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ABSTRACT

The methods and problems encountered in the development of a prototype human resources data handbook are discussed. The goal of the research was to determine whether it was feasible to consolidate, in a single comprehensive handbook, human resources data applicable to system design and development. Selected for this purpose were data on the functions performed by the 32XXX avionics career field on the fire control system of nine Air Force fighter systems. The report discusses the methods used and the problems encountered during the development of the prototype handbook. The prototype handbook, presented in Appendix A, was designed for ease of use and was organized into three major data sections. Section 1 was reserved for data comparisons on system design, training, manpower, occupational tasks, maintenance procedures, etc. Included in Section 2 were data on past, current, and projected numbers of personnel, various skill levels, etc. Section 3 was reserved for technical information that could be generalized to a wide variety of problems. Included in the last section were data on the effects of task difficulty, error rates in performing maintenance activities, performance time, and experience level. An alphabetical index of contents concludes the handbook. (Author)

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DEVELOPMENT OF A PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEMS ENGINEERING:

AN APPLICATION TO FIRE CONTROL SYSTEMS

By

Lawrence E. Reed
Melvin T. Snyder
Harry A. Baran

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

Susan L. Loy
James G. Curtin
McDonnell Douglas Astronautics Company — East
St. Louis, Missouri 63166

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BROOKS AIR FORCE BASE, TEXAS 78235

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
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Approved for publication.

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SUMMARY

1. PROBLEM

The importance of Air Force human resources to overall system effectiveness is drawing considerable attention among decision makers involved in system design and development. This interest is firmly rooted in economic factors and the realization that human resources contribute heavily to the total life-cycle cost of systems. If human resources data are to be used effectively in the system engineering process, it follows that they must be made available to this process. Unfortunately, however, human resources data are scattered throughout government and contractor facilities, data banks, operational commands, etc. Unlike other areas of technology there has been no attempt to consolidate human resources data into usable reference handbooks or guides. The purpose of this research, then, was to determine the feasibility of such a handbook or guide. It seemed desirable, however, to develop a limited prototype as a first step. Since the focus was on demonstrating the feasibility of the concept, this effort was carried to the extent required to accomplish this purpose.

2. APPROACH

The first step was to identify the desirable characteristics of an ideal handbook. Design requirements were then extracted from these characteristics to serve as guidelines for the development of a prototype handbook. These guidelines included the: (1) identification and selection of potential user groups, (2) selection of data content, scope, and data sources, (3) methods for data analysis and presentation, and (4) design of the physical layout of the handbook.

For the development of the prototype handbook, it was decided to limit the target user group to those involved in the design and development of fire control systems. Included in this group were specialists in human factors, design engineering, personnel and training, and cost. The selection of data content and scope were dictated by the needs of these users. For the purpose of the prototype handbook, the data were limited to the functions performed by the Air Force 32XXX avionics career field on the fire control system of nine fighter aircraft systems. These systems included the F-106A/B, F-105D, F-4C, F-4D, F-4E, F-111A, FB-111A, A-7D, and the F-15. Data were then collected from a variety of sources, including technical and management reports, technical orders, computer banks, surveys, expert opinion, etc. The data were combined, analyzed, and prepared for presentation in the handbook. Close attention was paid to the data formatting to insure easy interpretation by potential users.

Emphasis was placed on illustrations at the expense of text. All written material was kept to a minimum and limited to the specific data presented in the illustrations. Also, an indexing scheme was developed to minimize data search time. Finally, the physical layout of the handbook was designed for ease of use. With few exceptions, all information necessary to understand specific data relationships was placed on a single page.

3. RESULTS AND CONCLUSIONS

The research discussed previously resulted in the development of a prototype data handbook. The contents were organized into three major sections. The first section provided operational data relationships between specific systems and subsystems and the applicable population of Air Force human resources. The data included comparisons between system design, training, support manpower, occupational jobs/tasks, maintenance procedures, logistics support, and various costs. The second section included information pertinent to past, current, and projected numbers of personnel having various skills and experience levels. The purpose of this section was to allow the user to assess the impact of projected human resources on the design requirements of systems under development or planned for future design and development. The third section was designed for more generalizable technical information. Included in this final section were data on the effects of task complexity, time required for Air Force maintenance, personnel to acquire certain skills, performance time, error rates in maintenance, etc. Introductory material to the handbook included the purpose, scope, organization, and the use of the indexing scheme.

4. DIRECTIONS FOR FUTURE RESEARCH

The next step in handbook development should be to test and evaluate: (1) the acceptability and usability of the handbook by potential users, (2) the acceptability of the data presentation and indexing techniques, and (3) the possible impact of the handbook on system design decisions. Test and evaluation should be conducted to assess the concept of this type of handbook, rather than to evaluate the data content. Recommendations resulting from this program can be used to guide the development of a more comprehensive handbook.

PREFACE

This study was directed by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 1124, "Human Resources in Aerospace System Development and Operation," and Task 1124 03, "Human Factors Engineering Technology for Development of Weapon Systems." Mr. Melvin T. Snyder was the Project Scientist and Mr. Lawrence E. Reed was the Task Scientist. Major Duncan Dieterly assumed the responsibility as Project Scientist upon the retirement of Mr. Snyder on 4 January 1974. The research was performed as a cooperative effort among government and contractor personnel. Major portions of the prototype handbook contained in the appendix to this report were prepared by the McDonnell Douglas Astronautics Company - East, St. Louis, Missouri, under Contract F33615-72-C-1582 with Mr. James Curtin, Engineering Psychology Department, as the Principal Investigator. The research under contract was conducted during the period from 1 April 1972 through 15 March 1974. The government effort was conducted by the Personnel and Training Requirements Branch of the Advanced Systems Division during the period from 31 October 1971 through 30 June 1975.

The authors wish to acknowledge the many government and contractor personnel who contributed valuable suggestions throughout the course of the research. Special thanks are due Dr. Gordon A. Eckstrand and Dr. Ross L. Morgan who reviewed the manuscript. The authors also thank Messrs. L. R. Anderson and A. McCormick of McDonnell Douglas who assisted in the contract effort. Finally, the authors acknowledge the substantial assistance provided by Lt. Col. W. E. Miller, Lt. Col. Sexton, Major E. H. Schmidt, Captain L. Redman, C. L. Niblock, and H. L. Dorman of Randolph Air Force Base, Texas; Col. G. Brown and D. O. Gilder of Lowry Air Force Base, Colorado; C. Feeley and J. B. Kinder of Wright-Patterson Air Force Base, Ohio; Col. J. B. Carpenter and Dr. R. A. Bottenberg of the Air Force Human Resources Laboratory, Lackland Air Force Base, Texas; Mr. J. Jori of Hq. Air Force, Washington, D. C.

This report was completed subsequent to the retirement of Mr. Melvin T. Snyder. One would be remiss, however, not to acknowledge his contributions to this and closely related efforts. Those contributions went well beyond what is implied [illegible] his authorship of this report. His constant dedication to solving Air Force human resources problems, and his breadth of understanding of those problems, inspired this research and provided many useful insights during its conduct. It is hoped that the final product does justice to his original concept of a human resources handbook for application to Air Force system development problems.

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I. INTRODUCTION

OVERVIEW OF THE PROBLEM

The importance of Air Force human resources to overall system effectiveness presently is drawing considerable attention among decision makers involved in system design and development. This new interest is rooted in basic economic factors and the realization that human resources contribute heavily to the total life-cycle cost of systems. Yet, as emphasized by Lintz et al., (1973), the human resources requirements often are introduced late, or not at all, into the system design and development process. Why human resources have had little impact in this process was the subject of controversy and research for many years. Perhaps the problem can be reduced to factors associated with: (1) the period in system design in which human resources must be introduced for greatest impact, and (2) the communications among the many specialists involved in making system decisions.

After devoting many years to these two problems, Askren (1973) reported that the preferred point of entry is during the period in which system design tradeoff decisions are made. In addition to being an ideal point of entry, this period also serves as a vehicle for maximum communications between the engineering and human factors specialists.

If it is possible to determine the periods in which human resources information is best introduced into system design, then why are these data often ignored? Three interrelated problems appear to be responsible for this discrepancy. First, the definition of human resources and what the term encompasses is vague. Second, the characteristics of the data remain unclear and are difficult to translate into engineering requirements. The third, and perhaps the most important problem, pertains to the availability of human resources data for application to the system design and development process. Each of these problem areas is discussed briefly.

<u>A Definition of Human Resources Data</u> To enhance communications, it is necessary that all participants be able to understand the terms being used. Unfortunately, there appears to be no general consensus on what human resources really means. Perhaps the best, and most inclusive, discussion on this topic was presented by Askren (1973). Faced with a similar dilemma, he proceeded to develop his own definition, which is quoted, in part, here:

> Human Resources refer, obviously, to the people of an organization, be it a military unit, an

> industrial corporation, a governmental agency, or educational activity. Human Resources concerns the people as a resource that can be drawn upon in the accomplishment of the purpose of the organization... (These) resources may be likened to other resources of the organization, such as equipment, facilities, land, raw materials, etc...
>
> Human Resources Data...are those data which describe the people of an organization in terms of what they can contribute, how much they cost, how available they are, how perishable they are, and how many of them are needed.
>
> What people of an organization can contribute to its purpose, refers...to their performance, capability, productivity, etc. This could be the skill of the pilot...the capability of a maintenance man to troubleshoot and repair a failed equipment... What the people of an organization cost is measured quite simply as dollars (although) the dollar figure is an exceedingly complex issue...Availability (is defined) as the probability that a given quantity of people of specific skill capability will be on-site at the operational unit/as required by the weapon system schedule...Availability...is influenced by many factors such as quantity and the kind of career airmen, recruiting rate of new airmen, training time of new personnel, transfer of experienced personnel from phasing-out systems, and attrition rate. Perishability of the human resources of an organization is partially measured by the attrition and turnover rate of people. However, a large part of perishability would have to do with retention of useful skills...How many people are needed by an organization resolves to how many people, of what skill, and what level of proficiency...The quantity, type, and proficiency of personnel needed ultimately evolves from their capability, cost, availability, and perishability. In one sense, this is the ultimate question asked by the manager of an organization, or the engineer with regard to his design (p. 5-7).

It is noteworthy that the definition of human resources is highly complex and encompasses many different factors. The definition presented above includes five classes of data, namely, personnel (1) capability, (2) cost, (3) availability, (4) perishability, and (5) quantity. Implicit in the definition is the caution that these classes of data are not mutually exclusive. Also, the elements within these classes are interdependent. Nevertheless, this definition of human resources does provide the necessary specificity for communications and is used in this report for that purpose.

Characteristics of Human Resources Data. In contrast to other types of data (for example, those of engineering and the basic sciences), human resources data are usually contaminated by outside influences, such as uncontrollable or unidentifiable variables that have an effect on the data. The differences between human resources data and data obtained under controlled conditions can be easily exemplified. The basic sciences normally obtain data from systematic research in which the variables to be tested are well defined. Also, the experimental procedures provide the appropriate controls, and the environment is well selected and described. The results of such experiments are used to confirm or disconfirm an hypothesis or set of hypotheses. Given that all conditions are met, the same results are obtained whenever the experiment is repeated. Human resources data, on the other hand, are usually collected under operational field conditions or through experimental procedures in which the variables cannot be well controlled. The number of unknown or uncontrollable variables that impinge on the experimental results often prevents the investigator from extracting meaningful and systematic patterns in the data, which would allow him to make precise predictions. Aside from the difficulties of providing adequate experimental controls, changes in economic, political, and operational philosophies contribute to the fluctuation of human resources data. Thus, for example, available manpower will often depend on economic factors.

The lack of precision in making predictions can be illustrated by the effects resulting from the termination of the draft in January 1973. Prior to the introduction of the zero-draft force, it was thought that the number of high-aptitude personnel (coming into critical Air Force jobs) would decline drastically. Subsequent research (Vitola et al., 1974) has shown that the decline was in some areas of aptitude and not in others. Also, it was found that the removal of the draft did not result in a serious drop in average aptitude, as had been expected. Obviously, there are many unpredictable social, economic, and political factors that contributed to these findings. Yet, these types of predictions are necessary to determine trends of manpower availability.

The crucial difference between human resources and engineering data is that the former are dynamic and the latter are more static. The dynamic-static dichotomy is limited to the varying effects of numerous outside influences that impinge on human resources data. Thus, the same classes of data will vary from one time period to another depending on the specific conditions (e.g., the socio-economic environment) existing at the time that the data were collected, or on the methods used to collect the data. In contrast to the more static data, precise cause-effect relationships are exceedingly difficult to isolate. This does not mean, however, that general principles, functional relationships, or trends cannot be established even though they must depend on loosely defined statistical probabilities. The relationship between skill level, performance, and training, for example, can be determined from data obtained in personal interview, questionnaires, observation, or other methods. The <u>interpretation</u> of these relationships, however, must be made with caution and with the realization that the relationships may change with time (i.e., the data may become rapidly obsolete), or with the introduction of new technologies.

The purpose of the preceding discussion was not to paint a bleak picture of current state-of-the-art in human resources technology. In fact, the remainder of this report will proceed on the assumption that meaningful human resources data relationships can be sought, analyzed, and reported. It is through this process that human resources information can be identified, defined, and finally introduced into applicable areas of system engineering.

<u>Availability of Human Resources Data</u>. Askren (1973) has shown that methods can be developed to insure that human resources data are given adequate consideration in the system engineering process. The application of these methods, however, is dependent on the availability of data. Unfortunately, human resources data are scattered throughout various government and contractor facilities, data banks, technical reports, operational commands, and in the form of expert opinion. Unlike other areas of human factors technology (e.g., human engineering) there has been no attempt to systematize and consolidate human resources information into usable reference handbooks, guides, or even simple lists of data sources. If human resources data are to be used effectively (or used at all) in the system engineering process, it follows that they <u>must</u> be made readily available to the specialists involved in this process. Not only should the data be made available, but they must also be presented in a format that is easily understood by specialists in different disciplines.

HISTORICAL ANTECEDENTS

Rapid technological advances require that specialists be kept abreast with the new information in their specific area of interest. Computer-based reference systems, handbooks, and other forms of data storage are commonly used to enhance communications. In fact, almost every field of technology has created effective measures to insure efficient and rapid dissemination of information to interested users. Traditionally, the major vehicle of communication has been the data handbook. More recently, computer-based data banks have played an increasing role in this process. Both of these methods of information dissemination will be discussed in terms of their use in human factors technology in general, and human resources in particular.

The Use of Handbooks. Recognition of the importance of reference works is demonstrated in the December 1963 Special Issue of Human Factors, the Journal of the Human Factors Society (Saul and Ronco, 1963). This issue of Human Factors contains the various papers presented during a symposium at the 1963 annual convention of the American Psychological Association. The purpose was to critically appraise the state-of-the-art in documentation in the human factors field, identify the faults and weaknesses of existing reference works, make recommendations, and identify future trends. The emphasis was on reference works in the area of human engineering technology. In fact, only one author (Sinaiko, 1963) recognized the need to include manning and training information in future reference works. He stated: "Human factors references should contain much more information on how many of what type of people are required to perform certain jobs, how much time is required, what errors are likely to be made, and so on (p. 596)." It is noteworthy that twelve years after publication, the recommendation remains unheeded.

Notwithstanding the above critical comment, many authors of the Special Issue of Human Factors presented their views on changes that should be made to substantially improve the use of current reference works. Again, it is interesting to note that many of these recommendations remain unfulfilled twelve years later! Some of the most important recommendations are repeated here:

- General Principles "The codification of general principles in human factors for use in a guidebook is far more difficult than the tabulation of specific data. However, this sort of guidance is extremely important to the designer, particularly in the early phases of system design (Devoe, 1963, p. 585)."

- Gross Format With regard to the overall format of reference works, Sinaiko (1963) stated: "It would be space well used if editors emphasized illustrations at the expense of words in the near future. There should be more graphic material, less theory and text. Overall references should be shorter, more easily searched, and self explanatory (p. 594)." Further, Devoe pointed out that a "comprehensive guide must be big. Cramming a big work into a single volume immediately creates a host of problems...I therefore envisage my ideal guide as a set of volumes, each of manageable size (p. 587)."

- Indexing "No guide can approach the ideal unless the required guidance can be located easily and quickly. The indexing of the material within the ideal guide, then, is one of the most important considerations involved in developing the guide, and, in my opinion is the weakest factor in our present human factors reference works (Devoe, 1963, p. 588)."

- Cross-Referencing "An ideal guide will have to insure that the user obtains all information bearing on his problem, regardless of his point of entry into the work...Internal cross-referencing is necessary to relate principles, methodology, and data (Devoe, 1963, p. 588)."

- Updating "One of the greatest deficiencies in current guides is the time lag, which seems insuperable, between the completion of applicable research and the inclusion of the results in a guide. An ideal guide must be up to date (Devoe, 1963, p. 589)."

Clearly, these recommendations should be followed to produce an ideal reference work. Attempts have been made to remove the deficiencies in existing handbooks. Thus, for example, the various human engineering guides provide some information on general principles. The importance of developing improved formats was emphasized in a study conducted by Meister and Farr (1967). These investigators found that design engineers strongly preferred handbook information to be in pictorial or graphical form. Meister and Farr report: "Designers tend (they say) to reject human factors handbooks on the basis of their 'wordiness.' They downgrade verbal information because they do not want details. They prefer specific answers to specific questions (p. 86)." Indexing and cross-referencing remain the weakest link between reference works and the user. Most current reference works provide the usual table of contents and alphabetical index to help the user gain access to needed information. Some current handbooks have even eliminated the alphabetical index, making data access tedious and sometimes almost impossible. A major deficiency of most reference works in human factors is that they become quickly obsolete. In a limited number of cases, this problem is remedied by providing loose-leaf volumes. This approach permits periodic updating by insertion, or deletion, of material.

Whether general principles are presented in a reference work depends on the state-of-the-art of a particular area of technology. Problems associated with the gross formats can be eliminated by redesign. Improved indexing, cross-referencing, updating, and methods for making information available to more users can be provided with the support of computer-based reference systems. However, the problems with computer-based systems as replacements for hard-copy reference works are many. These problems are discussed next.

The Use of Computers. The information explosion during recent years has resulted in greater use of computers. The computer-based bibliographical and data services in current use have served to improve the dissemination of information and to decrease the search time for specific data references. Since human resources data tend to decay rapidly, it would seem that computer-based systems would be more efficient than hard copy volumes. The problems and costs associated with these systems, however, are enormous. First, not everybody has access to computer terminals. Second, the transmission of pictorial or graphical information (the preferred mode of data presentation) is very costly. Third, rapid access to small amounts of data drawn from a large data base content is not necessarily cost effective. Fourth, the convenience of obtaining data from a well organized hard copy volume cannot be duplicated by state-of-the-art computer technology. This does not mean that computers should not be used. In fact, it would be desirable to have the computer compile, format, and output entire handbook volumes. The data base content would be kept current and outdated volumes revised and new ones mailed to subscribers. More on this topic will be presented in conjunction with the recommendations made in Section IV of this report. Suffice it to say that computer-based systems can, and should, play a significant role in the development and maintenance of reference works.

II. RESEARCH OBJECTIVES AND REQUIREMENTS

The objective of a Human Resources Data Handbook for Systems Engineering would be to consolidate in one source document all human resources data relevant to the design of complex man-machine systems. The development of such a handbook, however, would be a major task and, in fact, there was no assurance that such an undertaking was feasible. It seemed desirable, therefore, to develop a limited prototype handbook as a first step. The focus was on demonstrating the feasibility of the concept; therefore, this effort was carried only to the extent required to accomplish this purpose.

RESEARCH OBJECTIVES

The development process of a limited handbook must start with the identification of the desirable characteristics of the ideal handbook. Design requirements may then be extracted from these characteristics to serve as guidelines for the development of a prototype handbook. The desirable characteristics of the ideal handbook are described below.

Applicability. The scope of the handbook must be one in which the contents can be put to practical use during the various phases of the system life cycle. Usability and timeliness are key descriptors of what is required. Thus, the handbook should provide an important opportunity to influence system design decisions, rather than merely react to momentary problems. This means that the handbook should play an integral part in the system design process.

Relevancy. The contents of the handbook must be drawn from actual Air Force system data sources. Applicability and relevancy are considered to be inextricably related. In order that the handbook be used to influence system design decisions, emphasis must be placed on the presentation of relevant data rather than theory or other information that is of little concern to target users. Irrelevant data only serve to distract the user.

Diversity. The handbook must provide a diversity of meaningful human resources data relationships tailored to a variety of potential users. Different users will be interested in different data or may be interested in the same data, but at different levels of indenture. Thus, some users will seek specific data points (e.g., the number of specialists required to maintain particular hardware), while others will want to know something about the general principles governing certain relationships (e.g., to what extent does task difficulty have an effect on maintenance time). Obviously, the handbook cannot be a panacea, but it must provide sufficient content diversity to be usable.

Accessibility. The handbook must be made available to as many users as possible. Accessibility need not mean that all users maintain personal copies of the handbook. In fact, size and cost considerations may render general distribution impossible. On the other hand, updating and printing costs must be kept low enough to allow distribution to all organizations and specialists having an established need for the data. Wider distribution is possible if ways are found to defray cost.

Simplicity. Both the presentation and discussion of data must be kept as simple as possible to enhance the effectiveness and use of the handbook. Terminology used to interpret both qualitative and quantitative information must be clear to all users. Also, discussions must be kept relevant and limited to the data presented. Finally extensive use should be made of tables and graphs at the expense of text.

Usability. Users must be able to locate specific data and data relationships easily and quickly. This means that the index and cross reference must be flexible enough to allow the user to find all relevant data that have a bearing on a particular problem.

Amenability to Updating. The structure of the handbook must allow for easy updating. Updating must be possible to specific levels of data relationships, the associated discussion, and both the index and cross reference.

REQUIREMENTS

The characteristics listed above can be used to identify specifiable design requirements for the development of a handbook. The requirements must cover all of the necessary elements to be considered in the preparation of an ideal handbook, and also must specify those elements that can be applied to a prototype handbook. These latter requirements must serve as guidelines for the preparation of a technical approach (procedure) for the development of the prototype handbook.

The requirements presented here are classed into four major areas: (1) target users, (2) data content, (3) data analysis and presentation, and (4) handbook structure. Each of these areas is discussed below, together with a listing of specific requirements for the prototype handbook.

Target Users. A handbook, no matter what purpose it is to serve, cannot be prepared in a vacuum. Any handbook development program must have an identified set of potential users. This need to identify users becomes particularly critical in cases where data generated by one discipline are to be used by another. Engineers of different specialties, system planners, etc., may have a need for human resources data, but their requirements will differ. Thus, in order to determine the specific types of data to be included in the handbook, as well as to determine how these data are to be presented and discussed, something must be known about the potential users.

The identification of users, however, is not without problems. Many specialists feel no pressing need for these data, or are totally unaware that the data exist. Thus, interviews with potential users may be of little consequence. A better approach to the problem is to identify potential users, determine their specific function in system development, and then decide whether certain human resources data may be of help in their work.

Finally, it is important to determine the type of data formats best suited to their needs. Most specialists make use of handbooks or other reference works in their own areas of interest; thus, they have become familiar with, and accustomed to, certain methods of data presentation. The presentation of data in the handbook must be such that users will not have difficulty with the extrapolation of relevant information.

In summary, the user himself becomes a necessary source from which handbook requirements in general may be obtained. For the development of a prototype handbook, the minimum requirements are:

- Identify potential target user disciplines
- Specify the levels of responsibility that target users exercise in system development
- Select representative sample of target user disciplines

Data Content. Perhaps the most difficult task in handbook design and development is the selection of data to be considered for inclusion. The scope to be covered in the handbook must be relatively well defined to insure that irrelevant material is not included and that the total size of the handbook is kept within reasonable bounds. Yet, the constraints on content and size must remain somewhat flexible so that changes and additions to the content as well as handbook size (e.g., single vs. multiple volumes) can be accommodated during handbook development.

The principal objectives of handbook development require that emphasis be placed on data drawn from field or applied research rather than the laboratory (data gathered in an experimental laboratory for the purpose of supporting theory). Also, existing data sources must be sought so that costly and time consuming field research is avoided. Many data sources exist from which relevant information may be obtained. These sources must be sought from government organizations that maintain records on logistics, cost, and personnel for systems that are currently in operational use, and from those that are in various stages of development. Another source that must be considered is the expert opinion of system specialists. Relevant applied research conducted by government, industry, and educational institutions must also be given consideration.

The selection of data sources is based on the types of data to be included in the handbook. As noted earlier, human resources encompass a wide spectrum of data, not all of which are pertinent to system planning, design, and development. An attempt to bridge the gap between different disciplines requires that care be taken in selecting what is potentially meaningful and useful information.

Since the handbook contents must be limited to applicable system information, it is important that all data be oriented to selected systems/subsystems, operational mission requirements, and applicable populations of Air Force personnel. For the prototype handbook, it is important that a class of aircraft systems be selected from which relevant operational data are readily accessible. These systems must be sufficiently representative so that detailed comparative analysis across hardware and personnel data can be accomplished to produce meaningful relationships. For example, if mean time to repair is to be compared across systems, this relationship will be meaningful if the activity is accomplished by personnel having the same specialty and is conducted on equipment that performs the same type of function. This same relationship can be taken to an even lower level of specificity by comparing the same equipment across the same type of aircraft, or similar classes or aircraft (e.g., fighters).

For development of a prototype handbook, the minimum requirements are:

- Define the scope and data contents
- Select representative data
- Select data sources

Data Analysis and Presentation. Analysis refers to the ways in which data must be reduced or combined for inclusion in the handbook. Presentation refers to the way or ways in which data are formatted for easy interpretation by users. Taken together, these areas of consideration are, perhaps, the most important in handbook development. In fact, most problems associated with handbook usability can be traced to these two areas. Several factors tend to complicate the procedures for analyzing and presenting human resources, in contrast to other kinds of data (e.g., human engineering). First, the data to be included in the handbook must be drawn from many different sources, including some in which the data are in a constant state of flux. Second, data belonging to the same categorical class (e. g., manpower quantities), but on different systems (e.g., F-111A vs. F-4E) may have been derived from different sets of variables or models. Third, the method of collecting data in support of different systems may differ. Fourth, data obtained from operational organizations usually are generated by different people (e.g., various maintenance personnel) with the resultant increase in data variability. Fifth, the same classes of data, but on different systems, may have been drawn from expert opinion, questionnaires, maintenance summaries, or various sophisticated computer-based simulation models. Thus, the unstructured environment in which human resources data are obtained may lead to large variances in the data. Yet, as indicated in the Introduction, most of the information to be presented in the handbook necessarily must be drawn from these kinds of sources.

Given the sources of data variability discussed in the preceding paragraph, all attempts to reduce, analyze, and combine human resources data must proceed with caution. Forcing data into certain relationships can lead to gross misrepresentations. How inappropriate analysis can distort handbook data inputs is easily illustrated. Suppose, for example, that manpower estimates are to be presented for the same maintenance activities on two different systems but the data are drawn from different kinds of sources. If it is found that the estimates were derived from different sets of assumptions or different models, should both estimates be combined into a single chart representing the two systems? The answer is clearly in the negative since such a comparison would be misleading and would not represent a meaningful relationship to the potential handbook user. On the other hand, if both estimates appear to be important, or are the only ones available, then both should be presented, but on different charts and with detailed comments to caution the user against possible misinterpretations.

While data analysis and data presentation appear to be separate problem areas of handbook development, they are in fact closely interwoven. The data should be analyzed and combined so that the final product can be presented in a graph or table. This procedure is not always simple. Thus, some types of data can be presented as continuous functions. A relationship showing maintenance manhours on different systems, for example, must be presented in a table or bar graph. A relationship between performance time and years of experience, on the other hand, can be presented as a continuous function. Finally, it is not possible to pair-off all data to show logical and systematic correspondences. It is the responsibility of the handbook developer to insure that the data are meaningful and can be combined in accordance with accepted statistical scaling procedures.

Other areas of consideration that cannot be separated from data analysis and presentation include the use of text and the methods for indexing and cross-referencing handbook data. It was already noted that illustrations should be emphasized at the expense of words. The handbook user must not be burdened with lengthy theoretical arguments that have little or no bearing on the applicability of the data. This does not mean that text be altogether eliminated. It does mean, however, that written material be kept to a minimum and be limited to areas of clarification of the data.

It would be time well spent and space saved if written materials emphasize the applicability of the data to certain classes of system design problems. This is a difficult task to accomplish and requires the writer to have considerable knowledge of the data and their possible applications to system engineering problems. Nevertheless, the acceptability of the handbook among potential users may very well depend on this factor.

The handbook will be completely abandoned unless the user can gain easy and quick access to specific data. The entry into the handbook must be made simple and must avoid the need for endless cross-referencing. This does not mean that the user should not learn how to enter the handbook. Rather, it simply means that the data be classified and indexed so that search time is minimized. Also, the need for parsimony does not mean that the user be limited to a single procedure to enter the handbook. In fact, in the name of parsimony and practical economy, more than one indexing scheme may be needed to fulfill user needs.

Once the user has entered the handbook and found needed data, he also should be provided with internal cross-references to related information. It is only through a process of cross-referencing that the unitary quality of a handbook is achieved. Care must be taken to insure that the cross-references help provide all the information bearing on a problem, without making the process a chore.

Finally, the indexing and cross-referencing scheme should be closely tied to the data classification structure used in the handbook. Devoe (1963, p. 588) stated that: "The aim (of a good index) should be to anticipate every verbal way in which a user may come to the work for information and to have his own terms on hand to guide him." Thus, subject areas could be arranged in a matrix to show the various classes of data and data combinations contained in the handbook. This method of entry would be supplemented with an alphabetical listing of subject areas.

For the development of the prototype handbook, the minimum requirements are:

- o Develop and select methods for analyzing and combining relevant data
- o Select best methods to present given data relationships
- o Develop methods to index and cross-reference handbook data

<u>Handbook Structure</u>. Structure deals with the gross physical layout of

the handbook. This includes: (1) the design of data formats, (2) the use of loose leaf or bound volumes; (3) the use of section tabulations, (4) allowances for expansion or deletion of data, (5) the location of indexes, and (6) the organization and location of written introductory materials, including guidance in the use of the indexing scheme or schemes. The utility of the handbook will be seriously restricted if the physical layout makes it cumbersome to use. Given that the appropriate data are selected, analyzed, prepared for presentation, and appropriately indexed, it is then the responsibility of the handbook developer to insure that the total layout allows the user to satisfy his needs with minimum difficulty.

For the development of a prototype handbook, the minimum requirements are:

- Prepare a usable format structure
- Organize contents, including introductory material and indexes, data sections, etc., for maximum ease of use

III. METHODS

The methodological approach was directed to the development of a limited prototype handbook of human resources data. This handbook would then serve to: (1) assess the feasibility of combining human resources data into relationships that convey meaningful information to potential users, and (2) assess the feasibility of designing and developing a handbook that is simple to use. Accordingly, each step in the preparation of the prototype handbook was taken with one primary consideration, namely, the ultimate user. Close attention was paid to the types of design requirements discussed in Section II of this report. It must be kept in mind, however, that the purpose was to approach an ideal design, rather than actually develop an optimal full-scale handbook. The prototype handbook is provided as an appendix to this report. To avoid repetitive and excessive details in the discussion of the procedures, the reader is asked to review Appendix A.

PROCEDURES

Identification and Selection of Target User Groups. As indicated earlier, the primary objective of the handbook is to facilitate communications between technical specialists in different disciplines. This does not mean that the prototype handbook must satisfy the requirements of all potential users of human resources data. Such an undertaking would require extensive analysis of user disciplines and user needs at all levels of responsibility and at all levels of indenture. Accordingly, for the limited prototype handbook, it was decided to limit the target user sample to those involved in the design and development of fire control subsystems. Levels of responsibility within this sample ranged from managerial to technical specialists directly involved in system design. The technical disciplines included specialists in the areas of human factors, design engineering, personnel and training, and cost. This breakdown was somewhat arbitrary, but did provide workable boundaries. It must be pointed out that these boundaries were limited to users who need access to human resources data as defined in the Introduction. Thus, not all human factors specialists involved in the design of fire control systems require these types of data; neither do all design engineers, cost specialists, etc. The objective, then, was to direct the design of the prototype handbook to those that have a pressing need for human resources data.

Data Content. The selection of data content and scope was dictated by the specific needs of the users. For the prototype handbook the data were limited to the functions performed by the Air Force 32XXX avionics career field on the fire control system of nine fighter systems. These systems included the F-106A/B, F-105D, F-4C, F-4D, F-4E, F-111A, FB-111A, A-7D and the F-15. The classes of data collected were, in part, determined by what the investigator thought to be relevant, and by the availability of data. No attempt was made to systematically survey user needs, although such an investigation might have been beneficial. A listing of the classes of data selected is presented in the Master Index of the prototype handbook (see the Appendix) and will not be repeated here.

Once the scope of the prototype handbook was defined, it was necessary to seek primary data sources and then extract the relevant data from these sources. A non-exhaustive list of data sources, together with the types of data, and samples of data content collected from these sources, is shown as follows:

PRIMARY SOURCES	TYPES OF DATA	SAMPLE DATA CONTENT
Technical and Management Reports	Theoretical	Performance curves, effects of experience, etc.
	Models	Mathematical models to determine various costs, personnel attrition, manning requirements, manhours, etc.
	Field research and expert opinion	Types of maintenance tasks, task difficulty, effects of experience, etc.
	Assessment	Personnel qualification and aptitude.
	Personnel Structure	Projected distribution of personnel to future years.
	Logistics	Logistic support costs.

CONTINUED:

USAF Technical Orders and Engineering Reports	Engineering block diagrams	Functional flows and interrelationships of fire control systems.
	Subsystem information	Types of subsystems, number of associated subsystems, etc.
Computer Data Banks	Logistics	Identification of subsystems and components, performance time, maintenance actions taken, costs, etc.
	Occupational surveys	Types of tasks, time to perform, etc.
Letter and Personal Communications	Occupational surveys	Types of tasks, time to perform, distribution of skill levels, etc.
	Manpower projections	Projected personnel needs to future years.
	Training information	Personnel training time, costs, etc.

While the above listing is only representative, it is noteworthy that the data sources and content are extremely diverse. No single source was sufficient to provide even the minimal information required for the prototype handbook. Any future work directed to the development of a full-scale handbook would require an exhaustive search for potential data sources.

Data Analysis and Presentation. The problems associated with data analysis and presentation are many and complex. Any attempt to analyze and organize information drawn from diverse sources will result in the discovery of data redundancies, conflicting data, missing data points, questionable data, etc. For the purpose of the prototype handbook, many of these problems were resolved through a process of strict source selection. Also, outdated or other information that had only peripheral relevance were avoided. To avoid the inclusion of redundancies, the collection of certain classes of data was restricted to single data sources. Thus, for example, most of the data on maintenance manhours were obtained from logistics data banks. Finally, there were a few attempts to integrate highly selected data that were drawn from different sources, but logically belonged to the same class of information. This procedure was found to be extremely difficult to apply and often resulted in the formatting of inappropriate data relationships and the presentation of misleading interpretations of these relationships. Unless there is ample justification, this type of procedure should be avoided.

Several attempts were made to model the prototype handbook around specific types of design problems. Thus, the development of the handbook would require data directly relevant to these problems. This attempt was abandoned in the early stages of development. In place of an overall model, a method was sought to tie some of the data to a common baseline. Selected for this purpose was a technique that allowed the dividing of the nine fire control systems into two levels of state-of-the-art technology. These two levels represented major changes in design technology (e.g., the use of semi-automatic test equipment; the use of microcircuits). The data were then formatted to show the effect of these changes on manpower, manhours required to maintain certain equipment, training time, etc. The use of the handbook, however, was not to be restricted to these divisions.

In order to adhere to the design requirements discussed in Section II, emphasis was placed on the presentation of graphical information, rather than text. Theoretical statements were avoided or totally eliminated from the written materials. All discussion was restricted to two areas, namely, comments and implications. The former provided a short description of the data, methods used to collect data, definitions, etc. Where possible, the latter provided a short summary of possible implications of the data to Air Force system engineering problems.

Two modes of entry to the prototype handbook were developed. The first allows the user to search for specific data relationships. This mode of entry is dependent on the direct application of numerical levels of indenture provided by an indexing scheme and requires the user to follow three simple steps. The lowest level of indenture (i.e., the level in which the most detail is found) also serves as the page number. The second mode of entry is an alphabetical listing of the major topic areas. Finally, internal cross-referencing is provided at various levels of indenture, but primarily at the lowest. For the prototype handbook, this cross-index allows the user to obtain selected information referenced in the text (i.e., under the comments or implications).

Handbook Structure. The design of the data formats was adapted, with modifications, from Price and Tabachnick (1966). Each format was structured to insure that all necessary information pertaining to the data was presented with clarity. This included the placing of the tables and graphs, the title, written comments, references to applicable models, a short title of the data contents, cross-references, and the indexed page number. With few exceptions, all necessary information was placed on a single data page. This procedure simplified problems of adding or deleting (i.e., updating) handbook entries.

The physical layout of the prototype handbook was designed for ease of use. Data formats were first placed into three major sections. The first section was reserved for data comparisons between system design, training, support manpower, logistics, various costs, etc. Included in the second section were data formats pertinent to past, current and projected numbers of personnel, various skill levels, enlistee aptitudes and qualifications, etc. Finally, the third section was reserved for technical information that could be generalized to a wide variety of problems. Included in this final section were formats containing information on the effects of task difficulty, maintenance activities, mathematical models pertinent to the classes of data found in the other sections, etc.

Introductory material to the handbook included the purpose, scope, organization, and the use of the indexing schemes. The steps necessary to find data were illustrated in a figure to provide the user with a better understanding of the indexing scheme. The master index, master index table of contents, and list of abbreviations followed immediately after the introductory material. The alphabetical listing of major topic areas was placed in the back portion of the handbook. Rather than reiterate the procedures required to enter the handbook, it is recommended that the reader review Appendix A.

IV. CONCLUSIONS AND RECOMMENDATIONS

The research described in this report investigated the feasibility of developing a handbook of human resources data for application to systems engineering problems. A prototype handbook, limited to fighter fire control systems, was prepared to determine whether such a handbook could be developed in accordance with design requirements of an ideal guide. As in most exploratory investigations of this kind, there were many problems to be resolved and many iterative steps to be taken. Unfortunately, it was not always possible to resolve all problems or adhere to all design requirements. Accordingly, the prototype handbook is not exhaustive in content and does not contain all of the desired design features. It does, however, represent an initial step in an important, but heretofore neglected, area of technology.

The accumulated experiences gained in research usually result in a product and recommendations for futher research. The recommendations listed below are based primarily on these experiences.

1. The next step must test and evaluate: (a) the acceptability and usability of the handbook by potential users, (b) the acceptability of the data presentation and indexing techniques, and (c) the possible impact of the handbook on system design decisions. Test and evaluation should be conducted to assess the concept of this type of handbook, rather than to evaluate the data content. Recommendations resulting from this test and evaluation program should be used to guide the development of a more comprehensive handbook.

2. Greater attention should be paid to the use of computers in the development and updating of handbooks. The problems associated with the maintenance of loose leaf handbooks are many. It would seem cost-effective to have computers output hard copy reports, which can then be reproduced. Since human resources data become rapidly obsolete, the use of pulp paper is justified to reduce the cost of reproduction. Rather than update single pages of the handbook, entire volumes would be periodically output, reproduced, and disseminated to paying subscribers. In fact, the use of computers for this purpose would allow the preparation of handbook volumes tailored to different user needs.

3. Extensive surveys need to be conducted to identify all potential sources of data. In cases where data cannot be drawn from existing sources, it will be necessary to plan and initiate new data gathering efforts. In this regard, it is recommended that greater reliance be placed on field research and expert opinion.

