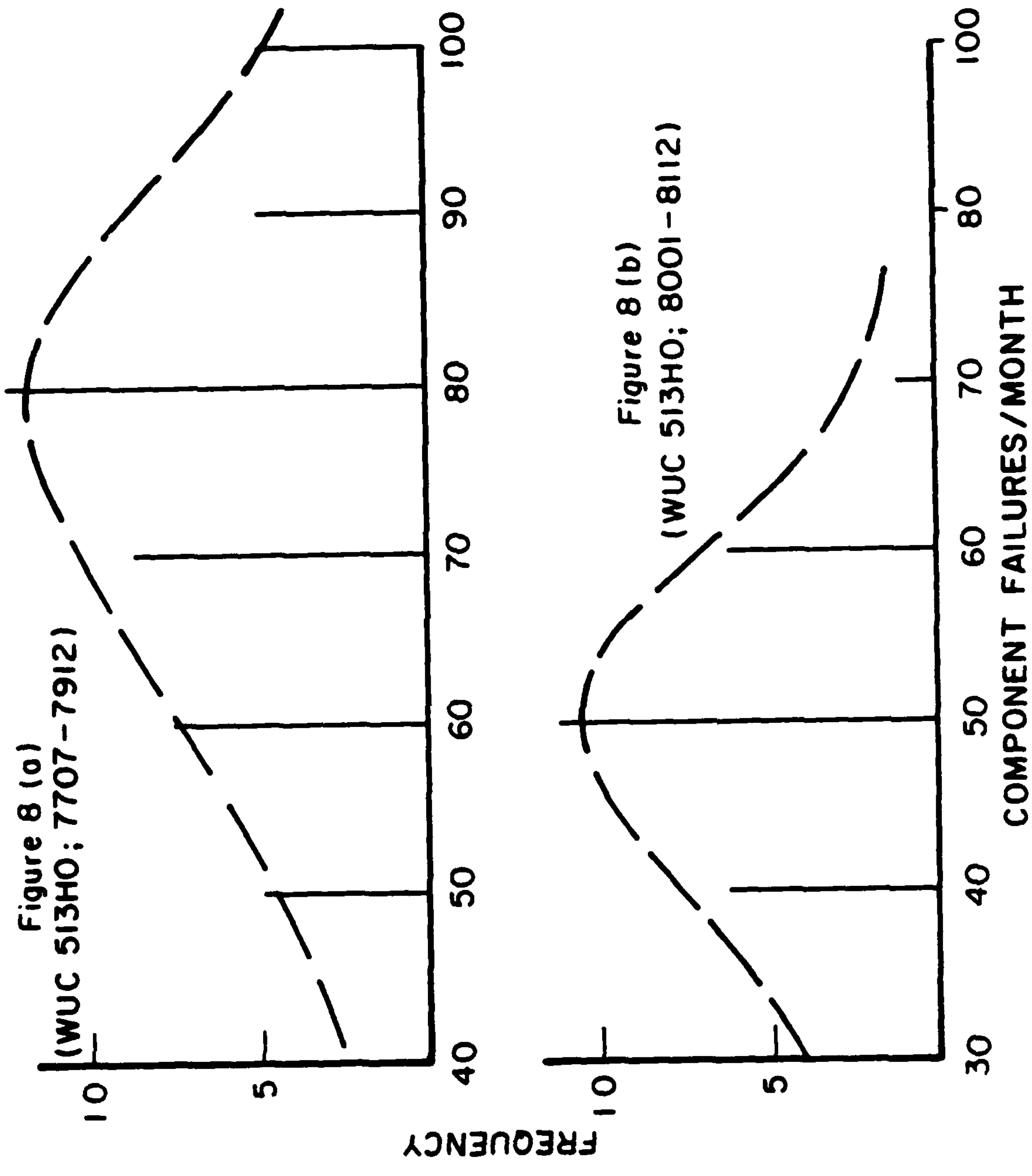


Figure 8 (a)
(WUC 513HO; 7707-7912)

Figure 8 (b)
(WUC 513HO; 8001-8112)

Figure 9
TIME SERIES PLOT OF FAILURES/MONTH
(WUC 51360)

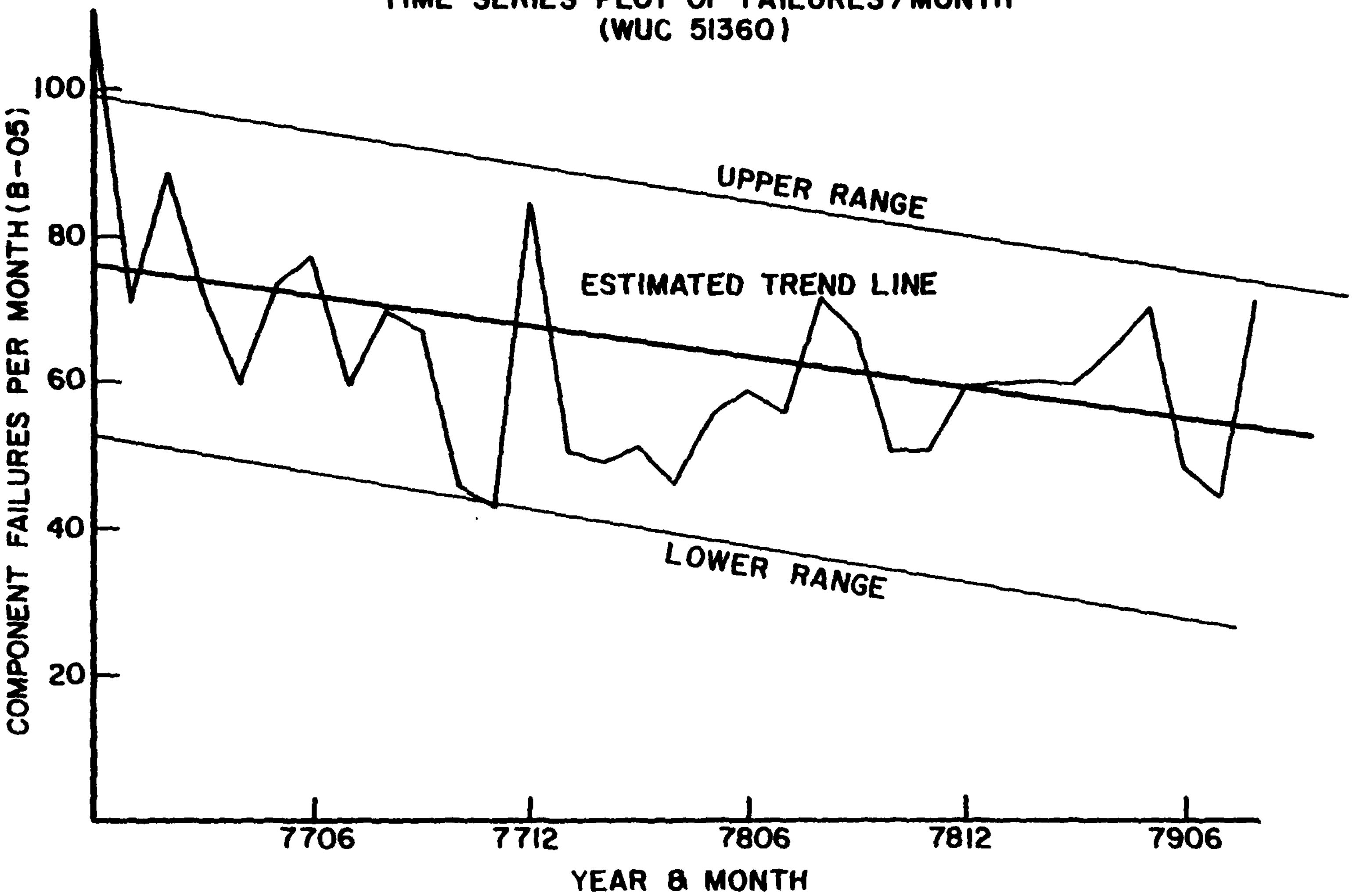
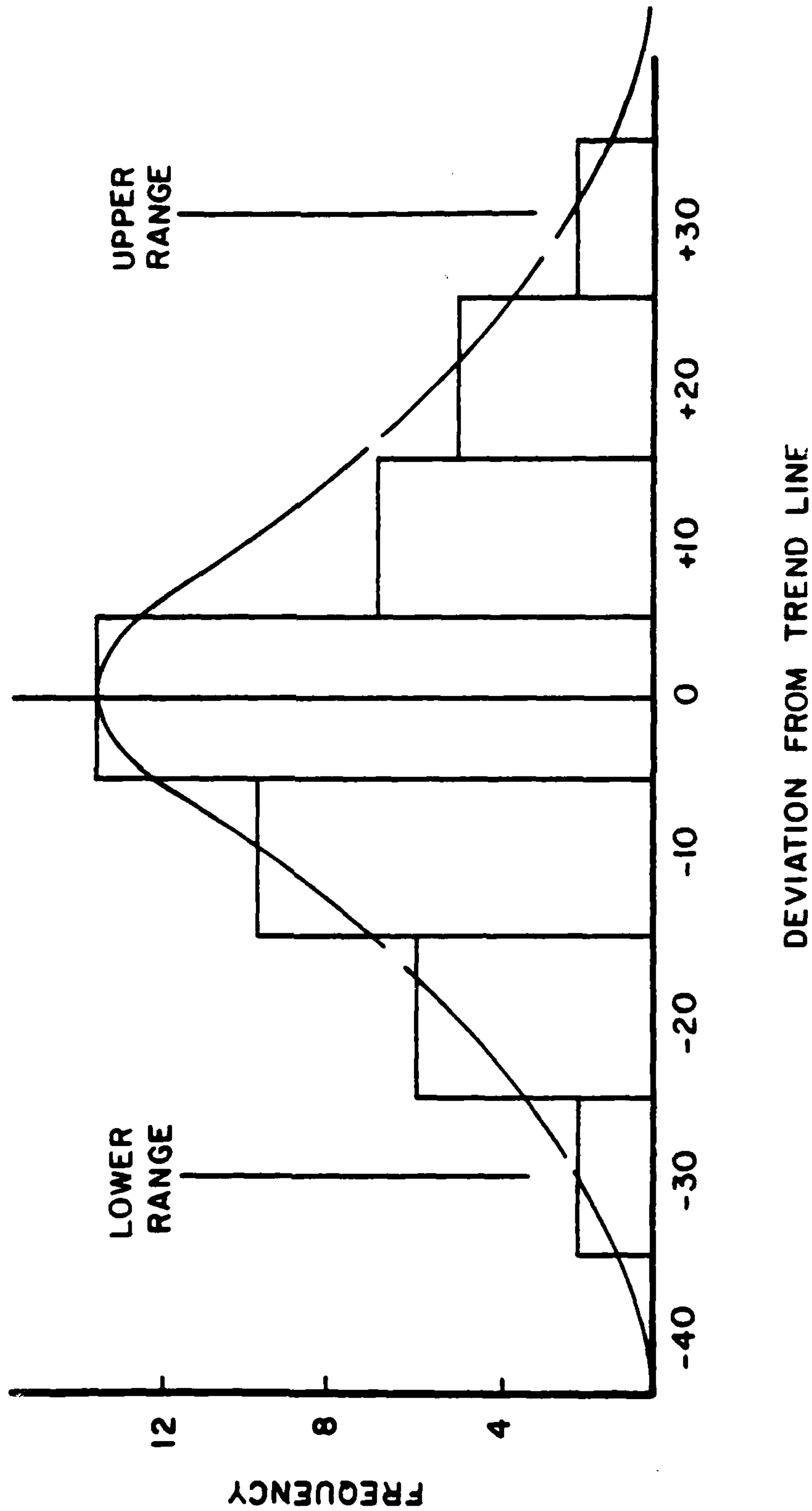


