# A STUDY OF PRODUCT DEFICIENCIES IN LARGE ORGANIZATIONS

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## PREFACE

Industry is becoming more complex and specialized everyday. One problem arising from this change is the difficulty of top management surveillance over many of the operations of the company. One of the many important operations of a large organization is the analysis and control of product deficiencies. This thesis proposes an operation with particular application and integration with methods now being used by the United States Air Force. Although many Air Force terms are utilized in the examples, this is not to imply that the Air Force is the only group that can utilize this system to great benefit. The primary reason for using the Air Force system as an illustration is that the author has had some experience with this particular system while employed as an Electronics Engineer at Tinker Air Force Base, Oklahoma, during the summer of 1960.

There are, undoubtedly, various ways to analyze and control the materiel deficiencies in large companies. One method is presented in this thesis although other items and ideas useful in other methods are also mentioned frequently. The analysis of deficiencies presented in this paper is based on the assumption that the total number of deficiencies is more important than any other item. The control of the deficiencies consists mainly in concentrating the time of the engineers and statisticians on the parts with the greatest number of deficiencies; as a result most deficiencies can be found and removed rapidly.

Indebtedness is acknowledged to my major advisor, Professor Paul A. McCollum, for his many helpful suggestions in the writing of this thesis; to the following for providing me with information on the thesis subject: Danny Forson and James Smith of the Integrity Branch, Bobby L. Barnes and Charles Dimick of the Electronic Branch of the Science and Engineering Division at Tinker Air Force Base in Oklahoma City; to the many other engineers and secretaries in the Electronic Branch at Tinker Field for assistance in producing some of the charts and tables presented in this paper; and to my wife, Jean, whose constant encouragement as well as good typing made this thesis a reality.

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## CHAPTER I

## INTRODUCTION

### PURPOSE OF STUDY

The purpose of this study is to discuss techniques of collecting data for and controlling some of the deficiencies inherent in most large organizations. Every large group of activities that is concerned with a great volume of merchandise has a problem of product depreciation because of deficiencies. The large companies, especially those whose equipment production and/or utilization is not geographically concentrated, usually need an analysis branch that will collect information on all deficiencies.

The deficiency analysis branch can provide the company management and/or product manufacturer with information on part failures. The management can then adjust the manhour and monetary allotments to improve the maintenance techniques. Also, the manufacturer, whether or not a part of the same company, can use the failure data to improve the design of the equipment. As a result, the analysis group helps to increase not only the company efficiency but also the product reliability.

### A PRELIMINARY OF THE OTHER CHAPTERS

Some ideas involved in a specialized maintenance structure will be discussed in Chapter 2. It will be assumed that the company has delegated all the maintenance responsibility and authority to one division of the company called the maintenance organization. This group has full control of all maintenance deficiency data and manhour allotment necessary to accomplish the maintenance function.

A manhour reporting and control system is always an economic asset for any concern that employs a great number of people. This system can help the management estimate future manhours needed as well as re-allot the personnel to positions more advantageous to the company. Such a system will be discussed in Chapter 3.

Obviously, a good data collection and processing system is necessary if, in a large scale system, sufficient and valid data is to be made available to the analysis expert. A deficiency data collection and processing system will be discussed in some detail in this dissertation. Some of the important aspects of this system are (1) the type of data recorded, (2) method of recording, (3) accuracy of data, and (4) amount of data recorded and/or processed. After some information is given on the product deficiency data collection system in Chapter 4, a certain area of this system will be used in the statistical analysis of Chapter 6.

A statistical analysis of deficiency data in large scale systems is dictated by the large volume of data being processed. It would be impossible to investigate every deficiency that is reported in a large scale system; therefore, a good statistical analysis, compared to other analysis methods, will be more apt to point to possible problem areas. The available manpower can then be most efficiently concentrated in these areas. It is assumed that the companies interested in this study do have a large quantity of deficiency data; therefore, the statistical approach will be given more emphasis than any other type of analysis. Several techniques of statistical analysis are discussed in Chapter 5 in addition to those used in the numerical example on electronic systems in Chapter 6.

Many of the techniques discussed in this study of deficiencies will be those recommended and utilized by the United States Air Force (hereafter referred to as U.S.A.F.) in its world wide program. The Air Force Manual (hereafter referred to as A.F.M.) 66-1 explaining the organizational and field maintenance management concept of the U.S.A.F. will supply many of the techniques described in this thesis. Because all Air Force manuals are periodically changed, it is quite conceivable that a new manual will imply obsolescence of some methods suggested in this study, even before it is completed.

## HISTORICAL BACKGROUND

Since many of the ideas discussed in this paper have been found through a study of the A.F.M. 66-1 concept of organizational and field maintenance, a little history of this concept and a discussion of its predecessor appear to be in order.

The A.F.M. 66-1 concept of organizational and field maintenance management was service tested for approximately three or four years at Dover Air Force Base, Delaware, under project "Airfoam." The purpose of this concept was to develop a standard manhour accounting system for the U.S.A.F. Different commands had different procedures.

In July, 1958, the present A.F.M. 66-1 was initially issued. It is revised only on a yearly basis. The first major revision was issued in July, 1959. Another revision made in July, 1960 is forthcoming.

Basically, A.F.M. 66-1 provides a system for collecting and accounting for manhour expenditure at Wing/Base level. It is a tool designed to provide the wing commander or base commander with improved management of his available manpower and maintenance functions.

Superimposed over the manhour accounting system in A.F.M. 66-1 is a mechanized material deficiency data collection system.

Because of the new A.F.M. 66-1 system being activated, most of the old unsatisfactory report system has been deleted by the Air Force Technical Order 00-35D-54 dated 1 April 1960. The routine unsatisfactory reports have been discontinued, but the emergency unsatisfactory reports have remained.

The routine unsatisfactory reports were very detailed reports of deficiencies compared to the present reports under the A.F.M. 66-1 system. However, it was becoming increasingly more difficult to find maintenance personnel time to complete the necessary number of forms as well as to find sufficient engineering manhours needed to analyze each report; this of course, was caused by the increasing complexity of our air force equipment with its natural higher failure rate.

Because a few weeks' delay is anticipated in the data processing and analysis work, U.S.A.F. management feels that the emergency unsatisfactory reports should be continued to prevent a major problem in some areas.

At the present time, the A.F.M. 66-1 manhour accounting and material deficiency collection system works in conjunction with the old emergency unsatisfactory reports system.

## GENERAL INFORMATION ON ANALYSES

In addition to the A.F.M. 66-1 analyses that will be discussed subsequently in this thesis, some other analysis techniques will be considered. A few of these have been developed and used by the U.S.A.F. in the Analysis Section of the Product Improvement Branch (Science and Engineering Division) at Tinker Air Force Base in Oklahoma City. Still another method of analysis to be considered was developed and used by the author while he was employed by the Electronic Branch (Science and Engineering Division) at Tinker Air Force Base during the summer of 1960.

The statistical analysis illustrated in Chapter 6 takes into consideration the concepts discussed in the first five chapters. The analysis recommended is really a basis for statistically analyzing maintenance deficiency data. It is assumed that new methods and increased efficiencies will continually develop in the reporting system and as a result periodic innovations in the analysis techniques will be warranted. The approach discussed here is fairly simple since the reliability of some processed data does not justify the attempt to reduce percentage errors by complex methods at this time. However, the decision of whether or not to use complex analysis methods should be dependent upon the specific information that is being sought after. It is felt by the author that the analysis discussed here is one of the more feasible ways of finding the information sought in this problem. The primary information sought here are the deficiency areas that are large in terms of number of actual or true failures. Some secondary goals will be discussed in the statistical analysis on electronic systems.

## CHAPTER II

## SPECIALIZED MAINTENANCE CONCEPT

Complexity is the rule rather than the exception in most large organizations. Therefore, to gain high efficiency certain efforts must be delegated to specialists. This is certainly true of the maintenance effort which is of prime concern in this thesis.

A good maintenance organization may contain as many variations in operation as there are divisions of the organization. However, there are certain general functions and responsibilities that remain fixed although the size of the divisions or the complexity of the equipment may vary. One very effective way to accomplish a maintenance effort is to identify certain functions and put each under the control of a well qualified supervisor; a senior maintenance supervisor can then be placed in charge of all functions with, of course, a well constructed operational channel from the senior supervisor through the intermediate management to the lowest level of supervisors.

Most of the remainder of this chapter will be devoted to describing briefly the position of the senior maintenance supervisor or chief. This brief description of the position of chief should give some information about what a specialized maintenance organization is. The positions of two subordinate supervisors will be discussed in later chapters concerned mostly with the details of the manhour reporting and the deficiency data collecting functions.

The senior maintenance chief is the executive manager of the maintenance organization. Therefore, he must have outstanding abilities in leadership and administration. This leadership and management ability must be used continually in this position if the subordinate supervisors are to have the guidance they need to make the operation efficient. If the senior supervisor maintains a well qualified staff, the information necessary will be flowing smoothly through all the supervisory positions. In other words, if the senior supervisor controls the over-all function by delegating authority and responsibility to qualified personnel in a manner understandable to everyone concerned, the efficiency of the operation can be very good.

Some of the functions over which the senior supervisor has jurisdiction are the following: training control, maintenance control, quality control, maintenance standardization, and analysis, records and reports. Some of these areas will be discussed rather briefly later in this thesis.

In supervising the total maintenance effort the senior chief must keep the work balanced at all times. That is, the time, money and personnel available must be continually re-allotted to those areas that will accomplish the maintenance function most effectively. For example, the product reliability can be improved if information on manhour distribution and deficiency data is compiled and utilized.

# CHAPTER III

## MANHOUR REPORTING AND CONTROL

A good manhour reporting system can provide management with information about where the available and assigned maintenance manhours are expended. One advantage of having this knowledge is that management can then decide whether or not the available man-hours can be re-alloted more advantageously among the various jobs in the different divisions of the company.