4. The development of a full-scale handbook will require a very large effort. Such an effort is possible only under the auspices of a responsible agency. In this regard, Devoe (1963) emphasized that: "the existence of such an agency is intended to imply...that it has the authority and financial support to do the job. Without such an agency, any guide, no matter how ambitious, will be a one-shot effort and will rapidly become outdated. In fact, my opinion is that this is the one serious hurdle in our path; given an agency with support, the technical problems of creating a near-ideal guide are solvable (p. 589)."

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APPENDIX A:

PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEM ENGINEERING: FIRE CONTROL SYSTEMS

PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEMS ENGINEERING

INTRODUCTION: This prototype handbook was prepared: (1) to assess the need for a technical reference containing human resources data, and (2) to determine whether it is feasible to combine human resources data obtained from many different sources into a format that conveys meaningful information to potential users. As the title implies, the intention was to develop a limited handbook containing samples of data that must be given consideration in a full-scale handbook development program. It is well known that human resources data are difficult to obtain and are often unavailable. Thus, the development of a full-scale handbook will require the collection of field data where necessary. While this prototype handbook does contain a limited amount of data gathered from various training and operational organizations, they do not present a complete picture of Air Force human resources utilization. Since the primary intention of this document is to assess the need for a human resources handbook, all readers are invited to submit recommendations and comments to: Air Force Human Resources Laboratory (AFHRL/ASR), Wright-Patterson AFB, Ohio 45433.

HANDBOOK CONTENTS

PURPOSE

The Human Resources Data Handbook for Systems Engineering, henceforth referred to as the Handbook, presents a wide variety of human resources data on manpower, personnel skills, training, maintenance performance, logistics, and costs as they relate to, and interact with, operational systems and subsystems. The objective is to convey quantitative relationships between human resources and hardware in a way that can be made meaningful and useful to specialists actively engaged in system design and development. Potential users of the handbook include human factors specialists, training planners, design engineers, configuration managers, system planners, etc. The intent, then, is for this handbook to fulfill the following needs:

1. Consolidate, in a single comprehensive volume, human resources data applicable to system design and development. These data are usually scattered in many government and contractor data banks, technical reports, operational commands, and in the form of expert opinion. The handbook should serve to bridge the gap between these sources of data and the user.

2. Assist the user to determine how human resources are influenced by system design and vice versa.

3. Provide a means by which specialists involved in system design and development can make optimal use of human resources data. The influence of human resources data on design should result in maximizing the balance between total life cycle cost and mission effectiveness by optimally matching the design with the available human resources.

4. Present data from different disciplines in a manner that not only reveals interrelationships, but also presents the information in a form which is easily understood by the user.

5. Provide a means by which certain design problems can be identified and resolved.

6. Facilitate communications and interchange of data among specialists in different disciplines. Thus, the handbook should allow design tradeoff decisions to take into account the constraints of the Air Force human resources.

SCOPE

The handbook is limited to data on the functions performed by the 32XXX avionics career field on the fire control system (FCS) of nine fighter systems. These systems include the F-106A/B, F-105D, F-4C, F-4D, F-4E, F-111A, FB-111A, A-7D, and the F-15. In general, the handbook deals with (1) the quantitative interrelationships between human resources and operational system hardware, (2) the projected human resources posture, and (3) technical information which can be generalized to a wide range of problems. As indicated in the Introduction, complete sets of data on all factors of the Air Force human resource are difficult to obtain or are totally unavailable. Thus, the prototype handbook does not contain all of the information desirable in a full-scale handbook. While the scope of this handbook is rather limited in both depth and breadth, the information it does contain should serve as an example of the types of data that must be included in a full-scale handbook.

ORGANIZATION OF THE HANDBOOK

The handbook is organized into three data sections and two indexing schemes, which provide the user with a simple method to gain access to needed data. It is recommended that users of this handbook first review the material provided under Use of the Indexing Scheme prior to initial use of the handbook.

The three data sections of the handbook are:

SECTION I - Empirical Data on Fire Control Systems

In general, this section contains comparisons between system designs, training, support manpower, occupational jobs/tasks, maintenance procedures, logistic support, and various costs. The purpose of this section is to provide operational data interrelationships between specific systems and subsystems, and the applicable populations of Air Force human resources. Thus, the data should provide some insight into how the various resources were used and allocated, the consequences of these allocations, and the possible impact of changing technology which interact with the use of these resource allocations.

SECTION II -Human Resources Posture

This section contains information pertinent to past, current, and projected numbers of personnel with various skill and experience levels. This section also compares the characteristics of enlistees prior to the termination of the draft with enlistees of the all-volunteer force. The objective is to allow the user to assess the impact of projected human resources on design requirements of systems under development or planned for future design and development.

SECTION III-General References

This section contains technical information which can be generalized to a wide range of problems. Included in this section are data on the effects of task complexity, the time required for Air Force maintenance personnel to acquire certain skills, error rates in performing maintenance activities, performance time, etc. This section also contains mathematical models which may have practical application in deriving system life cycle cost. Most of these models are concerned with, and make use of, the classes of data contained in Sections I and II.

With few exceptions, each data page in this handbook contains a set of relationships that stands alone and is relatively self explanatory. To reduce confusion, each page has the same headers and is of the same or similar format. The upper third of the data page presents a set of functions, a table, functional flow, bar chart, or other form of showing the pertinent data relationships. The headers and contents of each are listed and described below:

1. TITLE - A descriptive title of the data relationships shown.

2. COMMENTS - A short description of the data, the methods used to collect the data, the population which was sampled, definitions, or other pertinent information.

3. IMPLICATIONS - A short summary of the possible implications of the data to Air Force system design, development, operations, etc. In many cases this summary is limited to an interpretation of the data relationships and possible contributing factors, or sources of variance, that led to the shown data relationships. In general, the implications of the data relationships are the best interpretation provided by the writer. Thus, the user of this handbook may wish to apply his own interpretation.

4. DATA SOURCES - A list of references from which the data were obtained. The list of references is numbered and each appears as a superscript in the appropriate place of the Comments or Implications. Where possible, the references contain enough information for the user to gain access to the original sources. In other cases, the reference is to a more general source, such as the Air Force data banks containing maintenance summaries.

5. MODELS FOR DATA APPLICATION - An index number(s) to a mathematical model(s) contained in Section III (see Use of the Indexing Scheme). The particular predictive models selected for a set of variables are conceptual.

6. SUBJECT - A short title of data contents with an emphasis on the key words appearing in the Master Index Tables of Content (see Use of the Indexing Scheme).

7. INDEX - The two major index numbers, keyed to the Master Index (see Use of the Indexing Scheme).

8. CROSS-INDEX - A reference to a data page containing related information. In order to obtain complete information on data being discussed under the Comments or Implications, the user should also review the page referred to in the Cross-Index (see Use of the Indexing Scheme).

9. PAGE NUMBERS - The page numbers are keyed to the indexing scheme of this handbook. The use of this method for sequencing the pages allows for rapid deletion or addition of entire pages without requiring an update of other pages.

USE OF THE INDEXING SCHEME

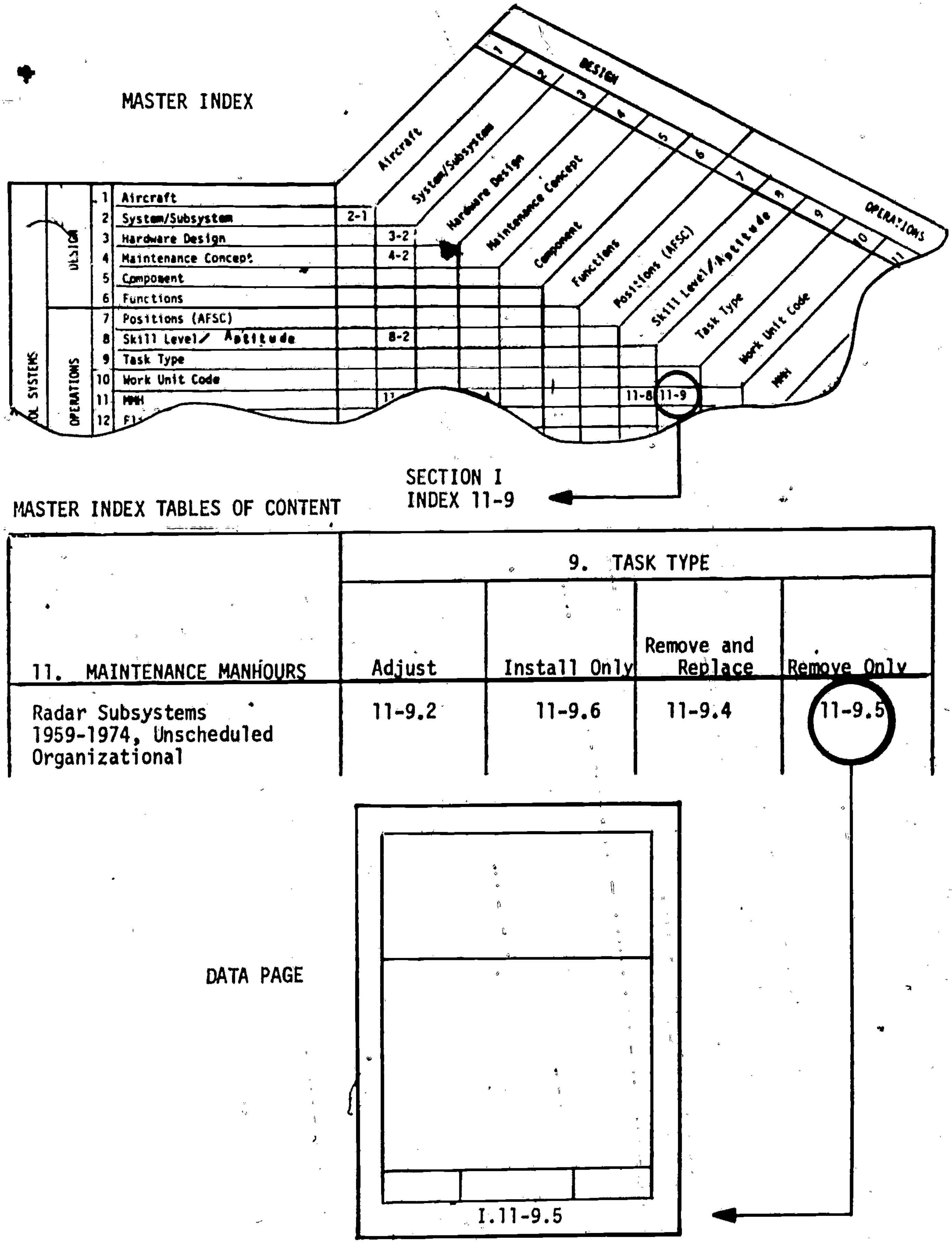
There are two procedures which can be followed to gain access to needed data. The first procedure allows the user to search for specific data relationships. If he is interested in determining the relationship which may exist between maintenance manhours and certain subsystems, he must turn to the Master Index and the Master Index Tables of Content. The second procedure provides the user with an alphabetical listing of major topic areas covered in the handbook. This listing is located in the back portion of the handbook. In order for the user to apply either of these two procedures, he should first gain an understanding of the indexing scheme used for numbering the pages.

Index Numbers: The index number is composed of four numbered elements, each separated by a dash or period (e.g., I.11-9.5). The first element is a Roman numeral that identifies the section of the handbook. The next two elements, in Arabic numerals, are keyed to the Master Index. The first of these two elements is drawn from the numbers in the left-hand vertical margin of the Master Index and the second from the diagonal margin. The last element, also in Arabic numerals, is keyed to the Master Index Tables of Content.

Steps to Find Data: The procedures for finding needed data in the handbook require three simple steps. The steps to be exemplified here are also illustrated in Figure 1. Say that the user would like to know whether there is a difference in maintenance manhours (MMH) for removal actions of fire control radar subsystems on the various fighter systems. First, the user must turn to the Master Index to determine whether this type of information exists in the handbook. By scanning the left-hand margin he finds that maintenance manhour information is in Section I under the general subtitle, Operations, and has the index number 11. The user then matches this index number with one provided in the diagonal margin. For maintenance removal actions, the appropriate index number is 9. Thus, the appropriate cell in the Master Index is 11-9. (If the cell is blank, then the handbook will not contain the needed information.) The next step is to proceed to the Master Index Tables of Content located immediately following the Master Index page. The index numbers at the top of each Table are in sequential order and match those in the cells of the Master Index. In the example provided here, the user seeks Table 11-9 for Section I data and finds that the needed information is on Page I.11-9.5. The last numeral of the index is found under the appropriate column of the Table.

The above procedures can be summarized as follows:

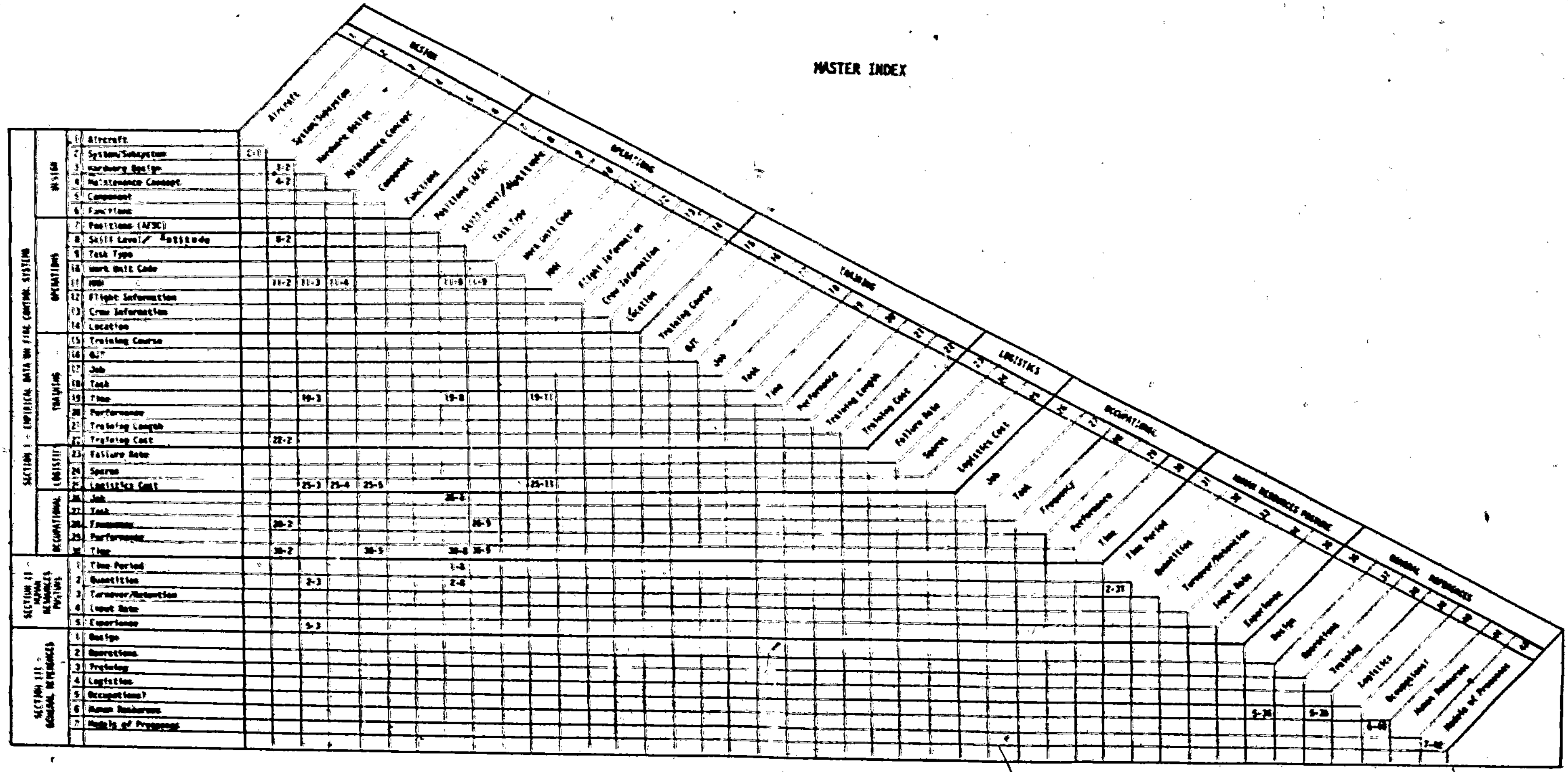
1. Determine the section number in which the needed data may be found.
2. Find the appropriate index number from the Master Index.
3. Determine the page number from the Master Index Tables of Content.



	9. TASK TYPE			
11. MAINTENANCE MANHOURS	Adjust	Install Only	Remove and Replace	Remove Only
Radar Subsystems 1959-1974, Unscheduled Organizational	11-9.2	11-9.6	11-9.4	11-9.5

Figure 1. Steps to Find Data

MASTER INDEX



MASTER INDEX TABLES OF CONTENT

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	1. AIRCRAFT			
2. SYSTEM/SUBSYSTEM	F-106 A/B	F-105D	F-4C	F-4D
Fire Control System Tie-In Block Diagram	2-1.1	2-1.2	2-1.3	2-1.4

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	1. AIRCRAFT			
2. SYSTEM/SUBSYSTEM	F-4E	F-111A	FB-111A	A-7D
Fire Control System Tie-In Block Diagram	2-1.5	2-1.6	2-1.7	2-1.8

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	1. AIRCRAFT			
2. SYSTEM/SUBSYSTEM	F-15			
Fire Control System Tie-In Block Diagram	2-1.9			

	2. SYSTEM/SUBSYSTEM			
3. HARDWARE DESIGN	Fire Control Systems 1959-1974	Radar Subsystems 1959-1974		
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In-Flight Testing and Fault Isolation	3-2.1			
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<table>
<tr><th rowspan="2">8. SKILL LEVEL</th><th colspan="4">2. SYSTEM/SUBSYSTEM</th></tr>
<tr><th>Fire Control Systems 1959-1974</th><th></th><th></th><th></th></tr>
<tr><td>No. of Technicians Per Squadron</td><td>8-2.1</td><td></td><td></td><td></td></tr>
</table>

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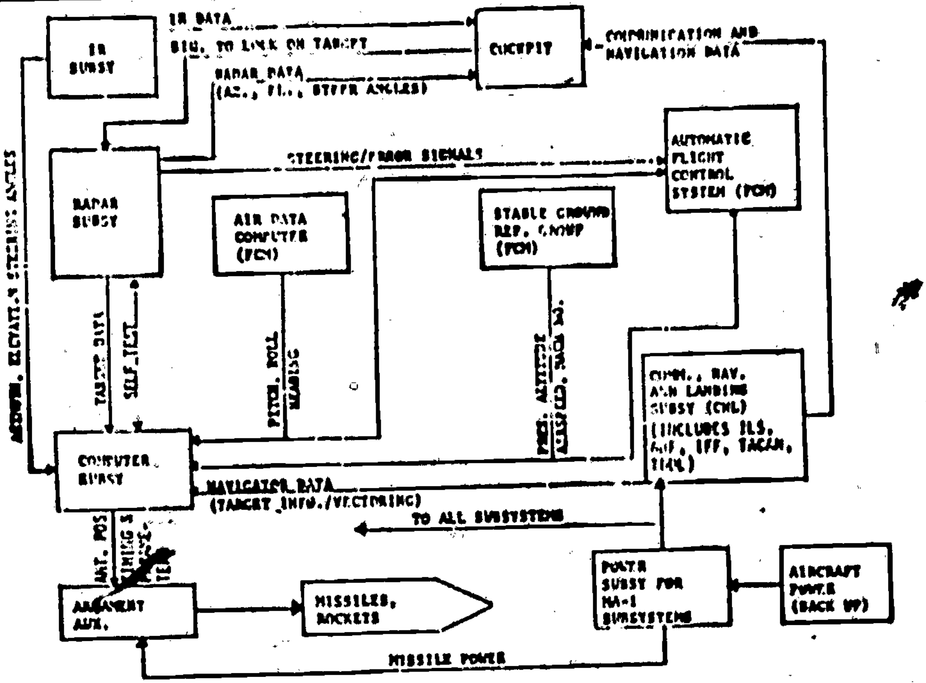
LIST OF ABBREVIATIONS

AFB	Air Force Base
AFQT	Air Force Qualification Test
AFSC	Air Force Specialty Code
AGE	Aerospace Ground Equipment
AQE	Airman Qualifying Examination
ATE	Automatic Test Equipment
BITE	Built-In Test Equipment
FSC	Fire Control System
FH	Flight Hours
FL	Flight-Line
IR	Infra-Red
LRU	Line Replaceable Unit
LSC	Logistics Support Cost
MELEC	Microelectronics
MMH	Maintenance Manhours
MTBF	Mean Time Between Failures
MTTR	Mean Time to Restore
OJT	On-the-Job Training
SATE	Semi-Automatic Test Equipment
TAFMS	Total Active Federal Military Service
USAF	United States Air Force

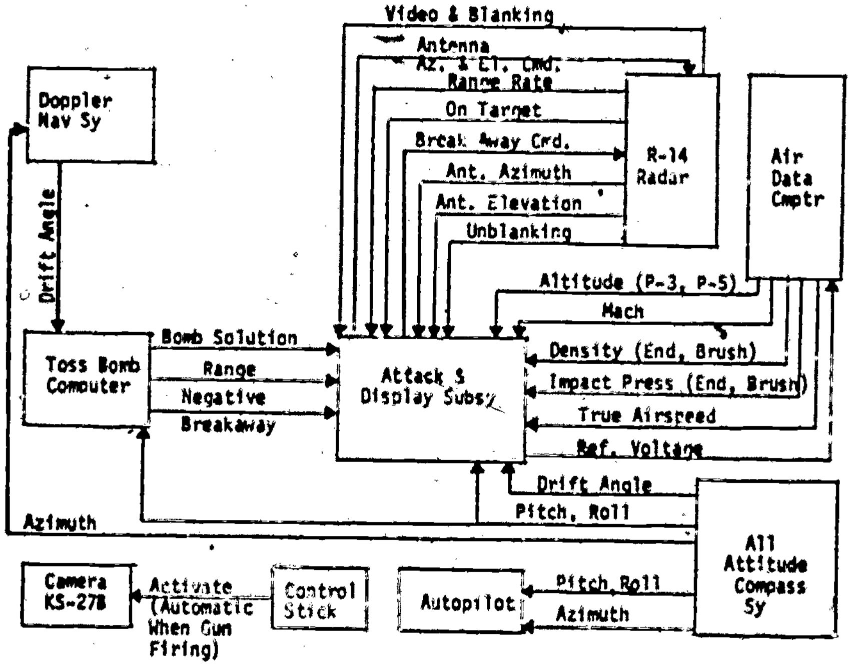


TITLE: F-106A/B Fire Control System Tie-In Block Diagram

COMMENTS: The F-106A and F-106B are single-place and two-place high-speed, delta-wing interceptors designed for high altitude, all-weather operations. The integrated F-106A MA-1 system consists of the MA-1 radar and IR, armament subsystem, communications-navigation-landing system, flight control and measurement, digital computer, and the power supply and is associated with 15 other subsystems in its signal processing network.[1] The F-106A/B was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order 1F-106A-2-27-5.

MODELS FOR DATA APPLICATION: III.7-42.1(A) III.7-42.1(B)	SUBJECT: F-106A/B Fire Control System Block Diagram	INDEX: 2-1 CROSS-INDEX: I.3-2.1

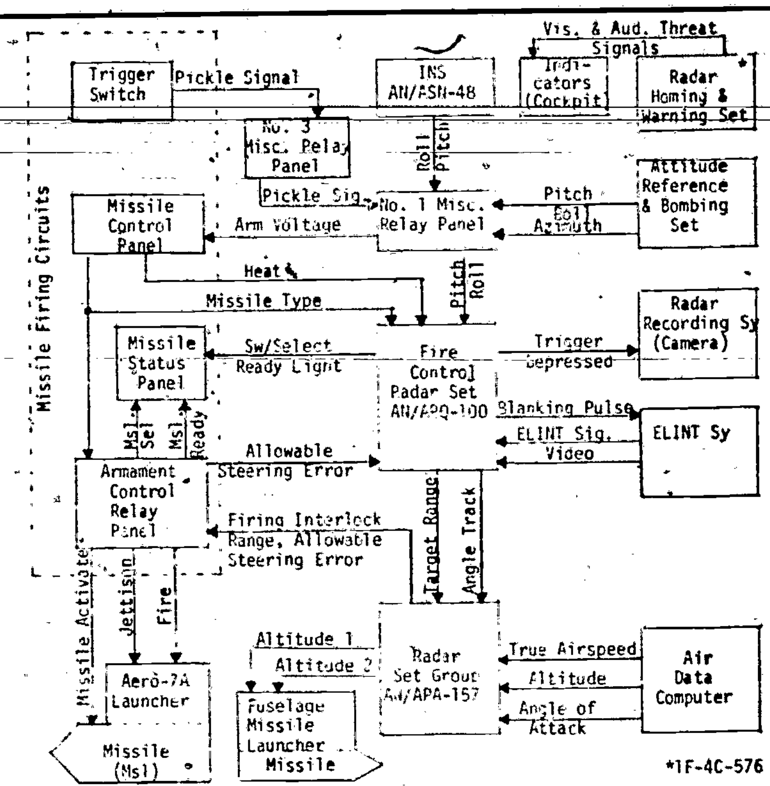


TITLE: F-105D Fire Control System Tie-In Block Diagram

COMMENTS: The F-105D, a single-place all-weather fighter-bomber, is equipped with the NASARR monopulse radar system and doppler radar for night or bad weather operation. The Fire Control System ASG-19 consists of the attack and display subsystem R14A/G radar subsystem, and the bomb tossing computer subsystem and is associated with six other subsystems in its signal processing network. The F-105D was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order IF-105D-2-11-2.

MODELS FOR DATA APPLICATION: III.7-42.1(A) III.7-42.1(B)	SUBJECT: F-105D Fire Control System Block Diagram	INDEX: 2-1 CROSS-INDEX: I.3-2.1



TITLE: F-4C Fire Control System Tie-In Block Diagram

COMMENTS: The F-4C is a two-plate tandem, supersonic, all-weather, tactical aircraft with the capabilities of delivering combinations of missiles, bombs and rockets. The Fire Control System consists of the APQ-100 radar subsystem, APA-157 radar set group, and the missile firing circuits and is associated with 14 other subsystems in its signal processing network.[1] The F-4C was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order IF-4C-2-19.

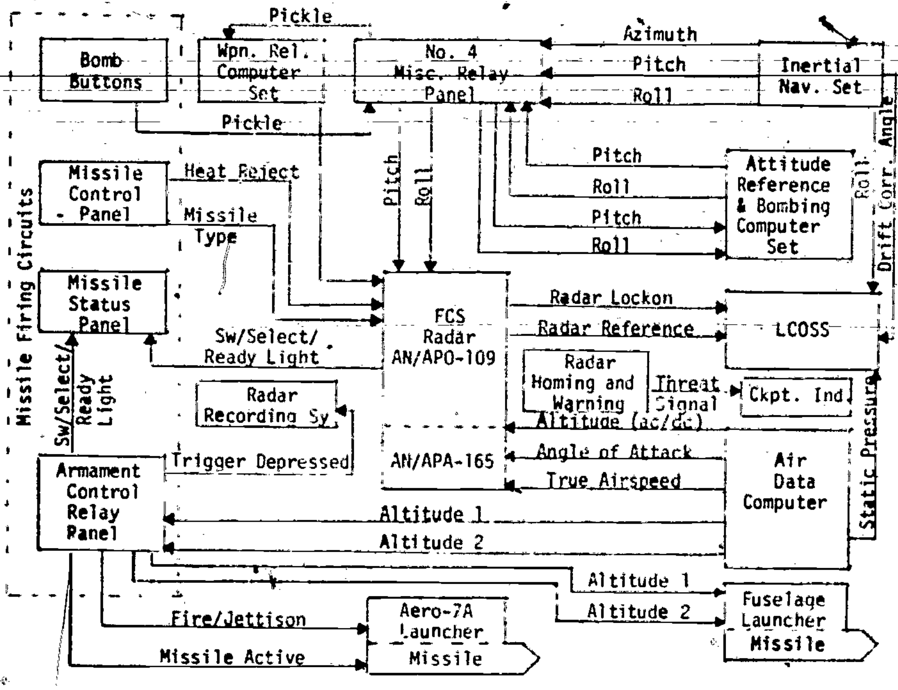
MODELS FOR DATA APPLICATION:

III.7-42.1(A)
III.7-42.1(B)

SUBJECT:
F-4C Fire Control System Tie-In Block Diagram

INDEX: 2-1

CROSS-INDEX: I.3-2.1



TITLE: F-4D Fire Control System Tie-In Block Diagram

COMMENTS: The F-4D is a two-place tandem, supersonic, all-weather, tactical aircraft with the capabilities of delivering combinations of missiles, bombs and rockets. The Fire Control System consists of the APQ-109 radar subsystem, APA-165 radar set group, distribution group, and the missile firing circuits and is associated with 15 other subsystems in its signal processing network.[1] The F-4D was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

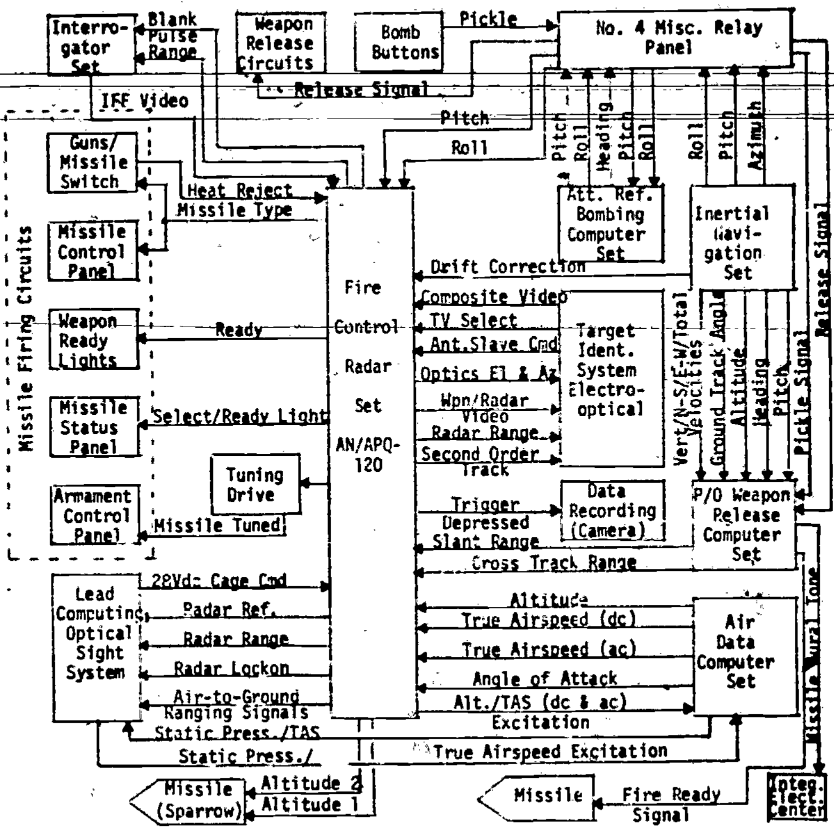
DATA SOURCES: 1. USAF Technical Order 1F-4D-2-19.

MODELS FOR DATA APPLICATION:
III.7-42.1(A)
III.7-42.1(B)

SUBJECT:
F-4D Fire Control System Tie-In Block Diagram

INDEX: 2-1

CROSS-INDEX: I.3-2.1

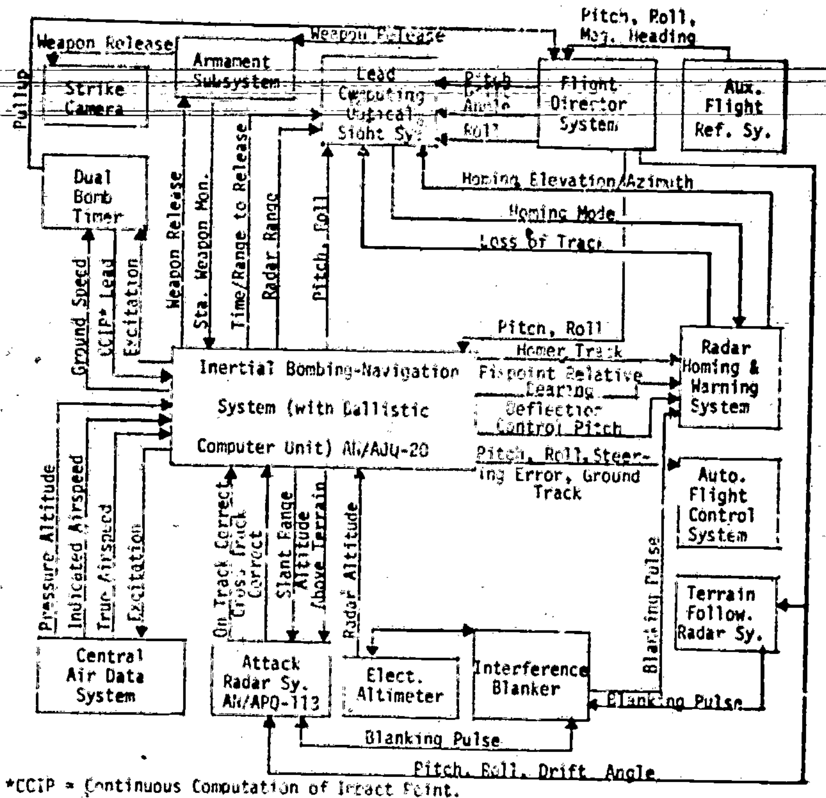


TITLE: F-4E Fire Control System Tie-In Block Diagram

COMMENTS: The F-4E Phantom II is a two-place, tandem, supersonic, long range, all-weather fighter-bomber. The Fire Control System consists of the APQ-120 radar subsystem, missile auxiliary group, and missile firing circuits and is associated with ten subsystems in its signal processing network.[1] The F-4E was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order 1F-4E-2-19.

MODELS FOR DATA APPLICATION: III.7-42.1(A) III.7-42.1(B)	SUBJECT: F-4E Fire Control System Tie-In Block Diagram	INDEX: 2-1 CROSS-INDEX: I.3-2.1



*CCIP = Continuous Computation of Impact Point.

TITLE: F-111A Fire Control System Tie-In Block Diagram

COMMENTS: The F-111A, a two-place, side-by-side long-range fighter, has a fire power control system designed for all-weather supersonic operation at both low and high altitude. Some major subsystems are attack radar subsystem APQ-113, inertial bombing-navigation subsystem AJQ-20 and lead computing optical sight subsystem ASG-23. It was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1) for the purpose of providing an overall perspective of its operational performance. This historical perspective is valued for its potential use in future system trade studies of analogous systems.

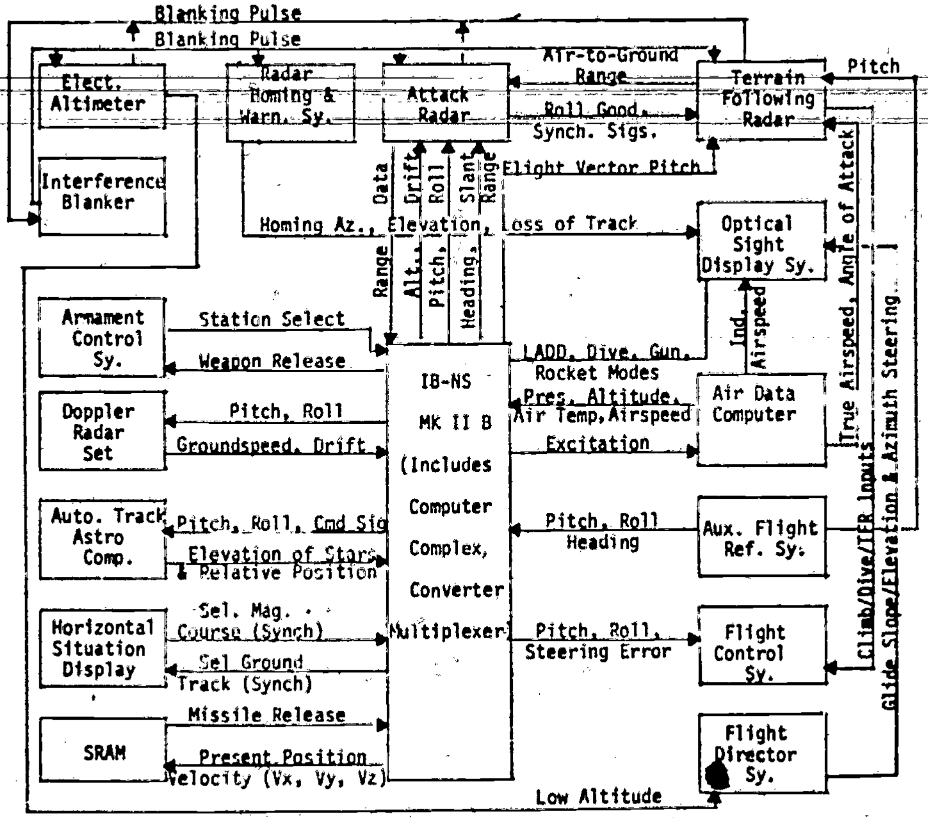
DATA SOURCES: 1. USAF Technical Order 1F-111A-2-5-1.

MODELS FOR DATA APPLICATION:
III.7-42.1(A),
III.7-42.1(B)

SUBJECT:
F-111A Fire Control System Tie-In Block Diagram

INDEX: 2-1

CROSS-INDEX: I.3-2.1

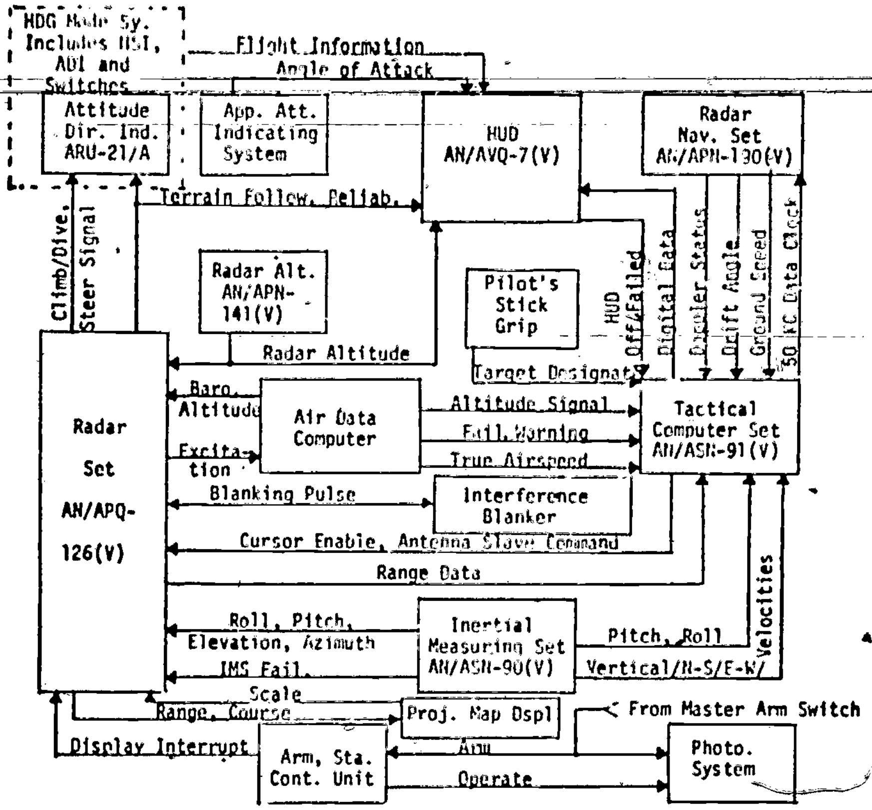


TITLE: FB-111A Fire Power Control System Tie-In Block Diagram

COMMENTS: The FB-111A is a two-place, side-by-side, all-weather, high and/or low altitude, supersonic, strategic bomber with inflight selectable wing sweep. It was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order 1F-111(B)A-2-5-1.