Figure 10
DEVIATION OF ACTUAL PLOT FROM TREND VALUES
(from Figure 9)



APPENDIX I

Test Data WUC 65AA0

APV - 101 (v) PRT LOG

Document Number	Date of Report	Lot No.	Unit "ON" Per PRT	Hours Cumulative	Relevant Per PRT	Failures Cumulative	MTBF Per PRT	MTBF Cumulative
SDRL-68-870030-E71-1	2/15/78	1	2520.3	2520.3	4	4	630.0	630.0
SDRL-68-870030-E71-2	2/15/78	2	1849.4	4369.7	2	6	924.7	728.3
CDRL-USAF-A00G-1	4/20/78	1	2197.0	6566.7	3	9	732.3	729.6
CDRL-USAF-A00G-2	9/7/78	2	1826.0	8392.7	2	11	913.0	763.0
CDRL-USAF-A00G-3	3/27/79	3	1142.0	9534.7	0	11	1142.0	866.8
CDRL-USAF-A008-1	6/12/79	1	2152.0	11686.7	3	14	717.3	834.8
CDRL-USAF-A008-2	9/26/79	2	1108.0	12794.7	0	14	1108.0	913.9
CDRL-USAF-A00G-5	10/30/79	4	1464.0	14258.7	1	15	1464.0	950.6
CDRL-USAF-A008-3	4/28/80	3	1116.8	15375.5	0	15	1116.8	1025.0
CDRL-USAF-A00G-6	5/7/80	5	2146.2	17521.7	3	18	715.4	973.4
CDRL-USAF-A008-4	10/15/80	4	1128.0	18649.7	0	18	1128.0	1036.1
CDRL-USAF-A00G-7	10/15/80	6	1118.0	19767.7	0	18	1118.0	1098.2
942-1005-01(A00G-8)	12/22/80	7	1260.0	21027.7	0	18	1260.0	1168.2
992-A008-5	4/2/81	5	1629.0	22656.7	1	19	1629.0	1192.5
992-A008-6	9/18/81	6	1131.2	23787.9	0	19	1131.2	1252.0
942-1005-02	9/21/81	2	1121.2	24909.1	0	19	1121.2	1311.0
942-1005-02	10/21/81	2	1121.2	24909.1	0	19	1121.2	1131.0*
942-1005-04	6/3/82	3	1128.8	26037.9	0	19	1128.8	1370.4

*Reported again with test process revised.

TELEDYNE DATA
65AA0

TELEDYNE
ELECTRONICS
649 LAWRENCE DRIVE
NEWBURY PARK CALIFORNIA 91320
805, 498-3621 TWX 910 336-1263

22 November 1982

Dr. Eugene Jones
K. L. 364 E
University of Dayton
Dayton, Ohio 45469

Dear Dr. Jones,

It was a pleasure to talk with you about Teledyne's RT-1063C/APX-101 Transponder. I've taken far too long in gathering some data for you - I apologize for the delay. I am sending along a portion of a recent proposal which describes our transponder, the maintenance concept (recently revised), and configuration and quality control. Some of the additional data, such as the list of final reports, may also be of interest.

I am also sending a copy of our PRT Log. As you can see, it is a compilation of 4½ years of data with over 26,000 hours of accumulated testing. Let me summarize our experience in reliability testing.

The AN/APX-101 Transponder has undergone several formal demonstration tests where equipment time and relevant failures were carefully monitored. The results of these tests (F-15 Category I, F-15 Category II and Production Reliability Tests) are given in the following paragraphs. These tests consistently show a demonstrated MTBF greater than 1200 hrs.

The F-15 Category I Flight Test Program resulted in three (3) relevant failures in 3767 operating hours for the AN/APX-101. This equates to a demonstrated MTBF of 1256 hours. Source: "F-15 Reliability Demonstration Report for Category I Flight Test Program" MCAIR Report MDC A3536, dated 10 December 1975.

The F-15 Category II Flight Test Program resulted in two (2) relevant failures in 2466 operating hours. This equates to a demonstrated MTBF of 1233 hours. Source: "F/TF-15 AFDT&E Reliability and maintainability Evaluation" Air Force Report FTC-TR-76-2, dated February 1976.

To date eighteen Production Reliability Tests have been conducted at Teledyne in accordance with USAF contracts. All tests have been conducted with government witnessing. Currently all Test Reports are reviewed and approved by ASD. To date, the AN/APX-101 has accumulated 19 relevant failures in 26,038 operating hours. This equates to a demonstrated MTBF of 1370 hours.

With respect to field MTBF, Air Force AFM 66-1 D056 reports for the A-10 Aircraft have consistently shown a field MTBF in flight hours of between 400 and 500 hours for the APX-101. In accordance with RADC Report No.

RADC-TR-76-366, an average factor of two should be used to convert from flight hours to operating hours. Therefore, the AN/APX-101 field MTBF in operating hours for the A-10 aircraft is between 800 to 1000 hours.

In summary, the AN/APX-101 demonstrated MTBF based on USAF documents, or USAF approved documents, exceeds 1200 hours; the field MTBF for the A10 Aircraft is between 400-500 hours in flight hours and between 800-1000 hours in operational hours. Since it is general knowledge that many IFF system failures are currently being mistakenly attributed to the transponder one can easily assume an MTBF greater than that reported in the D056 data.

In addition to the above, the Air Force has recently completed CERT tests on the AN/APX-101 using the A-10 profile for testing parameters. These tests resulted in an MTBF in excess of 1000 hours. Source: Flight Dynamics Lab., Wright Patterson AFB.