There are probably many good systems for reporting and controlling maintenance manhours. The particular method to be discussed here takes into account any deviation from the normal and is designed to provide a maximum accuracy at a minimum cost. The name of this accounting system is exception time. It will give indications of abnormal distributions and help determine reasons for them so corrections can be made. The U.S.A.F. has used this type of accounting for some time so the structure of the U.S.A.F. program is referred to for most specific terminology and examples used in this study.

The following discussions are focused on a reporting center, the work of its supervisory personnel, and some reports that show the distribution of manhours expended.

### REPORTING UNITS

The maintenance division is composed of a group of reporting units which are called "work centers." The purpose of this breakdown is to establish elements of control necessary in the exception time accounting system. There are two types of work centers: one is the reporting work center and the other is a nonreporting work center.

Reporting work centers are located within the maintenance division itself, such as the squadron maintenance offices, flights, periodic docks, etc. Nonreporting work centers are outside the maintenance activity or function; typical examples are orderly rooms, group or wing headquarters activities, and food services.

The analysis, records and reports activity usually coordinates with the maintenance activity to establish work centers for the entire maintenance group. The quantity and location of work centers is based on the number of personnel assigned to an activity, span of control, work load, work schedules and duty schedules. A work center is set up at any place that a maintenance man may be assigned or loaned to work.

After the work centers are assigned completely, the analysis, records, and reports section then coordinates with the statistical services in setting up work center codes. These codes consist of a maximum of five digits arranged so as to allow consolidation of manhour information for each level of maintenance management by dropping successive digits from the end of the code. The following is an example of a portion of a wing organizational coding system.

| | |
|---|---|
| 10000 | Wing Headquarters |
| 10100 | Director of Materiel |
| 20000 | Air Base Group |
| 21000 | Food Service Squadron |
| 30000 | Maintenance Group |
| 30100 | Group Personnel |
| 31000 | Chief of Maintenance |

32000 Field Maintenance Squadron
32010 Squadron Headquarters
32100 Squadron Maintenance
32200 Power Plant
32210 Jet Engine Minor Repair
32211 Jet Engine Teardown

In order to determine how maintenance labor was used, it is necessary to know how many manhours are available to a work center. A master roster of all personnel at each activity is used for this purpose. The personnel are listed by name, rank, work center code and labor distribution code of assignment. The labor distribution code of assignment specifies the major specialty area of the workers. For example, a line chief has a certain amount of administrative work as part of his assigned duties. He is a supervisor, primarily, and, therefore, his labor distribution code of assignment will be 03 (supervision).

The analysis, records, and reports branch collects the master roster data and forwards it to the statistical services for listing by work center and labor distribution code. After going through a correction procedure (sending roster to work centers and back to analysis section), the analysis, records, and reports section notifies the statistical services of the original assigned manhours for each man for the reporting period along with the corrected roster. The assigned manhours is computed by multiplying the number of normal duty days in the reporting period by eight hours each day. A forty-hour work week is considered normal unless a holiday is present. Any time over the normal work week is reported as overtime on exception cards. Because all the necessary information accrued comes through the work center, a study of the work center supervisor's position will help clarify the exception time accounting.

The work center supervisor is responsible for many items important to the flow of accurate information to the analysis group. A few of these items will be discussed now.

After the statistical services supplies the work center with an initial supply of exception time cards on each employee, the work center supervisor is responsible for keeping a reasonable number of cards on hand continually. These cards must be kept accurate in every detail. Since the master roster listing needs to be very accurate, the center chief must coordinate each entry with the appropriate maintenance activity.

There are many different types of exception cards used by the center chief. The following cards discussed are typical. An "assigned card" must be made for statistical services on each new employee assigned to the work center. A "revision card" is necessary when any personal data is incorrect. A "transferred card" is used to indicate anyone transferring from the work center. "Correction cards" should be submitted anytime an error is found in the 'daily labor exception listing'. Other exception cards to be forwarded to statistical services are those to indicate expended manhours (1) in any labor code other than that covered by the assigned labor distribution code, (2) loaned to another activity or work center, and (3) used in overtime work.

The work center supervisor receives, analyzes, and takes any necessary action on the work center daily labor exception listing, semi-monthly, and monthly actual manhour utilization reports, all of which will be described subsequently.

## MANHOUR REPORTS

There are in the U.S.A.F. exception time accounting system four reports that are mandatory. They are designed to give maintenance management a good picture of trends in manhour utilization as well as some specific information on applications. The low management level reports contain more detailed summations of data taken from the daily listings than do the higher management level reports because higher levels of management are not interested in some details.

If all levels of management do not use all available reported information, then obviously, the system will not work very effectively. Therefore, all echelons of management must be well trained in the utilization of the reported data. Some immediate action may need to be taken in many instances such as excessive absenteeism or other nonproductive excesses so these situations must be recognized by those who have jurisdiction over them.

To get some ideas about how the exception time accounting system can help maintenance management, it seems logical that a knowledge of the information put into the four various types of reports is necessary. Some of this data will be discussed now along with some possibilities for utilization.

Report number one is the daily labor exception listing which is prepared by the punch card accounting machine (P.C.A.M.) in the statistical services. Each labor transaction that affects a work center will be entered on this listing. The daily report is used by the work center supervisor for several reasons.

One advantage of the daily report is to permit the supervisor to check loans and borrows from the previous day to determine whether or not the actions were correctly reported. If errors are found, then correction cards will need to be submitted.

Another purpose of the daily report is to indicate trends or abnormalities which may need to be corrected immediately. For example, a work center may very often be charged for details beyond that considered as normal. If this is allowed to continue, the normal productiveness of this particular work area will decrease. Also, the daily listing indicates the manhours charged to labor distribution code of assignments different from those originally assigned; so comparisons can be made between original estimates and actual use. Absences can be compared to the total manhours assigned to a work center so unproductive labor percentages can be determined. The supervisor may in many cases control the absences from the work center. The overtime information listed will help the work center chief reschedule his personnel work hours.

Report number two is the semi-monthly actual labor utilization report. This report is used by both work center supervisors and branch chiefs. Problem areas can be determined by using this report in conjunction with the production semi-monthly reports. Past accomplishments are compared with present accomplishments both in production and labor utilization.

This report has a special purpose of providing a half way mark evaluation for most of the programs which are set up on a monthly basis. Management, at this point, is given an opportunity to correct any significant abnormalities in the program before the beginning of the next monthly period. The direct labor expenditures cn these reports should be compared with the direct labor reported in the maintenance data system to be discussed in the next chapter. These two expenditures should be very close.

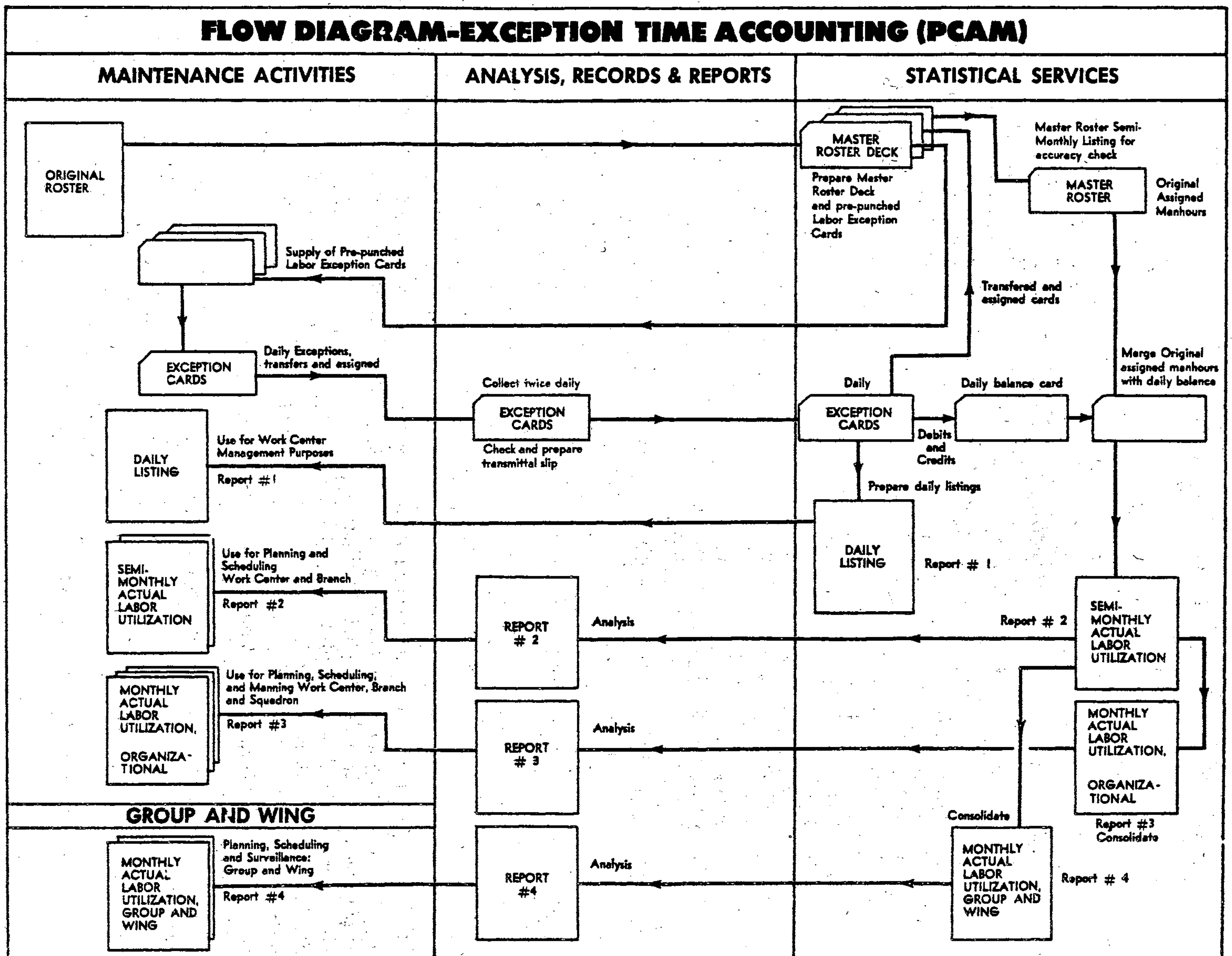
Nonmaintenance manhour drainage can also be determined by this report so as to provide criteria for decisions relating to reduction of this type of manhour utilization.