MODELS FOR DATA APPLICATION: III.7-42.1(A) III.7-42.1(B)	SUBJECT: FB-111A Fire Power Control System Tie-In Block Diagram	INDEX: 2-1 CROSS-INDEX: I.3-2.1

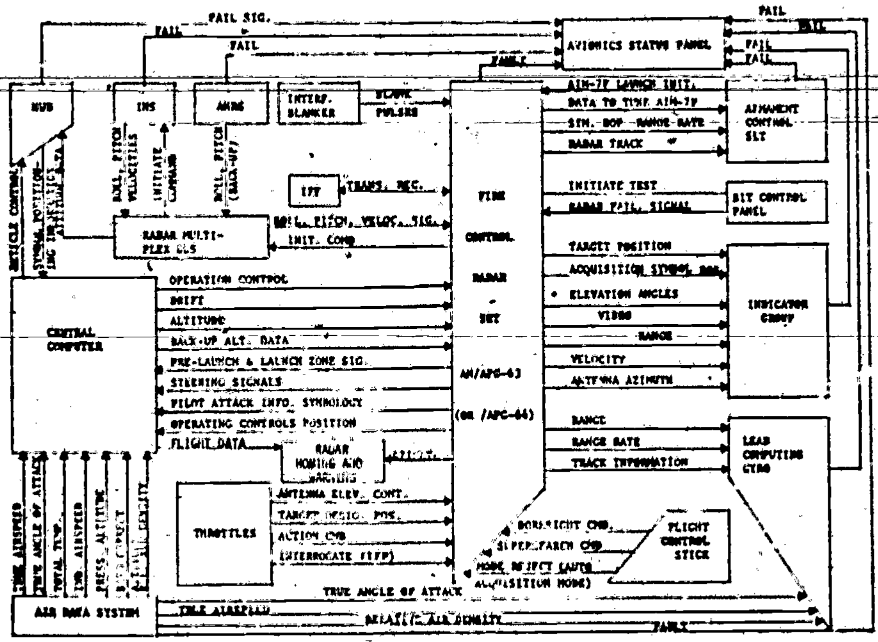


TITLE: A-7D Weapon Control System Tie-In Block Diagram

COMMENTS: The A-7D, a subsonic single-seat tactical fighter, has a continuous-solution navigation and weapon delivery system and has all-weather radar bombing delivery capability. Some major subsystems are the radar set APQ-126, tactical computer set ASN-91, and heads-up display AVQ-7. It was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on an analogous system. Consequently, the historical perspective is valued for its potential use in future system design trade studies.

DATA SOURCES: 1. USAF Technical Order 1A-7D-2-14.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 2-1
III.7-42.1(A) III.7-42.1(B)	A-7D Weapon Control System Tie-in Block Diagram	CROSS-INDEX: I.3-2.1



TITLE: F-15 Fire Control System Tie-In Block Diagram

COMMENTS: The F-15A is a single-place high performance air superiority tactical fighter. Its prime mission is air-to-air operations and it has ground support capability. The Fire Control System consists of the radar set APG-63, lead computing gyro subsystem, indicator group, and the heads-up display set AVQ-20 and is associated with 13 other subsystems in its signal processing network.[1] The F-15 was selected as representative of contrasting generations of avionics systems in the period 1959-1974 (see Chart I.3-2.1). An implicit assumption in prediction methods is that estimates on specific parameters of interest such as operational performance, logistics support, and personnel skill manning would be proportional to similar parameters on analogous systems. Consequently, overall perspectives of the operations and support performances of functionally comparable systems are valued for their potential application to future design trade studies.

DATA SOURCES: 1. F-15 Quantitative and Qualitative Personnel Requirements Information, 1973.

MODELS FOR DATA APPLICATION: III.7-42.1(A) III.7-42.1( )	SUBJECT: F-15 Fire Control System Tie-In Block Diagram 80	INDEX: 2-1 CROSS-INDEX: I.3-2.1

<table>
<tr><th colspan="9">Fire Control Systems</th></tr>
<tr><td>1959</td><td>1960</td><td>1963</td><td>1965</td><td>1967</td><td>1967</td><td>1968</td><td>1968</td><td></td></tr>
<tr><td>F-106A/B</td><td>F-105D</td><td>F-4C</td><td>F-4D</td><td>F-4E</td><td>F-111A</td><td>FB-111A</td><td>A-7D</td><td>F-15</td></tr>
<tr><td colspan="9">DESIGN CONCEPT 1: Use of Semi-Automatic Test Equipment (SATE). Equipment is usually constructed as consoles or test stations connected to a computer or having a computer as an integral part and designed to semi-automatically test functional units such as a control box, display unit, etc., when placed in the test console and the test routine is initiated by the test station operator. Some degree of manual control is required by the operator to complete the test.[1]</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td colspan="9">DESIGN CONCEPT 2: Use of Integrated Systems. Systems are combined into a common package. The packaged systems perform mutually supporting roles to serve a common function. This type of system is distinguished from interfacing systems which are aided or augmented by separate and distinct equipment. A specific example of integration is an on-board central computer complex which receives inputs from, and outputs to, various equipment.[1]</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td colspan="9">DESIGN CONCEPT 3: Use of Integrated Circuits. These devices are composed ~~of~~ active and passive components made by diffusion, deposition, or subtractive (selective etching) processes. Interconnections may be formed by diffusion and related processes, or by wire-bonding techniques. Such a device cannot function if its parts are separated.[1,2]</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td colspan="9">DESIGN CONCEPT 4: Use of Microcircuits. Small circuits constructed of integrated circuits, thin-film circuits, hybrid microcircuits, and similar miniature circuits. A microcircuit is considered as a single part composed of interconnected elements on or within a single substrate to perform an electronic circuit function.</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td colspan="9">DESIGN CONCEPT 5: Use of Built-In Test Equipment. Test equipment and/or circuitry included as part of functional end items of systems/equipment to provide for self-testing, in-flight or on-the-ground, of the system/equipment of which it is a part.[1]</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
</table>

MODELS FOR DATA APPLICATION:	**SUBJECT:** Comparison of Fire Control System Designs	**INDEX:** 3-2 **CROSS-INDEX:**

TITLE: Comparison of Fire Control System Designs

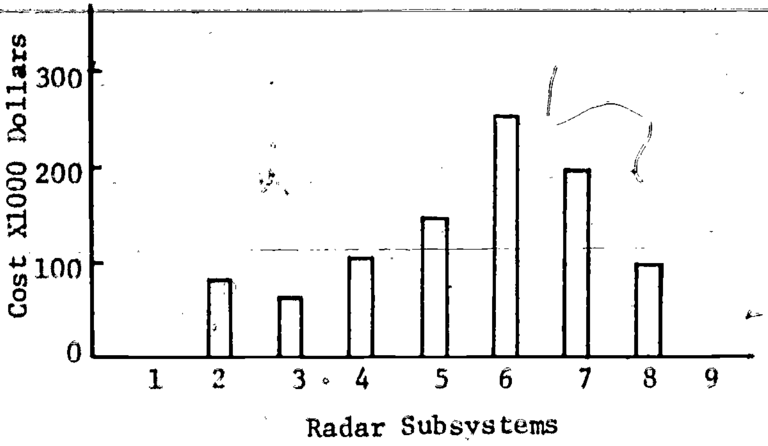
COMMENTS: These Fire Control Systems, acquired by the U.S. Air Force over successive intervals of time between 1959 and 1968, were selected for review and comparative analysis of impact of technology on operations, training, logistics, and human resources. Their selection was influenced primarily by major changes in design technology, of which five are enumerated above. The selected systems represent varying gradations of application of each design concept; however, the amount by which they differ has not been quantified. Consequently, they were categorically grouped A or B, where A represents a past generation of equipment with relatively low application, and B represents a current generation of equipment with relatively high application of these design concepts. If the current generation of equipment (Group B) is considered as a forecast of future design trends,[1] then compelling reasons exist for (a) using this type of categorical grouping to initialize comparisons and for (b) conducting additional research with refinements in study methodology to improve the accuracy of the data as well as to establish cause-effect relationships.

IMPLICATIONS: Past reports, studies, and literature have examined developments in electronics technology and have estimated their general effects, projected to 1980 on operations, training, logistics, and human resources.[1] On the basis of these design developments, two representative contrasting generations of Fire Control Systems were examined on a comparative basis to determine whether certain relationships would reveal differences between the two groups. Thus, for example, it may be of interest to determine whether technological advances, as represented by Groups A and B, have had an influence on maintenance manhours expended on equipment repair. The establishment of such cause-effect relationships presents a difficult problem since they must be based on data obtained from operational organizations. The relationships presented in Section I were, in fact, determined by manipulating data from various Air Force data banks, not from the results of controlled experiments. Consequently caution must be exercised in the interpretation of certain cause-effect relationships shown in Section I. What may appear to be due to technological change may actually be the result of other, but unidentifiable, variables. In some cases, strong evidence is found to support the effects of technological change (e.g., manpower needs for certain Group B hardware repair being much smaller than for Group A); in others no such evidence is found. Finally, it must be emphasized that the purpose for classifying the systems into two groups was primarily to create a conceptual model for comparative analysis. The data in Section I, however, are presented in a format that does not require direct use of the groupings.

DATA SOURCES: 1. Air Training Command, Ad Hoc Committee, The Impact of Microelectronics and Integrated Systems on Technical Training, April, 1970.

2. United States, Department of the Air Force, Communications-Electronics Terminology, AFM 11-1, Vol. III, November 15, 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Comparison of Fire Control System Designs.	INDEX: 3.2 CROSS-INDEX:



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
~~A~~	~~F-106A/B~~	~~7-59~~	~~1~~	
A	F-105D	5-60	2	80
A	F-4C	5-63	3	65
A	F-4D	12-65	4	101
A	F-4E	10-67	5	149
B	F-111A	10-67	6	255
B	FB-111A	7-68	7	200
B	A-7D	12-68	8	100
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

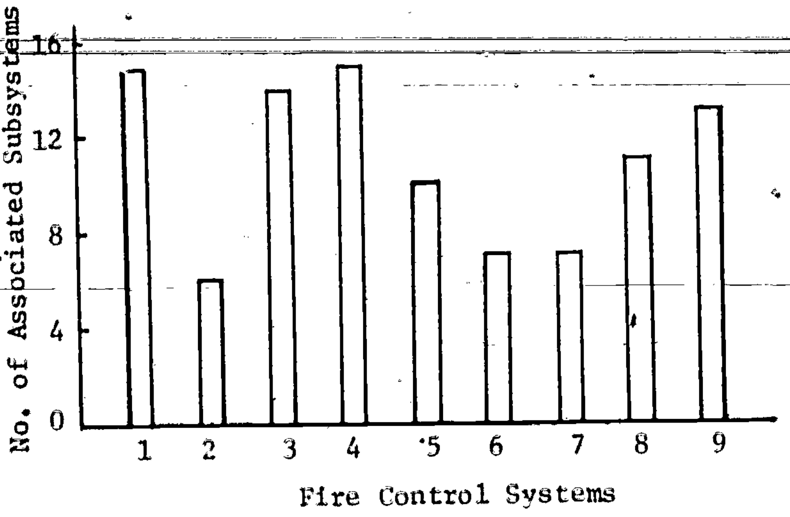
TITLE: Comparison of Fire Control Radar Subsystem Cost

COMMENTS: Past studies indicated a relationship between equipment cost and technological sophistication. The costs[1] for an assembled subsystem were compared between two generations of radar subsystems. The mean difference between the groups showed an average higher cost of $87,000 for Group B. A proportion of this was due to inflation.

IMPLICATIONS: Findings indicated that for each unit of investment cost in Group A designs, there were 1.9 units of investment cost in Group B designs, with some proportion due to inflation. A major cost parameter was the research, design and development of technological concepts such as integrated systems, microcircuit applications, built-in test equipment, and semi-automatic test equipment. Since the magnitude of application of these design concepts was greater for Group B than A, the cost difference seemed logical. However, the long-term gains accruing from the initially higher investment can only be measured over the life cycle of a system, considering the operation and support effects of the equipment.

DATA SOURCES: 1. Air Force Logistics Command, Wright-Patterson AFB, Ohio.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 3-2
III.7-42.1(B) III.7-42.1(C)	Comparison of Fire Control Radar Subsystem Costs	CROSS-INDEX: I.3-2.1



Gp.*	Equipment	Mo.-Yr.**	Axes X	Axes Y
A	F-106A/B	7-59	1	15
A	F-105D	5-60	2	6
A	F-4C	5-63	3	14
A	F-4D	12-65	4	15
A	F-4E	10-67	5	10
B	F-111A	10-67	6	7
B	FB-111A	7-68	7	7
B	A-7D	12-68	8	11
B	F-15		9	13

* See Chart I.3-2.1

** Data Entered AF Inventory

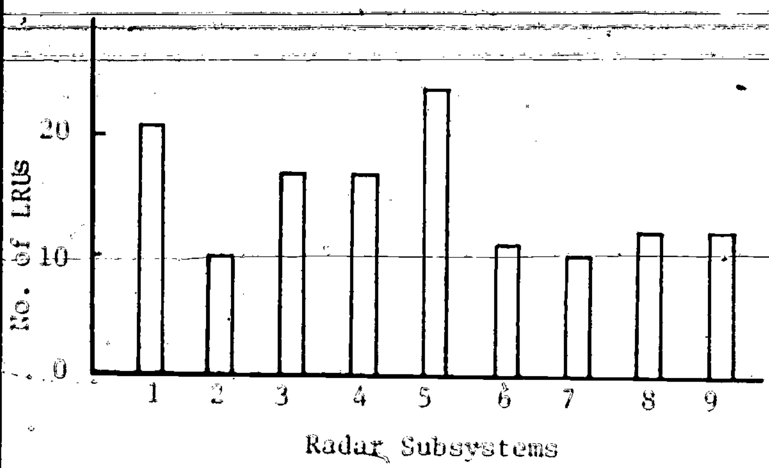
TITLE: Hardware Design - Relation of Number of Associated Subsystems to Fire Control System Type

COMMENTS: The number of subsystems[1] associated with the Fire Control System signal processing network provides an evaluative measure of system interdependence. This initial comparison does not distinguish between integrated systems and aided or augmented systems (see Chart I.3-2.1).

IMPLICATIONS: The mean number of associated subsystems is slightly higher for Group A systems. When the acknowledged increased complexity and broader capability of Group B designs is taken into consideration, the fact that this group of equipment also has fewer associated subsystems reveals an inverse relationship between these two factors, i.e., increased complexity and broader functional capability do not necessarily result in an increase in the number of associated subsystems. A plausible reason may be the application of compensating design concepts.

DATA SOURCES: 1. USAF Technical Orders 1F-106A-2-27-5, 1F-105D-2-11-2, 1F-4C-2-19, 1F-4D-2-19, 1F-4E-2-19, 1F-111A-2-5-1, 1F-111(B)A-2-5-1, 1A-7D-2-14; F-15A Quantitative and Qualitative Personnel Requirements Information 1973.

MODELS FOR DATA APPLICATION: III.7-42.1(B) III.7-42.1(D)	SUBJECT: Hardware Design - Number of Associated Subsystems vs. Fire Control System	INDEX: 3-2 CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	21
A	F-105D	5-60	2	10
A	F-4C	5-63	3	16
A	F-4D	12-65	4	16
A	F-4E	10-67	5	24
B	F-111A	10-67	6	11
B	FB-111A	7-68	7	10
B	A-7D	12-68	8	12
B	F-15		9	12

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Comparison of Number of Line Replaceable Units (LRUs) in Fire Control Radar Subsystems - Organizational

COMMENTS: The maintenance concept incorporated in the line replaceable units[1] approach provides for the removal and replacement of faulty items as the major type of corrective and preventive organizational maintenance. The degree to which this concept is designed into the subsystems is reflected in the number of LRUs. Two generations of radar subsystems, Group A and B, were examined to determine whether any trend existed over time with respect to this maintenance concept.

IMPLICATIONS: Comparison of the mean number of LRUs for each group revealed an average difference of 6 LRUs, i.e., Group B, representing a current generation of equipment had, on the average, fewer LRUs than Group A. Since the number of pieces of equipment is a factor to be considered in logistics stocking and maintenance workload, it appears that the growing complexity of system design, as represented by Group B, does not necessarily result in an increase in number of LRUs. A plausible factor which may account for the difference is the integrated systems concept applied to Group B designs.

DATA SOURCES: 1. USAF Technical Orders LF-106A-2-27-5, 1F-105D-2-11-2, 1F-4C-2-19, 1F-4D-2-19, 1F-4E-2-19, 1F-111A-2-5-1, 1F-111(B)A-2-5-1, LA-7D-2-14; F-15A Quantitative and Qualitative Personnel Requirements Information 1973.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 4-2
III.7-42.1(F)	Maintenance Concept vs. Fire Control Radar Subsystems - Organizational	CROSS-INDEX: I.3-2.1

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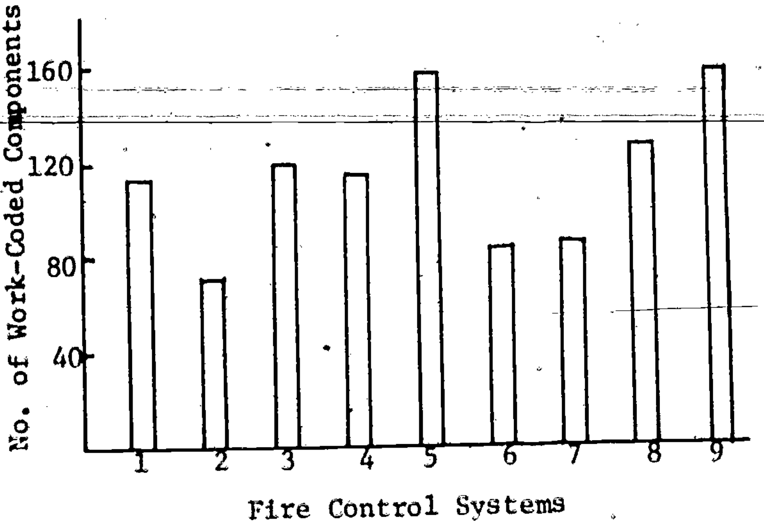


*Gp.	Equipment	**Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	112
A	F-105D	5-60	2	72
A	F-4C	5-63	3	119
A	F-4D	12-65	4	114
A	F-4E	10-67	5	154
B	F-111A	10-67	6	82
B	FB-111A	7-68	7	84
B	A-7D	12-68	8	124
B	F-15		9	156

* See Chart I.3-2.1

** Data Entered AF Inventory

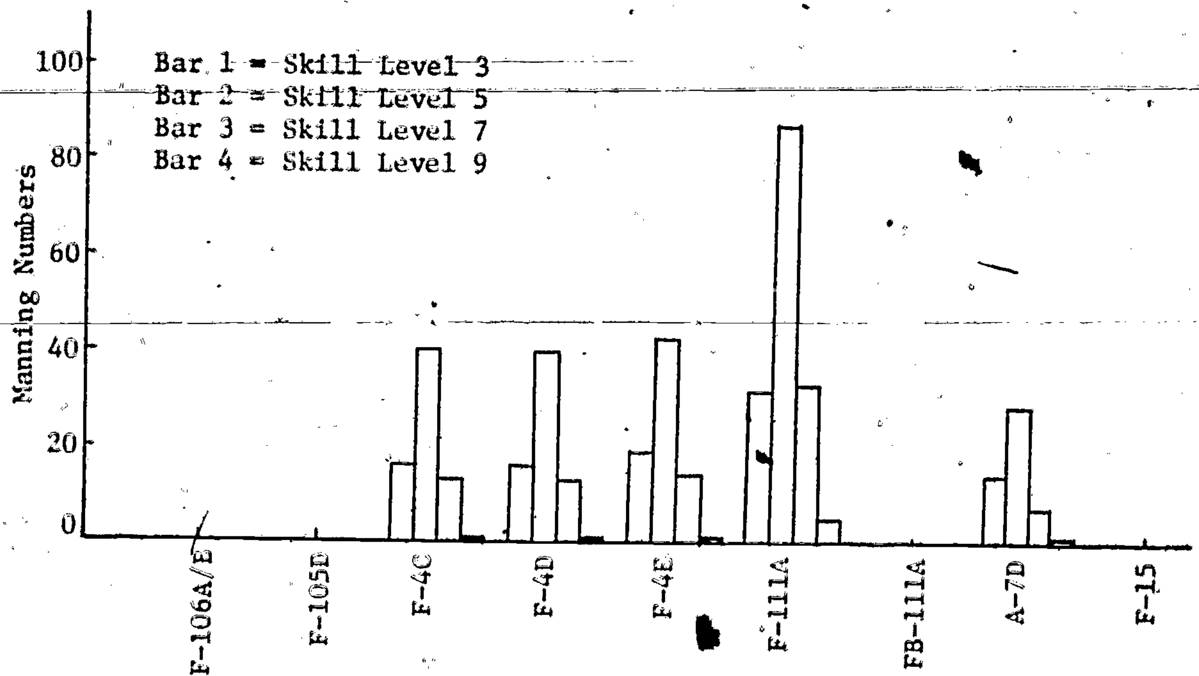
TITLE: Comparison of Number of Work-Coded Components in Fire Control Radar Subsystems - Intermediate

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components[1] to be fully repaired, partially repaired, or discarded. These components were quantified for two generations of Fire Control Systems, Groups A and B, and evaluated for trends. The mean number of work-coded components showed little difference - 114 vs. 112 for A and B, respectively.

IMPLICATIONS: Findings failed to reveal any significant difference between the groups in the number of components coded for maintenance work on the intermediate level of maintenance, despite the fact that Group B is considered to be more complex in design and generally provides increased performance capability. Since the number of work-coded components provides a measure for estimating maintenance and spares requirements, identifying the proportions of components to be fully repaired, partially repaired, or discarded would yield a more meaningful comparison.

DATA SOURCES: 1. USAF Technical Orders 1F-106A-2-27-5, 1F-105D-2-11-2, 1F-4C-2-19, 1F-4D-2-19, 1F-4E-2-19, 1F-111A-2-5-1, 1F-111(B)A-2-5-1, 1A-7D-2-14; F-15A Quantitative and Qualitative Personnel Requirements Information 1973.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 4-2
III.7-42.1(G)	Maintenance Concept vs. Fire Control Radar Subsystems - Intermediate	CROSS-INDEX: I.3-2.1



TITLE: Comparison of Manning on Fire Control Systems

COMMENTS: Important considerations in manpower calculations are location and system requirements. For a given location, the alert posture of the using command determines the level of constant physical presence of manpower. For a given system the number of men per position type and skill level are determined by the system workload. Squadron manning[1] of selected Fire Control Systems was compared for differences. The systems were representative of two generations of equipment (see Chart I.3-2.1).

IMPLICATIONS: The manning numbers and skill ratios were homogenous for the F-4s. F-111A had twice the manning numbers of the F-4s, although the skill ratios approximated the same distribution. A-7D had one-half the manning of the F-4s but the skill ratios were equivalent. Post-hoc operational data contained in Section I charts sampled unscheduled maintenance only; that set of data failed to yield evidence that would explain the higher manning level for F-111A. Since this was only one type of workload, comparing total system requirements, with alert posture requirements held constant, was not possible.

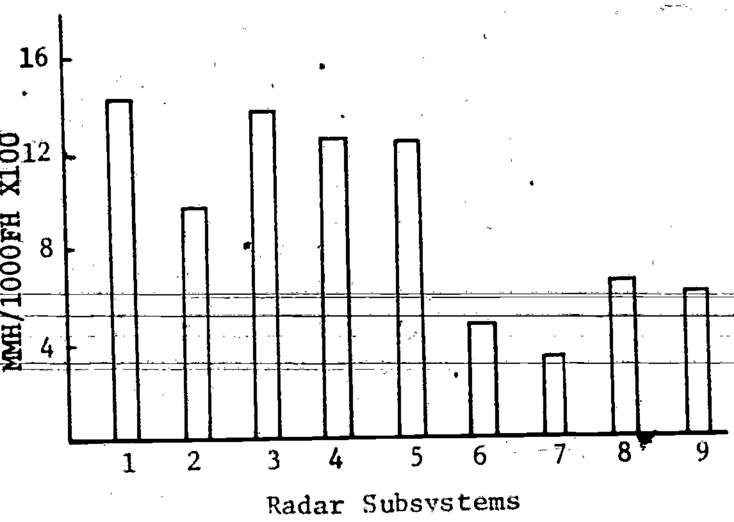
DATA SOURCES: 1. Air Force Human Resources Laboratory, Wright-Patterson AFB, Ohio. (Letter Communications, 1973)

MODELS FOR DATA APPLICATION:
III.7-42.1(K)
III.7-42.1(M)

SUBJECT:
Distribution of Skills on Fire Control Systems

INDEX: 8-2

CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	1425
A	F-105D	5-60	2	966
A	F-4C	5-63	3	1366
A	F-4D	12-65	4	1269
A	F-4E	10-67	5	1244
B	F-111A	10-67	6	472
B	FB-111A	7-68	7	331
B	A-7D	12-68	8	623
B	F-15		9	607

* See Chart I.3-2.1

** Date Entered AF Inventory

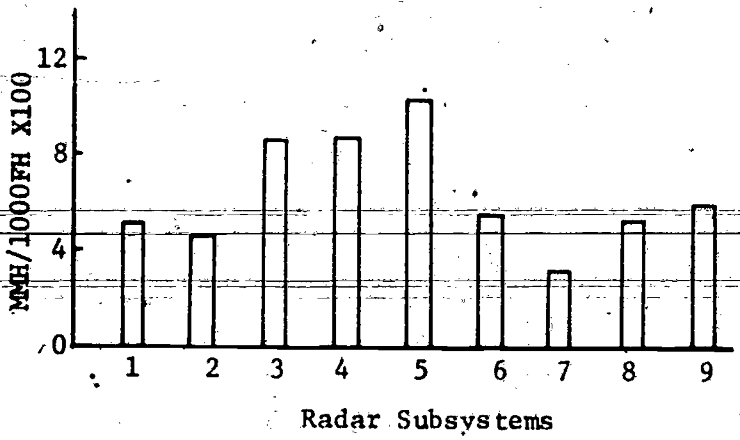
TITLE: Maintenance Manhours on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Unscheduled organizational maintenance[1] is a type of workload generated between scheduled maintenance, excluding servicing operations. The maintenance manhours were derived from flight hour bases ranging from 16025 to 202240. The only exception was F-15 which was estimated by the consensus of experts. The method of comparison considered the subsystems as representing two different generations of equipment, A and B.

IMPLICATIONS: Findings indicated a significant difference between the two groups. The current generation of equipment, B, had considerably lower unscheduled maintenance than A (508 manhours vs. 1254 manhours, or a difference ratio of 1:2.5). Apparently, factors operating in the time period represented by these subsystems had produced the net result of improved equipment reliability. The most likely contributors are (a) improvements in the inherent design, (b) changes in the scheduled maintenance concept which have reduced the probability of unscheduled failures, and (c) improved human reliability.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(L)	SUBJECT: Maintenance Manhours vs. Fire Control Radar Subsystems - Unscheduled Organizational	INDEX: 11-2 CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	502
A	F-105D	5-60	2	438
A	F-4C	5-63	3	851
A	F-4D	12-65	4	857
A	F-4E	10-67	5	1025
B	F-111A	10-67	6	540
B	FB-111A	7-68	7	317
B	A-7D	12-68	8	536
B	F-15		9	580

* See Chart I.3-2.1.
** Date Entered AF Inventory

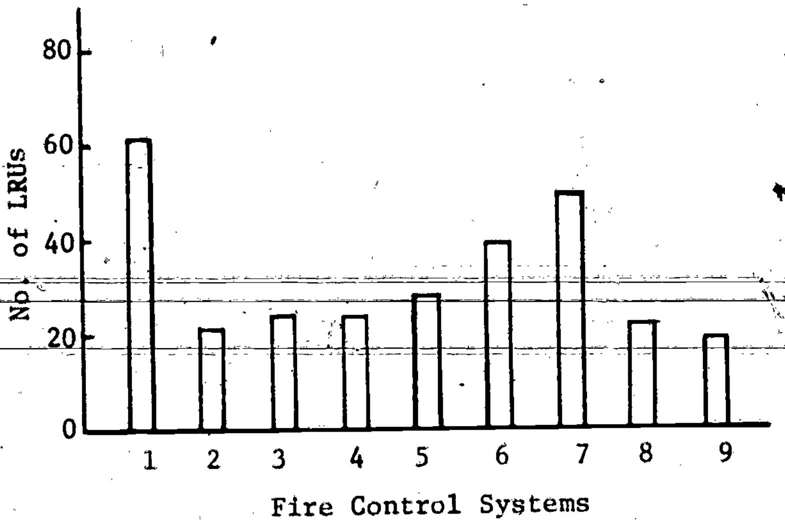
TITLE: Maintenance Manhours on Fire Control Radar Subsystems - Unscheduled Intermediate

COMMENTS: Unscheduled intermediate maintenance manhours[1] were compared across nine radar subsystems. The maintenance manhours were derived from flight hour bases ranging from 16025 to 202240. The only exception was F-15 which was estimated by the consensus of experts. The method of comparison considered the subsystems as representing two different generations of equipment, A and B.

IMPLICATIONS: Findings indicated some degree of difference between the two groups. The current generation of equipment, B, had lower unscheduled maintenance than A (493 vs. 734 manhours, or a difference ratio of 1:1.5). The direction of the difference was compatible with that found in evaluating unscheduled organizational maintenance (see Chart I.11-2.1). This was logical since a decrease in maintenance load on the first level (organizational) would yield fewer failed units being processed to the second level (intermediate) for disposition. However, the net improvement in maintenance manhours was better for organizational than intermediate. Generally, the influences operating on the organizational level would have relatable effects on the intermediate and depot level of maintenance.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-2
III.7-42.1(L)	Maintenance Manhours vs. Fire Control Radar Subsystems - Unscheduled Intermediate	CROSS-INDEX: I.3-2.1 I.11-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Y
A	F-106A/B	7-59	1	62
A	F-105D	5-60	2	22
A	F-4C	5-63	3	24
A	F-4D	12-65	4	24
A	F-4E	10-67	5	28
B	F-111A	10-67	6	39
B	FB-111A	7-68	7	49
B	A-7D	12-68	8	22
B	F-15		9	18

* See Chart I.3-2.1

** Date Entered AF Inventory

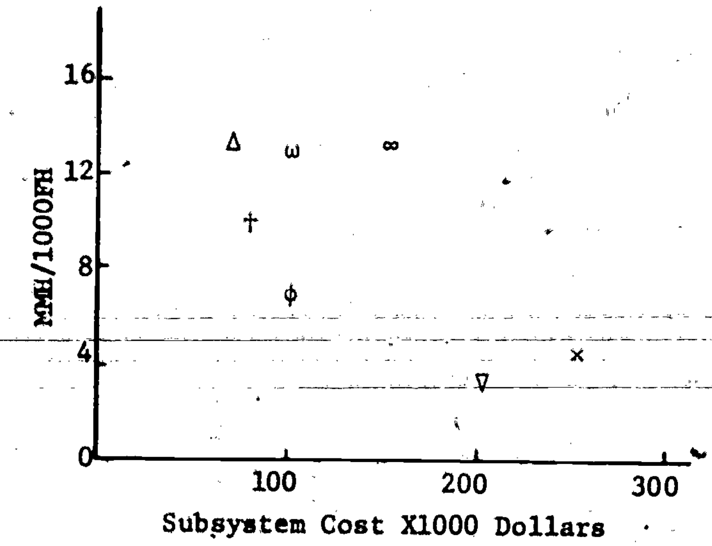
TITLE: Comparison of Number of Line Replaceable Units (LRUs) in Fire Control Systems - Organizational

COMMENTS: The maintenance concept incorporated in the line replaceable units approach provides for the removal and replacement of faulty items as the major type of corrective and preventive organizational maintenance. The number of LRUs was quantified for nine Fire Control Systems.[1] The quantification covered units of all subsystems that are considered a part of the Fire Control System. This quantification yielded the same mean number of LRUs for Groups A and B, which was 32. Evaluating the systems on an individual basis, the following were either substantially above (+) or below (-) the mean value: F-106A/B, +30, FB-111A, +17; F-15, -18; A-7D, -10; F-105D, -10. There appears to be no clear-cut trend that would distinguish Groups A and B.

IMPLICATIONS: Other factors being equal such as reliability of equipment, the frequency of replacements per unit operating time is expected to be higher for systems with greater numbers of LRUs, which would affect the maintenance workload. Likewise, logistics is affected by the number of different types of equipment that need to be stocked. Consequently, the point of comparison to be made between past and current generations of equipment is whether or not an increase in the functional capabilities of a system would result in an increase in pieces of equipment or whether the application of design concepts such as integrated systems, would nullify the effect.

DATA SOURCES: 1. USAF Technical Orders 1F-106A-2-27-5, 1F-105D-2-11-2, 1F-4C-2-19, 1F-4D-2-19, 1F-4E-2-19, 1F-111A-2-5-1, 1F-111(B)A-2-5-1, 1A-7D-2-14; F-15A Quantitative and Qualitative Personnel Requirements Information 1973.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 4-2
III.7-42.1(F)	Maintenance Concept vs. Fire Control System - Organizational	CROSS-INDEX: I.3-2.1



Sym-bol	Equipment	* Mo.-Yr.	Axes X X1000	Axes Y
O	F-106A/B	7-59		
†	F-105D	5-60	80	996
Δ	F-4C	5-63	65	1366
ω	F-4D	12-65	101	1260
∞	F-4E	10-67	149	1244
×	F-111A	10-67	255	472
∇	FB-111A	7-68	200	331
ϕ	A-7D	12-68	100	623
ε	F-15	—		

*Date Entered AF Inventory

TITLE: Hardware Design - Relation of Subsystem Cost to Unscheduled Organizational Maintenance

COMMENTS: The relationship of subsystem acquisition cost[1] to unscheduled organizational maintenance[2] was examined on selected Fire Control radar subsystems to determine whether a functional relationship existed between these two variables. Since higher subsystem acquisition cost was generally associated with more complex equipment, the effect of equipment complexity on maintenance workload was a measure of interest.

IMPLICATIONS: Data analysis revealed a moderate to strong inverse relationship. Higher subsystem acquisition cost tended to be associated with lower unscheduled organizational maintenance. The most likely reasons for this relationship was improved reliability in the design of the equipment and simplification of tasks on the organizational level.

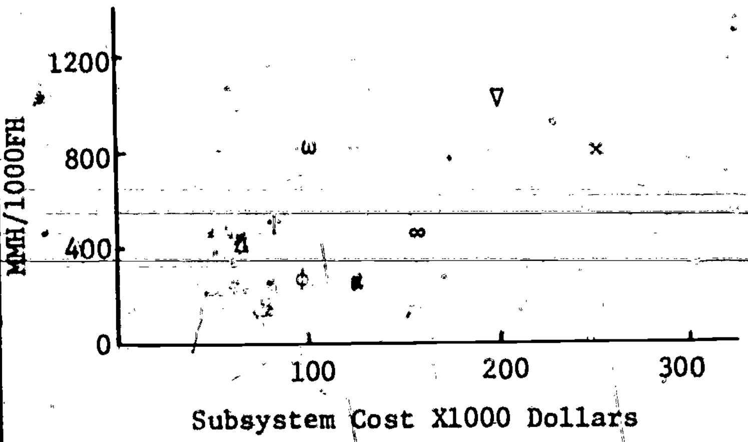
DATA SOURCES:
1. USAF Logistics Command, Wright-Patterson AFB, Ohio.
2. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(B)
III.7-42.1(C)
III.7-42.1(K)

SUBJECT:
Fire Control Radar Subsystem Cost vs. Unscheduled Organizational Maintenance

INDEX: 11-3

CROSS-INDEX:



Sym-bol	Equipment	* Mo.-Yr.	Axes x X1000	y
Θ	F-106A/B	7-59		
†	F-105D	5-60	80	502
Δ	F-4C	5-63	65	438
ω	F-4D	12-65	101	851
∞	F-4E	10-67	149	540
×	F-111A	10-67	255	857
∇	FB-111A	7-68	200	1025
ϕ	A-7D	12-68	100	317
ε	F-15			58

*Date Entered AF Inventory

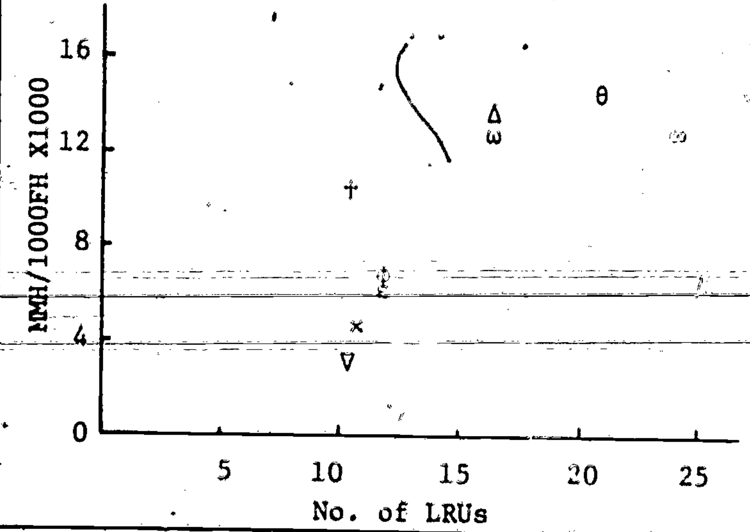
TITLE: Hardware Design - Relation of Subsystem Acquisition Cost to Unscheduled Intermediate Maintenance Manhours

COMMENTS: The relationship of subsystem acquisition cost[1] to unscheduled intermediate maintenance[2] was examined on selected Fire Control radar subsystems to determine whether a functional relationship existed between these two variables. Since higher subsystem acquisition cost was generally associated with more complex equipment, the effect of equipment complexity on maintenance workload was a measure of interest.

IMPLICATIONS: Data analysis indicated a strong relationship between subsystem acquisition cost and maintenance manhours. As subsystem acquisition cost increased unscheduled intermediate maintenance increased. This finding was in contrast to that revealed in Chart I.11-3.1 where an increase in subsystem acquisition cost was associated with a decrease in unscheduled organizational maintenance. A likely combination of factors which would explain the difference shown in the above chart was displacement of some of the organizational workload to the intermediate level, increased complexity of intermediate maintenance tasks, inadequate training, and ineffective skill mix.