The Production Reliability Test (PRT) for the AN/APX-101 is conducted in accordance with MIL-STD-781B, Test Plan III, Test Level F. This test includes simultaneous vibration cycling, voltage cycling, on-off cycling and temperature cycling between -54°C and +71°C. The objective of the test is to verify continued compliance with the specified mean-time-between-failures (MTBF). The PRT is performed on at least four samples out of each production lot (minimum of 16 units per year). The accept/reject criteria is based on the accept/reject criteria of MIL-STD-781B, using a specified MTBF of 500 hours. Eleven hundred failure free hours indicate an accept on the four APX-101's. With one failure, an additional 345 hours of operation is required. Only transponder "ON" time is applicable for determining the accept/reject. (See the attachment for a description of the test profile.)

All production APX-101's are subjected to a 72 hour burn-in consisting of eight nine-hour cycles. The burn-in cycle is identical to the PRT cycle. During the 72 hours of burn-in, the APX-101 BIT is being automatically monitored and, if a failure occurs, the APX-101 is removed, repaired and returned for additional burn-in.

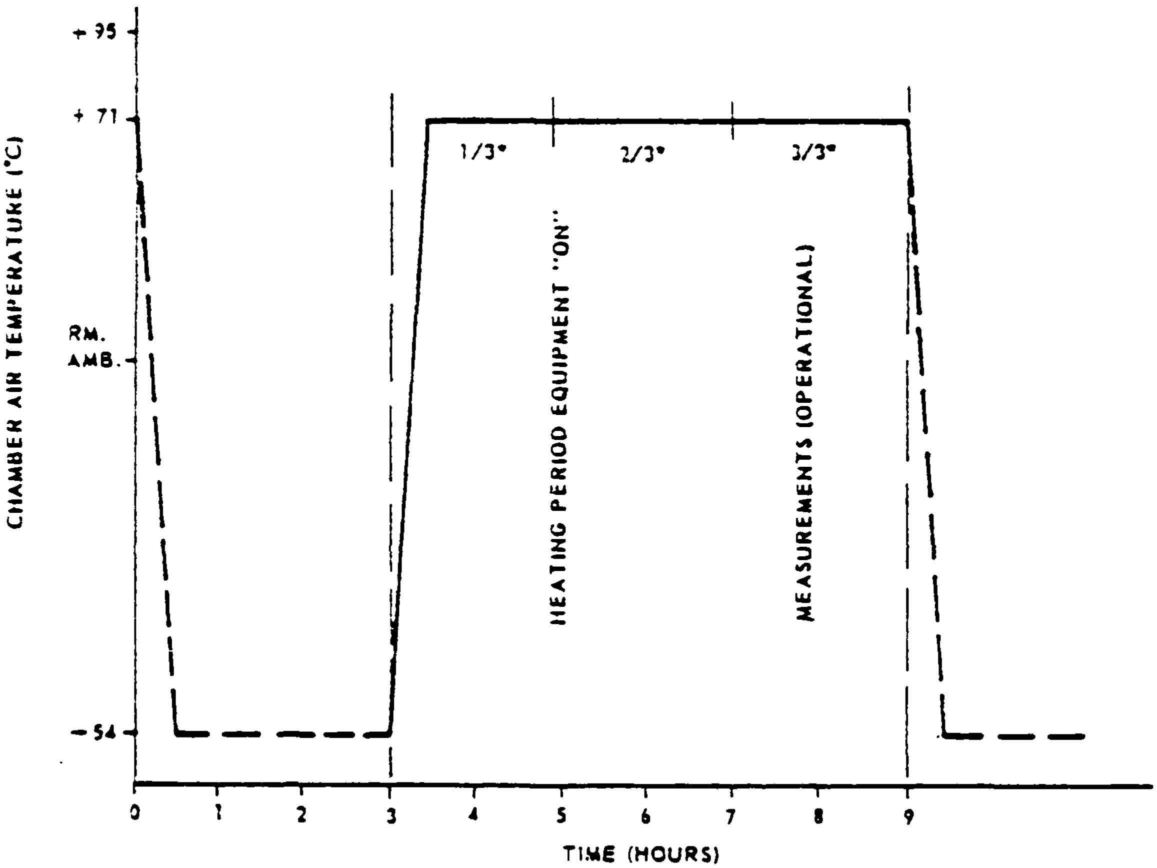
I hope these data will provide you a starting point for your investigation. At Teledyne, we feel there still exists problems in U.S.A.F. intermediate level maintenance of the APX-101. I would like to discuss this with you along with other experience on the program. So far, I have no plans to make a trip east in the near future. However, if something comes up I'll be sure to pass through Dayton. On the other hand, should you happen to be in the Los Angeles area, please let me know. If you have any trouble reaching me, feel free to contact Mr. Ed Lawson in my stead.

Very truly yours,

Jim Leighty

Jim Leighty, Manager
Intergrated Logistics Support

10 MINUTES VIBRATION DURING EACH HOUR EQUIPMENT "ON"
WITH THE INITIAL PERIOD OF VIBRATION TO START WITHIN
15 MINUTES OF TURN-ON AT LOW TERMPERATURE.



CODE: — — — — EQUIPMENT "OFF"

———— EQUIPMENT "ON"

*INPUT POWER - FIRST 1/3 "ON" TIME PERIOD = 28.5 VDC ± 1%
SECOND 1/3 "ON" TIME PERIOD = 28 VDC
FINAL 1/3 "ON" TIME PERIOD = 24 VDC ± 1%

Burn-In and PRT Test Profile

APPENDIX II

Samples of Operational Test Data for Selected Units

51EA0

74JXX

AEPRT - ADC

t_{ff} = 61 hours 0_0 = 800 hours

Month	No. of LAUs	Envir Cycles	ATP	Cum. No. of Failures	No. of OP. hrs. From ETI Reading	Cum. OP. Hrs.	No. of Pattern Failures Identified	Cum. MTBF
Mar '78	5	0	0	(0)	326	(326)	0	326
Apr '78	7	2	1	(3)	565	(891)	0	297
May '78	17	2	1	(6)	1346	(2237)	0	373
Jun '78	8	3	2	(11)	942	(3179)	1 ?	289
Jul '78	8	0	2	(13)	682	(3861)	2 ?	247
Aug '78	17	1	5	(19)	1523	(5384)	1 ?	283
Sep '78	10	0	0	(19)	666	(6050)	0	318
Oct '78	10	2	1	(22)	786	(6836)	0	311
Nov '78	5	0	0	(22)	322	(7158)	0	325
Dec '78	5	1	0	(23)	379	(7537)	0	328
Jan '79	8	0	2	(25)	629	(8166)	0	327
Feb '79	9	0	1	(26)	614	(8780)	0	338
Mar '79	12	0	0	(26)	720	(9500)	0	365
Apr '79	4	0	2	(28)	389	(9889)	0	353
May '79	9	2	2	(32)	884	(10723)	0	335
Jun '79	6	3	1	(36)	671	(11394)	0	316
Jul '79	9	1	3	(40)	1689	(13083)	1 ?	327
Aug '79	6	0	0	(40)	356	(13439)	2	336
Sep '79	3	0	0	(40)	194	(13633)	0	341
Oct '79	10	0	1	(41)	691	(14324)	0	349
Nov '79	6	0	5	(46)	692	(15016)	1	326
Dec '79	5	0	0	(46)	320	(15336)	0	333
Jan '80	11	0	1	(47)	760	(16096)	0	342
Feb '80	2	0	0	(47)	120	(16216)	0	345
Mar '80	7	0	0	(47)	419	(16635)	0	354
Apr '80	10	0	0	(47)	880	(17515)	0	373
May '80	0	0	0	(47)	0	17515	0	373
Jun '80	15	1	1	(49)	1050	18565	0	379
Jul '80	6	0	0	(49)	375	18940	0	387
Aug '80	15	2	1	(52)	1106	20046	0	386
Sep '80	3	0	0	(52)	192	20238	0	389
Oct '80	4	0	0	(52)	331	20569	0	396
Nov '80	19	2	0	(54)	1335	21904	0	406
Dec '80	5	0	0	(54)	335	22239	0	412
Jan '81	8	1	0	(55)	563	22802	0	415
Feb '81	12	1	4	(60)	1352	24154	0	403
Mar '81	8	0	0	(60)	497	24651	0	411
Apr '81	12	1	1	(62)	919	25570	0	412
May '81	15	1	0	(63)	996	26566	0	422
Jun '81	8	0	0	(63)	495	27061	0	430