Some information found in this report is: (1) the total number of manhours originally assigned, gained and transferred during the reporting period, (2) the total number of manhours expended in the work center by all labor distribution codes and by labor code, (3) the total manhours expended by work center personnel in all labor categories, (4) the total number of manhours loaned, borrowed, or expended in overtime by assigned personnel and by work centers affected. Various totals and subtotals are readily available for evaluation purposes.

Report number 3 is the organizational monthly actual labor utilization report. This monthly report of labor transactions is designed to give different levels of management a summary of data pertinent to their interest. In other words, each level of management receives a consolidation of lower level reports so that the problem areas for which they are responsible will be known to them. The three lower levels of management in the U.S.A.F. that receive these reports are the work center, branch and squadron. Also, some top level management personnel use these reports for system surveillance. The information and its presentation is similar to that of report number 2.

Report number 4 is the group or wing monthly actual labor utilization report. This monthly summary is primarily designed for top management evaluation. It provides information on the manhour availability and expenditures of the total maintenance function. This report does not give any details about work centers or organizations participating; specific details, when necessary, can be found in report number 3.

So far all the reports discussed were assumed to have been prepared by a statistical service branch using the punch card accounting machine. The use of the punch card accounting machine implies an organization that is sufficient in size to justify a statistical branch. Any organization the size of a U.S.A.F. squadron or a smaller unit would not normally warrant an automatic card punch programming system. Therefore, at locations having only a small unit, the data processing is done manually. The details of the data processing for a manual exception time accounting system will not be discussed. However, shown in Figures 1 and 2 are the flow diagrams for the punch card accounting machine and manual accounting time systems respectively. These diagrams should be self-explanatory because all the data processed has been discussed.



FLOW DIAGRAM-EXCEPTION TIME ACCOUNTING (PCAM)
MAINTENANCE ACTIVITIES
ANALYSIS, RECORDS & REPORTS
STATISTICAL SERVICES
ORIGINAL ROSTER
MASTER ROSTER DECK
Prepare Master Roster Deck and pre-punched Labor Exception Cards
Master Roster Semi-Monthly Listing for accuracy check
MASTER ROSTER
Original Assigned Manhours
Supply of Pre-punched Labor Exception Cards
Transfered and assigned cards
EXCEPTION CARDS
Daily Exceptions, transfers and assigned
Collect twice daily
EXCEPTION CARDS
Check and prepare transmittal slip
Daily
EXCEPTION CARDS
Debits and Credits
Daily balance card
Merge Original assigned manhours with daily balance
DAILY LISTING
Use for Work Center Management Purposes
Report #1
Prepare daily listings
DAILY LISTING
Report # 1
SEMI-MONTHLY ACTUAL LABOR UTILIZATION
Use for Planning and Scheduling Work Center and Branch
Report #2
REPORT # 2
Analysis
Report # 2
SEMI-MONTHLY ACTUAL LABOR UTILIZATION
MONTHLY ACTUAL LABOR UTILIZATION, ORGANIZA-TIONAL
Use for Planning, Scheduling, and Manning Work Center, Branch and Squadron
Report #3
REPORT # 3
Analysis
MONTHLY ACTUAL LABOR UTILIZATION, ORGANIZA-TIONAL
Report #3 Consolidate
Consolidate
GROUP AND WING
MONTHLY ACTUAL LABOR UTILIZATION, GROUP AND WING
Planning, Scheduling and Surveillance: Group and Wing
Report #4
REPORT #4
Analysis
MONTHLY ACTUAL LABOR UTILIZATION, GROUP AND WING
Report # 4


Figure 1

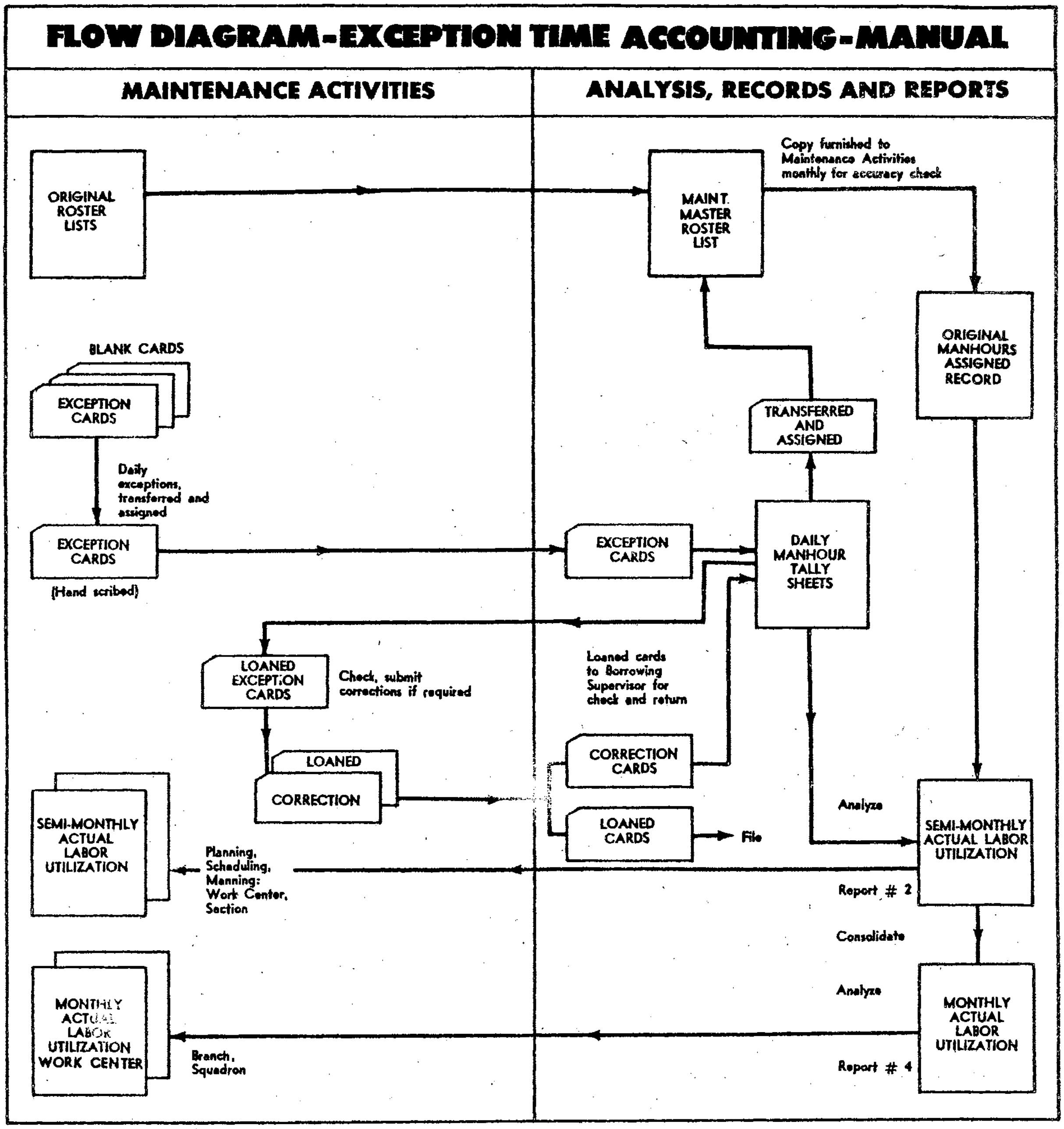

FLOW DIAGRAM-EXCEPTION TIME ACCOUNTING-MANUAL
MAINTENANCE ACTIVITIES
ANALYSIS, RECORDS AND REPORTS
ORIGINAL ROSTER LISTS
MAINT. MASTER ROSTER LIST
Copy furnished to Maintenance Activities monthly for accuracy check
ORIGINAL MANHOURS ASSIGNED RECORD
BLANK CARDS
EXCEPTION CARDS
Daily exceptions, transferred and assigned
EXCEPTION CARDS
(Hand scribed)
TRANSFERRED AND ASSIGNED
EXCEPTION CARDS
DAILY MANHOUR TALLY SHEETS
LOANED EXCEPTION CARDS
Check, submit corrections if required
Loaned cards to Borrowing Supervisor for check and return
LOANED
CORRECTION
CORRECTION CARDS
LOANED CARDS
File
Analyze
SEMI-MONTHLY ACTUAL LABOR UTILIZATION
SEMI-MONTHLY ACTUAL LABOR UTILIZATION
Planning, Scheduling, Manning: Work Center, Section
Report # 2
Consolidate
Analyze
MONTHLY ACTUAL LABOR UTILIZATION WORK CENTER
MONTHLY ACTUAL LABOR UTILIZATION
Branch, Squadron
Report # 4

Figure 2

## CHAPTER IV

## MAINTENANCE DATA COLLECTION SYSTEM

A maintenance data collection system is another tool of maintenance management because the data processed through this system is utilized by the management to make the maintenance function more productive.

The large amount of data processed through a maintenance data collection system can be used to improve the maintenance function efficiency, the product reliability, and many other important facets of the function.

A discussion of a specific operating data collection system will bring out some of the many possible ideas about what data can be processed and what methods can be used to analyze this data. Again a reference to the United States Air Force Manual 66-1 system will be made because it contains such a system.

The U.S.A.F. maintenance data collection system gives information to maintenance management on what jobs were performed by the manpower charged to direct labor in each organization or work center. The system also processes data on the number of direct manhours expended on each job (unit of work); why each repair was required (how malfunctioned); when the malfunction was discovered; and who did the repair work. All data is recorded so that comprehensive data can be made easily available for (1) analysis of failure rates versus airframe and engine time; (2) malfunctions as related to inspection period; (3) reliability expectancies for system components; and (4) frequency and volume of malfunctions as related to when discovered. There are many other relationships that can be shown if it is desirable to do so. Summary data taken from the system can be utilized in over-all manpower planning, labor distribution, equipment needs, budget calculations and cost analysis.