DATA SOURCES:
1. USAF Logistics Command, Wright-Patterson AFB, Ohio.
2. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-3
III.7-42.1(B) III.7-42.1(C) III.7-42.1(K)	Fire Control Radar Subsystem Cost vs. Unscheduled Intermediate Maintenance	CROSS-INDEX: I.11-3.1



Sym-bol	Equipment	* Mo.-Yr	Axes	
			X	Y
θ	F-106A/B	7-59	21	1425
†	F-105D	5-60	10	996
Δ	F-4C	5-63	16	1366
ω	F-4D	12-65	16	1269
ϖ	F-4E	10-67	24	1244
×	F-111A	10-67	11	472
∇	FB-111A	7-68	10	331
ϕ	A-7D	12-68	12	623
ε	F-15		12	607

*Date Entered AF Inventory

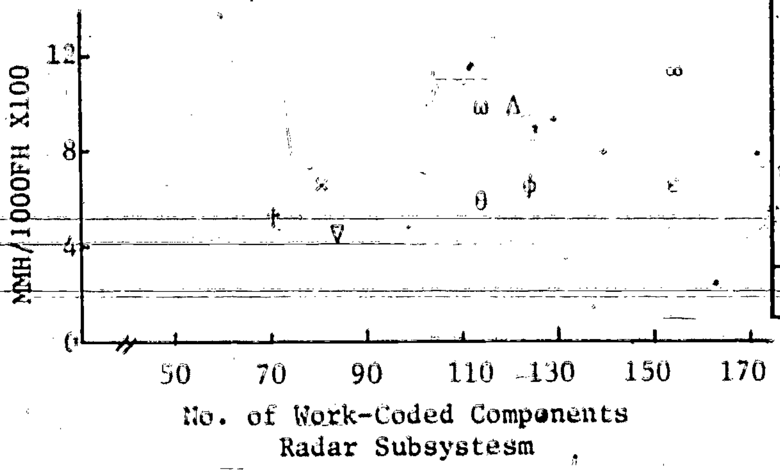
TITLE: Maintenance Concept - Fire Control Radar Subsystems; Relation of Number of Line Replaceable Units to Unscheduled Organizational Maintenance Manhours

COMMENTS: The maintenance concept incorporated in the line replaceable units approach provides for the removal and replacement of faulty items as the major type of corrective and preventive organizational maintenance. The degree to which this concept is designed into the subsystems is reflected in the number of LRUs. A count of these units was made on selected radar subsystems, and its relation to maintenance manhours was examined.[1]

IMPLICATIONS: Data analysis yielded a strong functional relationship between these two variables. An increase in number of line replaceable units was associated with an increase in organizational maintenance manhours. These findings were complemented by Chart I.25-4.1 where the number of line replaceable units, in relation to logistics cost, showed the same consistent effect.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-4
III.7-42.1(F)	Maintenance Concept - Line Replaceable Units vs. Unscheduled Organizational Maintenance	CROSS-INDEX: I.25-4.1



Symbol	Equipment	* Mo.-Yr	Axes X	Axes Y
θ	F-106A/B	7-59	112	502
†	F-105D	5-60	72	438
Δ	F-4C	5-63	119	851
ω	F-4D	12-65	114	857
∞	F-4E	10-67	154	1025
×	F-111A	10-67	82	540
∇	FB-111A	7-68	84	317
φ	A-7D	12-68	124	536
ε	F-15		156	580

*Date Entered AF Inventory

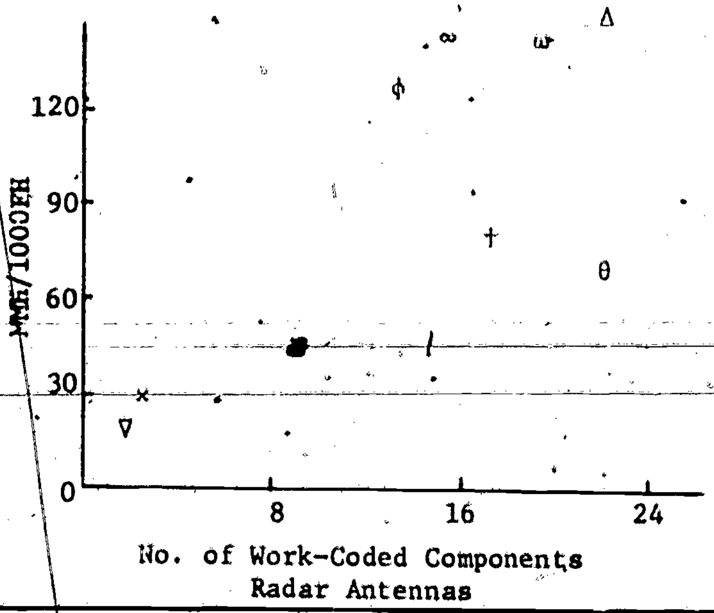
TITLE: Maintenance Concept - Fire Control Radar Subsystems; Relation of Numbers of Work-Coded Components to Unscheduled Intermediate Maintenance Manhours

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components to be fully repaired, partially repaired, or discarded. The work-coded components were quantified for nine radar subsystems, and the relation of this variable to maintenance manhours was examined.[1] The scatter diagram gives the empirical data on selected radar subsystems.

IMPLICATIONS: Data analysis yielded a strong functional relationship between these two variables. An increase in number of work-coded components was associated with an increase in intermediate maintenance manhours. These findings were in contrast to Chart I.25-4.2 where the number of work-coded components, in relation to logistics cost, not only failed to show consistent effects but provided, as well, some evidence, though negligible, to suspect an inverse relationship.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-4
III.7-42.1(G)	Maintenance Concept - Fire Control Radar Subsystems. Work Coded Components vs. Unscheduled Intermediate	CROSS-INDEX: I.25-4.2



Sym-bol	Equipment	* Mo.-Yr	Axes X	Axes Y
θ	F-106A/B	7-59	22	66
†	F-105D	5-60	17	70
Δ	F-4C	5-63	22	144
ω	F-4D	12-65	19	139
∞	F-4E	10-67	15	137
×	F-111A	10-67	3	25
∇	FB-111A	7-68	2	13
ϕ	A-7D	12-68	13	122
ε	F-15			

*Date Entered AF Inventory

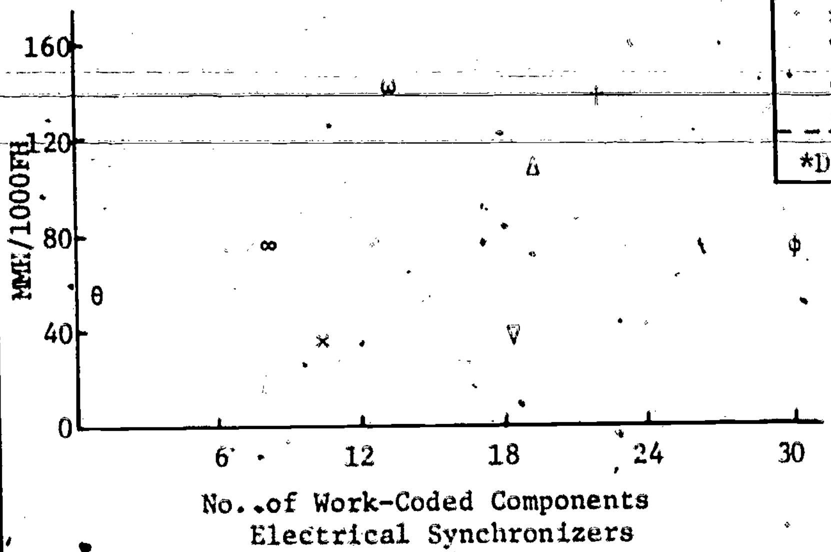
TITLE: Maintenance Concept - Fire Control Radar Antennas; Relation of Number of Work-Coded Components to Unscheduled Intermediate Maintenance Manhours

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components to be fully repaired, partially repaired, or discarded. The work-coded components were quantified for selected Fire Control radar antennas, and the relation of this variable to maintenance manhours was examined.[1] The scatter diagram gives the empirical data.

IMPLICATIONS: Data analysis yielded moderate evidence of a functional relationship between these two variables (i.e., an increase in work-coded components was associated with an increase in maintenance manhours). With F-106A/B and F-105D excluded, a best-fit line or curve for the remaining points on the scatter plot would adequately express the effects of work-coded components on maintenance manhours.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(G)	**SUBJECT:** Maintenance Concept - Fire Control Radar Antennas. Work-Coded Components vs. Unscheduled Intermediate	**INDEX:** 11-4 **CROSS-INDEX:**



Symbol	Equipment	* Mo.-Yr.	Axes X	Axes Y
θ	F-106A/B	7-59	1	55
†	F-105D	5-60	22	140
Δ	F-4C	5-63	19	111
ω	F-4D	12-65	13	147
∞	F-4E	10-67	8	79
×	F-111A	10-67	10	39
∇	FB-111A	7-68	18	37
ϕ	A-7D	12-68	30	77
ε	F-15			

*Date Entered AF Inventory

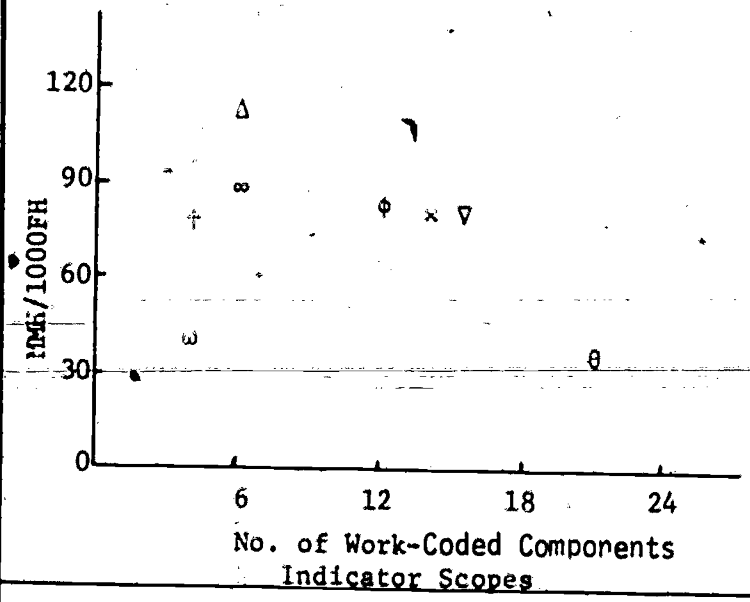
TITLE: Maintenance Concept - Fire Control Electrical Synchronizers; Relation of Number of Work-Coded Components to Unscheduled Intermediate Maintenance Manhours

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components to be fully repaired, partially repaired, or discarded. The work-coded components were quantified for electrical synchronizers of selected radar subsystems, and the relation of this variable to maintenance manhours was examined[1]. The scatter diagram shows the results of the quantification.

IMPLICATIONS: Data analysis yielded evidence that only a small proportion of the variation in maintenance manhours was attributable to differences in number of synchronizer components. It would appear that some other measures, such as types of tasks or complexity scaling of synchronizer components, would yield a better accountability of maintenance time expended.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-4
III.7-42.1(G)	Maintenance Concept - Fire Control Electrical Synchronizers. Work-Coded Components vs. Unscheduled Intermediate	CROSS-INDEX:



Symbol	Equipment	* Mo.-Yr	Axes X	Axes Y
θ	F-106A/B	7-59	21	39
†	F-105D	5-60	4	79
Δ	F-4C	5-63	6	115
ω	F-4D	12-65	4	37
∞	F-4E	10-67	6	89
×	F-111A	10-67	14	80
∇	FB-111A	7-68	15	81
ϕ	A-7D	12-68	12	83
ε	F-15			

*Date Entered AF Inventory

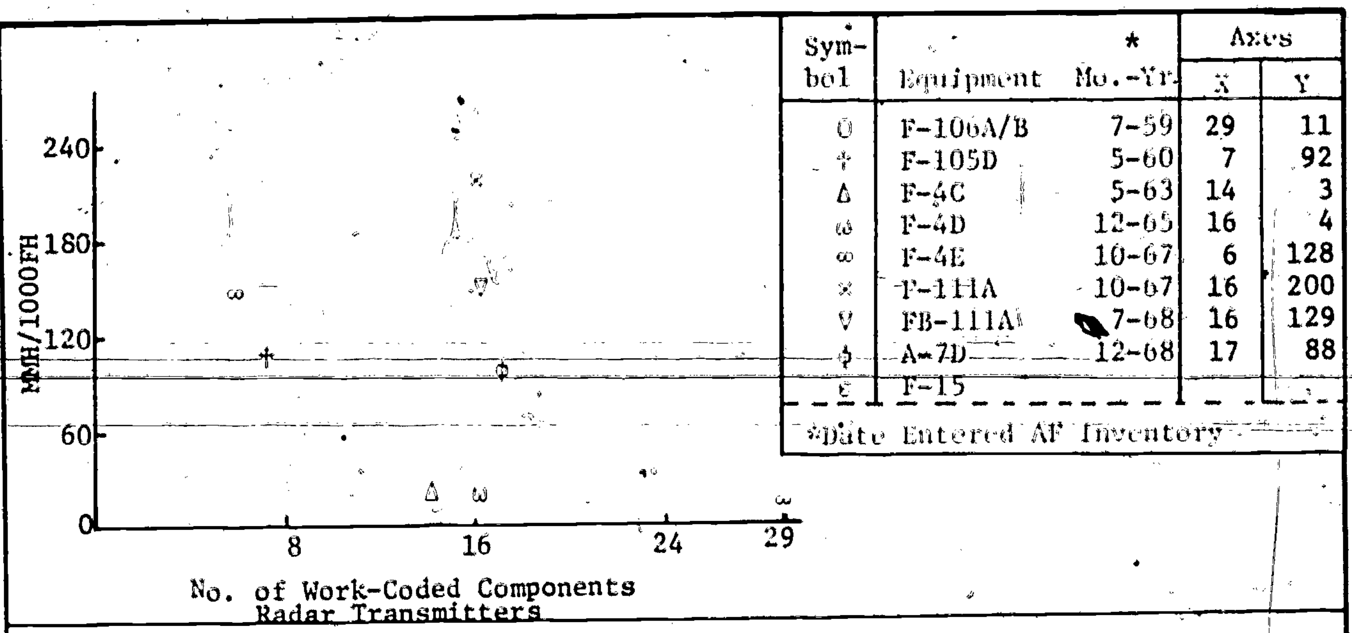
TITLE: Maintenance Concept - Fire Control Indicator Scopes; Relation of Number of Work-Coded Components to Unscheduled Intermediate Maintenance Manhours

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components[1] to be fully repaired, partially repaired, or discarded. The work-coded components were quantified for indicator scopes of selected radar subsystems, and the relation of this variable to maintenance manhours was examined.[1] The scatter diagram shows the results of the quantification.

IMPLICATIONS: Data analysis yielded a moderate inverse trend (i.e., a tendency for greater numbers of components to be associated with lower maintenance manhours). It is suspected that the major contributing factors were the proportion of discards to partial-full repairs and task simplifications which may, in some part, be associated with lower level of disassembly implied in the number of components per scope assembly.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-4
III.7-42.1(G)	Maintenance Concept - Fire Control Indicator Scopes. Work-Coded Components vs. Unscheduled Intermediate	CROSS-INDEX:



Symbol	Equipment	* Mo.-Yr.	Axes X	Axes Y
○	F-106A/B	7-59	29	11
†	F-105D	5-60	7	92
Δ	F-4C	5-63	14	3
ω	F-4D	12-65	16	4
∞	F-4E	10-67	6	128
×	F-111A	10-67	16	200
∇	FB-111A	7-68	16	129
ϕ	A-7D	12-68	17	88
ε	F-15			

*Date Entered AF Inventory

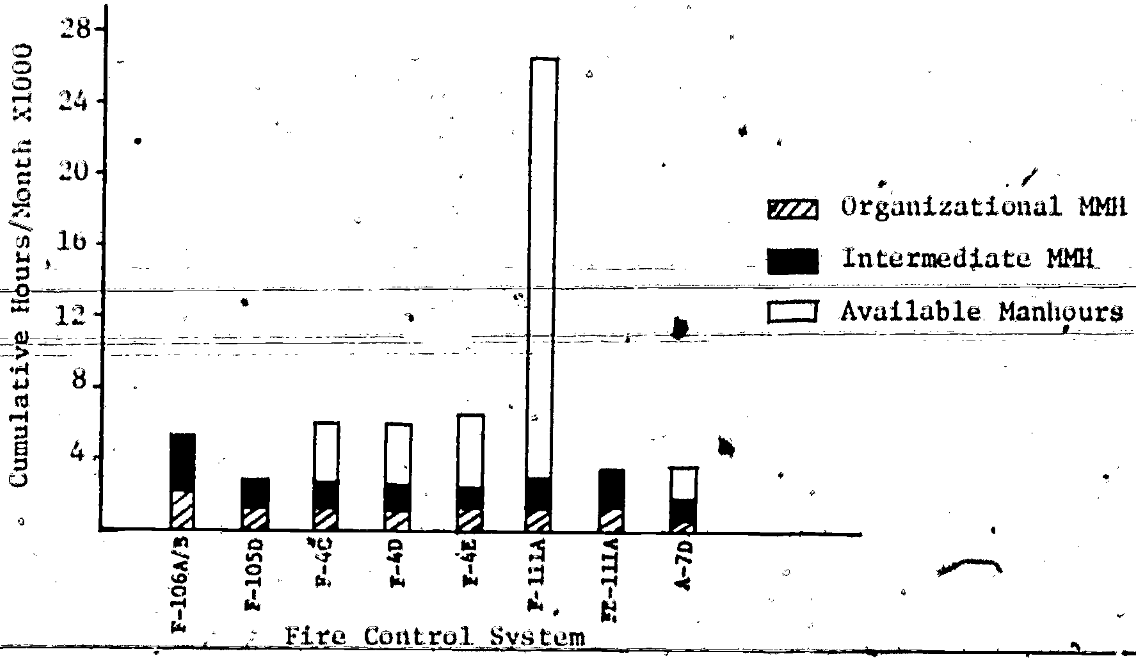
TITLE: Maintenance Concept - Fire Control Radar Transmitters; Relation of Number of Work-Coded Components to Unscheduled Intermediate Maintenance Manhours

COMMENTS: Intermediate maintenance policy is based on the number of work-coded components to be fully repaired, partially repaired, or discarded. The work-coded components were quantified for radar transmitters of selected radar subsystems, and the relation of this variable to maintenance manhours was examined. The scatter diagram shows the results of the quantification.

IMPLICATIONS: Data analysis yielded evidence that only a small proportion of the variation in maintenance manhours was attributable to differences in number of transmitter components. It would appear that some other measures, such as types of tasks or complexity scaling of transmitter components, would yield a better accountability of maintenance time expended.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-4
III.7-42.1(G)	Maintenance Concept - Fire Control Radar Transmitters. Work-Coded Components vs. Unscheduled Intermediate	CROSS INDEX:



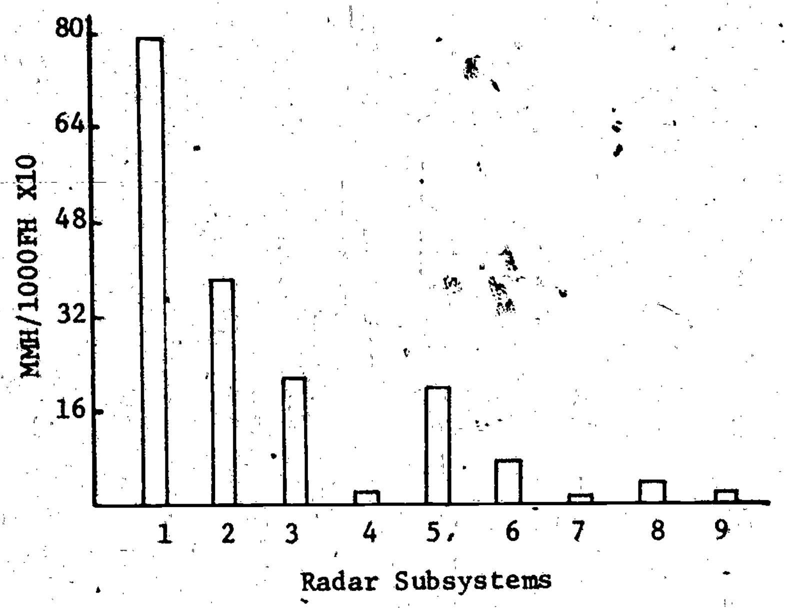
TITLE: Fire Control Systems - Comparison of Unscheduled Maintenance Manhours/Month to Skill Level Availability/Month per Squadron

COMMENTS: Important considerations in manpower calculations are location and system requirements. For a given location, the alert posture of the using command determines the level of constant physical presence of manpower. For a given system, the number of men per position type and skill level are determined by the system workload. The unscheduled workloads were calculated on the basis of 30 FH/aircraft per month x 18 aircraft/squadron x MMH/FH[1]. The skill level availability was calculated on the basis of 85.2 manhours/month for a 5-day, 40-hour week[2] x number of personnel[3]. The chart shows unscheduled maintenance manhours expended in relation to total available manhours. Squadron manning data were not available for F-106A/B, F-105D, and FB-111A; therefore, it was not possible to compare workload against available hours, on Fire Control Systems, of these aircraft.

IMPLICATIONS: It would appear that workloads unique to the F-111A system necessitated higher manning levels on that system than on F-4C, F-4D, F-4E, and A-7D.

DATA SOURCES:
1. USAF Worldwide Unscheduled Maintenance Summaries 1971.
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.
3. USAF Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-8
III.7-42.1(K) III.7-42.1(P)	Fire Control Systems - Maintenance Manhours vs. Skill Level Availability	CROSS INDEX:



			Axes	
* Gp.	Equipment	** Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	789
A	F-105D	5-60	2	347
A	F-4C	5-63	3	212
A	F-4D	12-65	4	18
A	F-4E	10-67	5	192
B	F-111A	10-67	6	63
B	FB-111A	7-68	7	5
B	A-7D	12-68	8	29
B	F-15		9	10

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Maintenance Manhours for Troubleshooting Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Maintenance manhours to troubleshoot on the organizational level were compared across selected radar subsystems. The subsystems represented two different design generations (see Chart I.3-2.1). The activity was identified by USAF Action Code "Y", on-equipment time to isolate the primary cause of a discrepancy. This code excluded repair time. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1]

IMPLICATIONS: Data analysis yielded a significant difference in maintenance manhours expended on troubleshooting. The difference ratio was 1:11.5. For each hour spent in troubleshooting in Group B, 11.5 hours were spent in Group A. Likely factors producing this result were task simplification, reallocation of some troubleshooting tasks to the intermediate level, improved equipment reliability, improved human reliability, and possibly the application of automatic test equipment and built-in test equipment.

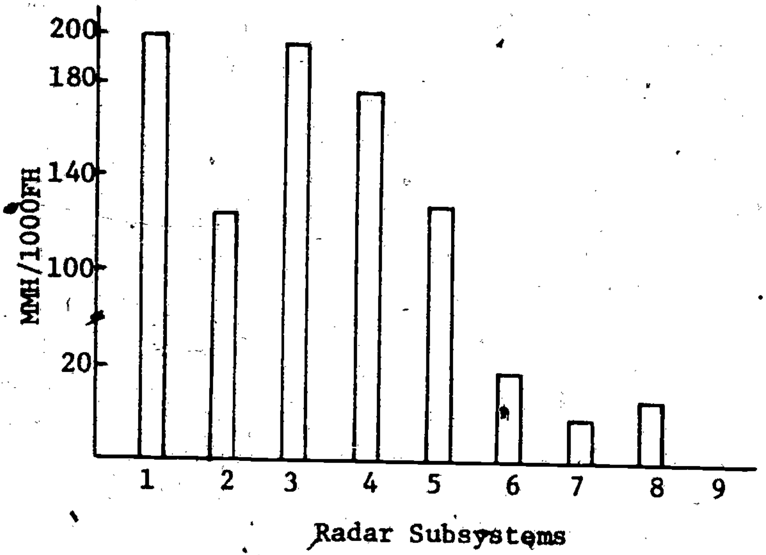
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(L)
III.7-42.1(N)

SUBJECT:
Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational

INDEX: 11-9

CROSS-INDEX: I.3-2.1



*		**	Axes	
Gp.	Equipment	Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	199
A	F-105D	5-60	2	123
A	F-4C	5-63	3	195
A	F-4D	12-65	4	176
A	F-4E	10-67	5	128
B	F-111A	10-67	6	18
B	FB-111A	7-68	7	8
B	A-7D	12-68	8	12
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Maintenance Manhours for Adjustment Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Maintenance manhours for adjustments on the organizational level were compared across selected radar subsystems. The subsystems represented two different generations of equipment (see Chart I.3-2.1). The activity was identified by USAF Action Code "L", discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging or fitting. This code excluded replacement of parts. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1]

IMPLICATIONS: Data analysis yielded a significant difference in maintenance manhours expended on adjustments. The difference ratio was 1:12.9. For each hour spent on adjustments in Group B, 12.6 hours were spent in Group A. A likely combination of factors producing this difference were lower adjustment requirements, reallocation of a portion of this activity to another level of maintenance, and simplification of adjustment tasks.

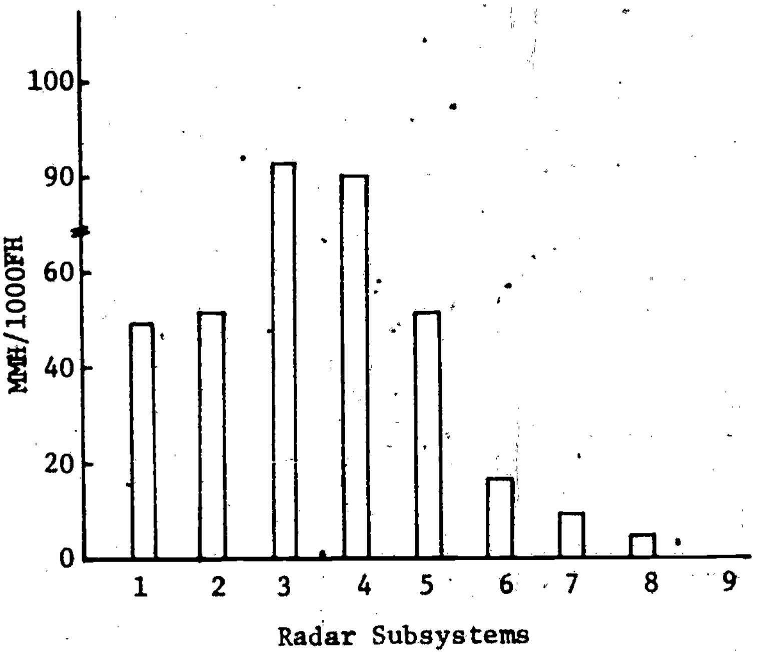
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(L)
III.7-42.1(N)

SUBJECT:
Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational

INDEX: 11-9

CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	48
A	F-105D	5-60	2	52
A	F-4C	5-63	3	93
A	F-4D	12-65	4	90
A	F-4E	10-67	5	51
B	F-111A	10-67	6	16
B	FB-111A	7-68	7	9
B	A-7D	12-68	8	6
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

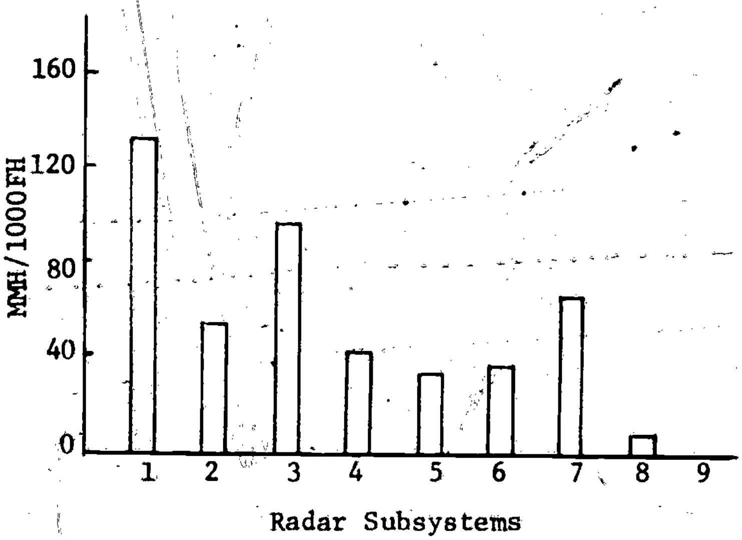
TITLE: Maintenance Manhours for Repair and/or Replacement of Minor Parts on Fire Control Radar Subsystem Type - Unscheduled Organizational

COMMENTS: Maintenance manhours for repair and/or replacement of minor parts were compared across selected radar subsystems. The subsystems represented two different generations of equipment (see Chart I.3-2.1). The activity was identified by USAF Action Taken Code "G", repair and/or replacement of minor parts, hardware, and soft goods such as seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners, and brackets. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1]

IMPLICATIONS: Data analysis yielded a significant difference in maintenance manhours expended on repair and/or replacement of minor parts. The difference ratio was 1:6.5. For each hour spent repairing and/or replacing minor parts in Group B, 6.5 hours were spent in Group A. A likely combination of factors to which the difference can be attributed were reduction of task requirements, and task reallocation to another level of maintenance.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-9
III.7-42.1(L) III.7-42.1(N)	Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational	CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	133
A	F-105D	5-60	2	55
A	F-4C	5-63	3	96
A	F-4D	12-65	4	41
A	F-4E	10-67	5	34
B	F-111A	10-67	6	38
B	FB-111A	7-68	7	65
B	A-7D	12-68	8	9
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

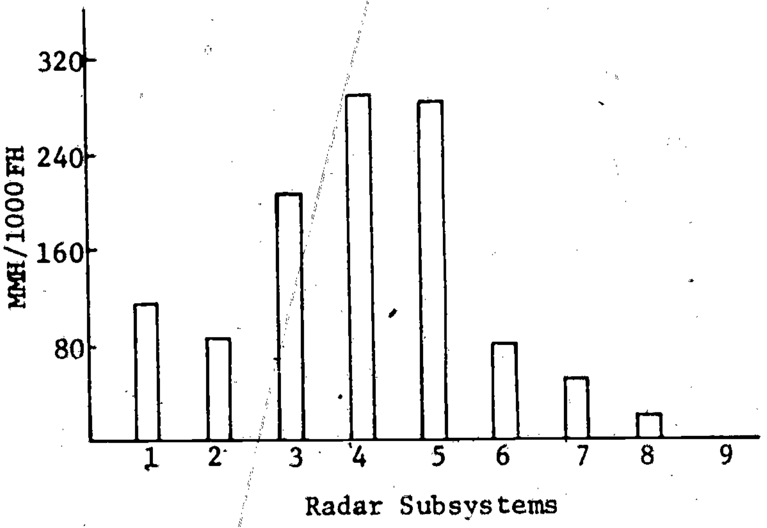
TITLE: Maintenance Manhours for Remove and Replace Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Maintenance manhours[1] to remove and replace equipment units on the organizational level were compared across selected radar subsystems. The subsystems represented two different generations of equipment (see Chart I.3-2.1). The activity was identified by USAF Action Code "R", item is removed and another like item is installed. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1]

IMPLICATIONS: Data yielded a difference ratio of 1:1.9. For each hour spent on this task in Group B, 1.9 hours were spent in Group A. The findings based upon group comparisons were not considered statistically significant. On a paired comparison basis, A-7D was substantially lower than all of the 7 subsystems with which it was compared. A likely combination of factors for observed differences of magnitude were improved equipment reliability and better accessibility.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-9
III.7-42.1(L) III.7-42.1(N)	Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems Unscheduled Organizational	CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	115
A	F-105D	5-60	2	82
A	F-4C	5-63	3	209
A	F-4D	12-65	4	292
A	F-4E	10-67	5	302
B	F-111A	10-67	6	80
B	FB-111A	7-68	7	46
B	A-7D	12-68	8	19
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

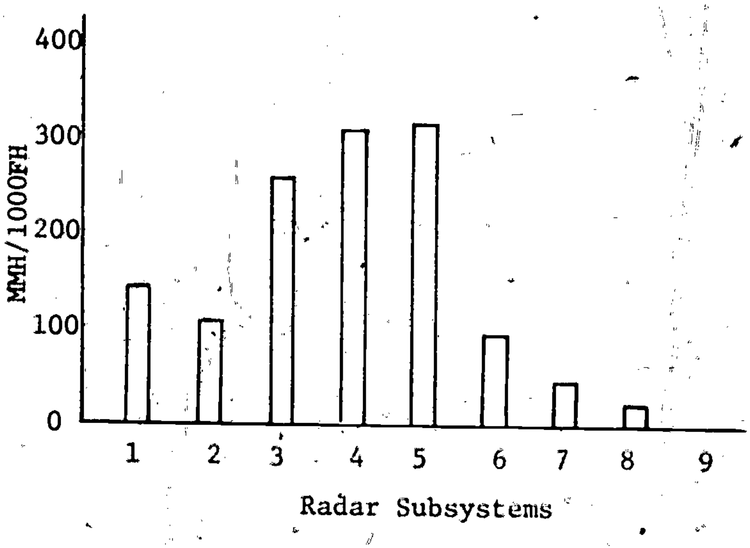
TITLE: Maintenance Manhours for Removal Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Maintenance manhours for removal actions were compared across selected radar subsystems. The subsystems represented two different generations of equipment (see Chart I.3-2.1). The activity was identified by USAF Action Taken Code "P" and covered removal actions only. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.

IMPLICATIONS: Data yielded a significant difference ratio of 1:4.1. For each hour spent on this activity on Group B equipment, 4.1 hours were spent on Group A equipment. The most likely combination of factors responsible for this difference were lower frequency of occurrence, improved fault isolation, and better accessibility to equipment units.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(L) III.7-42.1(N)	SUBJECT: Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational	INDEX: 11-9 CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	 Y
A	F-106A/B	7-59	1	141
A	F-105D	5-60	2	108
A	F-4C	5-63	3	262
A	F-4D	12-65	4	310
A	F-4E	10-67	5	320
B	F-111A	10-67	6	95
B	FB-111A	7-68	7	47
B	A-7D	12-68	8	23
B	F-15			

* See Chart I.3-2.1
** Date Entered AF Inventory.

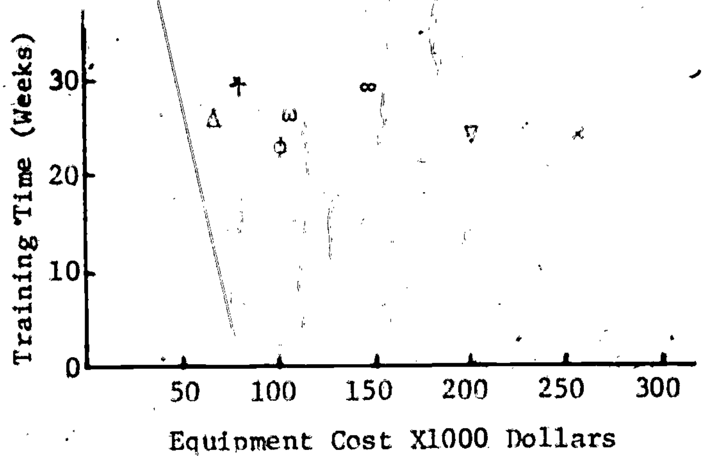
TITLE: Maintenance Manhours for Installation Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Maintenance manhours[1] to install an equipment item were compared across selected radar subsystems. The subsystems represented two different generations of equipment (see Chart I.3-2.1). This activity was identified by USAF Action Taken Code "Q" and covered installation actions only. The number of equipment units considered and the USAF identification codes associated with them were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746X; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1]

IMPLICATIONS: Data yielded a significant difference ratio which was identical to that found for remove only activities, 1:4.1. Since these two activities are related, the findings were expected. Group B showed lower maintenance manhours for this activity. For each hour expended on installation activities in Group B, 4.1 hours were expended in Group A.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 11-9
III.7-42.1(L) III.7-42.1(N)	Maintenance Manhours by Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational	CROSS-INDEX: I.3-2.1



Sym-bol	Equipment	Mo.-Yr*	Axes X X1000	Axes Y
O	F-106A/B	7-59		
†	F-105D	5-60	80	29
Δ	F-4C	5-63	65	26.6
ω	F-4D	12-65	101	26.6
∞	F-4E	10-67	149	29.4
×	F-111A	10-67	255	24
∇	FB-111A	7-68	200	24
ϕ	A-7D	12-68	100	23
ε	F-15			

*Date Entered AF Inventory

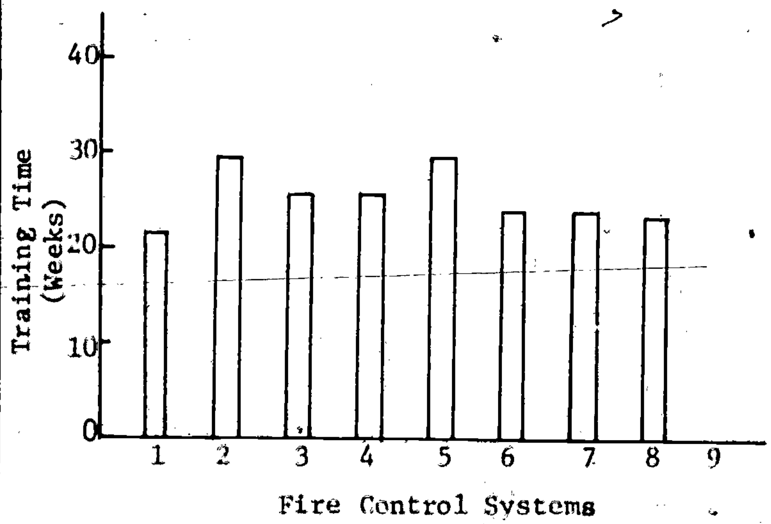
TITLE: Relation of 3ABR32231 Training Time to Fire Control Radar Subsystem Acquisition Cost

COMMENTS: Course 3ABR32231 provides formal school training[1] for Semi-Skilled Level 3 Mechanics on Fire Control radar subsystems. Using equipment acquisition cost[2] as a single logical descriptor of technological sophistication (see Chart I.3-2.1), its relationship to training time was examined.

IMPLICATIONS: Data failed to yield significant findings. However, there was a moderate negative relationship, i.e., a tendency for training time to decrease as subsystem cost increased.

DATA SOURCES: 1. ATC/ACMF, Randolph AFB, Texas, October 1972.
2. USAF Logistics Command, Wright-Patterson AFB.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 19-3
III.7-42.1(I)	Training Time vs. Fire Control Radar Subsystem Cost	CROSS-INDEX: I.3-2.1



* Gp.	* Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	22.0
A	F-105D	5-60	2	29.0
A	F-4C	5-63	3	26.6
A	F-4D	12-65	4	26.6
A	F-4E	10-67	5	29.4
B	F-111A	10-67	6	24.0
B	FB-111A	7-68	7	24.0
B	A-7D	12-68	8	23.0
B	F-15	.	9	

* See Chart I.3-2.1
** Data Entered AF Inventory

TITLE: Comparison of 3ABR32231 Training Time on Fire Control Systems

COMMENTS: Semi-skilled Grade E-3 rank is awarded to graduates of Course 3ABR32231. This course prepares airmen for semi-skilled maintenance tasks on Fire Control Systems. Training time was compared on selected systems to determine to what extent the amount of training varied.

IMPLICATIONS: The data showed low variation in the amount of training across systems. It would appear that changing designs over time have not affected the amount of basic training given on Fire Control Systems as measured by the course length of 3ABR32231. This finding was of interest when the systems were viewed as representative of growing complexity. Since basic training was more closely allied to organizational maintenance than it was to intermediate maintenance, it was considered more directly reflective of organizational than intermediate requirements. For impact of changing designs on intermediate maintenance performance, Skill Levels 5 and 7 training data would be appropriate.