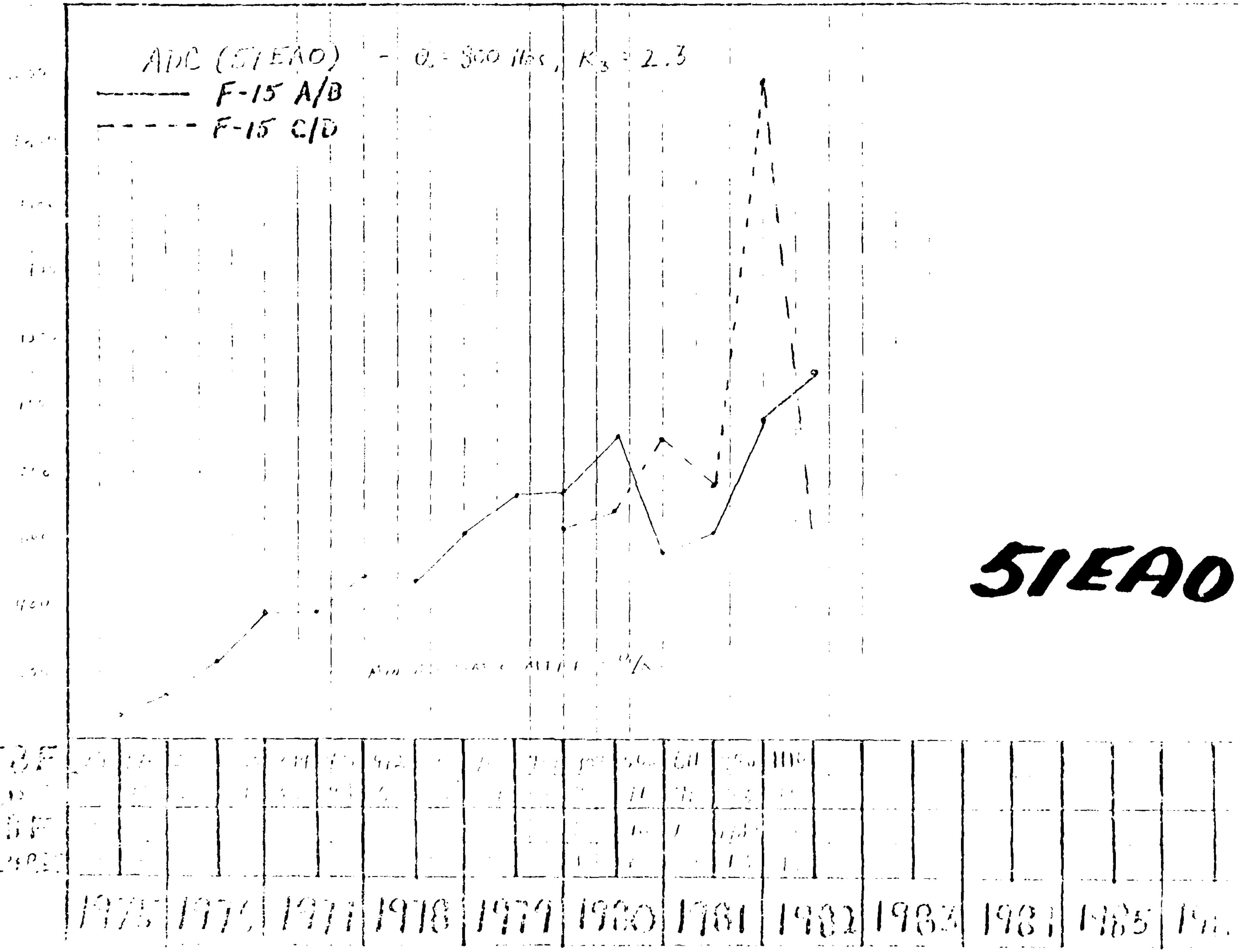
51EAO

AEPRT - ADC

t_{ff} = 61 hrs. 0_0 = 800 hrs.

Month	No. of LRUs	Envir. Cycles	ATP	Cum. No. of Failures	No. of OP. Hrs. From ETI Readings	Cum. OP Hrs.	No. of Pattern Failures Identified	Cum. MTBF
Jul '81	9	4	3	(70)	1057	28118	0	402
Aug '81	12	1	0	(71)	771	28889	0	407
Sep '81	5	0	0	(71)	315	29204	0	411
Oct '81	6	0	0	(71)	369	29573	0	417
Nov '81	0	0	0	(71)	0	29573	0	417
Dec '81	12	0	2	(73)	935	30508	0	418
Jan '82	4	0	0	(73)	245	30753	0	421

51EAO


ADC (51EAO) - Q = 300 Hrs, K_3 = 2.3
F-15 A/B
F-15 C/D
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985

51EAO

ADC
(Air Data Computer)

0_0 = 800 0_1 = WUC = 51EAO QPA = 1 CONTRACTOR: Sperry

Type of Test	Lot S/N Range	S/N's Tested	Date Started	Date Completed	Total Test Time	Rel. Fail	Total Fail	Point Est. of MTBF	LCL 90%	Initial Approval	Final Report Approved
RQT			73/1/29	73/9/9	5665	7		809			75/6/2
AFDTAE		M Req. from EC 76301A328AG19 Spec (Part I) MEDT for Unsched. Maint. 0.97 hrs O-Level No Sched. Maint. 1.83 hrs I-Level Verification 18 monthes IOC using actual data from Cat I - 6 Cat II and operational bases									
PRT											
Lot 1 (60+)	32-95	(3) 84,86,91	75/11/17	76/8/23	8240	14		589	409	76/10/29	
Lot 2 (60+)	96-158	(3) 128,133, 151	76/9/2		8030*	14*		574*	399*		
(PRT testing suspended 13 June 1977 to allow trial AEPRT)											
Lot 3 (60+)	159-220	(3) 204,209,212									
Lot 4 (65-)	221-292	(3) 288,290,300									
Lot 5 (60-)	293-395	(3)									
Lot 6 (60-)	396-455										
Lot 7 (15+)	AST as proposed by AEPRT ECP 960-M7										

* Data that is available so far.

AEPRT started in March 1978

51EAO

VSD Or Indicator Group

θ_0 = 500 θ_1 = WUC = 74JXX QPA = CONTRACTOR: Sperry

Type of Test	Lot S/N Range	S/N's Tested	Date Started	Date Completed	Total Test Time	Rel. Fail	Total Fail	Point Est. of MTBF	LCL 90%	Initial Approval	Final Report Approved
RQT	---	---	73 Apr 27 74 Feb 27	73 Aug 31 75 Jan 2	921 2846	6 5	22	Reject 569			
PRT											
Lot 1 (120)		(2)									
Lot 1 (120)	2nd Attempt	(2)	76/12/1		1803*	7					
Lot 2		(2)	77/2/8		529*	3					

(Test suspended in March 1977; started trial AEPRT)
ECP 962 447

* Data collected so far.

AEPRT started in March 1978.

74JXX

AEPRT - VSD or IG (AMNI) t_{ff} = 41 hrs

Month	No. of LRUs	Envir. Cycles	ATP	Cum. No. Of Failures	No. of OP Hrs. From ETI Readings	Cum. OP Hrs.	No. of Pattern Failure Identified	Cum. MTBF
Mar '78	9	0	0	(0)	442	(442)	0	442
Apr '78	14	11	6	(17)	1117	(1559)	0	92
May '78	12	7	1	(25)	852	(2411)	0	96
Jun '78	11	8	4	(37)	901	(3312)	0	90
Jul '78	8	4	0	(41)	644	(3956)	0	96
Aug '78	17	11	2	(54)	1115	(5071)	0	94
Sep '78	12	10	2	(66)	886	(5957)	0	90
Oct '78	20	10	2	(78)	1320	(7277)	0	93
Nov '78	14	8	1	(87)	846	(8123)	0	93
Dec '78	10	3	1	(91)	520	(8643)	0	95
Jan '79	10	2	0	(93)	505	(9148)	0	98
Feb '79	8	4	0	(97)	409	(9557)	0	99
Mar '79	8	8	0	(105)	512	(10069)	1	96
Apr '79	10	11	2	(118)	806	(10875)	0	92
May '79	9	3	0	(121)	512	(11387)	0	94
Jun '79	10	1	0	(122)	623	(12010)	0	98
Jul '79	11	2	2	(126)	657	(12667)	0	101
Aug '79	10	5	2	(133)	599	(13266)	1 ?	100
Sep '79	6	2	1	(136)	372	(13638)	0	100
Oct '79	9	4	6	(146)	763	(14401)	0	99
Nov '79	10	3	1	(150)	607	(15008)	0	100
Dec '79	8	1	2	(153)	437	(15445)	0	101
Jan '80	16	10	4	(167)	1238	(16683)	1	100
Feb '80	14	4	3	(174)	841	(17524)	0	101
Mar '80	18	4	2	(180)	1030	(18554)	0	103
Apr '80	8	1	0	(181)	361	(18915)	0	105

74JXX

AEPRT - VSD or IG (SDP) t_{ff} = 44 hrs.