## A DISCUSSION OF WORK DOCUMENTS

This particular data collection system consists of providing a section on each work document for recording, through the use of codes, essential information that can be removed later by statistical services, and machine processed into punched cards and summary reports. The summary reports are then utilized by maintenance management to plan, schedule and control the maintenance effort.

Special duplicate card decks are sometimes made up by the statistical services to satisfy reporting requirements of the engine management system, technical order compliance system, and the over-all product improvement program. Chapter 6 contains an analysis based on statistical data summarized from duplicate card decks for the purpose of determining procedures in the product improvement program.

All maintenance work is recorded on a form of some kind by the mechanic or specialist doing the work. This record is then coded to be used later. All record forms are designed to provide for the collection of maintenance data.

Some of the information recorded on these forms is collected from every area in the U.S.A.F. that records this type data; this information is then analyzed to give a picture of certain problem areas or just to allow close surveillance on this phase of the system.

Other information recorded on the work documents is pertinent to the local organizations only and, therefore, is used by local management in planning and controlling their business.

The type of work form or document to be used to record work information is determined by the type of work required. Several work forms will be discussed later in this chapter.

## UNIT OF WORK

One article that requires definition because it is used continually throughout the data collection system is a unit of work. This item is defined as a job that has a definite beginning and end, the accomplishment of which requires the expenditure of productive direct labor manhours and its content is within the scope of the maintenance mission. Therefore, the total number of manhours reported as productive direct labor in the exception time accounting system should equal, approximately, the number of actual direct labor hours reported against units of work on the maintenance data collection document.

A reportable unit of work must be clearly defined and many units have been given specific common names. A few examples are listed below.

| Maintenance Area | Typical Unit of Work |
| --- | --- |
| Periodic Maintenance | Each different repair job<br>Each technical order compliance accomplished<br>Look check |
| Field Maintenance | Each repair, etc.<br>Bench check of an item |

It is very conceivable that there will be more than one report on a discrepancy because a report is made on each unit of work. For example, a report can be made on a look check during periodic maintenance (see previous listing) but when a discrepancy is found, another report is made on it at the time a fix (repair) is made. If, in a discrepancy analysis problem, the number of discrepancies is desired, counting the total number of reports on the discrepancies would not give the correct amount because the number would contain some redundancies. Therefore, in a statistical analysis problem of this type this is one problem the analyst must be aware of.

The recording of units and manhours must be well defined to prevent redundancies and/or ambiguities. Therefore, the basic center, a center at which the work was actually performed, will record the number of units and its own personnel manhours while any assisting work center will report no units but will report its own manhours expended on the project. All work documents will be turned into the basic work center.

## WORK UNIT CODE

After each work unit has been well defined, a work unit code composed of six characters is assigned to each work unit. This code identifies the work accomplished by specifying the general category of equipment worked on and the general category of action taken. The codes are evidently not large enough, in general, to completely describe the equipment or the actual work done. A code sufficient in size to do this would not be justified because of its complexity. However, the six character codes are divided into two broad categories of work. The first of these is all work performed to repair, inspect, or maintain whole aircraft. The second is all work performed in shops on items or components which are not on an aircraft at the time of repair. Also included in this category are the nonaircraft items. The second category is sometimes referred to as engines and commodities, or commodities.

The two general work codes are distinguishable by the first two characters of their codes. In aircraft codes, the first two characters are numerical but in engines and commodities the first character is alphabetic and the second is either alphabetic or numerical. Fairly detailed codes have been developed for each aircraft and field maintenance. Technical orders have been published containing all the codes usable.

A complete explanation of these codes may help one to understand some of the statistical analysis discussed in Chapter 6, so it will be given here and reviewed briefly in Chapter 6.

All on-aircraft codes have their first two characters identifying the major system worked on. The third, fourth, and fifth characters of this code identify the subsystem, major assembly and component respectively.

The first two characters of the work unit codes for engines and commodities identify the type of shop where the work is performed, i.e., bombing-navigation, electric, etc. The third, fourth, and fifth characters identify the system, subsystem, and component respectively, of the end item on which the work was done, i.e., generator, brushes, etc.

It is possible for local managers to require only some of the general code for work of which details are not important. In this case zeros will be placed in the uncoded character locations. For example, a complete aircraft servicing can be coded 01300.

The sixth character of all codes is alphabetic and identifies the action taken during the repair of the item. This character is uniform in all on-aircraft codes and in the bench check portion of all shop codes. The remainder of the engines and commodities codes are designed to fit a particular shop element. Some action taken codes will be discussed in the analysis of Chapter 6.

## HOW MALFUNCTIONED CODE

Along with the work unit code, another code is used for identifying the type of malfunction. This "How Malfunctioned" code provides an "adjective" description of the trouble occurring on, or in, the component identified by the work unit code. Some of these codes will be discussed in the Chapter 6 analysis.

A "When Discovered" code is also provided to indicate when a discrepancy was found, i.e., in flight, periodic maintenance, etc.

## SPECIAL WORK FORMS

There are many forms filled out by the mechanics performing any repair or service work. Because the analysis in Chapter 6 utilizes summary data listings containing information from several of these forms, they will be discussed now. There are three forms that data is taken from to provide an "aircraft" detail or summary listing for analysis. These forms are the Air Force Technical Order (A.F.T.O.) 781A, 26C and 26D. To make a "commodity" data detail or summary listing the 26K is the form used mostly although a new form, the 26M, is replacing the 26K in the electronics area. The individual forms will now be discussed briefly.

The A.F.T.O. form 781A called the Aircraft Discrepancy and Work Record contains data about individual component deficiencies found by the aircrew or maintenance personnel at the time it is generated, in-flight or on the flight line. A few of the more important data items will be shown and discussed in Chapter 6 along with those from other forms.

The A.F.T.O. forms 26C and 26D are secondary to form 781A but give similar information. The 26C form called Maintenance Discrepancy and Work Record, and the 26D form entitled Quality Discrepancy and Work Record are used for extensive maintenance in the docks (repair stations). These forms all provide a description and corrective action on defects discovered in the airplane. An important item to remember about the data supplied by these forms is that it does not contain part numbers. This means that a deficient part is not well isolated. However, the "commodity" data to be discussed later does contain more detailed information on part failures.

The 26K and 26M forms give part numbers as well as other details of the discrepancy. Therefore, if the aircraft data on the A.F.T.O. forms 781A, 26C and 26D can be used to flag difficulties in certain areas, then the commodity data on the 26K and 26M cards can frequently pinpoint the difficulty so that repair can be accomplished. Because there is a large amount of data processed on these cards, problem areas can be found, studied, and sometimes removed completely by using the correct method of analysis and corrective action.

## MAINTENANCE DATA REPORTS

If the maintenance data is organized and put into a good report, then it can be used advantageously by the appropriate levels of management. Therefore, some types of reports that have been or are now being used by the U.S.A.F. will be discussed. They are classified into two general categories: mandatory and optional. It will become evident that there are many variations possible and sometimes necessary in the reports that will be subsequently discussed. And many local circumstances will dictate other types of optional reports that could increase the efficiency of the system. Seven reports, four mandatory and three optional, are considered briefly with respect to format and utilization. All reports are prepared on the punched card accounting machine (P.C.A.M.). The company branches that are too small for a local statistical services section will hold all daily reports for a full semi-monthly period before forwarding to a statistical services elsewhere.

Report number 1 is a daily mandatory report which contains the following information:

Basic work center code
Work unit code including action code, when applicable
When discovered code
How malfunctioned code
Units produced
Job hours
Aircraft or engine designator or item class code
Aircraft or engine serial number or item part number
Time on aircraft or engine or time change item
Work order number
Date
Basic work center hours
Assisting work center and borrowed hours
Assisted work center and loaned hours
Identification of maintenance source document

The data in this report will be listed by work unit code per aircraft type. As a result, the work center supervisor has a good idea of the total number of direct manhours expended within his work center including those borrowed as well as those loaned to other work centers.

This report is used for the daily operation of maintenance. It provides workloading, production, and surveillance information for the lower level of management. This report can be used to check daily accomplishment against schedules and as an indicator of where trouble is likely to develop and where schedules require revision.

Report number 2 is a semi-monthly production summary. The reporting periods are the same as those for the exception time accounting system so that the reports may be compared. The report for the second half of the month includes the full month totals. This report contains the following information:

Work unit code
Summary of work performed by first two characters of the work unit code
Work order suffix
Units completed
Total job hours
Basic work center direct hours
Assisting work center
Borrowed direct labor hours
Assisted work center
Loaned direct labor hours

This report is used by intermediate management for work load planning and maintaining surveillance over the work performed. Again the results are compared with those of the exception time accounting system.

Report number 3 is a monthly work order summary. It contains the following information:

Work order number
Units produced
Direct labor hours
Work center code

This report is broken into two parts: aircraft and shop.

This report is the primary source of information used for budget and accounting purposes as well as for determining manhours expended and units produced against each work order.

Report number 4 is also a monthly report but is an aircraft system and component discrepancy report. The information contained in this report is as follows:

Work unit code
Action taken code
When discovered code
How malfunctioned code
Units produced
Job hours
Basic work center
Work order number
End item
Part serial number
Operating time
Date
Document identification

This report is used to determine the components that malfunction most frequently and those jobs that consume appreciable quantities of maintenance labor. It is the basic source document, a consolidated listing, for all the aircraft maintenance jobs performed. This report is also used to determine part consumption trends and increases or decreases in manpower requirements as the aircraft increase flying hours. The report provides, for the standardization function, a definite basis for study of those jobs which consume sufficient manpower to make method studies profitable. The training function uses this report to determine areas where further technical training may reduce manpower requirements. The analysis function may use this report for computing job standards and for following aircraft trouble and parts trends.

Report number 5 is the first of the optional reports. It is called the "When Malfunction Was Discovered" report. The following information is found in the report:

Aircraft type and model
Work unit code
When discovered
How malfunctioned
Frequency

This report is used to determine when the malfunctions, by type, are being discovered (in-flight, between-flights, during scheduled inspections, etc.). This information is used to determine adequacy of inspections and corrective maintenance and to recommend changes in time inspection criteria. This information is used to determine also at what aircraft hours certain malfunctions are appearing and how these are manifested.