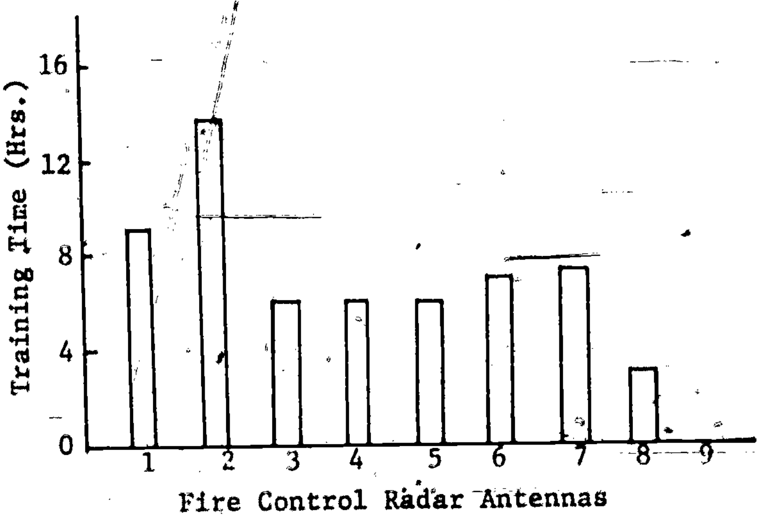
DATA SOURCES: 1. Lowry Technical Training Center, Lowry AFB, Colorado 80230 (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:
III.7-42.1(I)

SUBJECT:
3ABR32231 Training Time vs. Fire Control System

INDEX: 19-8

CROSS-INDEX: I.3-2.1



Gp.*	Equipment	Mo.-Yr.**	Axes	
			X	Y
A	F-106A/B	7-59	1	9.1
A	F-105D	5-60	2	13.8
A	F-4C	5-63	3	6.0
A	F-4D	12-65	4	6.0
A	F-4E	10-67	5	6.0
B	F-111A	10-67	6	7.1
B	FB-111A	7-68	7	7.3
B	A-7D	12-68	8	3.0
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

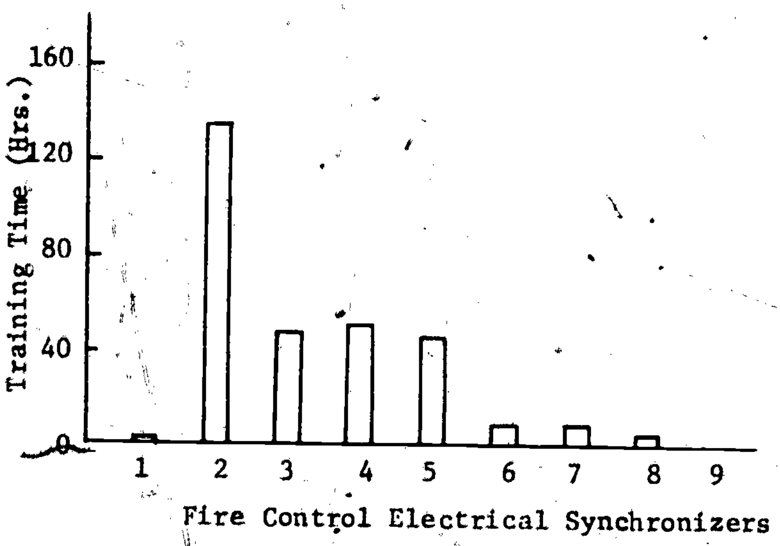
TITLE: Comparison of 3ABR32231 Training Time on Fire Control Radar Antennas

COMMENTS: Training times were compared on selected Fire Control radar antennas to determine to what extent the amount of training varied. The data were obtained from training experts at the technical training school where the courses were conducted.[1]

IMPLICATIONS: The amount of training was comparable for five of the eight antennas. F-106A/B and F-105D were distinctively high.

DATA SOURCES: 1. Lowry Technical Training Center, Lowry AFB, Colorado 80230 (Personal Communication, 1972)

MODELS FOR DATA APPLICATION: III.7-42.1(I)	SUBJECT: 3ABR32231 Training Time vs. Fire Control Radar Antennas	INDEX: 19-8 CROSS-INDEX: I.3-2.1



*		**	Axes	
Gp.	Equipment	Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	5.1
A	F-105D	5-60	2	136.6
A	F-4C	5-63	3	48.3
A	F-4D	12-65	4	50.3
A	F-4E	10-67	5	44.1
B	F-111A	10-67	6	9.1
B	FB-111A	7-68	7	9.2
B	A-7D	12-68	8	3.0
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

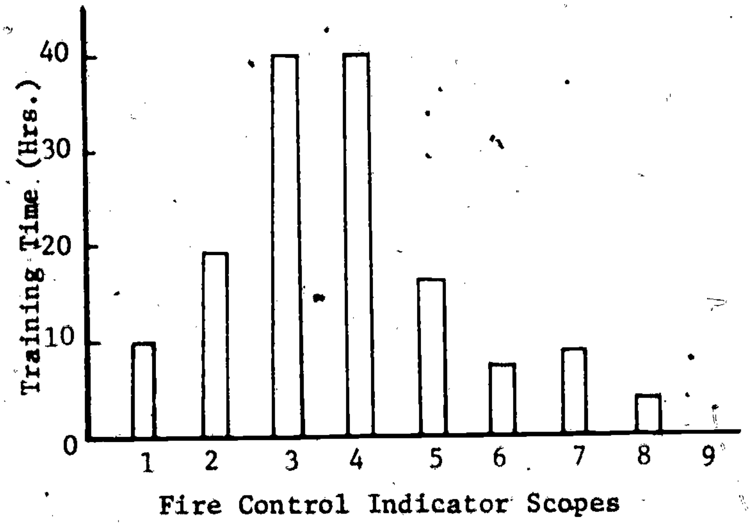
TITLE: Comparison of 3ABR32231 Training Time on Fire Control Electrical Synchronizers

COMMENTS: Training times were compared on selected Fire Control electrical synchronizers to determine to what extent the amount of training varied. The data were obtained from training experts at the technical training school where the courses were conducted.[1]

IMPLICATIONS: The data yielded significant differences among the synchronizers. The amount of training given on electrical synchronizers was lower for Group B than Group A Fire Control Systems. When these data were reviewed in conjunction with Charts I.30-9.2, I.30-9.6, I.30-9.10, and I.30-9.14, there was insufficient evidence to conclude that the lower performance times were associated with greater amounts of training time, or that high performance times were associated with low amounts of training. It appeared that the variations in training were caused, most plausibly, by differences in maintainability concept and differences in design acting in combination, with some smaller proportion of the variation attributable to instructional methods. It is significant to note the differences in training time on the F-106A/B and F-105D, both belonging to Group A.

DATA SOURCES: 1. Lowry Technical Training Center, Lowry AFB, Colorado 80230 (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 19-8
III.7-42.1(I)	3ABR32231 Training vs. Fire Control Electrical Synchronizers	CROSS-INDEX: I.3-2.1 I.30-9.2 I.30-9.6 I.30-9.10 I.30-9.14



Gp.*	Equipment	Mo.-Yr.**	Axes X	Axes Y
A	F-106A/B	7-59	1	9.3
A	F-105D	5-60	2	18.0
A	F-4C	5-63	3	39.5
A	F-4D	12-65	4	39.5
A	F-4E	10-67	5	16.7
B	F-111A	10-67	6	7.6
B	FB-111A	7-68	7	7.8
B	A-7D	12-68	8	3.0
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

TITLE: Comparison of 3ABR32231 Training Time on Fire Control Indicator Scopes

COMMENTS: Training times were compared on selected Fire Control indicator scopes to determine to what extent the amount of training varied. The data were obtained from training experts at the technical training school where the courses were conducted.[1]

IMPLICATIONS: The data yielded significant differences among the indicator scopes. The amount of training given on scopes was lower for Group B than Group A. When these training data were examined in terms of level of performance obtained as shown in Charts I.30-9.3, I.30-9.7, I.30-9.11, and I.30-9.15, there were singular cases where low amounts of training were associated with high performance times - F-106A/B and A-7D - which implicated under-training. In most instances, however, comparable performance levels were associated with varying amounts of training. It would appear that factors operating differentially on these indicator scopes have produced differences in training requirements. Suspected factors were maintainability concept and equipment design, with some smaller proportion of the variation attributable to instructional methods.

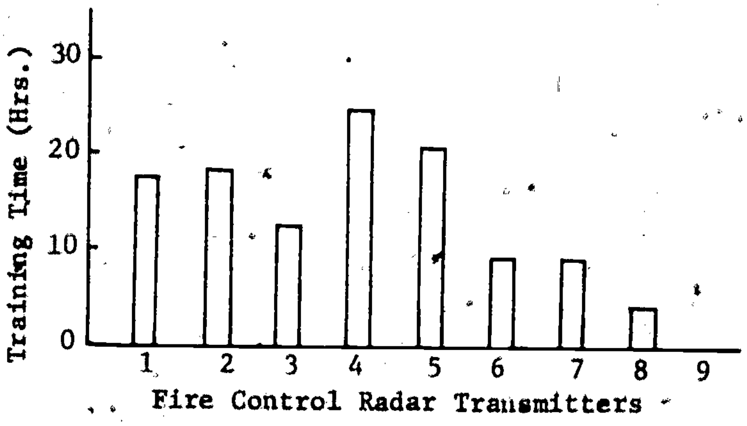
DATA SOURCES: 1. Lowry Technical Training Center, Lowry AFB, Colorado 80230 (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:
III.7-42.1(I)

SUBJECT:
3ABR32231 Training Time vs. Fire Control Indicator Scopes

INDEX: 19-8

CROSS-INDEX:
I.3-2.1
I.30-9.3
I.30-9.7
I.30-9.11
I.30-9.15



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	17.4
A	F-105D	5-60	2	17.7
A	F-4C	5-63	3	12.5
A	F-4D	12-65	4	24.5
A	F-4E	10-67	5	20.6
B	F-111A	10-67	6	8.9
B	FB-111A	7-68	7	8.9
B	A-7D	12-68	8	3.0
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

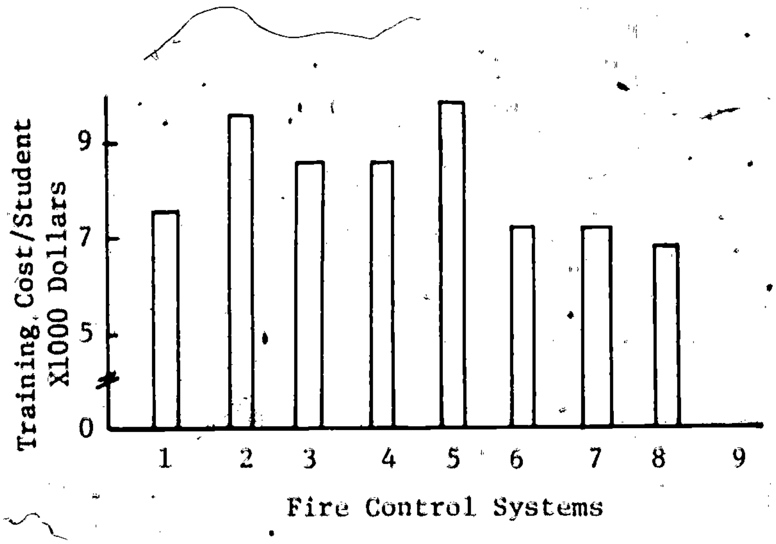
TITLE: Comparison of 3ABR32231 Training Time on Fire Control Radar Transmitters

COMMENTS: Training times were compared on selected Fire Control radar transmitters to determine to what extent the amount of training varied. The data were obtained from training school where the courses were conducted.[1]

IMPLICATIONS: Data yielded significant differences among the transmitters. The amount of training given on Group B designs was lower than for Group A designs. These training data were reviewed in conjunction with Charts I.30-9.5, I.30-9.9, I.30-9.13 and I.30-9.17 to determine the relationship between the level of performance obtained and the amount of training. Singular cases existed for A-7D where high performance times ~~were~~ associated with low training times, which implicated under-training. However, in general, there was insufficient evidence to conclude that the low performance times were associated with high amounts of training, or that high performance times were associated with low amounts of training. It appeared that varied amounts of training were required to produce comparable levels of performance. A plausible combination of reasons for these findings were differences in maintainability concept and equipment design, with some smaller proportion of the variation due to instructional methods.

DATA SOURCES: 1. Lowry Technical Training Center, Lowry AFB, Colorado 80230 (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 19.8
III.7-42.1(I)	3ABR32231 Training Time vs. Fire Control Radar Transmitters	CROSS-INDEX: I.3-2.1 I.30-9.5 I.30-9.9 I.30-9.13 I.30-9.17



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	7568
A	F-105D	5-60	2	9570
A	F-4C	5-63	3	8645
A	F-4D	12-65	4	8645
A	F-4E	10-67	5	9820
B	F-111A	10-67	6	7224
B	FB-111A	7-68	7	7224
B	A-7D	12-68	8	6831
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Comparison of 3ABR32231 Training Cost per Student for Fire Control Systems

COMMENTS: Training cost per student for semi-skilled level Grade E-3 award was compared across selected Fire Control Systems. Course 3ABR32231 is the basic technical course conducted in an Air Force technical training school to prepare airmen for system maintenance. The training cost per student included:

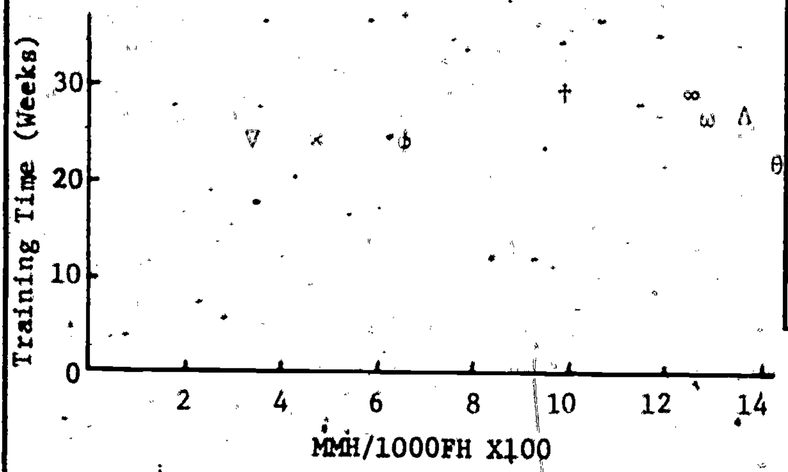
Direct Costs - Costs related to training operations.
Indirect Costs - Cost related to operation of base facilities.
Command Overhead - Proportionate share of major air command overhead.
Student Pay and Allowance - Standard military rate for the average grade (rank) of the student during the effective course length.

The cost data were derived in collaboration with Randolph Air Force Base. FY '71 costing was used.

IMPLICATIONS: It is apparent from the bar graph that the training cost per student was lower for Group B than Group A Fire Control Systems. Some portion of this was due to the course length itself (see Chart I.19-8.1). The findings implicated a difference in the basic training given for systems representing past and current generations of equipment. Conceivably, what was considered basic in Group A was not the case in Group B. In view of the fact that Group B equipment are considered more complex, plausible explanations for these findings are (a) the redirection of training to other skill levels and (b) augmented training through special courses. Training costs for other courses should be examined.

DATA SOURCES: 1. ATC/ACMF, Randolph Air Force Base, Texas, (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 22-2
III.7-42.1(I)	3ABR32231 Training Costs vs. Fire Control Systems	CROSS-INDEX: I.3-2.1 I.19-8.1



Symbol	Equipment	* Mo.-Yr.	Axes X	Axes Y
θ	F-106A/B	7-59	1425	22
†	F-105D	5-60	996	29
Δ	F-4C	5-63	1366	26.6
ω	F-4D	12-65	1269	26.6
∞	F-4E	10-67	1244	29.4
×	F-111A	10-67	472	24.0
∇	FB-111A	7-68	331	24
ϕ	A-7D	12-68	628	23
ε	F-15			

*Date Entered AF Inventory

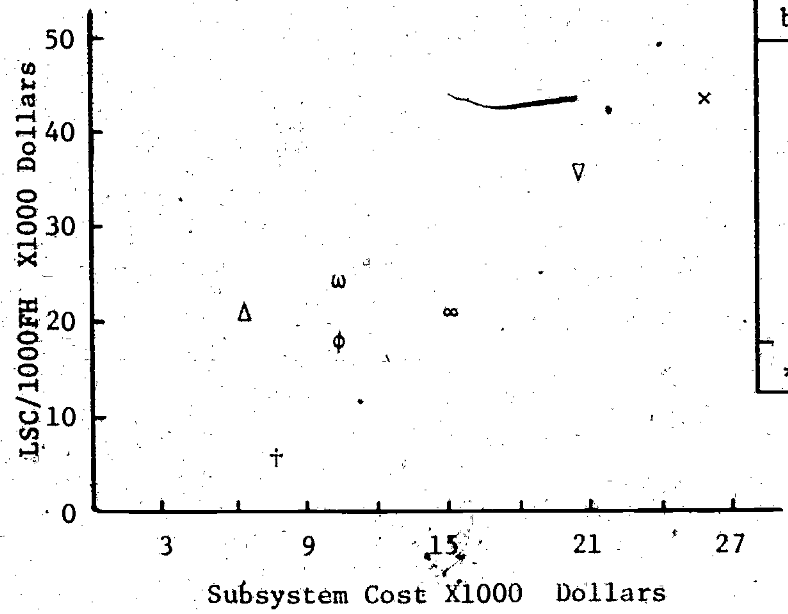
TITLE: Relation of 3ABR32231 Training Time to Unscheduled Organizational Maintenance Manhours - Fire Control Radar Subsystems

COMMENTS: Course 3ABR32231 provides formal school training[1] for Semi-Skilled Level 3 Mechanics on Fire Control radar subsystems. Its relationship to unscheduled organizational maintenance manhours was examined to determine whether the amount of training was influenced by unscheduled maintenance manhours. The assumption was that this type of maintenance occurred because of unpredicted or unexpected failures due to equipment unreliability, human unreliability, or a combination of both. One way to increase human reliability is to increase the training. Since Skill Level 3s were normally assigned to organizational level of maintenance, only that level of maintenance was examined.

IMPLICATIONS: The scatter plot failed to reveal any observable trend (i.e., the training remained relatively constant regardless of the amount of unscheduled organizational maintenance). However, when training was analyzed on specific line replaceable units (see Charts I.19-8.3 through I.19-8.5), significant differences in training were revealed). It would appear, therefore, that an analysis on too general a level could obscure the existence of true differences.

DATA SOURCES: 1. ATC/TTP, Randolph AFB, Texas, (Personal Communication, 1972)

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 19-11
III.7-42.1(I)	3ABR32231 Training vs. Unscheduled Organizational Maintenance Manhours - Fire Control Radar Subsystems	CROSS-INDEX: I.19-8.3 through I.19-8.5



Sym-bol	Equipment	* Mo.-Yr	Axes	
			X X1000	Y
θ	F-106A/B	7-59		
†	F-105D	5-60	80	6570
Δ	F-4C	5-63	65	22270
ω	F-4D	12-65	101	24890
∞	F-4E	10-67	149	22090
×	F-111A	10-67	255	43530
∇	FB-111A	7-68	200	36300
ϕ	A-7D	12-68	100	19200
ε	F-15			

*Date Entered AF Inventory

TITLE: Relation of Logistics Cost to Fire Control Radar Subsystem Cost

COMMENTS: The relationship between subsystem acquisition cost and logistics support cost was examined on selected Fire Control radar subsystems to determine whether a change in subsystem acquisition cost resulted in some consistent change in logistics cost. The logistics support cost considered the subsystem as a whole, and the cost factors included base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1] The subsystem acquisition cost was for an assembled subsystem.[2] The scatter diagram shows the pairs of values for these two variables on seven subsystems. F-106A/B subsystem acquisition cost was not available.

IMPLICATIONS: Data analysis yielded a clear-cut trend that significantly related these two variables functionally. As subsystem acquisition cost increased, logistics support cost also increased. For 5.44 units increase in subsystem acquisition cost there was one unit increase in logistic cost. It appeared that tne equipment cost itself had high predictive power in estimating logistics cost.

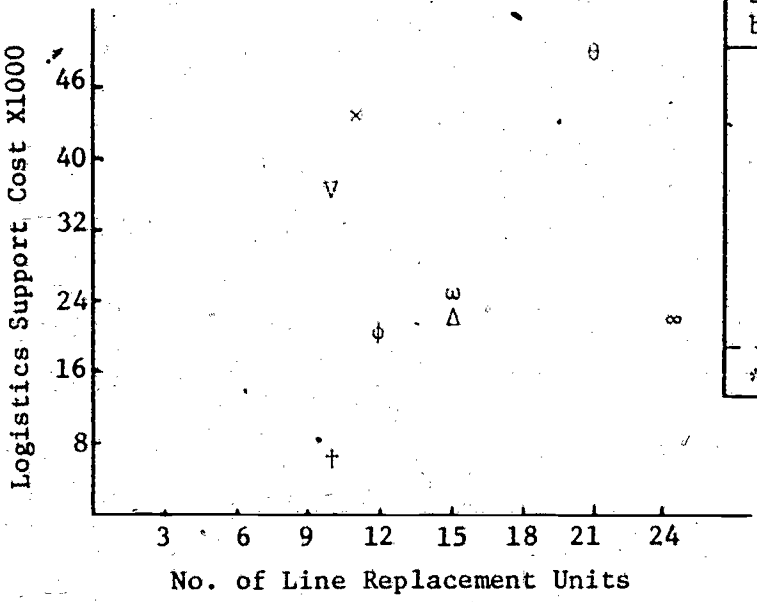
DATA SOURCES:
1. USAF Logistics Command, K0.51 PN4L Quarterly Logistics Report, December 1971.
2. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(B)
III.7-42.1(D)

SUBJECT:
Logistics Cost vs. Fire Control Radar Subsystem Cost

INDEX: 25-3

CROSS-INDEX:



Sym-bol	Equipment	* Mo.-Yr.	Axes X	Y
θ	F-106A/B	7-59	21	49100
†	F-105D	5-60	10	6570
Δ	F-4C	5-63	16	22270
ω	F-4D	12-65	16	24890
∞	F-4E	10-67	24	22090
×	F-111A	10-67	11	43530
∇	FB-111A	7-68	10	36300
ϕ	A-7D	12-68	12	19260
ε	F-15		12	

*Date Entered AF Inventory

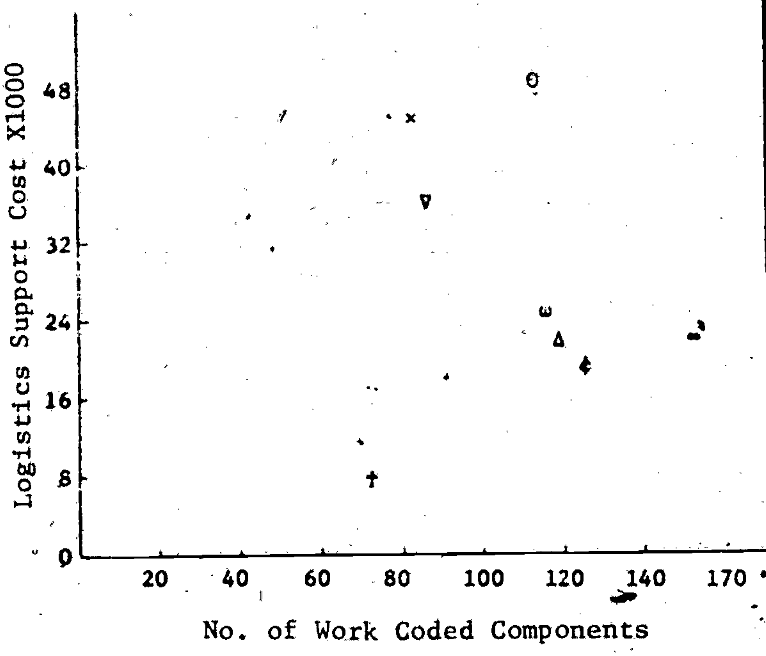
TITLE: Relation of Logistics Support Cost to Number of Line Replaceable Units in Fire Control Radar Subsystems - Organizational Maintenance

COMMENTS: The relationship between logistics support cost and line replaceable units (see Chart I.4-2.1) was examined on selected Fire Control radar subsystems to determine whether a change in number of units resulted in some consistent change in logistics cost. The logistics support cost considered the subsystem as a whole, and the cost factors included base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1] The scatter plot is based on pairs of values for these two variables.

IMPLICATIONS: Statistical test yielded a low positive relationship, indicating some tendency for logistics support cost to increase as numbers of line replaceable units increased. It appeared from an examination of the scatter plot that two separate curved lines would fit the data points better than one -- the first connecting FB-111A, F-111A and F-106A/B, and the second connecting F-105D, A-7D, F-4C, F-4D and F-4E. Both lines yielded approximately the same form, with the first on a higher plane. When these data were viewed in conjunction with the findings of Chart I.25-3.1, it appeared that the number of units in combination with equipment unit costs were responsible for the dollar differences in logistics support. Also, when compared with Chart I.25-4.2, contrasting trends were noted; LRUs and logistics tended to vary in the same direction, while an increase in intermediate level components was accompanied by a decrease in logistics cost; in both cases, these functional relationships were low.

DATA SOURCES: 1. USAF Logistics Command, KO.51 PN4L Quarterly Logistics Report, December 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 25-4
III.7-42.1(B) III.7-42.1(D) III.7-42.1(H)	Logistics Cost vs. Maintenance Concept on Fire Control Radar Subsystems - Organizational	CROSS-INDEX: I.4-2.1 I.25-3.1 I.25-4.2



Symbol	Equipment	* Mo.-Yr.	Axes X	Axes Y
Θ	F-106A/B	7-59	112	49100
†	F-105D	5-60	72	6570
Δ	F-4C	5-63	119	22270
ω	F-4D	12-65	114	24890
∞	F-4E	10-67	154	22090
×	F-111A	10-67	82	43530
∇	FB-111A	7-68	84	36300
ϕ	A-7D	12-68	124	19260
ε	F-15			

*Date Entered AF Inventory

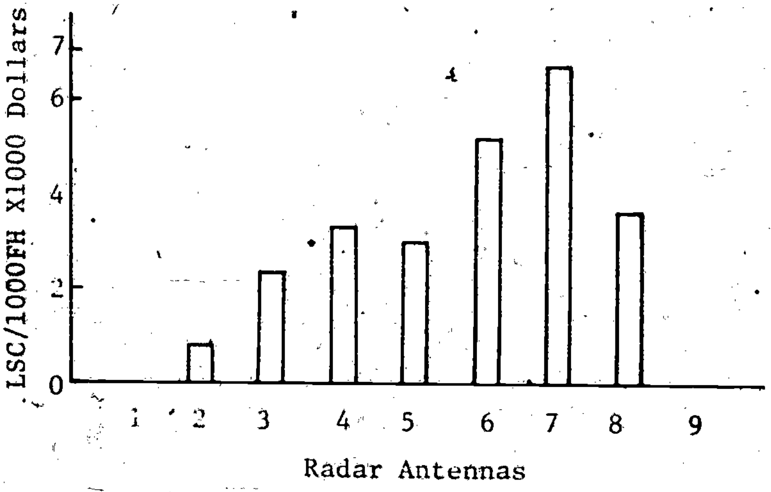
TITLE: Relation of Logistics Support Cost to Number of Work-Coded Components in Fire Control Radar Subsystems - Intermediate Maintenance

COMMENTS: The relationship between work-coded components (see Chart I.4-2.2) and logistics support cost[1] was examined on selected Fire Control radar subsystems, on the logical contention that spares provisioning would be influenced by the number of work-coded components that needed to be stocked. The logistics support cost considered base labor, depot labor, materials, condemnations, transportation, packing and shipping. The scatter plot is based on pairs of values for these two variables.

IMPLICATIONS: Considering all pairs of values, the data did not exhibit any clear-cut relationship, either positive or negative. However, there was a slight tendency for lower numbers of components to be associated with higher logistics cost. If F-105D, which is outside of the general cluster of points, is excluded, then this inverse relationship becomes very obvious. There is, therefore, evidence to suspect that the level of unit disassembly, as measured by the number of components is functionally related to logistics cost. Theoretically the lower the level of dissembly, the less complex the unit becomes, and the lower the logistics support cost.

DATA SOURCES: 1. USAF Logistics Command, KO.51 PN 4L Quarterly Logistics Report, December 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 25-4
III.7-42.1(B) III.7-42.1(D) III.7-42.1(H)	Logistics Cost vs. Maintenance Concept on Fire Control Radar Subsystems - Intermediate	CROSS-INDEX: I.4-2.2



*Gp.	Equipment	**Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	–
A	F-105D	5-60	2	736
A	F-4C	5-63	3	2328
A	F-4D	12-65	4	3365
A	F-4E	10-67	5	2948
B	F-111A	10-67	6	5056
B	FB-111A	7-68	7	6812
B	A-7D	12-68	8	3597
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

TITLE: Logistics Support Costs on Antennas of Fire Control Radar Subsystems

COMMENTS: The logistics support costs considered base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1] F-106A/B data were not available.

IMPLICATIONS: Findings yielded a significant difference between the two generations of equipment. For each unit of logistics cost spent in Group A designs, 2.2 units were spent in Group B designs. In view of Chart I.25-3.1 where a strong functional relationship was found between subsystem cost and logistics cost, it appeared that substantially the same kind of relationship would be obtained if a cost comparison were made on the subassembly and component levels. These findings were also suggestive of differences in the proportions of restore vs. discard actions existing among the equipment units.

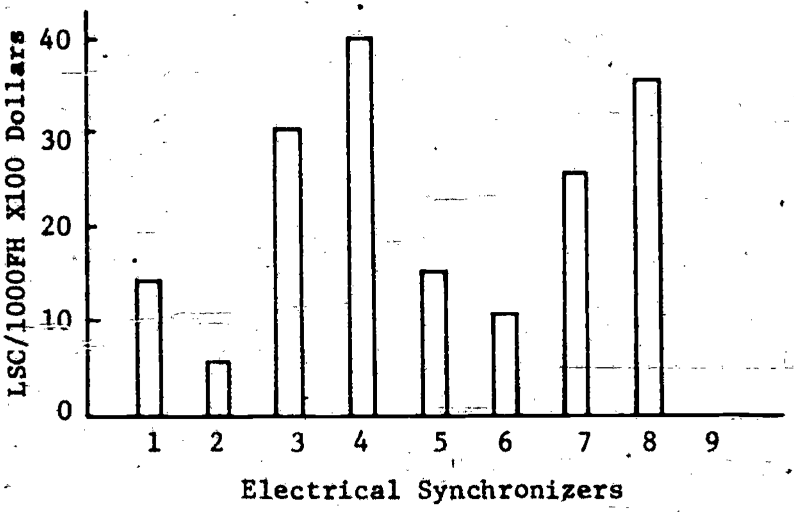
DATA SOURCES: 1. USAF Logistics Command, K0.51 PN4L Quarterly Logistics Report, December 1972.

MODELS FOR DATA APPLICATION:
III.7-42.1(B)
III.7-42.1(D)

SUBJECT:
Logistics Support Costs - Antennas of Fire Control Radar Subsystems

INDEX: 25-5

CROSS-INDEX: I.3-2.1
I.25-3.1



*		**	Axes	
Gp.	Equipment	Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	1419
A	F-105D	5-60	2	592
A	F-4C	5-63	3	3035
A	F-4D	12-65	4	3927
A	F-4E	10-67	5	1502
B	F-111A	10-67	6	1113
B	FB-111A	7-68	7	2566
B	A-7D	12-68	8	3580
B	F-15		9	

* See Chart I.3-2.1
** Data-Entered AF Inventory

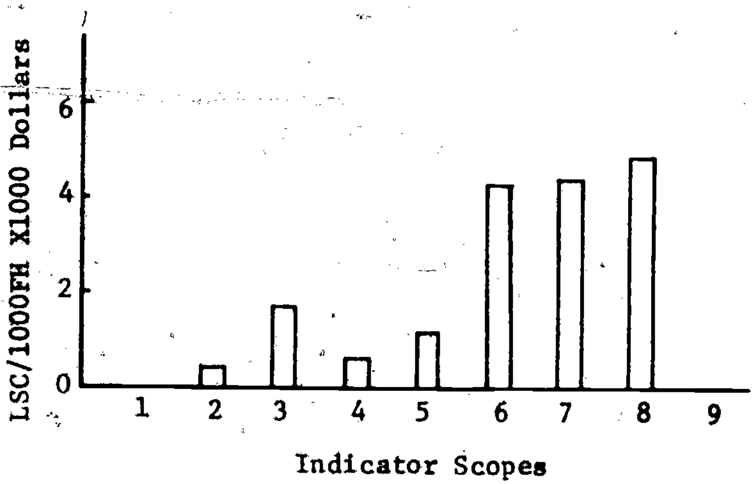
TITLE: Logistics Support Costs on Electrical Synchronizers of Fire Control Radar Subsystems

COMMENTS: The logistics support cost considered base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1]

IMPLICATIONS: Data analysis revealed extreme variations within each generation of equipment as well as between the two generations of equipment, A and B. The difference between the lowest and the highest cost was $3335. Chart I.19-8.3 provides a possible partial explanation for F-111A, FB-111A and A-7D. That chart revealed that the training time was very low for Skill Level 3. If this were generally indicative of the amount of training given to Skill Levels 5 and 7, for which no data were available, then it would appear that lowered requirements for skills training would be complemented by a higher ratio of discards to partial-full repairs. The primary contributors to logistics cost then would be the equipment cost itself, assembly, subassembly, and component levels, as well as the failure rate. Likewise, Chart I.19-8.3 indicated that substantially more training was given on the F-105D Fire Control electrical synchronizer than any of the other seven Fire Control electrical synchronizers with which it was compared, and the logistics cost for the F-105D synchronizer was the lowest. Some combination of factors such as maintenance policy, lower skill utilization equipment reliability, and adequacy of training would have the net effect of producing logistics cost differences.

DATA SOURCES: 1. USAF Logistics Command, K0.51 PN4L Quarterly Logistics Report, December 1971.

MODELS FOR DATA APPLICATION: II.7-42.1(B) III.7-42.1(D)	**SUBJECT:** Logistics Cost - Electrical Synchronizers of Fire Control Radar Subsystems	**INDEX:** 25-5 **CROSS-INDEX:** I.3-2.1 I.19-8.3



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	
A	F-105D	5-60	2	469
A	F-4C	5-63	3	1681
A	F-4D	12-65	4	589
A	F-4E	10-67	5	1225
B	F-111A	10-67	6	4312
B	FB-111A	7-68	7	4376
B	A-7D	12-68	8	4845
B	F-15	.	9	

* See Chart I.3-2.1

** Data Entered AF Inventory

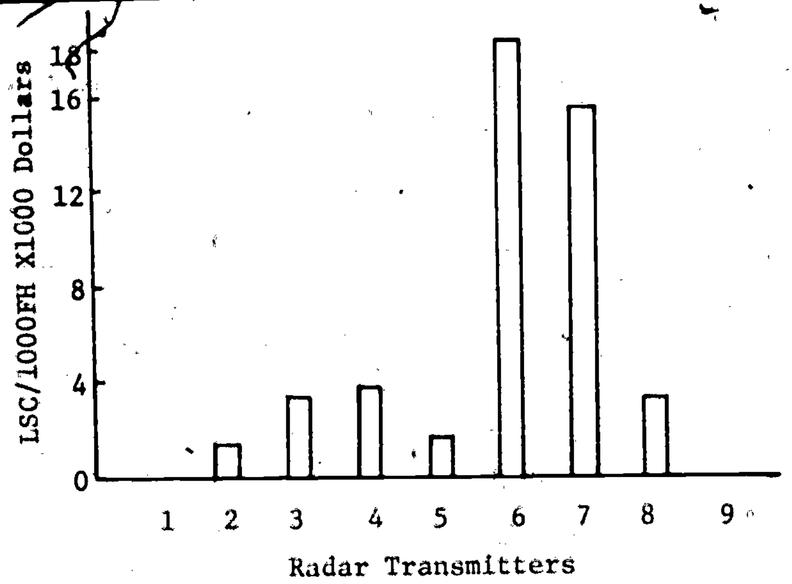
TITLE: Logistics Support costs on Indicator Scopes of Fire Control Radar Subsystems

COMMENTS: The logistics support costs considered base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1]

IMPLICATIONS: Findings yielded a significant difference between the two generations of equipment. For each unit of logistics cost spent in Group A designs, 5 units were spent in Group B designs. In view of Chart I.25-3.1 where a strong functional relationship was found between subsystem cost and logistics cost, it appeared that substantially the same kind of relationship would be obtained if a cost comparison were made on the subassembly and component levels. These findings were also suggestive of differences in the proportions of restore vs. discard actions existing among the equipment units.

DATA SOURCES: 1. USAF Logistics Command, KO.51 PN4L Quarterly Logistics Report, December 1972.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 25-5
III.4-72.1(B) III.4-72.1(D)	Logistics Cost - Indicator Scopes of Fire Control Radar Subsystems	CROSS-INDEX: I.3-2.1 I.25-3.1



*		**	Axes	
Gp.	Equipment	Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	
A	F-105D	5-60	2	1457
A	F-4C	5-63	3	3117
A	F-4D	12-65	4	3903
A	F-4E	10-67	5	1613
B	F-111A	10-67	6	18435
B	FB-111A	7-68	7	15536
B	A-7D	12-68	8	3115
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

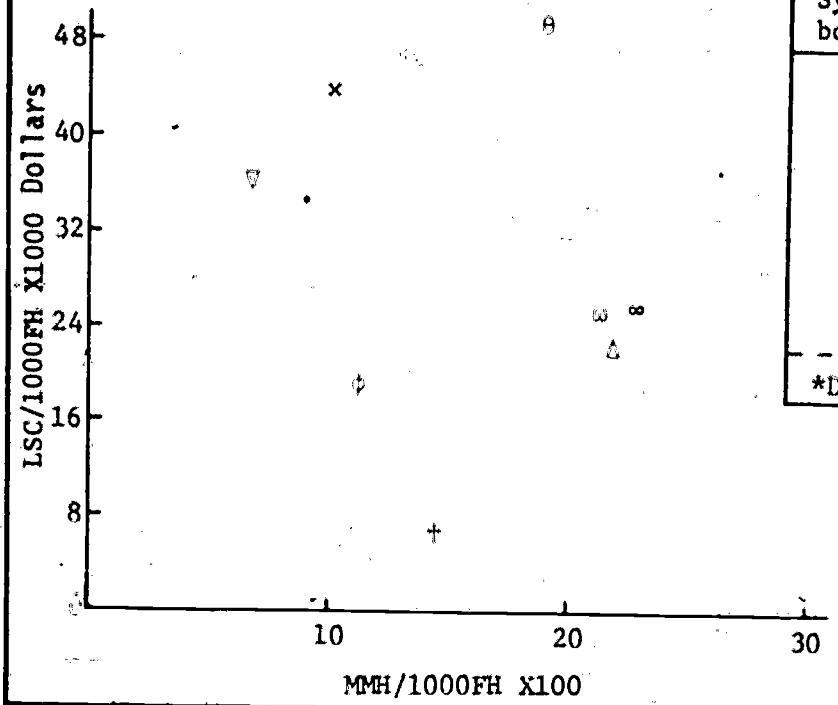
TITLE: Logistics Support Costs on Transmitters of Fire Control Radar Subsystems

COMMENTS: The logistics support costs considered base labor, depot labor, materials, condemnations, transportation, packing and shipping. F-106A/B data were not available.

IMPLICATIONS: Findings yielded a significant difference between the two generations of equipment. For each unit of logistics cost spent in Group A designs, 5 units were spent on Group B designs. Excluding A-7D, which differed drastically from F-111A and FB-111A, the ratio was 1:7 units. In view of the relationship between subsystem cost and logistics cost (see Chart I.25-3.1), it appeared that the same kind of relationship would be obtained if a cost comparison were made on the subassembly and component levels. These findings were also suggestive of differences in the proportions of restore vs. discard actions existing among the equipment units.

DATA SOURCES: 1. USAF Logistics Command, KO.51 PN4L Quarterly Logistics Report, December 1972.