Month	No. of LAUs	Envir Cycles	ATP	Cum. No. of Failures	No. of OP Hrs. From ETI Readings	Cum. OP Hrs.	No. of Pattern Failures Identified	Cum. MTBF
Mar '78	13	3	0	(3)	691	(691)		230
Apr '78	10	3	1	(7)	632	(1323)		189
May '78	10	1	1	(9)	850	(2173)		241
Jun '78	11	4	0	(13)	947	(3120)		240
Jul '78	9	4	0	(17)	853	(3973)		233
Aug '78	13	4	1	(22)	769	(4742)		216
Sep '78	9	2	2	(26)	602	(5344)		206
Oct '78	10	2	3	(31)	795	(6139)		198
Nov '78	11	4	2	(37)	691	(6830)		185
Dec '78	4	0	2	(39)	385	(7215)		185
Jan '79	12	4	0	(43)	679	(7894)		184
Feb '79	6	1	0	(44)	261	(8155)		185
Mar '79	8	0	0	(44)	343	(8498)	1	193
Apr '79	11	1	4	(49)	727	(9225)		188
May '79	8	4	2	(55)	655	(9880)		180
Jun '79	7	0	0	(55)	302	(10182)		185
Jul '79	3	0	0	(55)	136	(10318)		188
Aug '79	10	3	0	(58)	615	(10933)		188
Sep '79	8	2	0	(60)	335	(11268)		188
Oct '79	9	0	2	(62)	492	(11760)		190
Nov '79	6	4	0	(66)	391	12151	0	184
Dec '79	6	3	0	(69)	337	12488	0	181
Jan '80	10	4	2	(75)	596	13084	1	175
Feb '80	16	2	0	(77)	718	13802	0	179
Mar '80	12	2	0	(79)	591	14393	0	182
Apr '80	9	6	1	(86)	621	15014	0	175

74JXX

AEPRT - VSD or IG (AMNI) t_{ff} = 41 hrs

Month	No. of LRUs	Envir Cycle	ATP	Cum. No. of Failures	No. of OP Hrs. From ETI Readings	Cum. OP Hrs.	No. of Pattern Failures Identified	Cum. MTBF
May '80	10	1	2	(184)	673	(19588)	0	107
Jun '80	12	10	3	(197)	938	(20526)	0	104
Jul '80	3	1	0	(198)	164	(20690)	0	105
Aug '80	9	8	0	(206)	788	(21478)	0	104
Sep '80	17	3	3	(212)	1026	(22504)	0	106
Oct '80	16	6	1	(219)	991	(23495)		107
Nov '80	13	6	0	(225)	763	(24258)		108
Dec '80	17	4	3	(232)	917	(25175)		109
Jan '81	10	2	0	(234)	480	(25655)		110
Feb '81	13	6	2	(242)	983	(26638)		110
Mar '81	11	3	3	(248)	760	(27398)		110
Apr '81	10	6	5	(259)	989	(28385)		110
May '81	18	0	0	(259)	894	(29279)		113
Jun '81	18	3	0	(262)	927	(30206)		115
Jul '81	17	2	2	(266)	881	(31087)		117
Aug '81	8	2	2	(270)	545	(31632)		117
Sep '81	17	1	4	(275)	915	(32547)		118
Oct '81	6	6	3	(284)	511	(33058)		116
Nov '81	7	2	0	(286)	375	(33433)		117
Dec '81	4	0	0	(286)	169	(33602)		117
Jan '82	9	2	1	(289)	528	(34180)		118
Feb '82								
Mar '82								
Apr '82								
May '82	5	1	0	( )	303	( )	0	
Jun '82	10	4	2	( )	580	( )	0	

74JXX

AEPRT - VSD or IG (SDP) t_{ff} = 41 hrs.

Month	No. of LRUs	Envir Cycles	ATP	Cum. No. of Failures	No. of OP Hrs. From ETI Readings	Cum. of Hrs.	No. of Pattern Failure Identified	Cum. MTBF
May '80	13	3	0	(89)	573	(15587)	0	175
Jun '80	9	3	3	(95)	582	(16169)	0	170
Jul '80	2	1	1	(97)	120	(16289)	0	168
Aug '80	7	2	1	(100)	375	(16664)	0	167
Sep '80	18	4	0	(104)	823	(17487)	0	168
Oct '80	21	2	0	(106)	958	(18445)		174
Nov '80	10	8	0	(114)	580	(19025)		167
Dec '80	11	2	0	(116)	518	(19543)		168
Jan '81	7	5	2	(123)	454	(19997)		163
Feb '81	10	3	2	(128)	597	(20594)		161
Mar '81	8	3	2	(132)	490	(21084)		160
Apr '81	6	0	0	(132)	265	(21349)		162
May '81	5	1	0	(133)	217	(21566)		162
Jun '81	8	1	0	(134)	350	(21916)		164
Jul '81	3	0	0	(134)	166	(22082)		165
Aug '81	3	0	0	(134)	126	(22208)		166

74JXX

AEPRT - IG (PSDP) t_{ff} = 30 hrs 0_0 = 1000 hrs $t_{ff}/0_1$ = 0.06

Month	Number Delivered (Cum.)	Number Without Failure (Cum)	Cum. First Pass Yield	0_{yield}	Number With Only one Failure (Cum.)	Cum. Second Pass Yield	Total No. of Failure ENV/ATP	Cum. Failure	Number Failures per LRU (Cum)	Op. Hours (Cum)	0_{Time}
Jul '81	3(3)	2(2)	.67	74	0(0)	.00	1/1	(2)	.7(.7)	(135)	68
Aug '81	7(10)	6(8)	.80	134	1(1)	.50	1/0	(3)	.1(.3)	(372)	124
Sep '81	4(14)	2(10)	.71	89	2(3)	.75	1/1	(5)	.5(.4)	(530)	106
Oct '81	7(21)	7(17)	.81	142	0(3)	.75	0/0	(5)	.0(.2)	(813)	163
Nov '81	3(24)	3(20)	.83	165	0(3)	.75	0/0	(5)	.0(.2)	(908)	182
Dec '81	11(35)	8(28)	.80	134	2(5)	.71	2/2	(9)	.4(.3)	(1427)	159
Jan '82	15(50)	14(42)	.84	172	0(5)	.62	3/0	(12)	.2(.24)	(1987)	166
Feb '82											
Mar '82	40( )	31( )			6( )		9/4	(13)		( )	
Apr '82	28( )	20( )			7( )		6/4	( )	.36( )	( )	
May '82	21( )	19( )			2( )		0/2	( )	.10( )	( )	
Jun '82	31( )	23( )			5( )		5/8	( )	.42( )	( )	
Jul '82											
Aug '82											

74JXX

IFF TRANSPONDER, AN /APX - 101 (v)   RT - 10638   Predicted MTBF =1331 (from test report)

0_0 = 500 0_1 = 250   WUC = 65AAO   QPA = 1   CONTRACTOR: Teledyne Electronics

Type of Test	Lot S/N Range	S/N's Tested	Date Started	Date Completed	Total Test Time	Rel. Fail	Total Fail	Point Est. of MTBF	LCL 90%	Initial Approval	Final Report Approved
RQT	---	---	74/9/21	75/2/16	2287	3		762		---	77/7/1
PRT											
Lot 1 (120)	167-317	4) 206,213, 219,220	77/2/24	77/4/27	751	5	19	150		Reject Decision	
Lot 2(Lot 1)	167-31	4) 283,285, 287,289	77/7/1	77/9/27	2520	4	16	630	315, 1444	77/11/8	
Lot 3(Lot 2)	318-442	4) 330,366, 369,372	77/12/23	78/1/22	1849	2					
Lot 1		WP0015,30 46,60	78/2/17	78/3/29	2197	3		732	Teledyne Report		
Lot 2		WP100,140 160,200	78/7/11	78/8/19	1826	2		913	Teledyne Report		
Lot 3		WP0312,362 372,412	79/2/12	79/3/20	1142	0		>1142	Teledyne Report		
Lot 4		WP0500,570 630,710	79/8/30	79/10/14	1464	1		1464	Teledyne Report		
Lot 5		WP0850,930 995,1045	80/3/28	80/5/2	2146	3		715	Teledyne Report		

U.S. Air Force Data
65AAO

APPENDIX III

Samples of Key AFLC
Data System Reports

SUMMARIZED MAINTENANCE ACTIONS FOR SELECTED WORK UNIT CODES 81/10/30 C-C056P-R05-RX-217 PAGE 58
PERIOD ENDING 41SEP30 RCS: LOG-LCE(AR)7179
ALC: SALC SCAS TYP EQP: ACF CAD: C123 WUC: 72113
CNTL AMPLFR AM251 CAT INF C
PART II - SHOP ACTIONS