Report number 6 consists of information about malfunction of individual aircraft by flying hours, component, and action taken. It contains the following information:

Aircraft type, model and series
Aircraft serial number
Work unit code in flying hour sequence
Manhours required
When discovered

The report brings together all information concerning the work required to keep each individual aircraft in operation. The work requirements are presented in the flying hour sequence in order to group those jobs done at inspection intervals and to easily identify those jobs being done just before and just after scheduled inspections. This report is used primarily to increase the effectiveness of the inspection cycle and reduce the work being done between inspections. It also provides information for recurring malfunctions on the same aircraft which indicate requirements for a permanent rather than a temporary fix.

The last report, number 7, is the optional report on bench check data. The information given here is usually:

Work unit code
End item
Action taken
Work order number
Flying time
Date

This report provides a systematic presentation of the bench check program and the results of the bench checks. It is used to identify those items being removed that are actually serviceable and those reparable but needing only minor repair, etc. Usage trends can be developed from this data and accurate parts predictions made.

Obviously, the usefulness of the information contained in the foregoing reports is almost unlimited as far as analysis of specific problems is concerned.

It would probably be of some benefit at this point, before actually showing an analysis, to discuss some types or techniques of analysis that could be used. So the next chapter contains a few techniques that have been advantageous in large scale systems. If these techniques are kept in mind while studying Chapter 6, then new and better variations in the actual analysis may be discovered.

# CHAPTER V

## TECHNIQUES OF DATA ANALYSIS AND PRESENTATION

### A DISCUSSION OF STATISTICAL ANALYSES

This chapter contains a fairly brief discussion of some methods of presenting and interpreting statistical data. Only a brief discussion of statistics in this study is justified since the field of statistics is so large. The reader may gain a better appreciation for the science of statistics if the following formal definition is known.

> Statistics is the science and art of the development and application of the most effective methods of collecting, tabulating, and interpreting quantitative data in such a manner that the fallibility of conclusions and estimates may be assessed by means of inductive reasoning based on the mathematics of probability.[1]

The purpose of Chapter 6 is to illustrate a particular application of some statistical methods to the field of an electronic system's deficiencies. Therefore, most of the analysis techniques presented here will be of significance to this type of problem. A very accurate interpretation of the data shown will logically follow only from the use of more advanced statistical techniques known only by well qualified statisticians. However, much information can be gained on general categories with a very simplified tabulation of data. To gain more information on smaller categories or quantities, complex techniques

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[1]Anderson, R.L., and Bancroft, T. A., Statistical Theory in Research, (McGraw-Hill, 1952), p. 6.

are frequently necessary and justifiable.

Statistical work is part of the job of every maintenance supervisor who is interested in doing a good job of supervision. The analysis records and reports section has the statistical analysis of data as a large part of its function. Although either group mentioned might use different methods than the other, it can be assumed that all of the subsequently discussed methods are available to either group.

The first step toward a statistical analysis is determining the exact problem to be solved. However, other problems may consequently be discovered and solved as a result of the search for the solution to the primary objective.

The next step toward a good analysis is deciding what data is needed. Some data necessary for use in managing the over-all maintenance function of a large organization has been discussed in previous chapters. This data will change from time to time as the objectives and responsibilities of the maintenance function vary.

The third step in the analysis is that of arranging the data into a format that will clearly show the problem areas. The actual arranging of the data is usually physically simple to accomplish although it is time consuming; but the decision about how to arrange the data to give a clear picture of the problems is very difficult in many instances. Probably the best reasons for lack of analysis in the past have been the lack of knowledge about what can be done with the data and how to arrange the data for analysis. Obviously, there will be no valid analyses made unless well-trained analysts are employed.

It appears that data can be used for many types of surveillance, the actual types being limited only by the imagination of the analyst.

The following list contains only a few ideas that might help direct the imagination in devising new ways of utilizing maintenance data.

Determination of maintenance capabilities.
Forecasting maintenance conditions, requirements, weak areas, manpower requirements, manpower availability, etc.
Budgeting manpower, equipment, time, money, material, etc.

Before discussing various charts that are used by statistical analysts, it might be well to define both frequency distribution and class intervals. A frequency distribution is a table or chart on which a group of values of a variable condition are arranged in order according to their magnitude. Instead of plotting every point on a graph, a group of points are plotted as one. The reason for grouping is to simplify the analysis because there is normally a large amount of data available. The groups of data referred to here are called class intervals. The class interval size is determined by dividing the range of values by the number of intervals desired. The number of intervals is usually found by deciding how simple the presentation can be made while at the same time preventing any large inaccuracies. In other words the class interval must be small enough to adequately represent the data, yet wide enough to allow easy use. The concept of class intervals is not used in the analysis of Chapter 6 because the amount of data available for the parts concerned was not of sufficient size to justify this method.

Many analysts use various charts in their work. A few of the important ones will be briefly mentioned at this time. These charts will be classified as either analysis charts or presentation charts.

## SOME ANALYSIS CHARTS

Because frequency distribution is used frequently in analysis work, the analysis charts discussed here will be frequency distribution charts. They are the histogram, polygon, and the ogive graphs. A histogram is a column chart where the heights of the column are used to represent the frequencies of the class intervals. A polygon is a curve (or line) chart in which the midpoints of class intervals are used for points through which a curve is drawn. The ogive chart has two vertical scales. The one on the left is the value scale and the one on the right is in percent so that the top of each scale represents the maximum value. The steepest part of each curve represents the model class--the area of greatest concentration in the plotted values.

## SOME PRESENTATION GRAPHS

There are many presentation graphs of which the following are probably the most used: line chart, bar chart, pictograph, circle graph, ratio chart and relationship chart. The line chart which is the only one used in the analysis of Chapter 6 will be the only one discussed here. This type of chart has its best uses in the following:

(1) frequency distribution as mentioned previously
(2) comparison - two series of values on one chart
(3) to emphasize trend rather than actual values
(4) projection of trends
(5) relationships for two or more values.

The line chart utilized in the analysis of Chapter 6 is a good example of using all of the above listed advantages.

## PRESENTATION PRECAUTIONS

The last step in the analysis of data should be a very cautious one in that the conclusions, charts, etc. that are presented to the management organization should not contain any misrepresentations, either by accident or intention. The following precautions might help one to eliminate some common pitfalls in this area.

(1) The theory of sampling has definitely been proven to be effective, but the analyst must be able to recognize nonrepresentative samples which would of course not present the facts.

(2) Comparison can be used between quantities only if the quantities have a common base. For example, apples cannot be compared with bananas; however, if a common base such as "number sold" were chosen, then comparison is possible.

(3) Scales on all charts should always be chosen with a critical eye to prevent exaggerations.

(4) If a large number of people need to study the analysis results, then a simple presentation will reduce the chances of misinterpretation by anyone. So presentations sent to many people should be necessarily simpler than one sent to an expert interpreter, for example.

## CHAPTER VI

## A STATISTICAL ANALYSIS OF DEFICIENCIES

### INTRODUCTION TO THE PROBLEM

The discussion in this chapter emphasizes a particular engineering analysis and presentation technique. As mentioned previously, the specific example to be used will be concerned with some U.S.A.F. equipment, although any large organization could use the same technique. Much of the terminology discussed in previous chapters will be used in this chapter.

The specific problem to be studied is to identify B-52 aircraft electronic system parts with a large number of failures, and to provide other information that might give clues to the necessary correction procedures. Because the B-52 is a very large and complex system, the solution to the problem will be broken down into the following four major steps:

(1) Determination of the major systems with many failures
(2) Determination of the components with many failures
(3) Determination of the parts with many failures
(4) Determination of correction procedures using all "part" information available

The first three steps listed above make up a process of isolating the parts having a large number of failures from the many hundreds of thousands of parts contained in the B-52 aircraft. The fourth step is a utilization of all data available on parts having many failures, for the purpose of establishing procedures that will prevent the recurrence of these failures.

Definitions for "Major System," "Component" and "Part" might well give more meaning at this time to the three isolation steps mentioned previously. A "Major System" is an arbitrary collection of minor systems, "Components," or "Parts." For the B-52 aircraft there were 29 "Major Systems" chosen for the convenience of the specialized maintenance management. (See Table I.) The words "Component" and "Part" should not be confused. In some literature the word "Part" is used interchangeably with the word "Component," but in this thesis, a "Component" is a small unit composed of "Parts." An example of a "Component" is a transmitter whereas a resistor within this "Component" is considered a "Part."

It is assumed here that the B-52 aircraft contains sufficient maintenance deficiencies to warrant an investigation. A reason for initiating this action could have been found by analyzing the trend chart of Figure 3 containing three items considered quite important at this time. For example, if the trend for all the deficiencies was upward for no apparent reason, then an investigation might be necessary. A trend graph such as that shown in Figure 3 is not usually simple to analyze; it is best to use rather complex formulas for good results. These formulas take into consideration such things as the percentage of bases reporting, the increase or decrease in number of B-52 aircraft, present efficiency of data processing, reliability of data recorded, etc.