MODELS FOR DATA APPLICATION: III.4-72.1(B) III.4-72.1(D)	**SUBJECT:** Logistics Cost - Transmitters of Fire Control Radar Subsystems	**INDEX:** 25-5 **CROSS-INDEX:** I.3-2.1 I.25-3.1



Sym-bol	Equipment	* Mo.-Yr.	Axes X	Axes Y
θ	F-106A/B	7-59	1927	49100
+	F-105D	5-60	1404	6570
Δ	F-4C	5-63	2217	22270
ω	F-4D	12-65	2126	24890
∞	F-4E	10-67	2269	22090
×	F-111A	10-67	1012	43530
∇	FB-111A	7-68	648	36300
ϕ	A-7D	12-68	1159	19260
ε	F-15			

*Date Entered AF Inventory

TITLE: Relationship between Maintenance Manhours and Logistics Support Costs on Fire Control Radar Subsystems - Unscheduled Organizational and Intermediate Maintenance

COMMENTS: The relationship of unscheduled maintenance manhours to logistics support costs was examined on selected Fire Control radar subsystems to determine whether changes in maintenance manhours produced a consistent effect on logistics costs. The logistics costs considered the subsystem as a whole, and the cost factors included base labor, depot labor, materials, condemnations, transportation, packing and shipping.[1] The maintenance manhours were based on unscheduled organizational and intermediate level of maintenance and considered all task types and all equipment units work-coded for maintenance action on the organizational and intermediate levels.[2]

IMPLICATIONS: Analysis failed to yield any clear-cut trend that would relate these two variables functionally, although the logical contention was that some observable trend should exist. Statistically, there was a low tendency for the higher logistics costs to be associated with the lower maintenance manhours. A more precise measure would be obtained if depot maintenance data as well as scheduled maintenance for all levels were included. These data were not available.

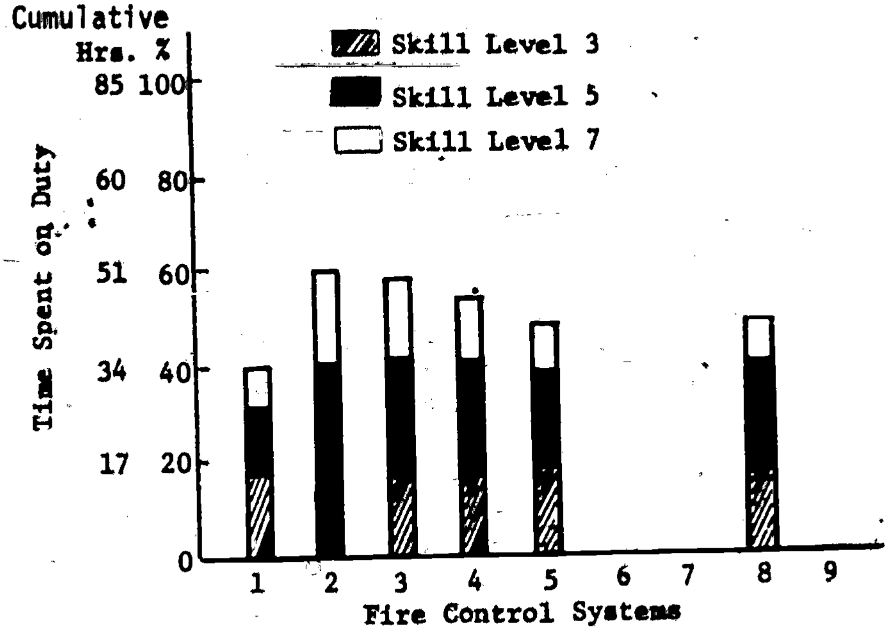
DATA SOURCES:
1. USAF Logistics Command, KO.51 PN4L Quarterly Logistics Report, December 1971.
2. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(B)
III.7-42.1(D)

SUBJECT:
Unscheduled Maintenance Manhours vs. Logistics Costs

INDEX: 25-11

CROSS-INDEX:



Gp.*	Equipment	Mo.-Yr.**	Axes X	Axes Y
A	F-106A/B	7-59	1	40
A	F-105D	5-60	2	60
A	F-4C	5-63	3	57
A	F-4D	12-65	4	54
A	F-4E	10-67	5	48
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	48
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

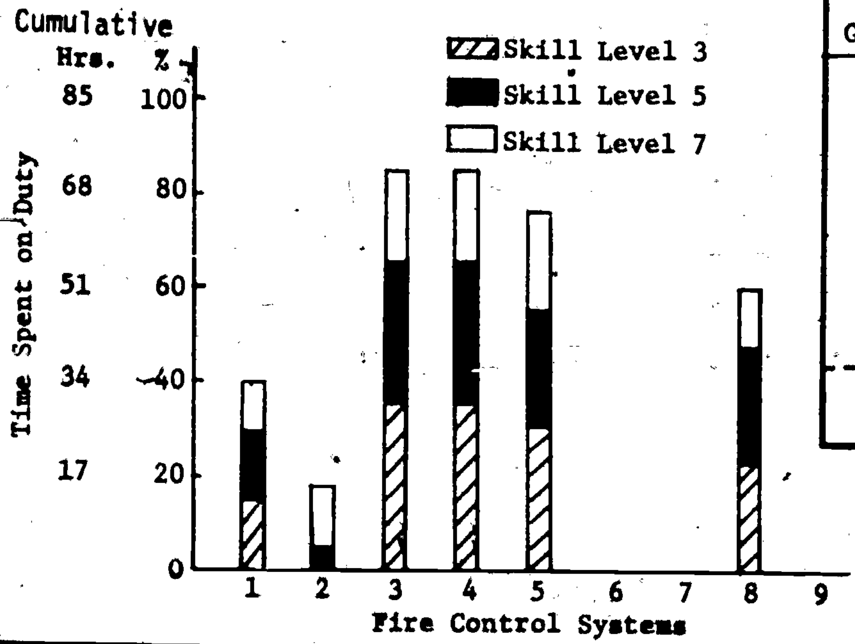
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on General Electronic Maintenance and Repair of Fire Control Systems by Performing Skills

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of general electronics equipment maintenance and repair. There were 27 tasks listed for this duty; 5 were trouble analyses; 7 were installation of components which included soldering, wiring, etc.; 5 were replacement of components; and 2 were testing of components. Combined they represented 70% of the duty. The percentage of time spent by performing skill levels was converted to manhours per month. The computation base was predicated on 85.2 available manhours/month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared to determine what variations existed on the amount of time spent on this duty. F-111A and FB-111A data were not available.

IMPLICATIONS: There was low variation across the Fire Control Systems. The combined times of Skill Levels 3, 5, and 7 showed that approximately the same amount of time was spent on this duty. The largest difference was 20 hours and this was between F-105D and F-106A/B. The ratios of Skill Levels 3:5, 3:7, and 5:7 were comparable and averaged 1.5%:1% in all cases. The one exception was F-105D; Skill Level 3 did not perform this duty. Since time spent and skill mixes showed relatively low differences, it appears that the demands of this duty have not changed substantially across Fire Control Systems.

DATA SOURCES:
1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION: III.7-42.1(P)	SUBJECT: Occupational Duty - General Electronic Maintenance and Repair vs. Performing Skills on Fire Control Systems	INDEX: 26-8 CROSS-INDEX: I.3-2.1



*		**	Axes	
Gp.	Equipment	Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	39.2
A	F-105D	5-60	2	17.0
A	F-4C	5-63	3	84.2
A	F-4D	12-65	4	84.2
A	F-4E	10-67	5	75.0
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	59.5
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

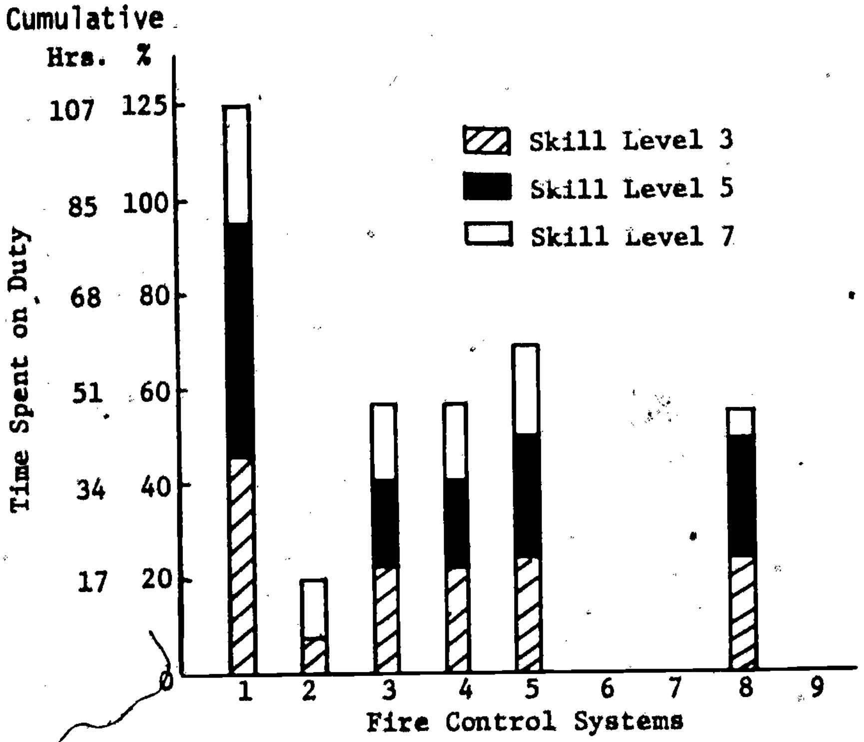
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on Power Off Inspections by Performing Skills on Fire Control Systems

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of power off inspections on weapons control systems. There were 46 tasks listed for this duty. Twelve were aircraft and aerospace ground equipment inspections and preparations and 28 were inspections of systems and system components. Combined they represented 87% of the duty. The percentage of time spent by performing skills was converted to manhours per month. The computation base was predicted on 85.2 available manhours/month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared to determine what variations existed in duty performance across different system desings. F-111A and FB-111A data were not available, thereby narrowing the comparisons to conventional systems(Group A).

IMPLICATIONS: Combining the time spent by all skills, the F-4s were relatively homogeneous on this measure but contrasted significantly with F-106A/B and F-105D. The time spent on this duty was at least two times greater for F-4s than for F-106A/B and F-105D. In terms of skill mixes, the F-4s and A-7D showed comparable ratios. F-105D was unique in that Skill Level 3 did not perform this duty and Skill Level 5 time was extremely low, while skill level 7 showed the largest amount of time. A plausible reason for the great disparity between the F-4s and F-106A/B and F-105D may be due in part to two place vs. one-place designs, where power off inspections in the former covered both cockpits.

DATA SOURCES: 1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 26-8
III.7-42.1(P)	Occupational Duty - Power Off Inspection vs. Performing Skills on Fire Control Systems	CROSS-INDEX: I.3-2.1



Gp.*	Equipment	Mo.-Yr.**	Axes	
			X	Y
A	F-106A/B	7-59	1	124.7
A	F-105D	5-60	2	20.0
A	F-4C	5-63	3	56.0
A	F-4D	12-65	4	56.0
A	F-4E	10-67	5	68.1
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	55.1
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

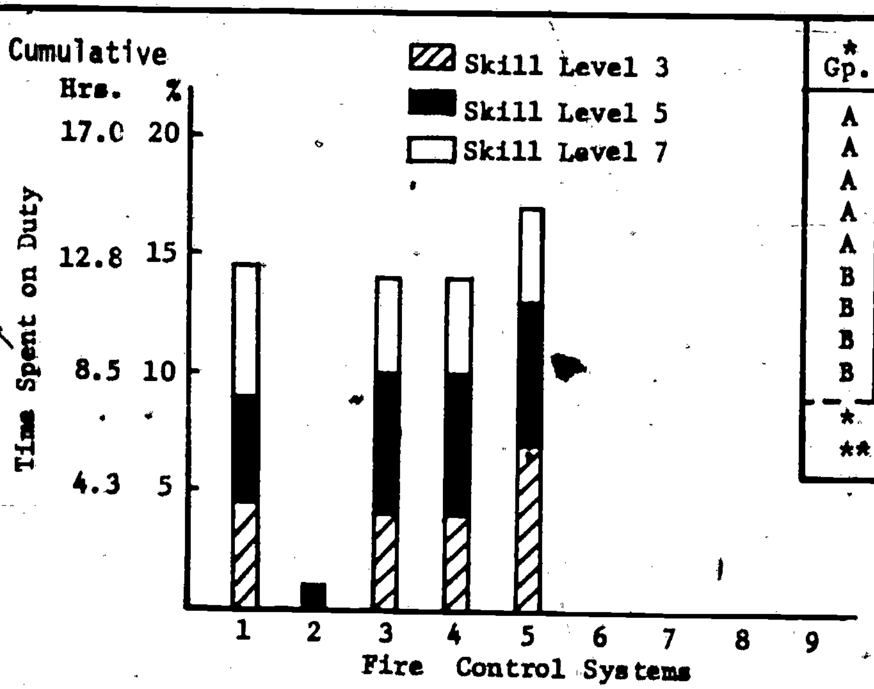
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on Flight-Line Checks and Adjustments by Performing Skills

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of flight-line checks and adjustments. The percentage of time spent by performing skill levels was converted to manhours. The computation base was predicted on 85.2 available manhours/month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared on this performance measure. F-111A and FB-111A data were not available, thereby narrowing the comparisons primarily to conventional systems (Group A).

IMPLICATIONS: The skill ratios as well as the total time spent were comparable for the F-4s and A-7D; there was a low difference. F-106A/B and F-105D represented the extreme high and low. The amount of time spent on the F-106A/B system was twice as high as that for any of the F-4s or A-7D, while F-105D was less than one-half the amount of time spent on F-4 or A-7D. A logical explanation was the number of different tasks that constituted this duty (see Charts I.27-2.1 and I.27-2.2). F-106A/B had the highest number of flight-line checks and adjustment tasks. The number of different tasks may be due to a mix of one-place and two-place versions for F-106A/B.

DATA SOURCES:
1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 26-8
III.7-42.1(P)	Occupational Duty - Flight-Line Checks and Adjustments vs. Performing Skill Levels on Fire Control Systems	CROSS-INDEX: I.3-2.1 I.27-2.1 I.27-2.2



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	13.9
A	F-105D	5-60	2	1.0
A	F-4C	5-63	3	14.0
A	F-4D	12-65	4	14.0
A	F-4E	10-67	5	17.0
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	0.0
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

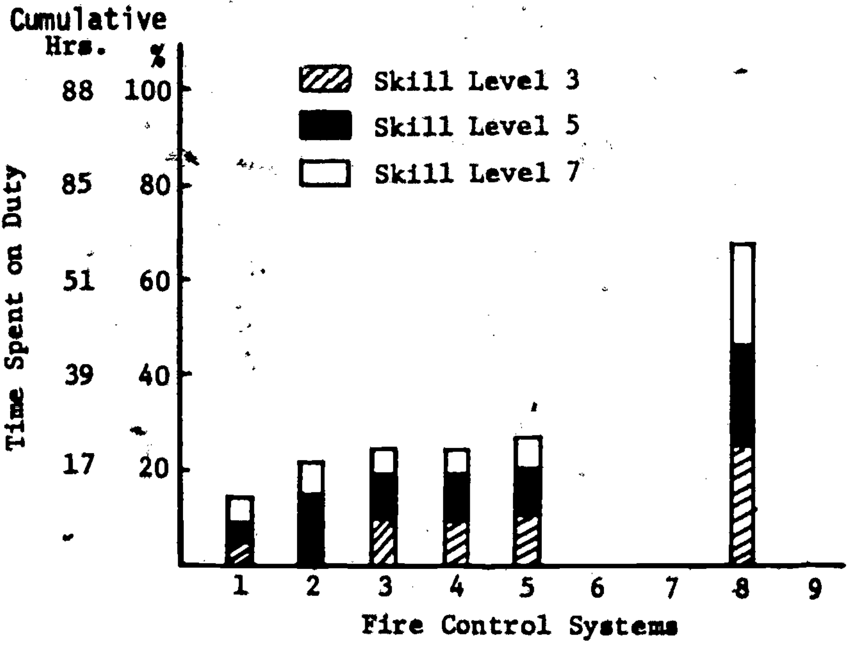
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on Field Shop Repair of Components or Subassemblies by Performing Skills

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of field shop repairs. The percentage of time spent by performing skill levels was converted to manhours. The computation base was predicted on 85.2 available manhours-month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared on this performance measure. F-111A and FB-111A data were not available. The job inventory data showed 0% of time spent on A-7D system; therefore, the only systems compared were F-106A/B through F-4E.

IMPLICATIONS: The amount of time spent on this duty appeared to have some relationship to the number of different task statements describing this duty (see Chart I.27-2.4). F-105D had the least number of task statements and also had the lowest amount of time spent on this duty. F-106A/B, which had more task statements than F-4E, showed less time spent; however, the difference was negligible. The skill ratios were also equivalent among F-106A/B and F-4s.

DATA SOURCES:
1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 26-8
III.7-42.1(P)	Occupational Duty - Field Shop Repair vs. Performing Skill Levels on Fire Control Systems	CROSS-INDEX: I.3-2.1 I.27-2.4



* Gp.	Equipment	** Mo.-Yr.	[illegible]	
			X	Y
A	F-106A/B	7-59	1	18.4
A	F-105D	5-60	2	21.0
A	F-4C	5-63	3	24.0
A	F-4D	12-65	4	24.0
A	F-4E	10-67	5	26.0
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	67.5
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

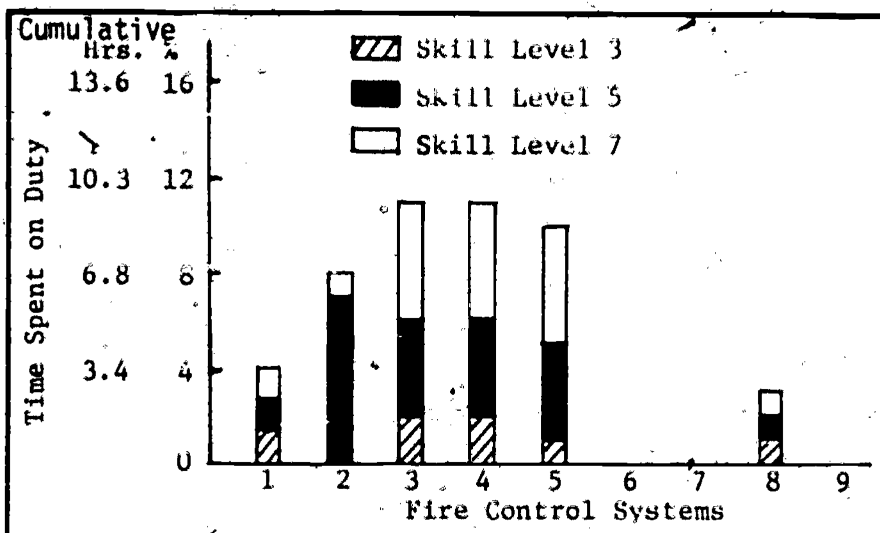
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on Field Shop Checkouts and Adjustments by Performing Skills

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of field shop checkouts and adjustments. The percentage of time spent by performing skill levels was converted to manhours. The computation base was predicted on 85.2 available manhours/month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared on this performance measure. F-111A and FB-111A data were not available, thereby narrowing the comparisons primarily to conventional systems (Group A).

IMPLICATIONS: Findings indicated an average increase of 45% in the amount of time spent on the A-7D system when compared with the others. The amount of time spent for all skills combined was comparable on the Group A systems. The skill ratios were likewise comparable, with the exception of F-105D where Skill Level 3 did not perform this duty, according to the data. The number of task statements (see Charts I.27-2.3 and I.27-2.5) did not provide any lead to explain the differences between A-7D and the Group A systems. It is likely, therefore, that the unique nature of the tasks themselves in combination with the number of tasks were responsible for the increase in time spent.

DATA SOURCES:
1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 26-8
III.7-42.1(P)	Occupational Duty - Field Shop Checkouts and Adjustments vs. Performing Skills	CROSS-INDEX: I.3-2.1 I.27-2.3 I.27-2.5



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	4.0
A	F-105D	5-59	2	8.0
A	F-4C	5-63	3	11.0
A	F-4D	12-65	4	11.0
A	F-4E	10-67	5	10.0
B	F-111A	10-67	6	
B	FB-111A	7-68	7	
B	A-7D	12-68	8	3.0
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

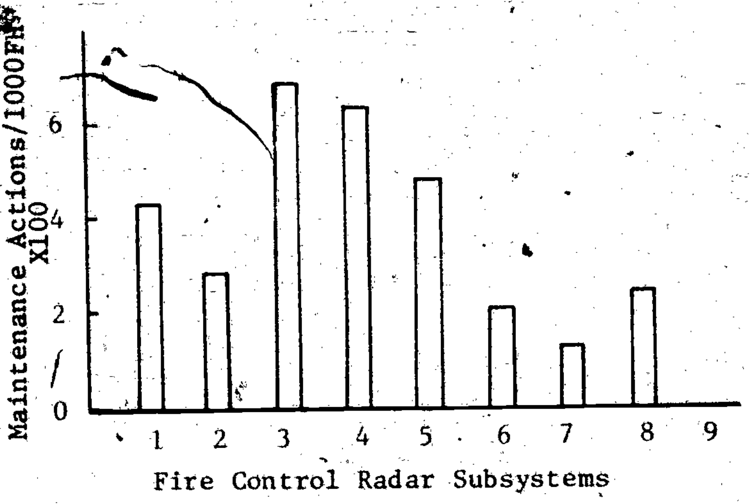
TITLE: Occupational Duty - 322X1 Weapon Control Systems Mechanic or Technician; Time Spent on Calibration and Maintenance of Category II Test Equipment by Performing Skills

COMMENTS: Job inventories[1] conducted by the U.S. Air Force in 1972 resulted in a duty analysis of specific tasks performed by Skill Levels 3, 5 and 7 under the duty of calibration and maintenance of Category II Test Equipment. There were 52 tasks listed for this duty. Thirty-three of these were system-specific - 14 for F-4 11 for F-105s, 8 for F-106s -- and represented 64% of the duty. The percentage of time spent by performing skill levels was converted to manhours. The computation base was predicated on 85.2 available manhours/month for a 5-day, 40-hour week.[2] Selected Fire Control Systems were compared on this performance measure. F-111A and FB-111A data were not available, thereby narrowing the comparisons to conventional systems, Group A.

IMPLICATIONS: The amount of time spent on the duty was comparable across the F-4s and F-105D. The extreme lows were F-106A/B and A-7D. In most cases, considerably more Skill Levels 5 and 7 were used than Skill Level 3. The amount of time spent on this duty also appeared to be proportional to the number of system-specific tasks; the greater the number of system-specific tasks, the greater the time spent on this duty.

DATA SOURCES:
1. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas. (Letter Communications, 1973)
2. USAF Cost and Planning Factors, AFM 172-3, October 27, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 26-9
III.7.42.1(P)	Occupational Duty - Calibration and Maintenance of Category II Test Equipment vs. Performing Skill Levels on Fire Control Systems	CROSS-INDEX: I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	417
A	F-105D	5-60	2	282
A	F-4C	5-63	3	683
A	F-4D	12-65	4	634
A	F-4E	10-67	5	478
B	F-111A	10-67	6	196
B	FB-111A	7-68	7	118
B	A-7D	12-68	8	240
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

TITLE: Frequency of Maintenance Actions on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Frequency of unscheduled organizational maintenance actions was examined on selected radar subsystems. The data were derived from flight hour bases ranging from 16025 to 202240.[1]

IMPLICATIONS: There was a significantly lower incidence of unscheduled organizational maintenance actions for Group B subsystems than Group A subsystems. For each unscheduled action in Group B, there were 2.7 unscheduled actions in Group A. Approximately the same results were obtained when unscheduled organizational maintenance manhours were used as the variable of comparison (see Chart I.11-2.1). However, when the subsystem mean performance times were examined (see Chart I.30-2.1), differences did not show up clearly, although the component level of analysis (see Chart I.30-9.1) did provide strong evidence of differences. Apparently, it takes a number of parameters analyzed on a gross or detailed level to construct a factual picture of system operations. Possible combinations of factors resulting in lowered incidence of unscheduled maintenance are increased equipment reliability, increased human reliability, and changes in scheduled maintenance policy which have the net effect of reducing the probability of unscheduled failures.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 28-2
III.7-42.1(R)	Frequency of Maintenance Actions vs. Fire Control Radar Subsystems - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.11-2.1 I.30-2.1 I.30-9.1

Maintenance Tasks	Frequency per 1000 Flight Hours	
	Group A*	Group B*
	F-106A/B, F-105D, F-4C, F-4D, F-4E	F-111A, FB-111A, A-7D
Adjust - Discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting. No replacements.	380	46
Remove and Replace - Item is removed and like item is installed.	123	42
Remove Only - Only removal is taken into account.	572	120
Install Only - Only installation is taken into account.	547	161
Repair and/or Replace Minor Parts - Small hardware items such as seals, gaskets, electrical connections, etc.	126	21
Troubleshoot - On-equipment time to isolate the primary cause of a discrepancy. Repair excluded.	241	56

*See Chart I.3-2.1

TITLE: Frequency of Task Performance - Fire Control Radar Subsystems; Unscheduled Organizational

COMMENTS: Six different types of tasks[1] on selected radar subsystems were compared for frequency of performance. The flight hour base from which the data were derived ranged from 16025 to 202240. The maintenance actions considered all equipment units coded for organizational restoration. These were: F-106A/B, 22, Code 74AX; F-105D, 13, Code 746XX; F-4C, 17, Code 741X; F-4D, 19, Code 747X; F-4E, 25, Code 74BX; F-111A, 14, Code 73BX; FB-111A, 12, Code 73JX; and A-7D, 13, Code 73AX.[1] The selected subsystems were representative of two different generations of equipment, A and B.

IMPLICATIONS. Data yielded strong contrasting differences for all task types. In all task categories, there was considerably lower frequency of performance for Group B than A. As was logically expected, these findings were equivalent to those contained in Charts I.11-9.1 through I.11-9.6 where the measure of comparison was maintenance manhours. Since frequency of performance and maintenance manhours were highly correlated, either measure would be acceptable for a maintenance estimating model. With respect to the apparent differences existing between the two groups of design, it is possible that differences in equipment reliability, as well as differences in maintenance concept, account for the major proportion of the variations.

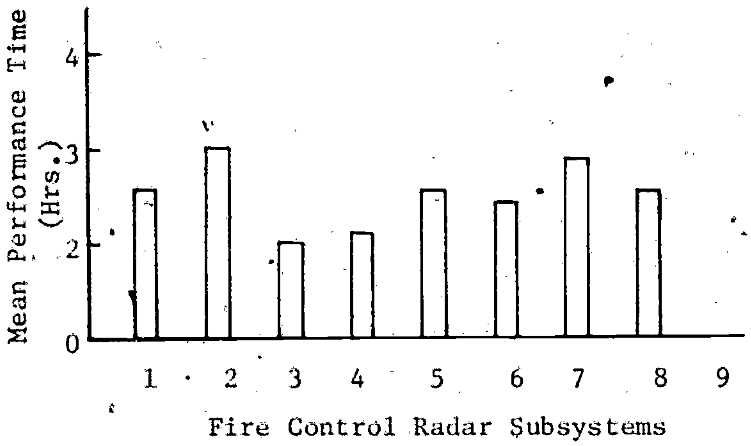
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(R)

SUBJECT:
Frequency of Task Type vs. Fire Control Radar Subsystems - Unscheduled Organizational

INDEX: 28-9

CROSS-INDEX: I.3-2.1
I.11-9.1
through
I.11-9.6



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	2.6
A	F-105D	5-60	2	4.0
A	F-4C	5-63	3	2.0
A	F-4D	12-65	4	2.1
A	F-4E	10-67	5	2.6
B	F-111A	10-67	6	2.4
B	FB-111A	7-68	7	2.8
B	A-7D	12-68	8	2.6
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

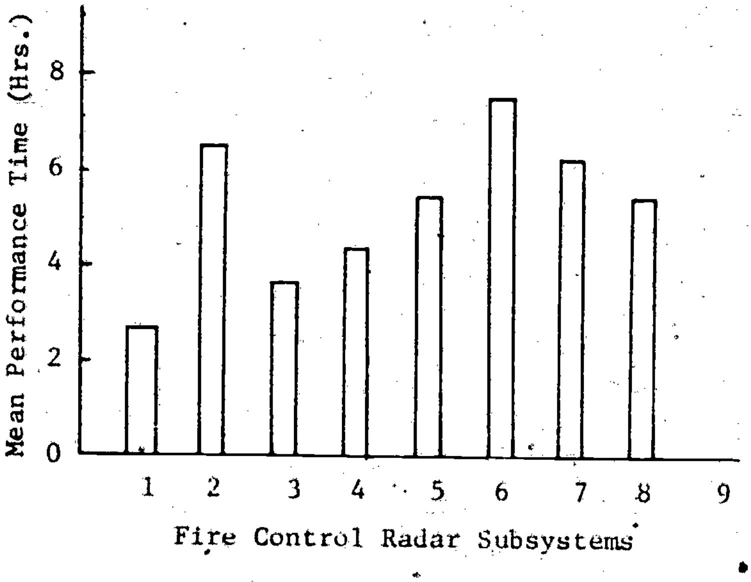
TITLE: Mean Subsystem Performance Time on Fire Control Radar Subsystems - Unscheduled Organizational

COMMENTS: Performance time was derived by combining all line replaceable units and all task types. The data consisted of flight hours ranging from 16025 to 202240.[1]

IMPLICATIONS: The average performance time for subsystems showed little variation either within or between groups. The means of Groups A and B were 2.7 and 2.6, respectively. These findings are not considered to contradict the results obtained on a more detailed level of analysis where components and task types were evaluated (see Chart I.30-9.1). In the latter method of analysis, there were strong indications that differences existed among component types as well as task types. Thus, average subsystem performance time should not be used as an index since it will fail to identify true differences. If this index of performance is used in estimating models to compare different weapon systems, it will result in an inaccurate picture of operational requirements.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-2
III.7-42.1(Q) III.7-42.1(R)	Mean Subsystem Performance Time vs. Fire Control Radar Subsystems - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-2.3 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	2.6
A	F-105D	5-60	2	6.5
A	F-4C	5-63	3	3.7
A	F-4D	12-65	4	4.3
A	F-4E	10-67	5	5.4
B	F-111A	10-67	6	7.5
B	FB-111A	7-68	7	6.2
B	A-7D	12-68	8	5.4
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

TITLE: Mean Subsystem Performance Time on Fire Control Radar Subsystems - Unscheduled Intermediate

COMMENTS: Performance time was derived by combining all work-coded components (see Chart I.4-2.2) and all task types. The data were based on aircraft flight hours ranging from 16025 to 202240.

IMPLICATIONS: The group means (4.5 hours for A and 6.2 hours for B) showed that the subsystem performance time tended to be 1.7 hours higher for B. One area that revealed high probability of differences between subsystems was bench-check of the radar transmitter (see Chart I.30-9.1). Sampling of other components should be pursued. Analysis on the component or task type level may locate specific areas of differences, whereas analysis at the subsystem level may not. The first approach permits the application of corrective actions, such as increased training or simplification of design for maintainability, in the proper area.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-2
III.7-42.1(Q) III.7-42.1(R)	Mean Subsystem Performance Time vs. Fire Control Radar Subsystems - Unscheduled Intermediate	CROSS-INDEX: I.3-2.1 I.4-2.2 I.30-9.1

Task Type	Subsystems								Sum of Ranks
	Group A					Group B			
	F-106A/B	F-105	F-4C	F-4D	F-4E	F-111A	FB-111A	A-7D	
Adjust *	3.8	3.4	2.6	2.2	2.9	1.6	1.6	3.2	
**	19.5	12.5	8.0	4.5	9.0	1.5	1.5	10.0	66.5
Remove and Replace	4.5	5.1	3.8	3.4	4.0	3.3	3.6	3.5	
	25.0	26.0	19.5	12.5	23.0	11.0	18.0	16.5	151.5
Repair	5.8	2.4	3.9	2.2	3.5	1.8	2.3	3.4	
	29.0	7.0	20.5	4.5	16.5	3.0	6.0	12.5	99.0
Troubleshoot	10.6	7.8	6.7	5.3	5.3	3.9	3.4	4.2	
	32.0	31.0	30.0	27.5	27.5	20.5	12.5	24.0	204.0
Sum of Ranks See Chart I.3-2.1	105.5	76.5	78.0	49.0	76.0	36.0	38.0	63.0	521.0

* Time (hours)
** Rank

TITLE: Mean Subsystem Performance Times by Task Type on Fire Control Radar Subsystems -- Unscheduled Organizational

COMMENTS: Mean maintenance times (hours) were derived by combining the averages for all line replacement units, i.e., examining the subsystem as a whole. Therefore, the mean times are for specific task types and consider all line replaceable units of a specific subsystem. The task types represented the chief maintenance actions practiced on the organizational level and were:

(a) Adjust - Discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting.
(b) Remove and Replace - Item is removed and another like item is installed.
(c) Repair and/or Replacement of Minor Parts, Hardware, and Soft Goods - Examples of such hardware items are seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners and brackets.
(d) Troubleshoot - On-equipment time to isolate the primary cause of a discrepancy. This excludes repair time.

These are official USAF definitions. The number of cases ranged from 21 to 13690 and were based on flight hours of 16025 to 202240.[1] The sum of ranks in the last

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-2
III.7-42.1(Q) III.7-42.1(R)	Mean Subsystem Performance Times on Fire Control Radar Subsystems - Unscheduled Organizational	CROSS INDEX: I.3-2.1 I.30-9.1

column was calculated by summing the ranks assigned to each row. The sum of ranks in the last row was calculated by summing the ranks within each column. The ranks were assigned by ordering all scores from low to high, and assigning 1 to the lowest, 2 to the next lowest, etc. For tied scores, the average of the tied ranks was assigned. This method provided a means of reducing the data for comparison purposes.

IMPLICATIONS: The type of task which generated the highest mean times was troubleshooting; the second highest was remove and replace; the third was repair and/or replacement of minor parts; and the fourth, or lowest, was adjust. Evaluating the subsystems on a group basis, A and B, the same findings were obtained within each group. Between groups, the mean differences favored Group B,(i.e., the mean times tended to be lower for B than A. Analyses on selected components summarized in Chart I.30.9-1 identified components where differences existed). The column ranks showed that when these four task types were combined to yield an index of subsystem mean times, Group B showed a lower figure. It appears that factors operating differentially between the two generations of equipment result in improved system maintenance performance for Group B.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-2
III.7-42.1(Q) III.7-42.1(R)	Mean Subsystem Performance Times on Fire Control Radar Subsystems - Unscheduled Organizational	CROSS INDEX: I.3-2.1 I.30-9.1

Equipment		Electrical Synchronizers	Indicator Scopes	Radar Antennas	Radar Transmitters	Sum of Ranks
Group A*	F-106A/B	2.2 [2.5]	4.7 [11.5]	4.1 [6.5]	1.9 [1.0]	[21.5]
	F-105D	4.9 [13.5]	9.0 [30.0]	8.0 [27.0]	12.5 [32.0]	[102.5]
	F-4C	3.8 [5.0]	3.5 [4.0]	4.4 [8.5]	2.2 [2.5]	[20.0]
	F-4D	4.7 [11.5]	4.1 [6.5]	5.0 [15.0]	4.4 [8.5]	[41.5]
	F-4E	4.9 [13.5]	5.4 [17.0]	5.6 [18.0]	6.4 [22.5]	[71.0]
Group B*	F-111A	10.2 [31.0]	6.5 [24.0]	6.3 [21.0]	8.6 [29.0]	[105.0]
	FB-111A	5.9 [20.0]	7.1 [26.0]	8.2 [28.0]	6.4 [22.5]	[96.5]
	A-7D	5.2 [16.0]	4.5 [10.0]	5.7 [19.0]	6.6 [25.0]	[70.0]
Sum of Ranks		[113.0]	[129.0]	[143.0]	[143.0]	[528.0]

*See Chart I-3.2-1

TITLE: Mean Component Performance Times on Fire Control Radar Subsystem Components - Unscheduled Intermediate

COMMENTS: Mean maintenance times (hours) were derived by combining averages of all intermediate level task types and all work-coded components (see Charts I.11-4.3 through I.11-4.6) for a specific line replaceable unit. The numbers of cases ranged from 137 to 7177 for the electrical synchronizers, 11 to 2222 for the indicator scopes, 104 to 4968 for the radar antennas, and 108 to 6583 for the radar transmitters. The flight hour base from which these data were drawn varied from 16025 to 202240.[1] The sum of ranks in the last column was calculated by summing the ranks assigned to each row. The sum of ranks in the last row was calculated by summing the ranks within each column. The ranks were assigned by ordering all scores from low to high, and assigning 1 to the lowest, 2 to the next lowest, etc., so that for the 32 scores shown in the graph, the rank of 32 identified the highest performance time in the series. For tied scores, the average of the tied ranks was assigned.

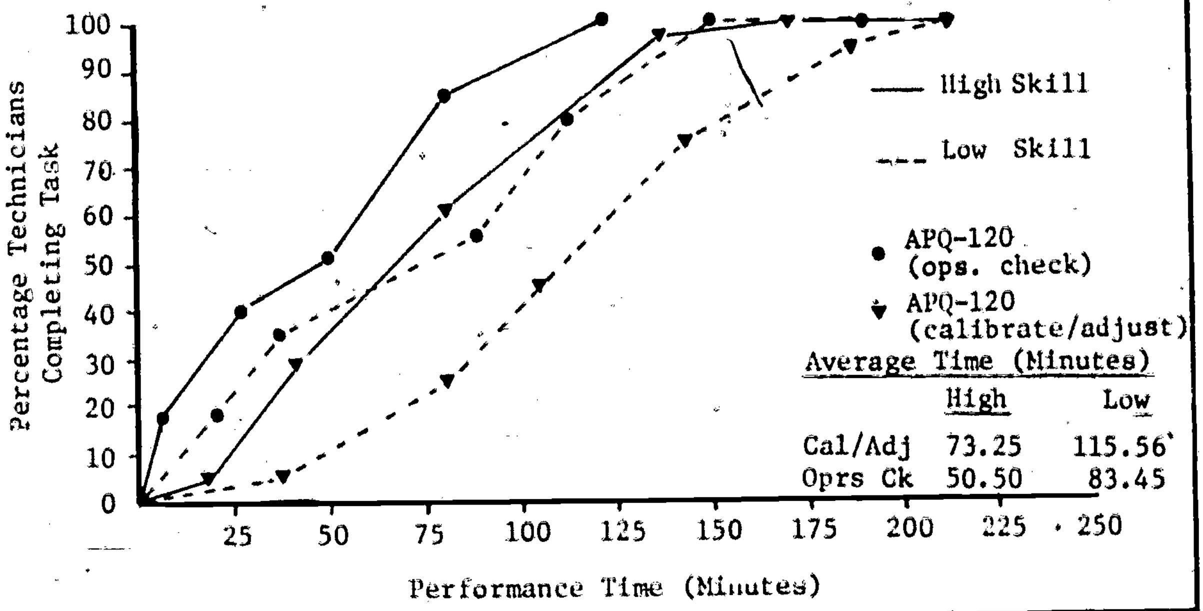
IMPLICATIONS: The components which generated the highest mean times were radar antennas and radar transmitters, which tied for first place. The third was indicator scopes, and the lowest was electrical synchronizers. However, the differences were not considered statistically significant, i.e., it appeared that one type of component was not considered more difficult than another type of component using maintenance performance time as the criterion measure. These findings were in contrast

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-5
III.7-42.1(Q) III.7-42.1(R)	Mean Component Performance Times on Fire Control Radar Subsystems - Unscheduled Intermediate	CROSS-INDEX: I.3-2.1 I.11-4.3 through I.11-4.6 I.30-2.3

to the significant results obtained when task types were analyzed on the organizational level (see Chart I.30-2.3). Evaluating the components on a group basis, A and B, all four components showed higher group means for B than A. The mean differences between the groups for the components in the order listed in the chart were 3.0, 0.7, 1.1 and 1.7 hours with the first, third, and fourth showing strong probability of true differences. The sum of ranks in the last column provides an index of the relative position of the subsystems based upon these four components only. The mean of the ranks was higher for Group B than A. It appears that factors operating differentially between the two generations of equipment had resulted in higher component maintenance times for Group B. Plausible suspects are task types, design characteristics, performing skill mix, and level of training.