B-05

FSC 5841 P/N 01-50301-1 - NIIN/MPC C06531683

--HOW MALFUNCTION--- CODE ACUN	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN V>Z UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	PARTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED COMN UNITS	HOURS
255 NO OUTPUT	1	11.8		.0		.0		.0					.0	1	11.8		.0
TOTAL	1	11.8		.0		.0		.0					.0	1	11.8		.0
BASE ACUN																	
VKLF WRALC MRS	1	11.8		.0		.0		.0					.0	1	11.8		.0
TOTAL	1	11.8		.0		.0		.0					.0	1	11.8		.0

FSC 5841 P/N 02-5038A-1 - NIIN/MPC C00269774

--HOW MALFUNCTION--- CODE ACUN	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN V>Z UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	PARTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED COMN UNITS	HOURS
901 INTERMITTENT		1.8		.0		.0		.0					.0		1.8	1	2.0
TOTAL		1.8		.0		.0		.0					.0		1.8	1	2.0
BASE ACUN																	
ML2? PICKNCKP AFR OM		1.8		.0		.0		.0					.0		1.8	1	2.0
TOTAL		1.8		.0		.0		.0					.0		1.8	1	2.0

FSC 5841 P/N AM251 - NIIN/MPC C02127031

--HOW MALFUNCTION--- CODE ACUN	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN V>Z UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	PARTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED COMN UNITS	HOURS
127 ADJUST IMPROP		.0	1	.7		.0		.0					.0	1	.7		.0
TOTAL		.0	1	.7		.0		.0					.0	1	.7		.0
BASE ACUN																	
VTFM WSTCVER AFB MAS		.0	1	.7		.0		.0					.0	1	.7		.0
TOTAL		.0	1	.7		.0		.0					.0	1	.7		.0

FSC 5841 P/N AM251AFN22 - NIIN/MPC C06531683

--HOW MALFUNCTION--- CODE ACUN	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN V>Z UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	PARTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED COMN UNITS	HOURS
037 FLUCTUATES	2	6.3		.0		.0		.0					.0	2	6.?	2	3.7
127 ADJUST IMPROP	3	4.5	2	2.8		.0		.0					.0	5	7.3	1	1.7
255 NO OUTPUT	5	11.9		.0		.0		.0		2			5.0	7	16.9	5	15.7
300 GARBLED ELECT	1	1.0		.0		.0		.0					.0	1	1.0		.0
383 LOCK ON MAL	13	21.0		.0		.0		.0					.0	13	21.0	2	5.9
799 NO EFFECT		.0		.0		.0	5	4.8					.0	5	4.8		.0
TOTAL	24	44.7	2	2.8		.0	5	4.8		2			5.0	33	57.3	10	27.0

BASE ACUN

Copy available to DTIC does not permit fully legible reproduction

ALC: WRALC TYP ECP: ACF EAC: C007A WUC: 12313

B-06

WUC / NOUN	MONTH	INV	CP TIME	ABC	MAINT ACTION FAIL	MAINT ACTION OTH/MAL	MAINT ACTION TOT	MTBM TYPE-1	MTBM TOTAL	MANHOURS SCHED	MANHOURS UNSCH	MANHOURS SHOP	SHOP ACTION UNITS REPR	SHOP ACTION UNITS CONDM	SHOP ACTION UNITS NRTS
12313 SAFETY BELT	SEP	35	891												
CAT CFA ACT LMT USE FACT	JUL	38	812	Abort				13052	13052						
C 32 1.00	JUN	38	837					12861	12861						
	MAY	38	747		6		6	12692	12692		1				
	TOTALS		5138		6		6	27420	27420		1				
12314 ATTACHMENT RAIL	SEP	35	891						5460						
CAT CFA ACT LMT USE FACT	AUG	29	935			2	2		5351	3					
C 4 1.00	JUL	38	812						9789						
	JUN	38	837						9646						
	MAY	38	747			1	1		9519						
	TOTALS		5138			3	3		6855	3					
123XX TROOP SEATS	SEP	35	891		4	3	7	8735	1506	6					
CAT CFA ACT LMT USE FACT	AUG	29	935		1	9	10	21403	1861	12					
F 16 1.00	JUL	38	862			12	12	3012	1450	7					
	JUN	38	837		1		1	2143	1929		4				
	MAY	38	747		12	2	14	2240	1904		12				
	APR	38	826		5		5	6320	2531	2					
	TOTALS		5138		23	26	49	3576	1679	27	16				
12XXX FUSELAGE COMP GEN	SEP	35	851		6	44	57	210	12	44	16	20	1		
CAT CFA ACT LMT USE FACT	AUG	29	975		5	106	116	297	13	203	27	48	5	1	
C 1 1.00	JUL	38	812		2	44	47	87	17	81	27	16	2		
	JUN	38	837		2	22	36	49	14	9	42	4	1		
	MAY	38	747		24	32	59	48	12	61	33	82	10		
	APR	38	826		23	54	81	72	14	171	95	55	11		
	TOTALS		5138		62	302	396	83	13	569	240	225	30	1	
13000 LANDING GEAR	SEP	35	851												
CAT CFA ACT LMT USE FACT	AUG	29	975								4				
A 3 1.00	JUL	38	812								21				
	JUN	38	837								4				
	MAY	38	747								26				
	APR	38	826						7119		28				
	TOTALS		5138								83				
130XX SUBSYSTEM SUMMARY	SEP	35	891												
CAT CFA ACT LMT USE FACT	AUG	29	935								4				
1 1.00	JUL	38	812								21				
	JUN	38	837								4				
	MAY	38	747								26				
	APR	38	826						2373		28				
	TOTALS		5138								83				
13100 MAIN GEAR ASSY	SEP	35	891			1	1	2730	1092	24	5				
CAT CFA ACT LMT USE FACT	AUG	29	935					2676	1070	105	7				
A 2 1.00	JUL	38	812		7		4	2448	979	67	20				
	JUN	38	837				1		2412	48	5				
	MAY	38	747						4759		7				
	APR	38	826			1	1		2373	1	2				
	TOTALS		5138		2	2	7	5141	1469	246	41				

ALC: WRALC TYP EQP: ACF FAD: C130B

WORK UNIT CODE	WCUN	CAT IND	PER CENT FAILS	FAILURES CURR QTR	FAILURES LAST 12 MOS	REPLACEMENTS P-R A/T CODES	MEANTIME BETWEEN MAINTENANCE TYPE-1 CURR QTR	AVG LAST 12 MOS	RATIO-CURR QTR/LAST 12	RATIO-CURR QTR/AL	MEAN SORTIES BCF
22XXX	SYSTEM SUMMARY		16.4	1195	5457	1093	54	43	1.26	.00	17
22EXX	SUB-SYSTEM SUMMARY		4.7	340	1608	428	189	145	1.30	.00	61
22EBC	THERMOCPL	B	1.6	118	320	119	9815	13079	.75	.01	3184
22EBD	AMPLIFIER TD	B	.9	65	379	25	990	614	1.61	2.83	321
22EAQ	CABLES	B	.8	56	520	205	13788	5366	2.57	3.77	4473
22EEA	SPEED SENS SW	B	.2	18	61	18	3575	3812	.94	1.14	1159
22EAG	COORDINATOR	B	.2	14	58	13	4596	4009	1.15	1.52	1491
22EAD	MECHANICAL	B	.2	12	52	3	5362	4471	1.20	2.31	1739
22EEL	THERMOCPL HARNESS	B	.2	12	40	12	10724	11626	.92	.79	3479
OTHER			.6	45	171	33			.00	.00	
22GXX	SUB-SYSTEM SUMMARY		3.7	271	1188	179	79	65	1.22	.00	19
22GBE	INDICATOR INTERGTD	A	.9	64	248	29	1340	1250	1.07	1.70	326
22GAA	IND TACH	B	.7	54	181	45	1589	1713	.93	1.63	386
22GCA	IND TIT	B	.5	36	144	27	2383	2153	1.11	1.15	579
22GAB	GENERATOR	B	.5	33	147	30	2600	2109	1.23	1.29	632
22GBD	TORQUEMETER SYSTEM	B	.3	19	75	3	1129	1033	1.09	2.78	274
22GGB	XMIT OIL QUANTITY	B	.2	16	111	12	5362	2793	1.92	3.12	1304
22GPA	IND TORQ	B	.2	14	76	5	6128	4079	1.50	3.08	1491
OTHER			.5	35	184	28			.00	.00	
225XX	SUB-SYSTEM SUMMARY		2.1	151	605	105	426	384	1.11	.00	138
22532	DATUM CONTROL	B	.7	49	232	11	1313	1002	1.31	1.61	426
2251E	FUEL CONTROL	B	.3	23	82	12	2798	2836	.99	1.72	907
22515	NOZZLE	B	.2	18	57	17	25023	28555	.88	.03	8118
2251F	SW ASSY PRESS	B	.2	12	46	12	5362	5055	1.06	2.17	1739
22536	PARALLELING	B	.1	8	26	7	8043	8943	.90	.01	2609
2253A	FUEL SHUT OFF	B	.1	8	30	8	8043	7751	1.04	1.73	2609
22511	PUMP	B	.1	4	12	4	16086	19376	.83	14.52	5219
OTHER			.4	29	101	32			.00	.00	