Some of the graphical and tabular terminology to be used later will be explained at this point. The term "Deficiency" refers to what

TABLE I

MAY, 1960 A.F.M. 66-1 SUMMARY DATA FOR THE B-52 AIRCRAFT BY MAJOR SYSTEM

| System | Code | Deficiency Units | Percent Deficiency Units | Units Serviced | Percent Units Serviced | Deficiency Manhours | Percent Deficiency Manhours | Manhours Serviced | Percent Manhours Serviced | Total Aborts | Percent Aborts |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Airframe | 11 | 17710 | 24.17 | 2491 | 8.75 | 17142.9 | 13.56 | 2577.1 | 8.35 | 11 | 3.34 |
| Fuselage | 12 | 1520 | 2.07 | 383 | 1.35 | 1517.6 | 1.20 | 322.1 | 1.35 | 3 | .91 |
| Landing Gear | 13 | 2796 | 3.82 | 877 | 3.08 | 6198.1 | 4.90 | 1471.9 | 4.77 | 5 | 1.52 |
| Flight Controls | 14 | 7413 | 10.12 | 932 | 3.28 | 9209.8 | 7.29 | 1147.2 | 3.72 | 8 | 2.43 |
| Turbojet Pwr.Plt. | 23 | 10523 | 14.36 | 2968 | 10.43 | 19572.5 | 15.48 | 2817.6 | 9.13 | 22 | 6.69 |
| Air Cond., Etc. | 41 | 1202 | 1.64 | 403 | 1.42 | 3418.6 | 2.70 | 770.9 | 2.50 | 13 | 3.95 |
| Elec. Power Supply | 42 | 2594 | 3.54 | 1575 | 5.53 | 5540.8 | 4.38 | 2465.7 | 7.99 | 11 | 3.34 |
| Lighting System | 44 | 2868 | 3.91 | 252 | .89 | 1914.0 | 1.51 | 137.2 | .44 | 10 | 3.04 |
| Hyd.and Pneu.Power | 45 | 4962 | 6.77 | 1091 | 3.83 | 6701.1 | 5.30 | 1004.7 | 3.25 | 14 | 4.26 |
| Fuel System | 46 | 1647 | 2.25 | 2975 | 10.45 | 8057.2 | 6.37 | 1668.0 | 5.40 | 15 | 4.56 |
| Oxygen System | 47 | 720 | .98 | 305 | 1.07 | 1050.6 | .83 | 139.6 | .45 | 5 | 1.52 |
| Misc. Utilities | 49 | 356 | .49 | 106 | .37 | 833.0 | .66 | 102.5 | .33 | 3 | .91 |
| Instr. General | 51 | 2514 | 3.43 | 1026 | 3.61 | 6730.2 | 5.32 | 2070.8 | 6.71 | 38 | 11.55 |
| Autopilot | 52 | 1026 | 1.40 | 243 | .85 | 2933.8 | 2.32 | 492.4 | 1.60 | 19 | 5.78 |
| HF Communication | 61 | 382 | .52 | 109 | .38 | 1604.4 | 1.27 | 261.5 | .85 | 2 | .61 |
| UHF Communication | 53 | 589 | .80 | 138 | .49 | 1101.2 | .87 | 234.3 | .76 | 7 | 2.13 |
| Interphone | 64 | 577 | .79 | 109 | .38 | 827.1 | .66 | 131.6 | .43 | 7 | 2.13 |
| I.F.F. | 65 | 185 | .25 | 37 | .13 | 346.3 | .27 | 89.4 | .29 | 2 | .61 |
| Emergency Radio | 66 | 1 | — | 2 | .01 | 5.0 | 0 | 5.0 | .02 | — | — |
| Misc. Comm. Eqpt. | 69 | 6 | .01 | 1 | — | 7.5 | .01 | .4 | — | — | — |
| Radio-Navigation | 71 | 466 | .64 | 123 | .43 | 923.2 | .73 | 205.4 | .67 | 2 | .61 |
| Radar-Navigation | 72 | 164 | .22 | 46 | .16 | 403.6 | .32 | 102.7 | .33 | 1 | .30 |
| Bombing-Navigation | 73 | 4916 | 6.71 | 2512 | 8.83 | 15688.3 | 12.41 | 6516.2 | 21.11 | 56 | 17.02 |
| Fire Control Sys. | 74 | 2792 | 3.81 | 869 | 3.05 | 6259.2 | 4.95 | 962.4 | 3.12 | 28 | 8.51 |
| Weapons Delivery | 75 | 1103 | 1.51 | 1257 | 4.42 | 1123.0 | .89 | 1770.0 | 5.73 | 2 | .61 |
| E.C.M. | 76 | 3849 | 5.25 | 6291 | 22.10 | 6861.5 | 5.43 | 2836.1 | 9.19 | 43 | 13.07 |
| Photo Reconn. | 77 | 178 | .24 | 257 | .90 | 168.3 | .13 | 252.8 | .82 | 1 | .30 |
| Emergency Eqpt. | 91 | 121 | .17 | 952 | 3.35 | 53.7 | .04 | 114.2 | .37 | 1 | .30 |
| Drag Chute Eqpt. | 93 | 92 | .13 | 132 | .46 | 255.2 | .20 | 194.2 | .63 | — | — |
| TOTAL | | 73272 | 100.00 | 28462 | 100.00 | 126447.7 | 100.00 | 30863.9 | 100.00 | 329 | 100.00 |
| Percent of Total | | 72.02 | -- | 27.98 | — | 80.38 | — | 19.62 | — | — | — |

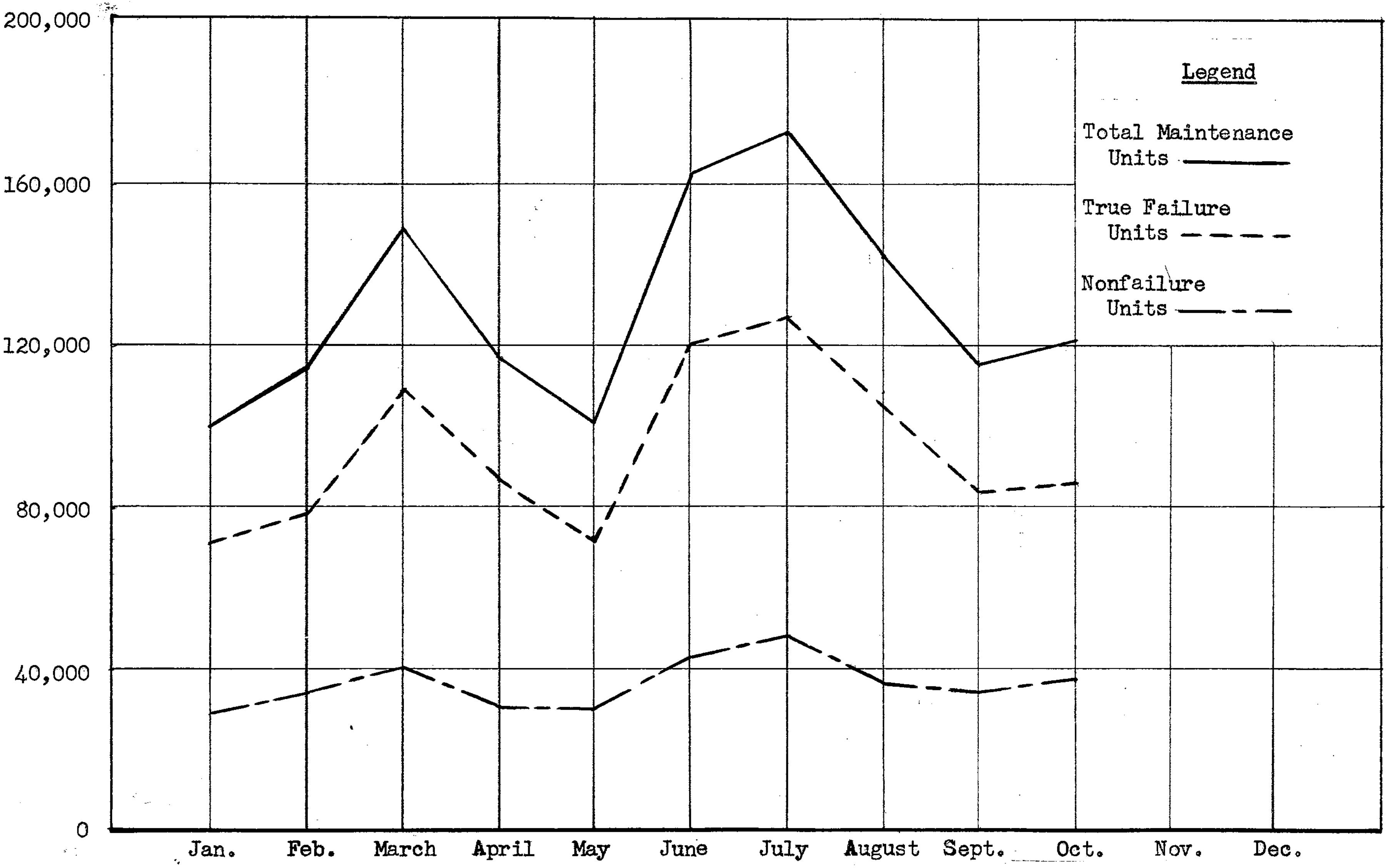


Figure 3. B-52 Aircraft Deficiencies, Nonfailures, and Total Maintenance Actions (1960)

one might call a true failure because the part does actually fail. The term "Nonfailure" refers to that unit of work performed on a "Part," "Component," etc., that did not actually fail (although it might have if this service had not been performed). The distinction between a "Deficiency" and a "Nonfailure" is specified more accurately by the action taken code associated with the unit of work performed. This code was discussed briefly in Chapter 4. Certain of the codes are used for "Deficiencies" while the rest are stipulated for "Nonfailures." Another term called "Abort" is used frequently to determine the importance of a "Deficiency." An "Abort" takes place any time a plane does not accomplish its mission; so a "Deficiency" causing this condition is obviously of great importance. "Aborts" are not considered to have much weight in this analysis because their number is small. However, in some tables they are included so weight can be attached to them in evaluating a problem, if it is felt necessary.

## DETERMINATION OF MAJOR SYSTEMS WITH MANY FAILURES

Step number one indicates that the first thing to look for in the solution of the problem is the "Major System or Systems" that have the largest number of failures. Table I contains all 29 major systems of the B-52 aircraft with several items being compared as indicated by the headings of the columns. Many of these items are not used by the author in the analysis presented here, but some or all of them should be considered in a more complex analysis.