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION	SUBJECT	INDEX: 30-5
III.7-42.1(O) III.7-42.1(R)	Mean Component Performance Times on Fire Control Radar Subsystems - Unscheduled Intermediate	CROSS-INDEX: I.3-2.1 I.11-4.3 through I.11-4.6 I.30-2.3



Average Time (Minutes)

	High	Low
Cal/Adj	73.25	115.56
Oprs Ck	50.50	83.45

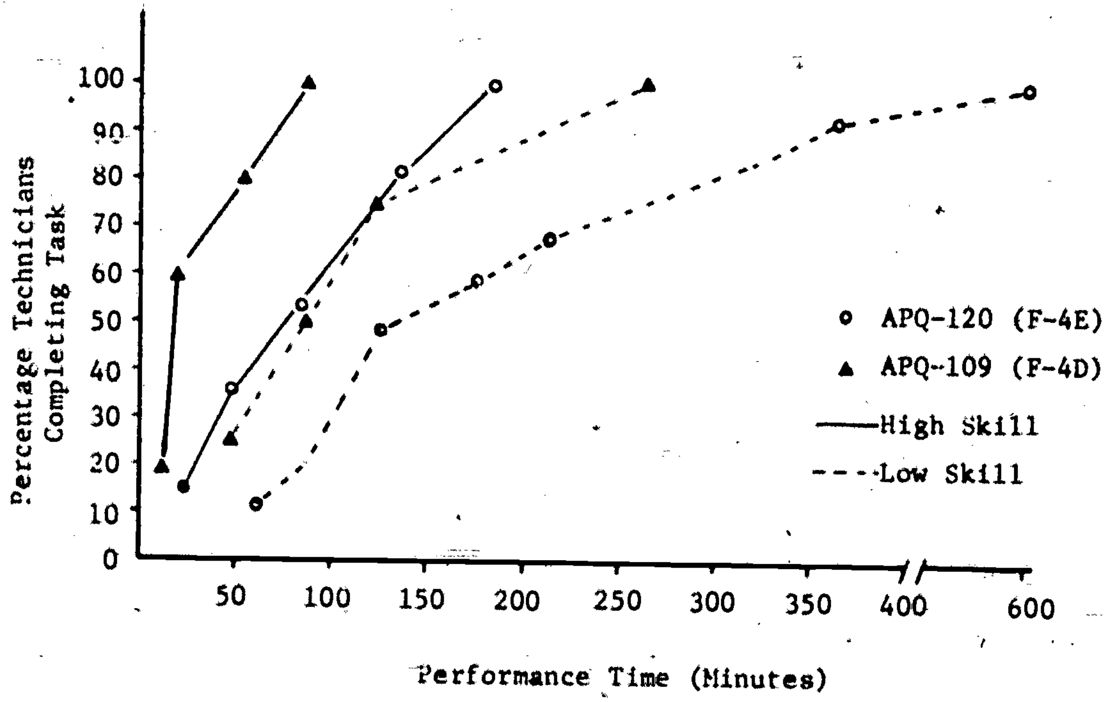
TITLE: A Comparison between Operations Check and Calibrate/Adjust Tasks in Organizational Maintenance of the APQ-120

COMMENTS: The percentage of technicians completing a check and calibrate/adjust task in time (x) is related to experience levels. Low performers tend to be associated with first term airmen; high performers with second term airmen.

IMPLICATIONS: Within a particular subsystem, time to perform a task not only depends on experience, but on the nature of the task. When operations check tasks are compared to calibrate/adjust tasks it is notable that experience has a greater effect on the latter. The implication is that maintenance training should emphasize the more difficult tasks or that a system should be designed such that these tasks can be accomplished with greater ease.

DATA SOURCES: 1. Lintz, L., ~~Loy, S.,~~ Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionics Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Mean Performance Times vs. Skill Levels and Task Type - APQ-120 Organizational	INDEX: 30-8 CROSS-INDEX:



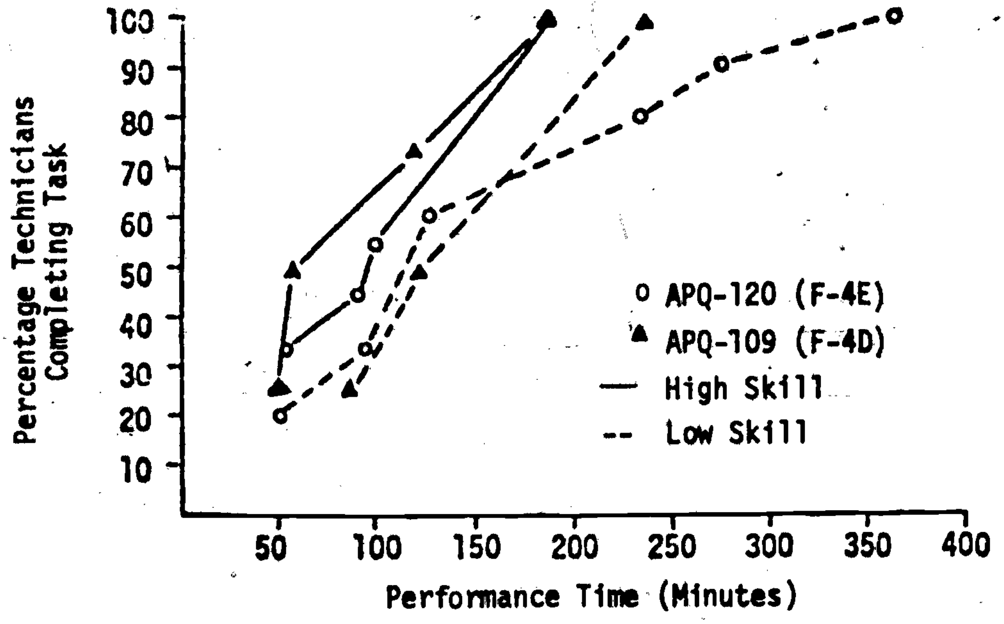
TITLE: Organizational - Functional Checkout of APQ-120 and APQ-109 Transmitter

COMMENTS: The percentage of technicians completing a checkout task in time (x) is related to experience levels. Low performance tends to be associated with first term airmen; high performance with second term airmen.[1] Variables affecting differences in checkout time between APQ-120 and APQ-109 include: (1) Number of checkout steps - APQ-120 = 531; APQ-109 = 430. (2) Test equipment - 2 for the APQ-120; none for the APQ-109. (3) Test points - APQ-120 = 39; APQ-109 = 74. (4) Complexity - APQ-120 has greater air-to-air and air-to-ground functional capability than APQ-109.

IMPLICATIONS: By increasing system capability, there is a resultant increase in checkout steps and time to perform.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionics Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Mean Performance Times vs. Skill Levels - Radar Transmitters, Organizational Maintenance	INDEX: 30-8 CROSS INDEX:



TITLE: Field - Functional Checkout of APQ-120 and APQ-109 Transmitter.

COMMENTS: The percentage of technicians completing a checkout task in time X is related to experience levels. Low skill performance tends to be associated with first-term and high skill performance with second term airmen. Relevant variables include: (1) Number of checkout steps - APQ-120 = 370; APQ-109 = 379. (2) Test equipment - APQ-120 = 4; APQ-109 = 2. (3) Test points: APQ-120 = 17; APQ-109 = 9. (4) Test equipment readings - 91% on the APQ-120 are quantitative; 53% for the APQ-109. (5) Complexity - Air-to-air and air-to-ground functional capabilities are greater for APQ-120 than APQ-109.

IMPLICATIONS: More complex diagnostics, requiring quantitative readings, results in greater performance time for both high and low skills (experience), but with greater impact on the latter.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionics Subsystems, AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Mean Performance Times vs. Skill Levels - Radar Transmitters of Maintenance	**INDEX:** 30-8 **CROSS-INDEX:**

Comparison of Mean Performance Times

Organizational Maintenance

Components	Adjust	Remove and Replace	Repair and/or Replace Minor Parts	Troubleshoot
Electrical Synchronizer	N.S. M-A-S	P=.036 S	P=.036 S	N.S. A-S
Indicator Scopes	P=.125	N.S. A-S	N.S. A-S	P=.018 S
Radar Antennas	N.S. M-A-S	N.S. M-S	N.S. M-S	N.S. M-A-S
Radar Transmitters	P=.071 S	N.S. S	N.S. S	N.S. M-S

Intermediate Maintenance

Components	Bench-Check	Repair Only
Radar Transmitters	P=.018	N.S. A-S

Legends:

N.S. = Not Significant
M = Missing Data (Excludes F-15)
A = Anomalies
S = Inadequate Sample Size

TITLE: Mean Performance Times by Task Type - Summary of Findings

COMMENTS: This chart provides a summary of the findings contained in Charts I.30-9.2 through I.30-9.19 on four equipment components and describes the limitations to be noted when interpreting the data. Findings which provided sufficient evidence to suspect that true differences existed are identified with a P value. The P value states the probability of chance occurrence. For example, troubleshooting indicator scopes show P=.018 which means that the probability of obtaining the differences reported in that specific chart (I.30-9.15) by chance alone is less than 2 in 100. The lower the probability of chance factors operating, therefore, the higher the probability of a true difference. Findings which yielded P values greater than .125 are reported as N.S. or not significant. The limitations on any interpretation based on these findings are predicated on (1) an understanding of the analytical tool used in the analysis, (2) the grouping of components (see Chart I.3-2.1 for rationale), and (3) the sampling method. The analytical tool was a relatively simple test (Mann-Whitney U), which is based on the idea that the particular pattern exhibited, when two sets of values are arranged together in increasing order of magnitude, provides information about their relationship. The criterion is based on the magnitudes of the values of one set in relation to the values in the other set. If most the values of one set are greater than most of the values of the other set, it is concluded that there is

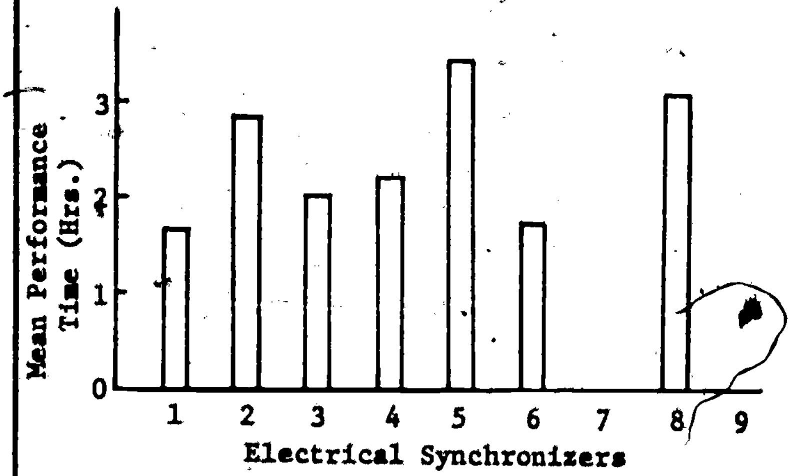
MODELS FOR DATA APPLICATION:	SUBJECT: Mean Performance Times by Task Type - Summary of Findings	INDEX: 30-9 CROSS-INDEX: I.3-2.1

no random mix and that the values are generally higher in one group than the other. The probability distribution for U provides the P values given in the summary chart. The two sets were derived by grouping F-106A/B, F-105D, F-4C, F-4D, F-4E together, and F-111A, FB-111A- A-7D, F-15 together. As explained in Chart I.3-2.1, this division was based on an identification of major design concepts that distinguished one group of equipment from the other, primarily to define technological advances over time on a gross basis and, secondarily, to serve as an initial capability for a preliminary analysis of post-hoc data without which very little could have been done. Therefore, these major design differences are not to be interpreted as the reasons to explain the findings. This would be a premature conclusion. The actual factors which caused the results, whether they be design, performing skill mix, training, etc., must be systematically investigated in future iterative refinement of handbook contents. Finally, the last limitation to be considered in any attempt to interpret the data is the sampling method. Sampling was limited to whatever field data were available. Thus, data are often missing or inadequate in sample size. These are identified M and S on the summary chart. The anomalies (A) are extreme high or low values within a group possibly due to inadequate sampling. Since the grouping method is indifferent to within group variations, one extreme point (as in Charts I.30-9.8 or I.30-9.11) can produce the effect of non-significant difference while a significant difference would have been obtained by excluding the extreme point. Alternative methods of analyzing data for differences would require adequate knowledge of the distribution of mean performance times for each subsystem by component and task type, which would permit paired as well as group comparisons.

IMPLICATIONS: The analyses of field data contained in Charts I.30-9.2 through I.30-9.19 revealed differences in performance times for specific components and tasks. Since these data were obtained from the Air Force data storage system, and since no information or inadequate information were obtained on performing skill mixes and amount of training, the specific influences producing the findings cannot be identified. Thus, it is possible that design, performing skill mix, and training may be contributing factors.

DATA SOURCE: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT: Mean Performance Times by Task Type Type - Summary of Findings	INDEX: 30-9 CROSS-INDEX: I.3-2.1 I.30-9.2 through I.30-9.19



*			Axes	
Gp.	Equipment	** Mo.-Yr.	X	Y
A	F-106A/B	7-59	1	1.7
A	F-105D	5-60	2	2.9
A	F-4C	5-63	3	2.0
A	F-4D	12-65	4	2.2
A	F-4E	10-67	5	3.4
B	F-111A	10-67	6	1.6
B	FB-111A	7-68	7	0
B	A-7D	12-68	8	3.2
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

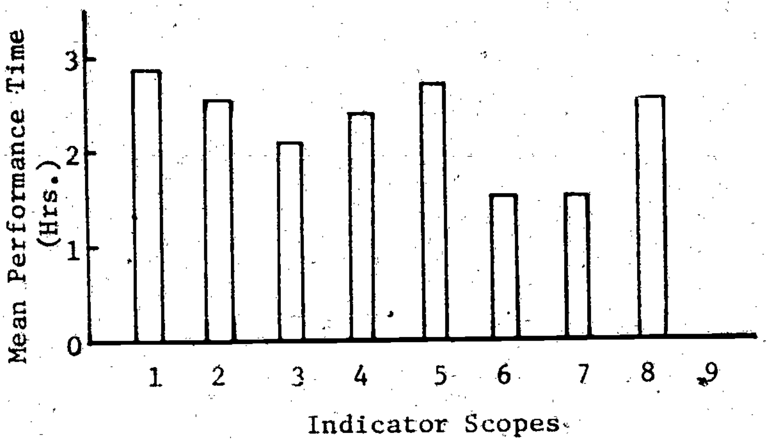
TITLE: Mean Performance Times to Adjust FCS Electrical Synchronizers - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 0 to 2326, and were identified by USAF Action Taken Code "L", discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting. This code excluded replacement of parts. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems, with the exception of FB-111A where no cases were recorded.

IMPLICATIONS: The information gained from the set of data revealed large variations within Groups A and B. In addition, the mean values failed to yield sufficient evidence that one group had consistently higher or lower performance times than the other group. Additional sampling, alternative groupings, or other methods of comparison should be pursued. Any inferences derived from these findings with respect to direct causal connections that would explain equality or inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1.USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by Task Type vs. FCS Electrical Synchronizers - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	2.8
A	F-105D	5-60	2	2.5
A	F-4C	5-63	3	2.1
A	F-4D	12-65	4	2.3
A	F-4E	10-67	5	2.7
B	F-111A	10-67	6	1.5
B	FB-111A	7-68	7	1.5
B	A-7D	12-68	8	2.6
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

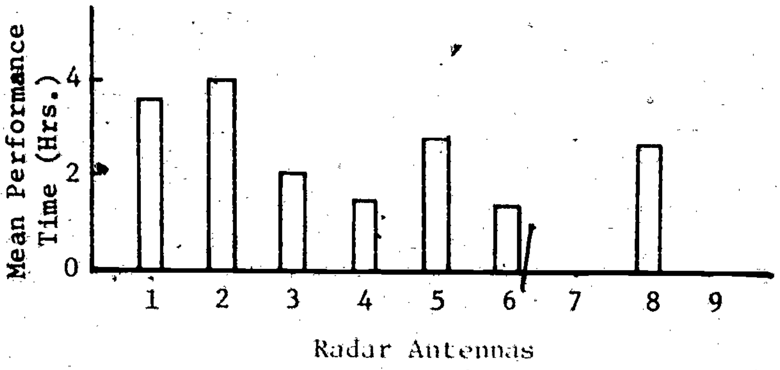
TITLE: Mean Performance Times to Adjust FCS Indicator Scopes - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 58 to 1211, and were identified by USAF Action Taken Code "L", discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting. This code excluded replacement of parts. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: ~~When~~ the mean values of both groups were combined and arranged from low to high, the resulting pattern exhibited some tendency for Group A values to be clustered together. As can be seen in the graph, Group B systems did not exhibit this type of clustering. The A-7D varied considerably from F-111A and FB-111A and showed greater similarity to the Group A systems. Based on these findings, it was tentatively concluded that insufficient evidence existed to suspect that the mean values of B were consistently lower than the mean values of A. Additional sampling would be desirable. Any inferences derived from these findings with respect to direct causal connections that would explain the apparent inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	SUBJECT: Mean Performance Times by Task Type vs. FCS Indicator Scopes - Unscheduled Organizational	INDEX: 30-9 CROSS-INDEX: I.3-2.1 I.30-9.1



Gp.*	Equipment	Mo.-Yr.**	Axes	
			X	Y
A	F-106A/B	7-59	1	3.6
A	F-105D	5-60	2	4.0
A	F-4C	5-63	3	2.0
A	F-4D	12-65	4	1.5
A	F-4E	10-67	5	2.7
B	F-111A	10-67	6	1.7
B	FB-111A	7-68	7	0
B	A-7D	12-68	8	2.3
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

TITLE: Mean Performance Times to Adjust FCS Radar Antennas - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 0 to 694, and were identified by USAF Action Taken Code "L", discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting. This code excluded replacement of parts. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems with the exception of FB-111A in which there were no cases recorded.

IMPLICATIONS: The information gained from this set of data revealed large variations within Group A. In addition, the pattern of variations exhibited by each group failed to yield sufficient evidence that one group had consistently higher or lower mean performance times than the other group. Additional sampling, alternative groupings, or other methods of comparison should be pursued. Any inferences derived from these findings with respect to direct causal connections that would explain equality or inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

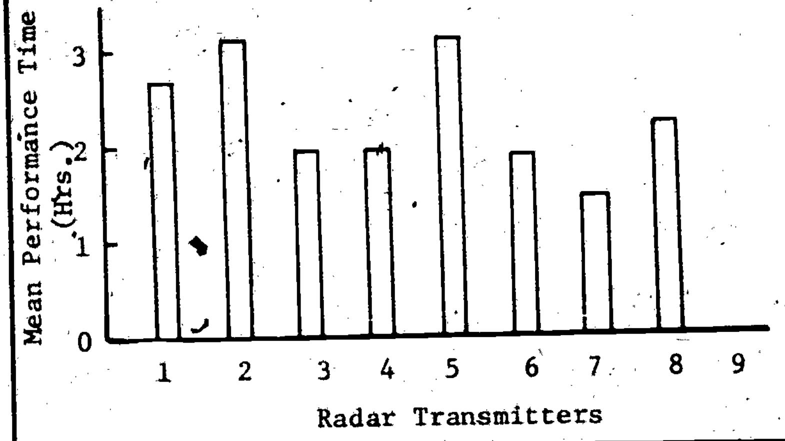
DATA SOURCE: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.4-72.1(Q)
III.4-72.1(R)

SUBJECT: Mean Performance Times by Task Type vs. FCS Antennas - Unscheduled Organizational

INDEX: 30-9

CROSS-INDEX: I.3-2.1
I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	2.7
A	F-105D	5-60	2	3.1
A	F-4C	5-63	3	1.9
A	F-4D	12-65	4	1.9
A	F-4E	10-67	5	3.1
B	F-111A	10-67	6	1.8
B	FB-111A	7-68	7	1.4
B	A-7D	12-68	8	2.2
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

TITLE: Mean Performance Time to Adjust FCS Radar Transmitters - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 5 to 2018, and were identified by USAF Action Taken Code "L", discrepancy cleared by adjusting, tightening, bleeding, balancing, rigging, or fitting. This code excluded replacement of parts. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: When the mean values of both groups were combined and arranged from low to high, the resulting pattern showed a clustering of Group A and B values at opposite ends of the distribution. The only break in this pattern was due to A-7D which failed to yield a consistent difference when paired with each value in Group A. Nevertheless, even considering this one anomaly, the probability of obtaining this kind of outcome by chance alone is 7 in 100. Based on these findings, there is a reasonable probability of a true difference in mean times between the two groups of transmitters. Additional sampling is desirable. Any inferences derived from these findings with respect to direct causal connections that would explain the possible inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

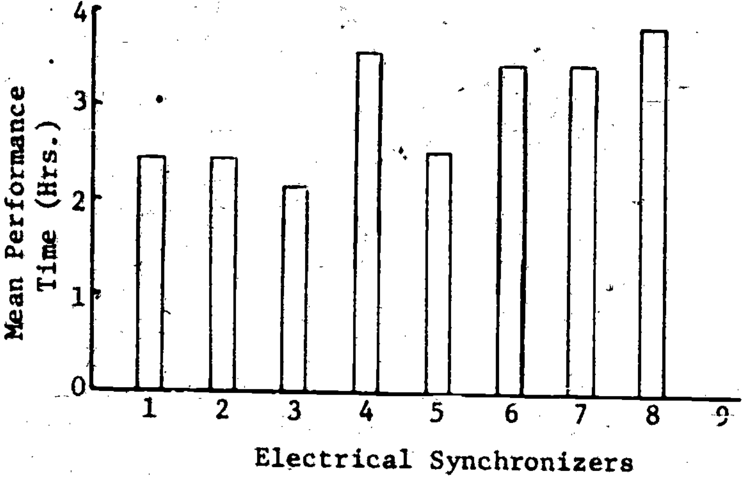
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(Q)
III.7-42.1(R)

SUBJECT:
Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Organizational

INDEX: 30-9

CROSS-INDEX: I.3-2.1
I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	2.4
A	F-105D	5-60	2	2.4
A	F-4C	5-63	3	2.1
A	F-4D	12-65	4	3.4
A	F-4E	10-67	5	2.5
B	F-111A	10-67	6	3.4
B	FB-111A	7-68	7	3.4
B	A-7D	12-68	8	3.8
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

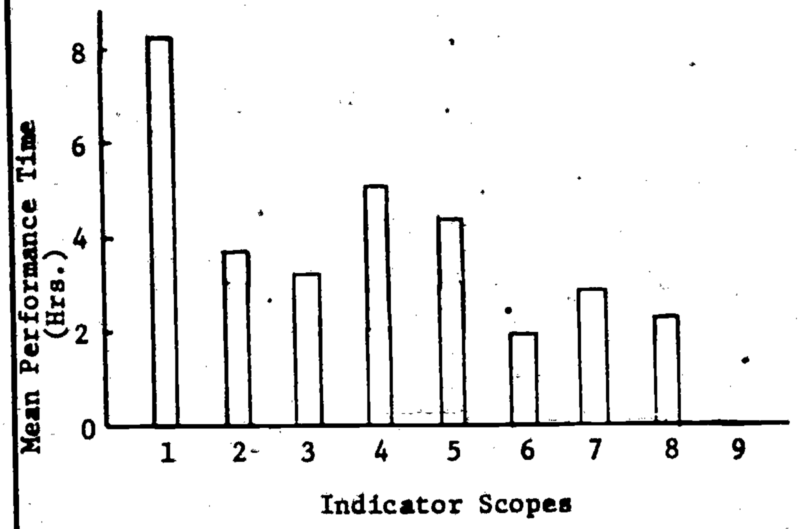
TITLE: Mean Performance Times to Remove and Replace FCS Electrical Synchronizers - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 52 to 397, and were identifed by USAF Action Code Taken "R", item is removed and another like item is installed. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data showed high probability of differences between Groups A and B, i.e., there was a definite tendency for most of the mean values of B to be greater than most of the mean values of A. An equivalent statement is that the mean performance time was generally higher for Group B electrical synchronizers than Group A. Any inferences placed upon these findings with respect to direct causal connections that would explain the apparent inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by Task Type vs. FCS Electrical Synchronizers - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	8.3
A	F-105D	5-60	2	3.7
A	F-4C	5-63	3	3.3
A	F-4D	12-65	4	4.9
A	F-4E	10-67	5	4.4
B	F-111A	10-67	6	1.9
B	FB-111A	7-68	7	2.7
B	A-7D	12-68	8	2.3
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

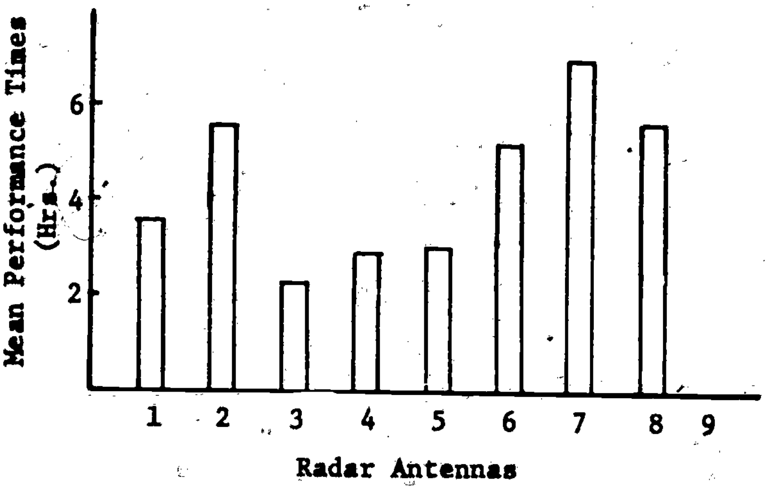
TITLE: Mean Performance Times to Remove and Replace FCS Indicator Scopes - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance1. The number of cases recorded in the summaries ranged from 16 to 188, and were identified by USAF Action Code Taken "R", item is removed and another like item is installed. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: When the mean values of both groups were combined and arranged from low to high, the resulting pattern yielded a clear-cut clustering of Group B means at the low end and Group A means at the high end. On the basis of these findings, the probability of obtaining this kind of an outcome by chance alone is so low that a true difference is suspected. With additional sampling from the same population, it appears highly likely that substantially the same results would be obtained (i.e., the mean time will generally be lower for Group B indicator scopes than Group A). Any inferences derived from these findings with respect to direct causal connections that would explain the inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	**SUBJECT:** Mean Performance Times by Task Type vs. FCS Indicator Scopes - Unscheduled Organizational	**INDEX:** 30-9 **CROSS-INDEX:** I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	3.6
A	F-105D	5-60	2	5.6
A	F-4C	5-63	3	2.3
A	F-4D	12-65	4	2.8
A	F-4E	10-67	5	3.0
B	F-111A	10-67	6	5.3
B	FB-111A	7-68	7	6.9
B	A-7D	12-68	8	5.2
B	F-15		9	

* See Chart I.3-2.1.
** Date Entered AF Inventory

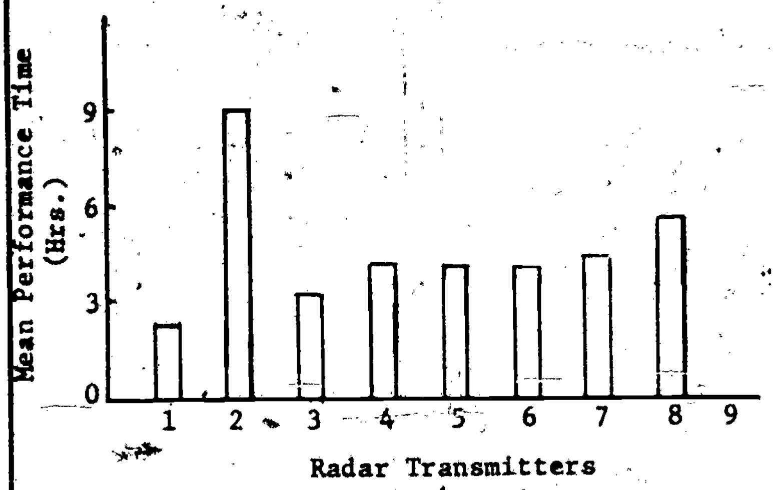
TITLE: Mean Performance Times to Remove and Replace FCS Radar Antennas - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 15 to 560, and were identified by USAF Action Taken Code "R", item is removed and another like item is installed. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: When the mean values of both groups were combined and arranged from low to high, the results showed a pattern of Group B values clustered together. The only exception was F-105D which, as can be seen in the graph, did not show a consistent relationship when compared with each of the values in Group B. Despite this one sample of extreme variation, the analysis yielded strong evidence that a true difference existed, and that the mean time to remove-and-replace radar antennas was generally higher for B than A. Any inferences derived from these findings with respect to direct causal connections that would explain the inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by Task Type vs. FCS Antennas - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	2.2
A	F-105D	5-60	2	9.0
A	F-4C	5-63	3	3.0
A	F-4D	12-65	4	3.8
A	F-4E	10-67	5	4.3
B	F-111A	10-67	6	4.2
B	FB-111A	7-68	7	4.4
B	A-7D	12-68	8	5.2
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Mean Performance Times to Remove and Replace FCS Radar Transmitters - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 29 to 422, and were identified by USAF Action Taken Code "R", item is removed and another like item is installed. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data showed low variation within Group B and high variation within Group A attributed primarily to F-105D. Excluding this one anomaly, and pairing each value in Group B with each value in Group A, the pattern exhibited by this comparison showed strong evidence of clustering which implies a general tendency for most of the mean values of B to be greater than most of the mean values of A. With F-105D included, however, no clear-cut group difference was revealed. Additional sampling, alternative groupings, or other methods of comparisons should be pursued. Any inferences derived from these findings with respect to direct causal connections that would explain equality or inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

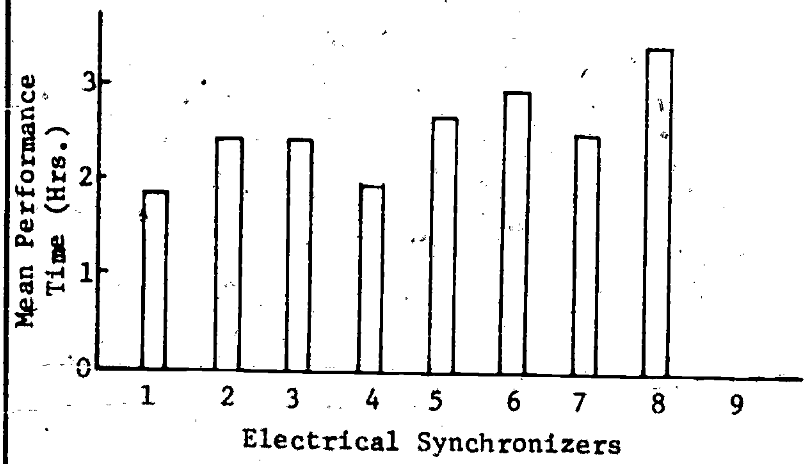
MODELS FOR
DATA APPLICATION:

III.7-42.1(Q)
III.7-42.1(R)

SUBJECT:
Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Organizational

INDEX: 30-9

CROSS-INDEX: I.3-2.1
I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	 Y
A	F-106A/B	7-59	1	1.8
A	F-105D	5-60	2	2.4
A	F-4C	5-63	3	2.4
A	F-4D	12-65	4	1.9
A	F-4E	10-67	5	2.7
B	F-111A	10-67	6	2.9
B	FB-111A	7-68	7	2.5
B	A-7D	12-68	8	3.4
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

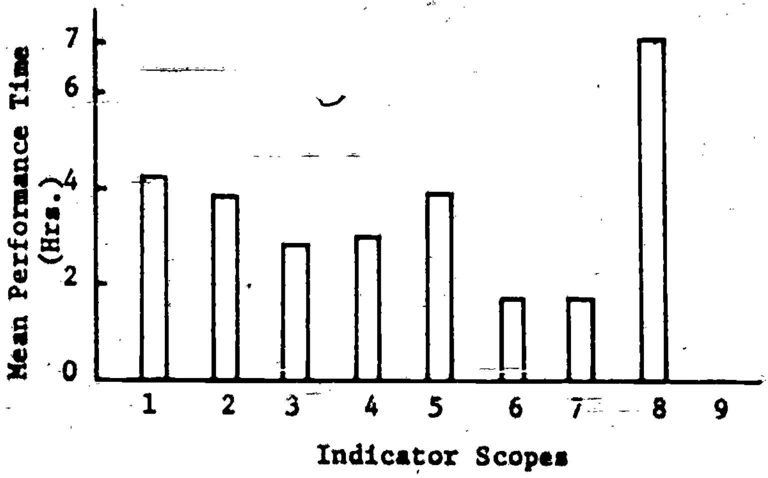
TITLE: Mean Performance Times for Repair and/or Replacement of Minor Parts on FCS Electrical Synchronizers - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 5 to 509, and were identified by USAF Action Taken Code "G", repair and/or replacement of minor parts, hardware, and soft goods such as seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners, and brackets. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data showed high probability of differences between Groups A and B (i.e., there was a definite tendency for most of the mean values of B to be greater than most of the mean values of A). An equivalent statement is that the mean performance time was generally higher for Group B electrical synchronizers than Group A. Any inferences placed upon these findings with respect to direct causal connections that would explain the differences in performance times must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	SUBJECT: Mean Performance Times by Task Type vs. FCS Electrical Synchronizers - Unscheduled Organizational	INDEX: 30-9 CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	4.1
A	F-105D	5-60	2	3.8
A	F-4C	5-63	3	2.7
A	F-4D	12-65	4	2.9
A	F-4E	10-67	5	3.8
B	F-111A	10-67	6	1.7
B	FB-111A	7-68	7	1.7
B	A-7D	12-68	8	7.1
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Mean Performance Times for Repair and/or Replacement of Minor Parts on FCS Indicator Scopes - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 26 to 324, and were identified by USAF Action Taken Code "G", repair and/or replacement of minor parts, hardware, and soft goods such as seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners, and brackets. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: When the mean values of both groups were combined and arranged from low to high, the resulting pattern yielded a clustering of Group A means at the high end of the distribution and Group B at the low end. The only exception, as can be seen in the graph, was A-7D which differed quite significantly from the other means of Group B. Excluding this one sample, the remaining data showed a consistent relationship (i.e., all the Group B means were lower than all the Group A means). However, because of the one extreme variation, additional sampling, alternative groupings, or other methods of comparisons should be pursued. Any inferences derived from these findings with respect to direct causal connections that would explain equality or inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

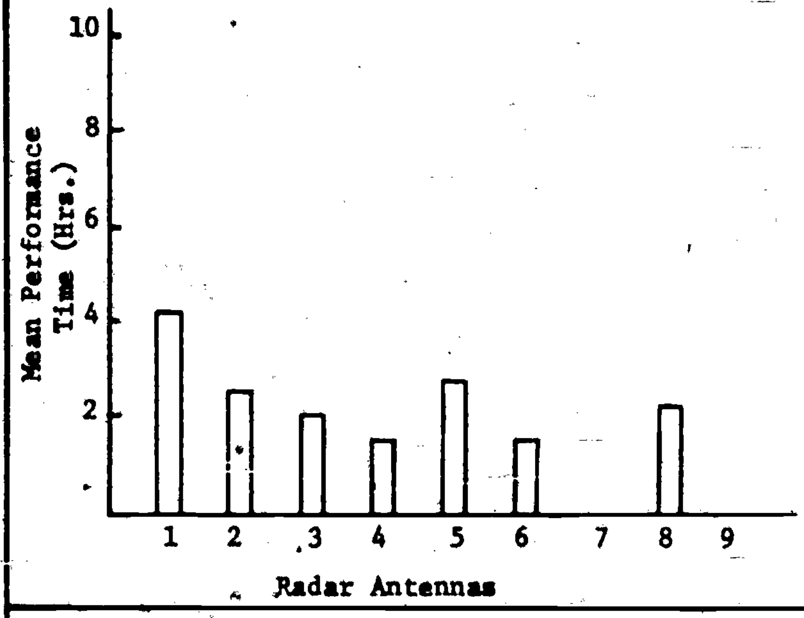
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(Q)
III.7-42.1(R)

SUBJECT:
Mean Performance Times by Task Type vs. FCS Indicator Scopes - Unscheduled Organizational

INDEX: 30-9

CROSS-INDEX: I.3-2.1
I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	4.2
A	F-105D	5-60	2	2.5
A	F-4C	5-63	3	2.0
A	F-4D	12-65	4	1.5
A	F-4E	10-67	5	2.8
B	F-111A	10-67	6	1.5
B	FB-111A	7-68	7	
B	A-7D	12-68	8	2.2
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

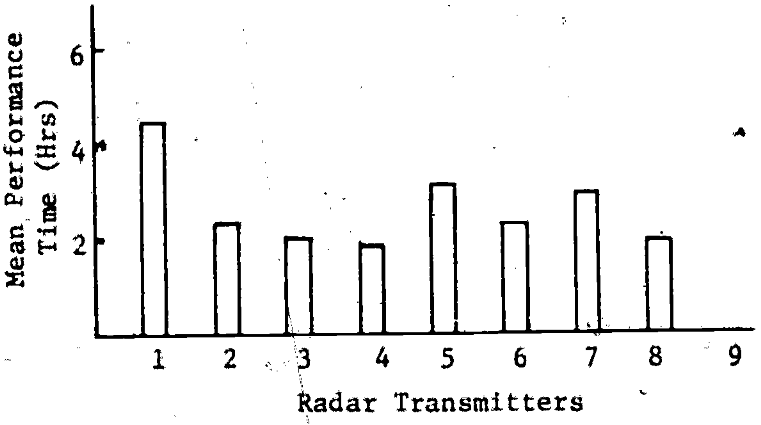
TITLE: Mean Performance Times for Repair and/or Replacement of Minor Parts on FCS Radar Antennas - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance1. The number of cases recorded in the summaries ranged from 1 to 898, and were identified by USAF Action Taken Code "G", repair and/or replacement of minor parts, hardware, and soft goods such as seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners, and brackets. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems with the exception of FB-111A in which only one case was recorded for that aircraft; therefore, it was excluded.