B-22

PERIOD ENDING 81SEP30RCS: LCG-LOE(AR)7104

ALC: WRALC TYP EQP: ACF FAD: C130
WUC: 77CF0

----------MEANTIME BETWEEN MAINTENANCE TYPE-1----------					--FAILURE TOTAL--					
CURRENT QUARTER	PREVIOUS QUARTER	LAST 12 MOS	RATIO-CURR CTR/LAST 12	RATIO-CURR CTR TO AL	CURRENT QUARTER	LAST 12 MOS	ACTION LIMIT	QPA	USE FACTOR	CAT INC
106	116	100	1.06	.82	14	58	COC130	001	1.10	B

- - - WHEN DISCOVERED CODE SUMMARIES FOR CURRENT QUARTER FAILURES - - -

CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS
B	BEFR FLT NOABRT	1	D	IN FLT-NO ABORT	11	F	BTWN FLT-GRD CR	2			

- - - HOW MALFUNCTION CODE SUMMARIES FOR CURRENT QUARTER FAILURES - - -

CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS
255	NO OUTPUT	2	381	LEAKING	2	525	PRESS INCORRECT	1	692	VIDEO FAULTY	7
721	IMP RE ELE INPT	2									

- - - ACTION TAKEN CODE SUMMARIES FOR CURRENT QUARTER FAILURES - - -

CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS	CODE	NOUN	FAILS
L	ADJUST	2	P	REMOVED	12						

- - - SUMMARY OF FAILURES BY BASE - - -

BASE	FAILS	BASE	FAILS	BASE	FAILS	BASE	FAILS
UNIDENTIFIED	14						

DATA FOR THE FOLLOWING WEAPON SYSTEM CAN BE IN THIS REPORT:
C130A C130D AC130A RC130A

END PRINT END PRINT END PRINT END PRINT

B-23

APPENDIX IV

Sample of Maintenance Codes and Determination of Component Failure Counts

SAMPLE AFM 66-1 MAINTENANCE REPORT ON EAIC

MAINTENANCE DATA COLLECTION RECORD

OMB NO. 21-R0227

1. JOB CONTROL NO.	3480607
2. WORKCENTER	
3. I.D. NO./SERIAL NO.	730095
4. MDS	
5. EQ/CL	
6. TIME	513.5
7. PRI	
8. SORTIE NO.	
9. LOCATION	
10. ENG. TIME	
11. ENGINE I.D.	
12. INST ENG TIME	
13. INST. ENG. I.D.	
14.	
15.	
16.	
17. TIME SPC REQ	
18. JOB STD.	
19. FSC	
20. PART NUMBER	ED741900-14
21. SER. NO. ~~OPER. TIME~~	491
22. TAG NO.	552664
23. INST. ITEM PART NO.	
24. SERIAL NUMBER	
25. OPER. TIME	

ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP DAY	I STOP HOUR	J CREW SIZE	K CAT LAB	L CMD ACT ID	M SCH CODE	N EMPLOYEE NUMBER
1	B		11PDO	P	F	290	01	14:00	348	14:30	2				
2															
3															
4															
5															

26. DISCREPANCY
L.H. A/C LATCHED AND LIGHT ILLUMINATED IN COCKPIT.

27. CORRECTIVE ACTION
REMOVED

28. RECORDS ACTION

*U.S.Government Printing Office: 1975 — 659-576

AFTO FORM MAY 75 349 PREVIOUS EDITION IS OBSOLETE.

ACTION TAKEN (A/T) CODES

REF. SECTION B, AFLCR 65-15

FAILURE CATEGORIES

B	BENCH-CHECKED-SERVICEABLE
E	INITIAL INSTALLATION
F	REPAIR
G	REPAIR/REPLACE MINOR PARTS
H	EQPT CHECKED-NO REPAIR REQD
J	CALIBRATED-NO ADJ REQD
K	CALIBRATED-ADJUSTMENT REQD
L	ADJUST OR RESET
P	REMOVED
R	REMOVE AND REPLACE
S	REMOVE AND REINSTALL
V	CLEAN
X	TEST-INSPECT-SERVICE
Z	CORROSION TREATMENT

MAINTENANCE ACTION CATEGORIES

A	BENCH CHECKED AND REPAIRED
C	BENCH CHECKED-REPAIR DEFERRED
D	BENCH CHECKED-TRANSFERRED TO ANOTHER BASE
1-7	BENCH CHECKED-NOT REPAIRABLE THIS STATION (LACK OF EQUIPMENT, TOOLS, TECHNICAL DATA ETC.)
8	BENCH CHECKED-RETURN TO DEPOT
9	BENCH CHECKED-CONDEMNED
M	DISASSEMBLE
N	ASSEMBLE
Q	INSTALLED
T	REMOVE FOR CANNIBALIZATION
U	REPLACED AFTER CANNIBALIZATION
Y	TROUBLESHOOT

HOW MALFUNCTION (H/M) CODE TYPES

REF. SECTION B, AFLCR 65-15

TYPE 1

INTERNAL FAILURE

ANY HOW MALFUNCTION CODE EXCEPT TYPE 2 OR 6 (SAMPLES)

70	BROKEN
127	ADJUSTMENT IMPROPER
169	INCORRECT VOLTAGE
190	CRACKED
290	FAILS DIAGNOSTIC TEST
585	SHEARED
943	DATA ERROR

(196 HOW MAL CODES)

TYPE 2

INDUCED FAILURE

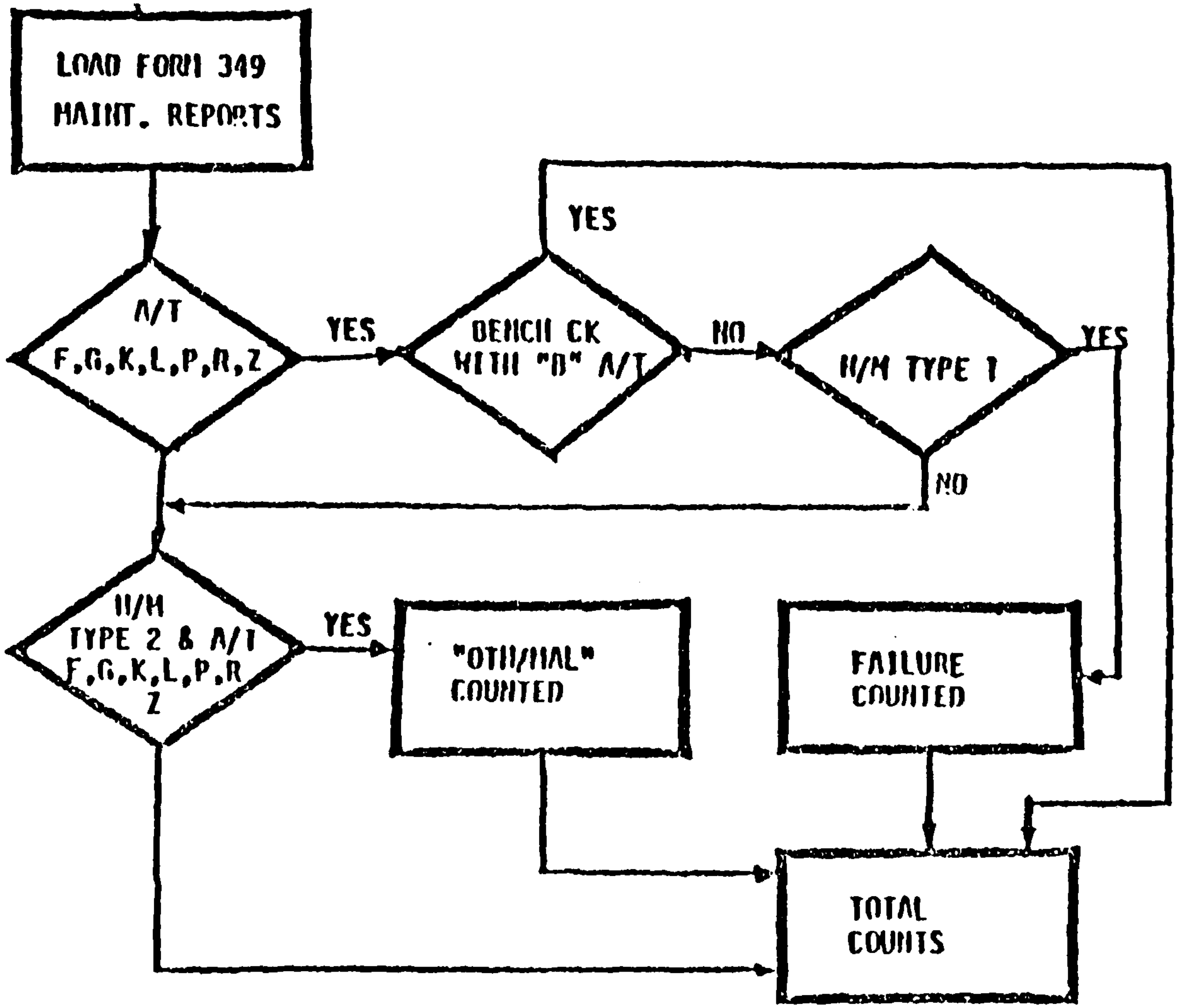
086	IMPROPER HANDLING
092	MISMATCHED
105	LOOSE/DAMAGE HARD
106	MISSING HARDWARE
108	SAFETY WIRE DAMAGE
158	LAUNCH DAMAGE
167	TORQUE INCORRECT
204	ACCIDENTAL EXPLOS.
230	DIRTY
246	IMPROPER MAINT.
301	FOREIGN OBJ. DAMAGE
303	BIRD STRIKE DAMAGE
424	EXT. POWER SOURCE
447	WRONG LOGIC
518	IMPROPER ROUTING
553	NOT TO SPEC
602	ASSOC. EQUIP. MALF.
697	FAULTY TAPE
698	FAULTY CARD
709	ADMIN. CONDEM.
731	BATTLE DAMAGE
877	TRANSPORT DAMAGE
878	WEATHER DAMAGE
931	INADVERT. OPER.
942	ILLEGAL OPER.
948	OPERATOR ERROR