True failures (maintenance deficiencies) are considered to have the most weight in this study; therefore, a study of the columns (in Table I) containing these "Deficiency" numbers or percents will indicate that the Bombing-Navigation System has more "Deficiencies" than any other major electronic system. The 4,916 deficiency units of the Bombing-Navigation system will be utilized in step number two. The airframe (a nonelectronic system) obviously has the greatest number of failures. All data found in Figure 3 and Table I was received on the A.F.T.O. Forms 781A, 26C and 26D (for details, see Chapter 4). This data was processed into detail listings and also into summary listings for use on graphs and in tables. The detail listing is called an "Aircraft" or "On-Aircraft" listing and is illustrated in Table II with the engines and commodity detail listing made from A.F.T.O. forms similar to the 26K. The "Commodity" detail listing information will be discussed later. Table III contains the aircraft summary listing showing the quantities thought important at this time.

## DETERMINATION OF COMPONENTS WITH MANY FAILURES

The second step of the analysis is to determine the "Components" of the Bombing-Navigation System that have a large number of true failures. The aircraft summary listing was used in this step. The 20 work unit codes having the highest number of true failures ("Deficiency" units) were put into Table IV. Also put in Table IV are:

- The names of the "Components" (found in A.F.T.O. 1B-52A-06)
- Total manhours needed to complete all deficiency units
- Total maintenance actions
- Total aborts
- Total true failures of component
- Total true failures of Bombing-Navigation System

The percent columns were then calculated.

In addition to a table containing the above information, a trend graph (Figure 4) was initiated for each "Component" located in the top ten positions. This graph should be self-explanatory except for two

TABLE II

AIRCRAFT AND COMMODITY MAINTENANCE DATA DETAIL LISTINGS

| AIRCRAFT | | | | | | | | | | TOTALS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Materiel Deficiency | | Services | | | |
| Model | Series | Serial Number | Work Unit Code | Action Taken | How Malfunctioned | When discovered | Operating Hours | Date | Base | Units | Man-hours | Units | Man-hours | Aborts | Non-abort |
| B-52 | G | 734 | 14144 | G | 106 | D | 01496 | 18-11 | 4620 | | | | | | |
| B-52 | D | 633 | 14144 | B | 118 | F | 01267 | 6-11 | 4620 | | | | | | |
| B-52 | D | 576 | 14144 | X | 190 | K | 01039 | 25-11 | 4690 | | | | | | |
| B-52 | D | 670 | 14144 | G | 730 | R | 01420 | 20-11 | 4620 | | | | | | |
| | | | | | | | | | | 5 | 19.7 | - | - | - | 5 |
| COMMODITIES | | | | | | | | | | | | | | | |
| Item Class | Part Number | | | | | | | | | | | | | | |
| 1650 | 503769 | | HE430 | B | 070 | C | 227 | 1-6 | 4630 | 3 | 15 | - | - | 1 | |
| 1650 | 508769 | | HE430 | B | 233 | B | unknown | 1-7 | 4672 | 1 | 5 | - | - | | 1 |
| 1650 | 508769 | | HE430 | C | 648 | B | unknown | 1-8 | 4691 | 1 | 6 | - | - | | 1 |

TABLE III

AIRCRAFT SUMMARY LISTING

| | | Totals | | | | | |
|---|---|---|---|---|---|---|---|
| | | Deficiencies | | Services | | | |
| Model | Work Unit Code | Units | Manhours | Units | Manhours | Aborts | Nonaborts |
| B-52 | 14144 | 5 | 19.7 | - | - | - | 5 |
| B-52 | 14145 | 1 | .4 | - | - | - | 1 |
| B-52 | 14146 | 1 | 10.5 | 1 | 1.0 | - | 2 |
| B-52 | 14148 | 7 | 21.4 | 3 | 10.0 | - | 10 |
| | | 14* | 52.0* | 4* | 11.0* | - | 18* |
| B-52 | 14151 | 3 | 12.0 | 1 | 10.0 | 1 | 3 |
| B-52 | 14153 | 1 | 3.0 | 2 | 15.0 | - | 3 |
| | | 4* | 15.0* | 3* | 25.0* | 1* | 6* |
| | | 18** | 67 ** | 7** | 36.0** | 1** | 24** |
| B-52 | 14211 | 10 | 34.0 | - | - | - | 10 |
| B-52 | 14212 | 1 | 3.0 | 8 | 24.0 | 1 | 8 |
| | | 11* | 37.0* | 8* | 24.0* | 1* | 18* |
| B-52 | 14289 | 1 | 3.0 | 3 | 4.2 | 0 | 4 |
| | | 1* | 3.0* | 3* | 4.2* | 0 | 4* |
| | | 12** | 40.0** | 11** | 28.2** | 1** | 22** |
| | | 30*** | 107 *** | 18*** | 64.2*** | 2*** | 46*** |

* Major Assembly Totals; ** Subsystem Totals; ***System Totals

## TABLE IV

### TOP 20 FAILURE "COMPONENTS" IN THE B-52 BOMBING-NAVIGATION SYSTEM

| Component | Work Unit Code | Total Manhours | Total Actions | Total Aborts | True Failures | Percent Failures in System | Percent Totals |
|---|---|---|---|---|---|---|---|
| Receiver-Transmitter | 73353 | 1082.0 | 207 | 7 | 179 | 3.64 | |
| Receiver-Transmitter | 73119 | 776.0 | 197 | 3 | 178 | 3.62 | |
| Desiccator | 73278 | 219.6 | 181 | 0 | 168 | 3.42 | |
| Radar Antenna | 73256 | 1252.6 | 193 | 1 | 133 | 2.70 | |
| Indicator IP-284 | 73448 | 320.6 | 131 | 0 | 116 | 2.36 | |
| Transmitter RT-324 | 73474 | 421.9 | 122 | - | 115 | 2.34 | |
| Converter, Polar | 73442 | 378.2 | 120 | 1 | 114 | 2.32 | |
| Radome Assembly | 73481 | 216.0 | 186 | 0 | 94 | 1.91 | |
| Camera Magazine | 73299 | 543.5 | 576 | 0 | 88 | 1.79 | |
| Synchronizer SN-158 | 73451 | 205.1 | 93 | - | 83 | 1.69 | 25.79 |
| Computer, Tracking | 73439 | 440.6 | 102 | 3 | 78 | 1.59 | |
| Amplifiers (Two) | 73111 | 313.3 | 88 | 0 | 75 | 1.53 | |
| Integrator, Velocity | 73252 | 399.1 | 100 | 1 | 73 | 1.49 | |
| Desiccator | 73429 | 65.0 | 73 | 0 | 69 | 1.40 | |
| Astro Tracker | 73183 | 735.7 | 139 | 0 | 66 | 1.34 | |
| Radar Modulator | 73262 | 1069.4 | 66 | 5 | 60 | 1.22 | |
| Amplifier MD-1 | 73454 | 179.9 | 66 | 0 | 60 | 1.22 | |
| Synchronizer SN-135 | 73456 | 131.1 | 60 | 1 | 57 | 1.16 | |
| Bombsight, Periscope Monocular | 73329 | 123.4 | 74 | 2 | 54 | 1.10 | |
| Computer, Bombing | 73441 | 166.8 | 60 | 1 | 53 | 1.08 | 38.92 |

May, 1960 Sum of <u>all</u> failures in the Bombing-Navigation System: 4,916

| | | | | | |
|---|---|---|---|---|---|
| Aborts | 0 | 2 | - | 4 | 0 |
| Percent Failures | 3.74 | 3.11 | - | 2.99 | 3.42 |