TYPE 6

NO DEFECT

632	EXPENDED
793	NO DEF.-TCTO KITS
797	NO DEF.-TOC CW
798	NO DEF.-T.O. N/A
799	NO DEFECT
800	NO DEFECT ACCESS
801	NO DEFECT-TOC
802	NO DEFECT-PAR
803	NO DEFECT-TIME CH.
804	NO DEFECT-SCHED.
805	NO DEFECT-OTHER
812	NO DEFECT-ASSOC.
911	ENG. TCTO CORRECTION

FAILURE COUNTING FROM AFM 66-1 DATA
RCS LOG-MMO(AR) COMPUTER PROGRAM



APPENDIX V

Sample Sets of Data
From AFLC Data Systems
on Key Parameters
Used in Research

AFBRMC DATA BASE
F-4E DATA WORK UNIT 513H0
DATES 7707-7912
Text File: F4EH0 DSD File: F4E513H0

YR/MO	OPTIME	MTBF	MTBM	FAIL	INVEN	MHRS	NRTS
7707	13826	178	99	102	692	849	11
7708	15139	161	90	95	688	790	6
7709	13968	145	80	100	686	847	6
7710	10320	144	79	79	564	630	6
7711	15208	152	86	81	659	602	6
7712	12944	160	94	81	670	591	21
7801	13044	175	103	74	694	816	13
7802	10624	153	88	84	676	766	5
7803	14636	179	100	56	690	509	11
7804	14530	172	99	92	682	818	7
7805	13321	182	97	86	682	860	10
7806	14128	176	99	61	665	507	7
7807	12302	177	99	78	628	646	12
7808	14407	183	112	84	652	784	10
7809	12969	184	113	54	646	585	10
7810	12500	192	117	70	651	623	18
7811	12632	193	123	73	654	563	9
7812	11826	172	115	72	653	565	8
7901	12667	174	121	68	590	577	4
7902	11733	163	110	82	656	685	5
7903	14190	167	109	81	637	763	27
7904	13725	176	107	62	607	633	15
7905	13969	168	104	106	637	867	6
7906	13694	160	102	90	609	778	9
7907	12557	145	101	81	627	693	16
7908	13962	161	111	79	574	742	14
7909	11991	146	103	103	562	945	14
7910	12869	164	112	54	538	419	5
7911	11353	149	103	86	586	759	14
7912	9666	162	112	69	570	507	16

AFBRMC DATA BASE
F4E DATA WORK UNIT 513H0 (CONT'D)
DATES 8001-8112
TEXT FILE: F4X2 DSD FILE F4E51X2

YR/MO	OPTIME	MTBF	MTBM	FAIL	INVEN	MHRS	NRTS
8001	11140	151	103	58	594	574	8
8002	11014	191	130	40	590	407	7
8003	11544	217	142	57	571	586	13
8004	11655	259	162	35	571	481	3
8005	10740	225	141	59	525	535	7
8006	11314	241	156	46	555	450	5
8007	9259	197	136	49	555	453	3
8008	9877	175	123	73	512	631	0
8009	9979	182	128	38	543	381	6
8010	9951	190	145	46	522	395	8
8011	7672	230	150	36	544	412	10
8012	9203	242	121	29	536	350	7
8101	8100	183	133	63	517	675	7
8102	9246	197	129	35	523	449	6
8103	10711	196	163	45	490	530	11
8104	9719	263	148	33	520	320	8
8105	9452	241	132	46	495	424	7
8106	9959	214	115	47	494	459	11
8107	10201	205	132	45	509	430	11
8108	9885	191	130	59	513	512	8
8109	8895	215	148	31	527	238	7
8110	9296	158	117	87	511	721	12
8111	8799	164	118	46	498	441	4
8112	8979	148	110	50	503	394	14

AFBRMC DATA BASE
F4D DATA WORK UNIT 513U0
DATES 7701-7912
CSD FILE F4D513U0
TXT FILE F4D3U0T

YR/MO	OPTIME	MTBF	MTBM	FAIL	INVEN	MHRS	NRTS
7701	7995	80	60	110	460	673	6
7702	8544	87	67	74	446	473	1
7703	9471	96	77	88	467	524	3
7704	9137	116	88	73	421	573	2
7705	11443	136	102	60	467	363	2
7706	8639	141	103	74	468	461	1
7707	7162	129	98	78	467	417	4
7708	9712	120	91	60	456	446	4
7709	7990	120	91	70	440	470	1
7710	6770	124	91	67	344	537	3
7711	9117	130	96	46	444	355	2
7712	6832	146	100	43	440	346	5
7801	6326	129	88	8[illegible]	458	595	7
7802	8046	118	77	52	405	418	3
7803	8940	126	79	49	462	372	6
7804	7861	162	102	52	427	305	10
7805	8922	174	110	47	426	442	6
7806	9260	168	114	56	665	382	5
7807	7231	157	100	59	456	491	5
7808	8897	148	96	57	454	559	10
7809	8390	130	86	73	453	478	6
7810	8323	130	92	67	458	403	7
7811	8514	132	95	51	443	393	4
7812	7301	142	99	52	653	463	9
7901	7349	142	101	60	402	364	12
7902	8032	132	99	60	441	389	4
7903	9537	138	110	61	437	374	6
7904	8846	147	110	59	442	491	8
7905	8656	147	104	64	449	457	12
7906	8251	133	94	70	425	483	5
7907	8397	140	100	48	443	435	6
7908	8891	158	117	44	416	317	23
7909	7750	154	117	71	394	589	10
7910	8463	149	115	54	395	422	3
7911	7303	126	98	62	410	523	4
7912	6720	154	118	30	448	240	2

AFBRMC DATA BASE
F4E DATA WORK UNIT 513U0
DATES 8001-8206 (8007+6 MSG)
CSD FILE: F4DU0X2

YR/MO	OPTIME	MTBF	MTBM	FAIL	INVEN	MHRS	NRTS
8001	7467	159	126	43	440	387	4
8002	7237	180	149	46	437	326	5
8003	7680	171	141	42	424	259	2
8004	7714	168	139	47	431	369	4
8005	7465	147	122	66	446	395	2
8006	7620	161	127	29	432	244	5
8007							
8008							
8009				(DATA MISSING)			
8010							
8011							
8012							
8101	7086	181	138	50	424	359	8
8102	7638	179	131	45	398	389	6
8103	7625	161	120	42	398	330	15
8104	7432	181	117	37	442	327	9
8105	7395	195	128	36	374	299	11
8106	7483	205	127	38	397	401	9
8107	7617	205	153	38	422	263	7
8108	7795	185	139	50	441	443	11
8109	6979	179	144	37	427	265	7
8110	7425	159	121	53	465	449	4
8111	6133	159	123	39	435	278	2
8112	6845	142	107	52	432	517	4
8201	5830	137	111	42	409	341	1
8202	6027	141	115	34	415	282	4
8203	8022	173	141	39	441	407	11
8204	7147	212	163	27	359	188	2
8205	6789	209	156	39	422	328	4
8206	7319	213	157	34	400	269	0