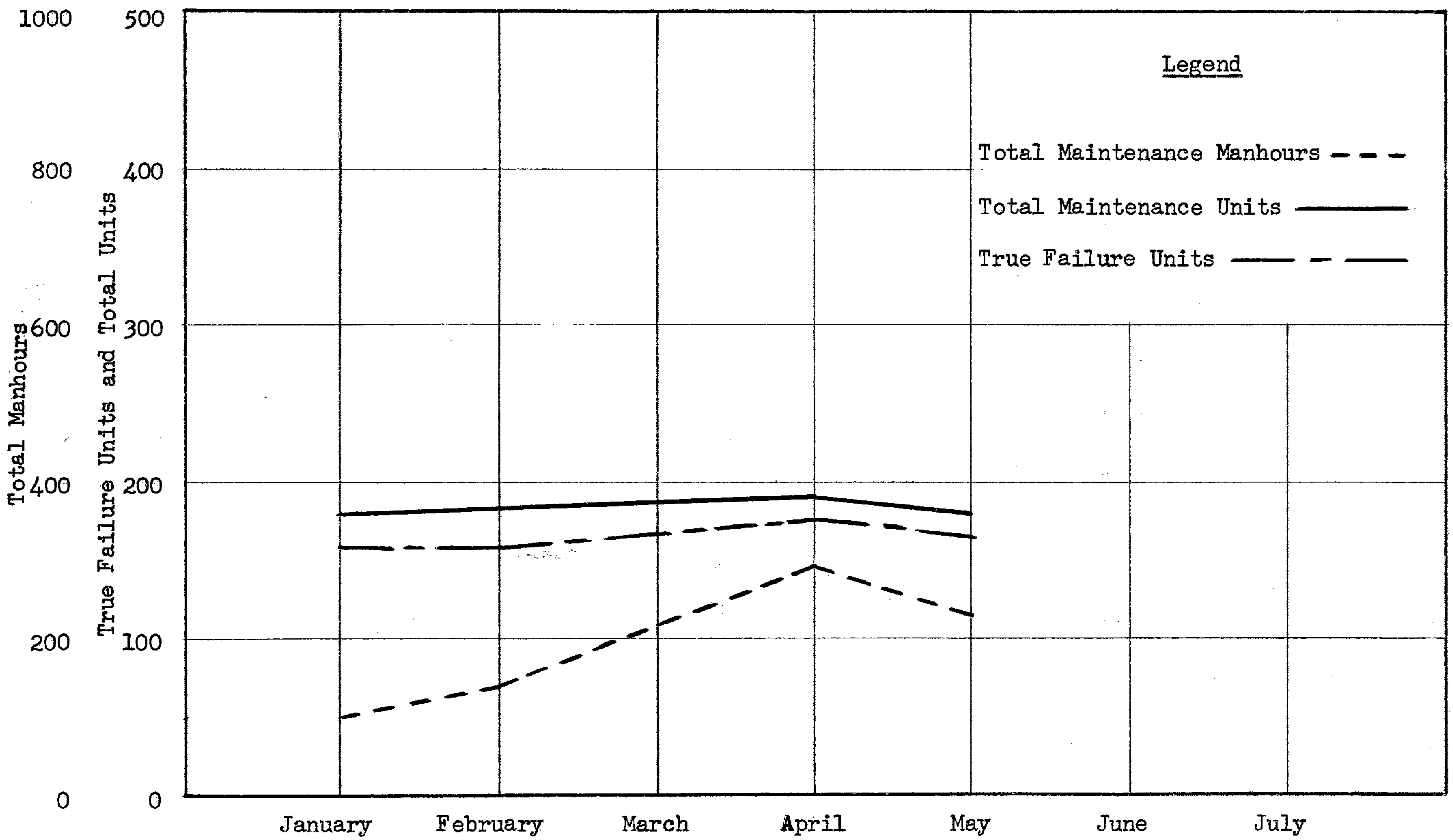


**Figure 4.** Desiccator Deficiencies in the Bombing-Navigation System of the B-52 Aircraft (Work Unit Code 73278)

items: "percent failures" which is the percent of the major system true failures attributed to this component; and "total deficiencies" which is the sum of true failures and nonfailures. This number of "Components" graphed was completely arbitrary. It may take a long complete analysis to determine an optimum number to be graphed monthly. In other words, the analysis time is unknown at present and may be too high to justify analyzing as many as ten "Components." Also, the trend graph for these "Components" may subsequently dictate a change in emphasis of analysis from one component to another.

## DETERMINATION OF PARTS WITH MANY FAILURES

The next step is the final isolation step: to determine the "Parts" failing. For an example here, the desiccator, item number three in Table IV, will be used. This desiccator is a waveguide dehumidifier. To get information on a "Component," it is necessary to obtain some "Commodity" data which is processed on a card similar to the A.F.T.O. 26K, as mentioned previously. At the time of the experimental work done here (August, 1960) the only "Commodity" data available to the author was that listed from A.F.T.O. 787-1 cards which have been replaced by A.F.T.O. 26M electronic equipment cards.

The "Component" was found in the "Commodity" listing and the information on true failures was again used as the primary factor for choosing the important item (the item here is a part). All "Parts" that had at least three failures for every month, February through May, 1960 are listed in Table V. For the desiccator there are only two parts, the blades and the motor, that had three or more failures each month.

## TABLE V

### 787-1 DEFICIENCY DATA ON "PARTS" OF THE DESICCATOR (WORK UNIT CODE 73278) IN THE B-52 AIRCRAFT BOMBING-NAVIGATION SYSTEM

| Month | Part | Percent | How Malfunctioned Codes 20 | 40 | 70 | 80 | 720 | Totals | Part Failures | Component Failures |
|---|---|---|---|---|---|---|---|---|---|---|
| February | Blades | 63 | 4 | 7 | 10 | | 1 | 22 | 22 | |
| | Motor | 9 | | | | 3 | | 3 | 3 | |
| | | 72 | | | | | | 25 | 25 | 35 |
| March | Blades | 62 | 5 | 5 | 15 | 3 | 6 | 34 | 34 | |
| | Motor | 5 | | 2 | | 1 | | 3 | 3 | |
| | | 67 | | | | | | 37 | 37 | 55 |
| April | Blades | 70 | 1 | 6 | 12 | 1 | 12 | 32 | 32 | |
| | Motor | 13 | | 1 | | 5 | | 6 | 6 | |
| | | 83 | | | | | | 38 | 38 | 46 |
| May | Blades | 57 | | 7 | 6 | | 2 | 15 | 16 | |
| | Motor | 11 | | 1 | 1 | 1 | | 3 | 3 | |
| | | 68 | | | | | | 18 | 19 | 28 |
| TOTALS | Blades | 63 | 10 | 25 | 43 | 4 | 21 | 103 | 104 | |
| | Motor | 9 | | 4 | 1 | 10 | | 15 | 15 | |
| | | 72 | 10 | 29 | 44 | 14 | 21 | 118 | 119 | 164 |

The following discussion is a brief explanation of some quantities shown in Table V. The third column contains the "Component" percent failures for each "Part" by month and for the four months' total.

The next five columns contain a "How Malfunctioned" code that gives a hint on what happened to the "Part" by giving the symptom observed. The number of times a code was reported each month is listed in the columns. Totals also appear at the bottom.

Column nine contains the sum of all "How Malfunctioned" codes for each "Part" each month. These are summed for all "Parts" each month and also for the four months (at the bottom).

Column ten contains the total number of times a "Part" was reported to have failed. Again it is by month and also for the four months. This number will differ from the "How Malfunctioned" total by the number of units reported that did not clearly have a "How Malfunctioned" code associated with them. In the example shown, the difference is never greater than one but for other components the difference may be greater and of more significance.

The last column contains the total number of true failures reported on the desiccator. The use of all of these columns will become clearer when a numerical example is discussed.

## DETERMINATION OF CORRECTION PROCEDURES USING ALL PART INFORMATION AVAILABLE

The last major step in the solution to the problem should now be undertaken. As previously mentioned, the first three steps isolate the "Part" (or "Parts") that had the largest number of failures. In the example discussed, these "Parts" are the blades and the motor.

The final step is to determine the actual reason for the "Part" failures and to recommend engineering changes that will tend to eliminate any excessive number of failures. The decisions reached during this step will be based not only on the data presented in Table V, but also on any other information available to an engineer who might be associated with this phase of the B-52 aircraft. Some additional "Part" information could be obtained from personal observation of equipment failures, High Rejection Rate Reduction Committee Reports, Emergency Unsatisfactory Reports, or any other available sources.

Because the blades of the desiccator have the largest number of failures, they will be discussed first. Refer to Table V. In column three, the blade failures are shown to represent at least 57 percent of any month's failures in the desiccator. It also shows that the blades represent an average of 63 percent over the four month period. This is quite obviously the largest problem "Part."

More information can be obtained from Table V, if necessary. For example, the information in the last three columns on the totals rows are sometimes used to advantage. The "103" appearing in the ninth column is the four months' total true failures that were reported with a "How Malfunctioned" code. The "104" appearing in the tenth column is the four months' total true failures for all true failures reported, not just those associated with a "How Malfunctioned" code. Shown in the last column is "164," the total true failures of the desiccator for the four months. The 63 percent in column three was obtained by dividing the 104 (in column 10) by the 164 (in column 11) or by averaging the monthly percent values.

Sometimes the "How Malfunctioned" codes indicate the remedy for the failure. In this case there are four codes that are predominant (see totals row). They are code 70 (Broken), code 40 (Binding), code 720 (Brush Failure), and code 20 (Worn Excessively). A.F.T.O. 1B-52A-06 has the listing of "How Malfunctioned" codes used here.

The conclusion drawn from the codes reported was that the desiccator blade assembly and blower housing should be redesigned to reduce binding of the blades. The binding was apparently causing the excessive wear and broken blades reported. No information other than that in Table V was available to the author at the time this conclusion was made.

The other "Part" in the desiccator that had many failures is the motor. By the same process as the one discussed for the blades, the motor failures can be evaluated. For this item, the codes 80 (Burned Out) and 40 (Binding) are the most important.

The conclusion for this "Part" was largely drawn by using the experience of some engineers familiar with this system. The motor, which is a part of the waveguide dehumidifier, is rated to operate for only 15 minutes of every hour. It is a sealed motor that will not dissipate its own heat fast enough if its operation exceeds 15 minutes of every hour. The burning out of the motor has occurred frequently because the waveguide with which it is associated has been found to leak excessively. This condition of leakage causes the motor to operate beyond its specified limits of operation. Therefore, both of the following actions are necessary: first, the waveguide system should be improved to prevent leakage; second, the motor should be redesigned to prevent burnout in case of leaky waveguides.

Additional recommendations could be made to effect a remedy to the

"Part" problem. Therefore, the point to note is that it is possible to use maintenance deficiency data of the type proposed here to help correct deficiency problems, although it may also, in many instances, require additional knowledge about the "Part" or system containing the "Part." This additional information can usually be found.

# CHAPTER VII

## SUMMARY

The problem associated with this thesis was to develop analysis techniques to aid in the reduction of equipment deficiencies in large scale organizations. The reduction in equipment deficiencies implies a savings in money and manhours, as well as an increase in product reliability.

The U.S.A.F. is an organization that is working on this particular problem, and the system used by this group is presented in some detail. The analysis techniques developed to solve the problem were designed to be integrated with the organizational and field maintenance concept, as outlined in A.F.M. 66-1, dated July, 1959.

The solution to the problem is found through a series of fairly straightforward but sometimes tedious procedures. An Air Force Electronic System, being used for a numerical example, is statistically analyzed through four major steps. The first three steps isolate the part or parts that are failing frequently, and the last step determines why the parts failed. The conclusions arrived at in the analysis were based mainly on two items that were reported by maintenance personnel: the number of actual failures and the reasons for the failures.

Also presented on a number of charts and tables are other items that could have been given weight in arriving at a solution to the problem. The additional items imply many opportunities for future research into this type of problem. However, the analysis presented here is recommended as a basis for a more complex analysis to be determined by a particular organization's problems. A more complex analysis would give some weight to other quantities of importance. For example, instead of determining a problem part only on the basis of the number of its true failures, the number of aborts and manhours could have been weighted quite strongly. The weights placed on items such as these will vary considerably from one company to another, depending on such things as the relative number of deficiencies, aborts, and manhours; cost per manhour, cost per deficiency, etc.

Many of the solutions to the problems of analysis and presentation of data discussed in this paper could be expedited by the use of various types of digital computers. One of the advantages of a computer for this type of application is its ability to produce results rapidly enough to give the management vital information before it is too old to be useful.

It is rather difficult at this time to determine the efficiency of the analysis discussed in this thesis; one reason is that the data collection system used is relatively new. But apparently the system does produce at least some statistical data which is reliable enough to give top management a much better picture of the important product deficiency areas than it ever had before.

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