IMPLICATIONS: Information gained from this set of data revealed little difference between Groups A and B (i.e., one group cannot be considered consistently higher or lower than the other group with respect to performance time). However, with tied values across groups, F-4D vs. F-111A, and FB-111A data missing, the meaningfulness of the comparison is severely diluted. Additional sampling, while always desirable, becomes absolutely necessary in this instance. Any inferences derived from these findings with respect to direct causal connections that would explain equality or inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	**SUBJECT:** Mean Performance Times by Task Type vs. FCS Antennas - Unscheduled Organizational 160	**INDEX:** 30-9 **CROSS-INDEX:** I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	4.4
A	F-105D	5-60	2	2.3
A	F-4C	5-63	3	2.0
A	F-4D	12-65	4	1.9
A	F-4E	10-67	5	3.2
B	F-111A	10-67	6	2.1
B	FB-111A	7-68	7	2.9
B	A-7D	12-68	8	1.9
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

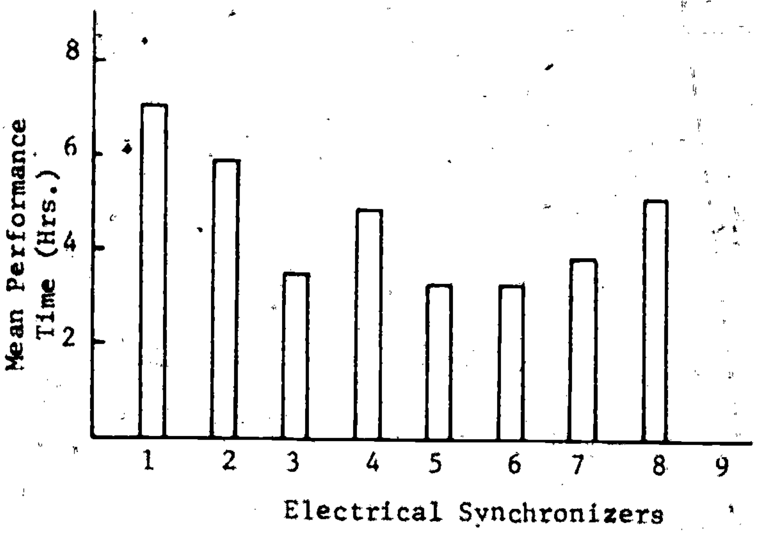
TITLE: Mean Performance Times for Repair and/or Replacement of Minor Parts on FCS Radar Transmitters - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 6 to 1747, and were identified by USAF Action Taken Code "G", repair and/or replacement of minor parts, hardware, and soft goods such as seals, gaskets, electrical connections, fittings, tubing, wiring, fasteners, and brackets. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data revealed little difference in mean values between groups as well as within groups. The only exception was F-106A/B. Based on these findings, it appeared that the mean time for repair and/or replacement of minor parts was about the same for 7 of the 9 radar transmitters. Any inferences placed upon these findings with respect to direct causal connections that would explain the apparent equality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1)

DATA SOURCES: USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	SUBJECT: Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Organizational	INDEX: 30-9 CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	7.0
A	F-105D	5-60	2	5.8
A	F-4C	5-63	3	3.5
A	F-4D	12-65	4	4.8
A	F-4E	10-67	5	3.3
B	F-111A	10-67	6	3.3
B	FB-111A	7-68	7	3.8
B	A-7D	12-68	8	5.1
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

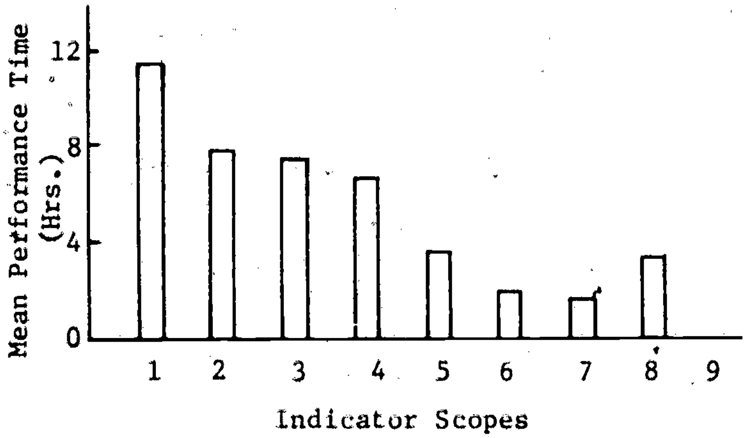
TITLE: Mean Performance Times to Troubleshoot FCS Electrical Synchronizers - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of troubleshooting cases recorded in the summaries were low and ranged from 3 to 91 and were identified by USAF Action Taken Code "Y", on-equipment time to isolate the primary cause of a discrepancy. This code excluded repair time. Although the sample size was less than 50 for five of the eight subsystems, the data, nevertheless, were analyzed for trends or variations in performance across successive designs.

IMPLICATIONS: The information gained from this set of data revealed large variations within Group A. Primarily because of this pattern of variation, pairing off each Group B value with each Group A value to compare relative position of means failed to yield sufficient evidence that one group had consistently higher or lower mean performance times than the other group. Any inferences derived from these findings with respect to direct causal connections that would explain the inequality or equality of means within or between Groups A and B must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1)

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION: III.7-42.1(Q) III.7-42.1(R)	SUBJECT: Mean Performance Times by Task Type vs. FCS Electrical Synchronizers - Unscheduled Organizational	INDEX: 30-9 CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	Axes Y
A	F-106A/B	7-59	1	11.4
A	F-105D	5-60	2	7.9
A	F-4C	5-63	3	7.4
A	F-4D	12-65	4	6.8
A	F-4E	10-67	5	3.7
B	F-111A	10-67	6	1.9
B	FB-111A	7-68	7	1.5
B	A-7D	12-68	8	3.1
B	F-15		9	

* See Chart I.3-2.1
** Data Entered AF Inventory

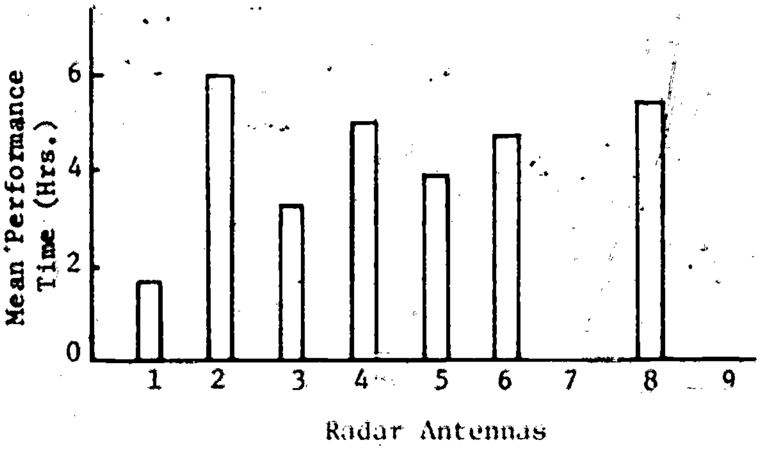
TITLE: Mean Performance Times to Troubleshoot FCS Indicator Scopes - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 2 to 72, and were identified by USAF Action Taken Code "Y", on-equipment time to isolate the primary cause of a discrepancy. This code excluded repair time. The sample size was small with six of the eight subsystems having less than 50 cases. The data, nevertheless, were analyzed for trends or variations in performance across successive designs.

IMPLICATIONS: Information derived from this set of data showed a high probability of differences between the two groups (i.e., all of the mean values of Group B were less than all of the mean values of Group A). Based on these findings, the probability of obtaining this kind of outcome due to chance alone is sufficiently low to suspect a true difference between the two groups. It is expected that the mean time to troubleshoot indicator scopes will generally prove to be lower for Group B than A. Any inferences derived from these findings with respect to direct causal connections that would account for the inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1.) USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by TAsk Type vs. FCS Indicator Scopes - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	1.6
A	F-105D	5-60	2	6.0
A	F-4C	5-63	3	3.0
A	F-4D	12-65	4	5.0
A	F-4E	10-67	5	3.8
B	F-111A	10-67	6	4.3
B	FB-111A	7-68	7	0
B	A-7D	12-68	8	5.4
B	F-15		9	

* See Chart I.3-2.1

** Data Entered AF Inventory

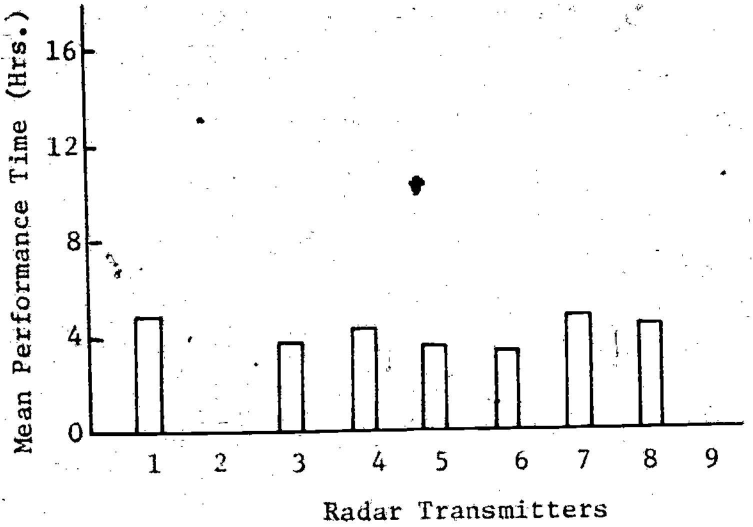
TITLE: Mean Performance Times to Troubleshoot FCS Radar Antennas - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. Since the number of troubleshooting cases recorded in the summaries were small, the entire sample was analyzed for trends or variations in performance across successive radar subsystems. There were no cases recorded for FB-111A; therefore, it could not be included in the analysis. The number of cases ranged from 0 to 60, and were identified by USAF Action TAken Code "Y", on-equipment time to isolate the primary cause of a discrepancy. This code excluded repair time.

IMPLICATIONS: The information gained from this set of data revealed large variations within Group A. Primarily because of this pattern of variation, pairing off each Group B value with each Group A value to compare relative position of means failed to yield sufficient evidence that one group had consistently higher or lower mean performance times than the other group. Any inferences derived from these findings with respect to direct causal connections that would explain the inequality or equality of means within or between Groups A and B must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.4-72.1(Q) III.4-72.1(R)	Mean Performance Times by Task Type vs. FCS Antennas - Unscheduled Organizational	CROSS-INDEX: I.3-2.1 I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes X	 Y
A	F-106A/B	7-59	1	4.9
A	F-105D	5-60	2	
A	F-4C	5-63	3	3.8
A	F-4D	12-65	4	4.2
A	F-4E	10-67	5	3.5
B	F-111A	10-67	6	3.3
B	FB-111A	7-68	7	4.7
B	A-7D	12-68	8	4.3
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

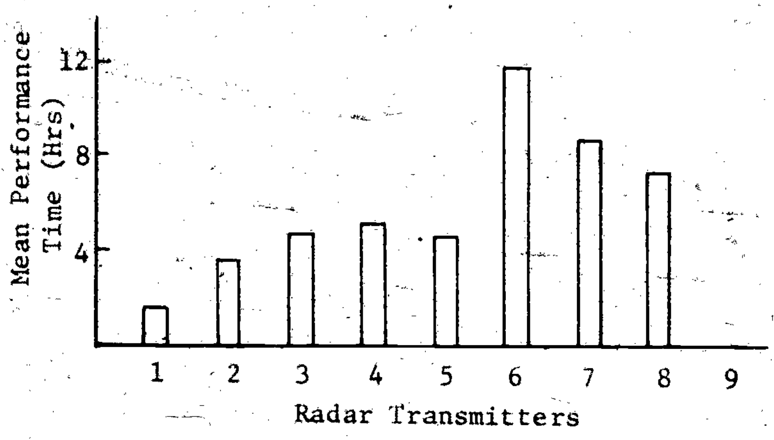
TITLE: Mean Performance Times to Troubleshoot FCS Radar Transmitters - Unscheduled Organizational

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 1 to 113, and were identified by USAF Action Taken Code "Y", on-equipment time to isolate the primary cause of a discrepancy. This code excluded repair time. With the exception of F-105D, where only one case was recorded, the entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data showed a high degree of similarity of means between Groups A and B as well as within each group. There are no consistent patterns of high or low values distinguishing one group from the other. An equivalent statement is that the mean time for each group will generally prove to be about the same. Any inferences placed upon these findings with respect to direct causal connections that would explain the apparent equality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Organizational	CROSS-INDEX: I.30-9.1 I.3-2.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	1.7
A	F-105D	5-60	2	3.7
A	F-4C	5-63	3	4.8
A	F-4D	12-65	4	5.2
A	F-4E	10-67	5	4.6
B	F-111A	10-67	6	11.9
B	FB-111A	7-68	7	8.8
B	A-7D	12-68	8	7.2
B	F-15		9	

* See Chart I.3-2.1

** Date Entered AF Inventory

TITLE: Mean Performance Times to Bench-Check FCS Radar Transmitters - Unscheduled Intermediate

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 40 to 1047, and were identified by USAF Action Taken Code "C", bench check accomplished and repair action deferred. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: Information gained from this set of data showed dissimilarity between the Groups A and B. All of the mean values of Group B were greater than all of the mean values of Group A. Based on these findings, there is significant evidence to suspect that a true difference existed between the two groups and that the mean time to bench-check transmitters was generally higher for B than A. Any inferences derived from these findings with respect to direct causal connections that would explain the difference in means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

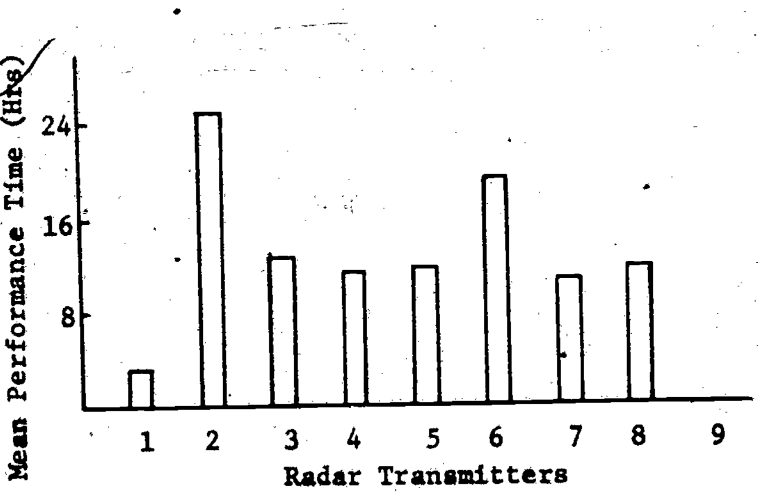
DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:
III.7-42.1(Q)
III.7-42.1(R)

SUBJECT:
Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Intermediate

INDEX: 30-9

CROSS-INDEX: I.3-2.1
I.30-9.1



* Gp.	Equipment	** Mo.-Yr.	Axes	
			X	Y
A	F-106A/B	7-59	1	3.4
A	F-105D	5-60	2	24.9
A	F-4C	5-63	3	12.2
A	F-4D	12-65	4	11.3
A	F-4E	10-67	5	11.8
B	F-111A	10-67	6	21.3
B	FB-111A	7-68	7	10.3
B	A-7D	12-68	8	11.4
B	F-15		9	

* See Chart I.3-2.1
** Date Entered AF Inventory

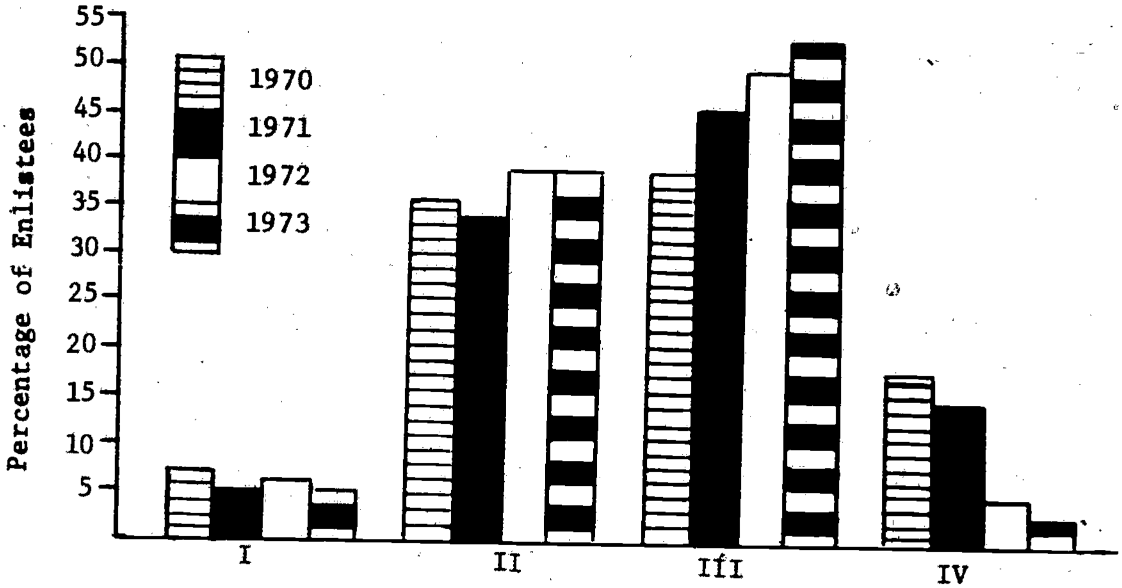
TITLE: Mean Performance Times to Repair FCS Radar Transmitters - Unscheduled Intermediate

COMMENTS: The data were extracted from the USAF summary records of unscheduled maintenance[1]. The number of cases recorded in the summaries ranged from 28 to 927, and were identified by USAF Action Taken Code "F", units of total repair performed in a shop environment which include cleaning, disassembly, inspection, adjustment, reassembly, and lubrication of minor components. The entire sample was used in analyzing for trends or variations in performance across successive radar subsystems.

IMPLICATIONS: The information gained from this set of data revealed large variations within Group A as well as Group B. In addition, the magnitude of the variations is comparable between the groups. In other words, high and low mean values are randomly mixed, but these data do not provide evidence that one group is consistently higher or lower than the other group. Additional sampling, alternative groupings, or other methods of comparisons should be pursued. Any inferences derived from those findings with respect to direct causal connections that would explain the apparent equality and inequality of means must consider the limitations under which this analysis of past data was made (see Chart I.30-9.1).

DATA SOURCES: 1. USAF Worldwide Unscheduled Maintenance Summaries 1971.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 30-9
III.7-42.1(Q) III.7-42.1(R)	Mean Performance Times by Task Type vs. FCS Radar Transmitters - Unscheduled Intermediate	CROSS-INDEX: I.30-9.1 I.3-2.1



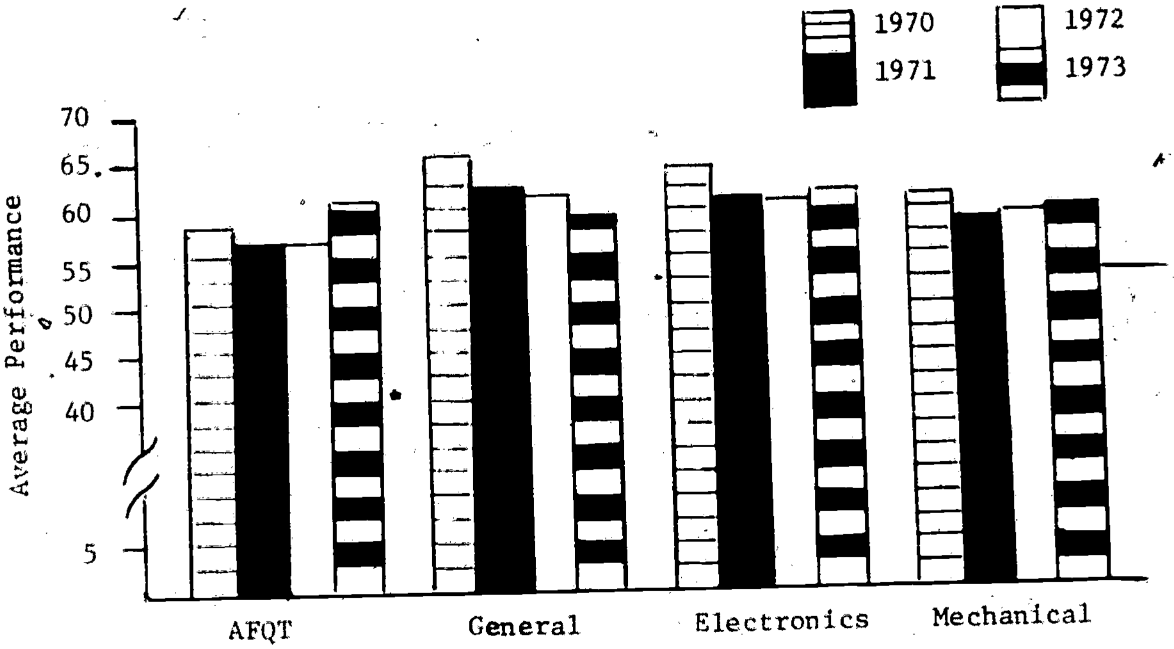
TITLE: Percentage Distribution of AFQT Mental Ability Categories for 1970 through 1973 Air Force Enlisted Personnel

COMMENTS: The data are based on male, non-prior service basic trainees who enlisted in the Air Force in 1970, 1971, 1972, and 1973. The Armed Forces Qualification Test (AFQT) yields centile scores which are translated into mental ability levels designated as Category I (93-99), Category II (65-92), Category III (31-64), and Category IV (10-30).

IMPLICATIONS: The characteristics of enlistees prior to the termination of the draft, which occurred in January 1973, are compared with enlistees under the all-volunteer force. It had been feared that the termination of the draft would result in a significant reduction of high aptitude personnel. This anticipated reduction did not occur. As shown in the above chart, Category I personnel decreased by only 1 percent between 1972 and 1973 and there was a significant reduction of Category IV personnel between 1970 and 1973 (15 percent).

DATA SOURCES: 1. Vitola, B.M., Mullins, C.J., and Brokaw, L.D. Quality of the All-volunteer Air Force - 1973. AFHRL-TR-74-35, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas, April 1974.

MODELS FOR DATA APPLICATION:	SUBJECT: Enlistee AFQT Scores vs. Year of Enlistment	INDEX: 1.8 CROSS-INDEX:



TITLE: Average AFQT Scores and AQE Aptitude Indexes for 1970 through 1973 Air Force Enlistees

COMMENTS: The data are based on male, non-prior service basic trainees who enlisted in the Air Force in 1970, 1971, 1972, and 1973. The AFQT centiles (see Chart II.1-8.1) and the Airman Qualifying Examination (AQE) indexes are compared. The AQE yeilds four aptitude composites: Mechanical, Administrative, General, and Electronics. The Administrative composite is not shown.

IMPLICATIONS: The characteristics of enlistees prior to the termination of the draft, which occurred in January 1973, are compared with enlistees under the all-volunteer force. An anticipated drop in mental ability (AFQT scores) due to the termination of the draft did not occur. Also, the Air Force has been unable to recuperate the drop in aptitude that occurred in 1971, but there was no additional drop due to the all-volunteer enlistees. Charts II.1-8.3 and II.1-8.4 show that there was a compression of scores at the very top of the aptitude scale starting in 1971, not after the termination of the draft.

DATA SOURCES: 1. Vitola, B.M., Mullins, C.J., and Brokaw, L.D. Quality of the All-volunteer Air Force - 1973. AFHRL-TR-74-35, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas, April 1974.

MODELS FOR DATA APPLICATION:	SUBJECT: Enlistee AFQT and AQE Scores vs. Year of Enlistment 169	INDEX: 1.8 CROSS-INDEX: II.1-8.1 II.1-8.3 II.1-8.4

AQE Aptitude Index	Percentage in Score Range on AQE Aptitude Composites			
	1970	1971	1972	1973
	General Composite			
80 and above	30	26	23	19
60 and above	74	61	58	51
40 and above	90	91	92	91
	Electronics Composite			
80 and above	33	30	30	27
60 and above	58	55	54	55
40 and above	86	84	85	90

TITLE: Cumulative Percentages of AQE General and Electronics Aptitude Indexes for 1970 through 1973 Air Force Enlistees

COMMENTS: The data are based on male, non-prior service basic trainees who enlisted in the Air Force in 1970, 1971, 1972, and 1973. The chart shows the score ranges on the AQE aptitude composite (see Chart II.1-8.2) for General and Electronics. Many of the critical Air Force specialties are selected from these two aptitude areas.

IMPLICATIONS: The AQE aptitude ranges of enlistees prior to the termination of the draft, which occurred in January 1973, are compared with enlistees under the all-volunteer force. The Air Force has been unable to recuperate from a drop in high aptitudes which occurred in 1971. This drop was not due to the all-volunteer force enlistees.

DATA SOURCES: 1. Vitola, B.M., Mullins, C.J., and Brokaw, L.D. Quality of the All-volunteer Air Force - 1973. AFHRL-TR-74-35, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas, April 1974.

MODELS FOR DATA APPLICATION:	SUBJECT.	INDEX: 1-8
	Enlistee Range of AQE Scores vs. Year of Enlistment	CROSS-INDEX: II.1-8.2
	170	

Index Centile	Percent Scoring at Each Aptitude Index 1970 %	 1971 %	 1972 %	 1973 %
	General Index			
95	8	5	4	5
90	6	4	4	3
85	8	8	7	4
80	8	9	8	7
Total	30	26	23	19
	Electronics Index			
95	12	9	8	5
90	6	5	6	6
85	7	6	6	7
80	8	10	10	9
Total	33	30	30	27

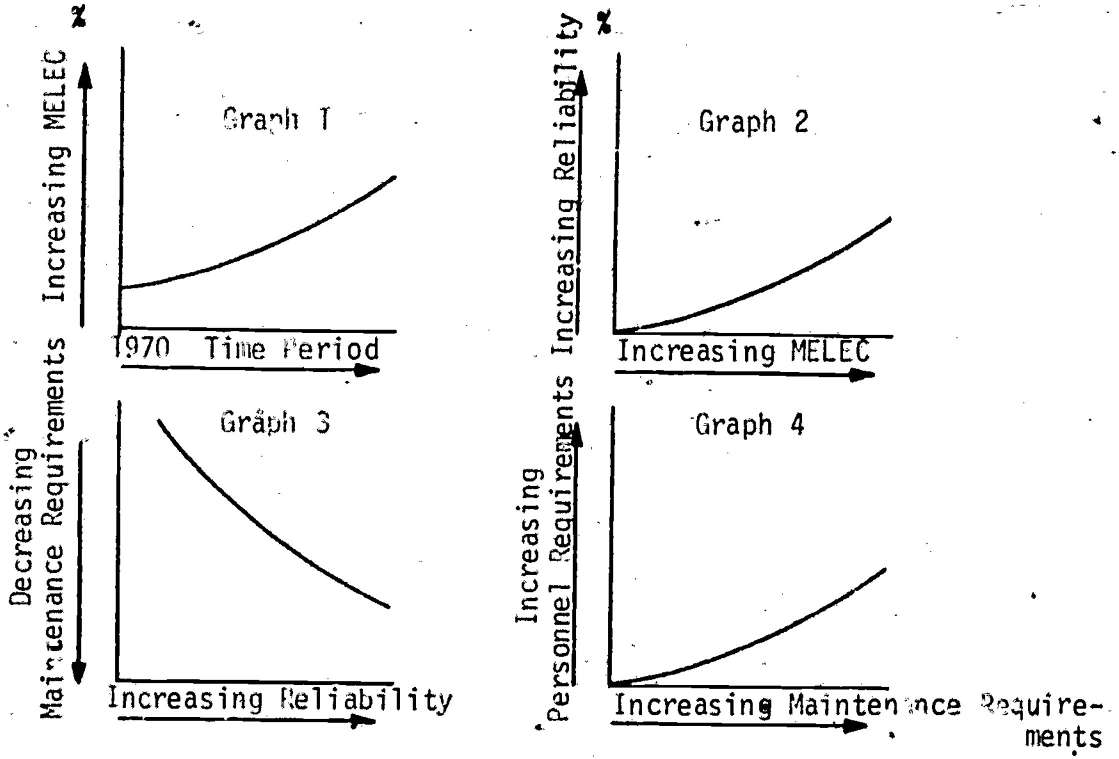
TITLE: Percentage of 1970 through 1973 Enlistees with Very High AQE-General and AQE-Electronics Scores

COMMENTS: The data are based on male, non-prior service basic trainees who enlisted in the Air Force in 1970, 1971, 1972, and 1973. This chart shows the composites for General and Electronics. Many of the critical Air Force specialties are selected from these two aptitude areas.

IMPLICATIONS: The very high aptitude scores of enlistees prior to the termination of the draft, which occurred in January 1973, are compared with enlistees under the all-volunteer force. The percentages of enlistees in the 80 and above group declined, with the loss being primarily in the upper ranges of this group. While the Air Force has been unable to recruit top aptitude personnel as readily as it did in 1970, it is clear that the drop in aptitude level was not due to the introduction of an all-volunteer force.

DATA SOURCES: 1. Vitola, B.M., Mullins, C.J., and Brokaw, L.D. Quality of the All-volunteer Air Force - 1973. AFHRL-TR-74-35. Air Force Human Resources Laboratory, Lackland Air Force Base, Texas, April 1974.

MODELS FOR DATA APPLICATION:	SUBJECT: High Scores on AQE vs. Year of Enlistment	INDEX: 1-8 CROSS-INDEX: II.1-8.2



TITLE: Effects of Microelectronics (MELEC) on Hardware Reliability, Maintenance Requirements and Numbers of Maintenance Personnel Required.

COMMENTS: Studies[1] conducted in 1970 predicted the impact of future avionics system on reliability, maintenance, and personnel requirements. Graphs 1 and 2 describe the predicted trends. Graph 1 shows that the use of microelectronics will increase with time. Graph 2 shows that equipment reliability can be explained as a function of microelectronics, i.e., as MELEC increases, equipment reliability increases. Graph 3 shows that maintenance requirements can be explained as a function of reliability, i.e., as reliability increases, maintenance decreases. Graph 4 shows that personnel requirements can be explained as a function of maintenance requirements, i.e., as maintenance requirements decrease, personnel requirements will also decrease.

IMPLICATIONS: Decreasing personnel requirements may eventually reduce training requirements, however, no significant reduction in training is expected within the next decade because of continued use of conventional systems. Reduction of personnel requirements may also depend on the maintenance philosophy chosen (black-box throw away vs. repair).

DATA SOURCES: 1. Air Training Command, Ad Hoc Committee, The Impact of Microelectronics and Integrated Systems on Technical Training, April 1970.

MODELS FOR DATA APPLICATION:	SUBJECT: Hardware Design Variable vs. Future Human Resources Quantities	INDEX: 2-3 CROSS-INDEX:

CAREER FIELD SUBDIVISION	As of 30 June 1965		As of 30 June 1968		As of 30 June 1970		As of 30 June 1971	
	Actual Nos.	% of Total in Subdivision	Actual Nos.	% of Total in Subdivision	Required Nos.	% of Total Subdivision Requirements	Actual Nos.	% of Total in Subdivision
321 BOMBING-NAVIGATION SYSTEMS	1370	46.4	991	59.2	574	58.6	841	66.4
322 FIRE CONTROL AND WEAPON CONTROL SYSTEMS	2618	35.1	3003	43.3	1464	57.3	2444	55.2
323 DEFENSIVE FIRE CONTROL SYSTEMS	1514	51.7	1413	69.8	941	62.6	986	77.7
324 PRECISION MEASURING EQUIPMENT	1346	80.9	1815	85.8	900	57.8	1538	73.7
325 AUTOMATIC FLIGHT CONTROL/INSTRUMENTS SYSTEMS	844	26.4	1181	31.1	1519	64.9	2601	47.6
326 INTEGRATED AVIONICS/ACE SYSTEMS	0	0.0	0	0.0	69	61.1	707	73.3

TITLE: Avionics Career Field 32 - Manpower Inventory of Skill Levels 7 and 9 vs. Career Requirements

COMMENTS: Between 1965 and 1971, the numbers of Skill Levels 7 and 9 increased for all career subdivisions, with the exception of 324XX. The average rate of increase within this period ranged from 3.3% to 4.3%; the exception, 324XX, showed a net drop of 7.6%. If it is assumed the same trend prevailed between 30 June 1968 and 30 June 1970, it appeared that the 1970 requirements for these skill levels were met. These data also provided information on the first build-up in the new career subdivision 326XX, which was approximately after 30 June 1968 and before 30 June 1970, on the assumption that the 1970 requirements were met.[1,2]

IMPLICATIONS: Analysis of past inventories indicated adequacy of the human resources pool to meet actual requirements. It also indicated that the greater percentage of the available pool were higher skill levels for most of the subdivisions, with the trend indicating an average yearly growth of 3.3 to 4.3%. As can be seen from Chart II.2-8.2, Skill Level 7 contributed substantially more to the

MODELS FOR DATA APPLICATION:

SUBJECT:
Avionics Career Field - Manpower Inventory of Skill Levels 7 and 9 for Six Career Subdivisions

INDEX: 2-8

CROSS-INDEX: I.3-2.1
II.2-3.1
II.2-8.2
II.5-3.2

percentage than Skill Level 9. The creation of a new subdivision was due to advanced systems being added to the Air Force inventory about that time (see Chart I.3-2.1). Presumably, based upon predictions (see Charts II.2-3.1 and II.5-3.2), the advanced systems would require lower numbers and lower skills to maintain, the number and skill distributions depending upon the level of maintenance.

DATA SOURCES:
1. United States Department of the Air Force. The USAF Personnel Plan, Volume III, Airman Structure Annexes, July 2, 1970.
2. Air Force Human Resources Laboratory, Personnel Research Division, Lackland Air Force Base, Texas. (Letter Communication, 1973)

MODELS FOR DATA APPLICATION:	SUBJECT: Avionics Career Field - Manpower Inventory of Skill Levels 7 and 9 for Six Career Subdivisions	INDEX: 2-8 CROSS-INDEX: I.3-2.1 II.2-3.1 II.2-8.2 II.5-3.2

321 Bombing-Navigation Systems
322 Fire Control and Weapon Control Systems
323 Defensive Fire Control Systems
324 Precision Measuring Equipment
325 Automatic Flight Control/Instruments Systems
326 Integrated Avionics/AGE Systems

As of 30 June	Skill Level 3			Skill Level 5			Skill Level 7			Skill Level 9		
	Nos.	% of Total	Change from Prior Period	Nos.	% of Total	Change from Prior Period	Nos.	% of Total	Change from Prior Period	Nos.	% of Total	Change from Prior Period
1965	2296	12.6	-	8202	45.1	-	6841	37.7	-	851	4.7	-
1968	1419	8.6	Down 4.0%	6718	40.6	Down 4.5%	6974	42.2	Up 4.5%	1429	8.6	Up 3.9%
1971	1204	7.8	Down 0.8%	5165	33.4	Down 7.2%	7669	49.6	Up 7.4%	1448	9.4	Up 0.8%

TITLE: Percent Distribution of Skill Levels of Avionics Career Field Subdivisions 321XX through 326XX

COMMENTS: Human resources were inventoried for 1965, 1968, and 1971. Skill Levels 5 and 7 combined accounted for more than 80% of the human resources. Both Skill Levels 3 and 5 showed a downward trend over time, while Skill Levels 7 and 9 showed an upward trend over time.

IMPLICATIONS: It appears that the problem of arresting the attrition of Skill Levels 3 and 5 will become more acute as advanced systems (see Chart I.3-2.1) are added to the equipment inventory.

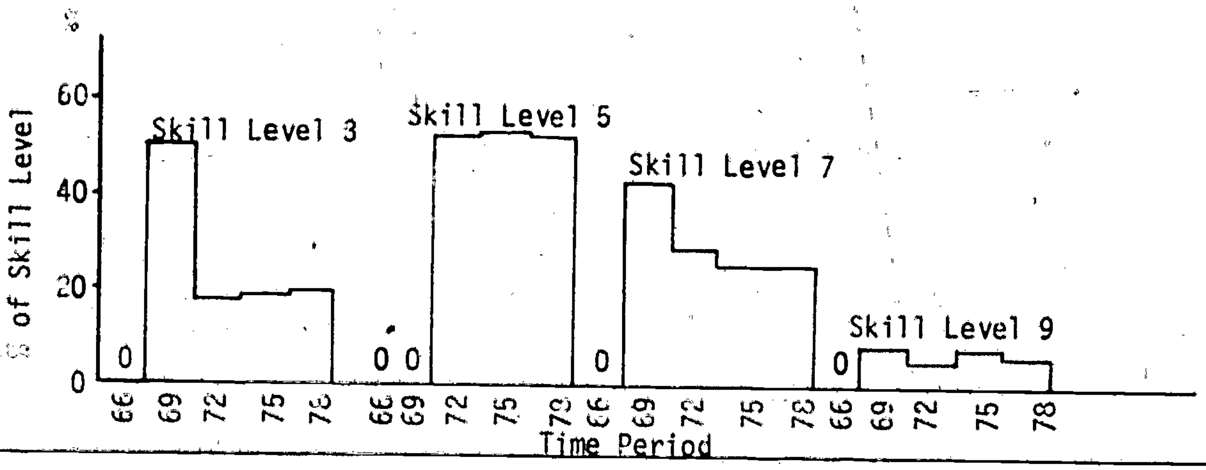
DATA SOURCES: 1. Air Force Human Resources Laboratory, Personnel Research Division, Lackland Air Force Base, Texas. (Letter Communication, 1973)

MODELS FOR DATA APPLICATION:

SUBJECT:
Percent Distribution of Skill Levels for Avionics Career Field Subdivisions 321XX through 326XX

INDEX: 2-8

CROSS-INDEX: I.3-2.1
II.5-3.2



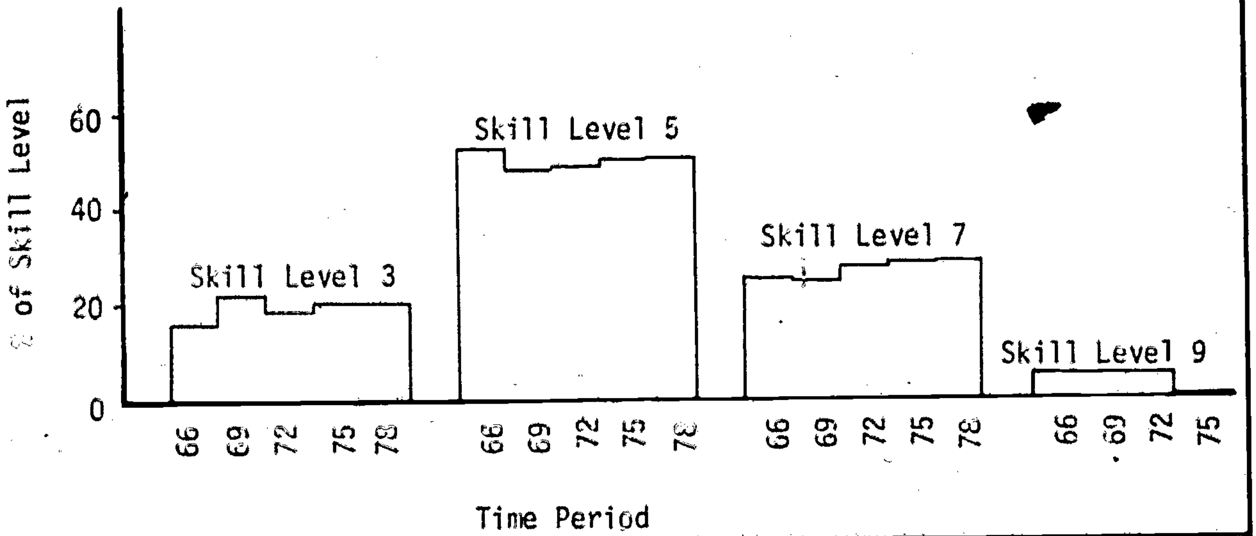
TITLE: Percent Distribution of Skill-Levels for Avionics Career Subdivision 326XX - Avionics AGE and Integrated Avionics Systems

COMMENTS: The creation of this career subdivision occurred approximately the same time as the introduction of systems into the United States Air Force that were distinguished by major application of advanced design concepts such as Group B systems on which this specialty is assigned to work (see Chart I.3-2.1). Requirements projected to 1978[1] show that future needs will be approximately the same as that for 1972.

IMPLICATIONS: The distribution of skills to maintain Group B systems approximates the distribution of skills to maintain Group A systems (see Chart II.2-8.4). However, the composite number may not be comparable nor the distribution of skills based on maintenance levels - organizational, intermediate, and depot. Since the manpower pool of higher skills is predicated on a buildup of lower skills, attrited rates reported for Skill Levels 3 and 5 in 1968 and 1971 (see Chart II.2-8.2) may signify possible problems in meeting the projected requirements. Reevaluation and restructuring of technical training as well as job functions represent two positive courses of action that might eventuate as satisfactory solutions.

DATA SOURCES: 1. United States Department of the Air Force. Manpower Data Systems Branch, AFPRM, Pentagon Washington, D.C., Document No. PCN-RRA-00035, April 3, 1973.

MODELS FOR DATA APPLICATION	SUBJECT: Percent Distribution of Skill Levels for Avionics Career Subdivision 326XX	INDEX: 2-8 CROSS-INDEX: I.3.2-1 II.2-8.2 II.2-8.4



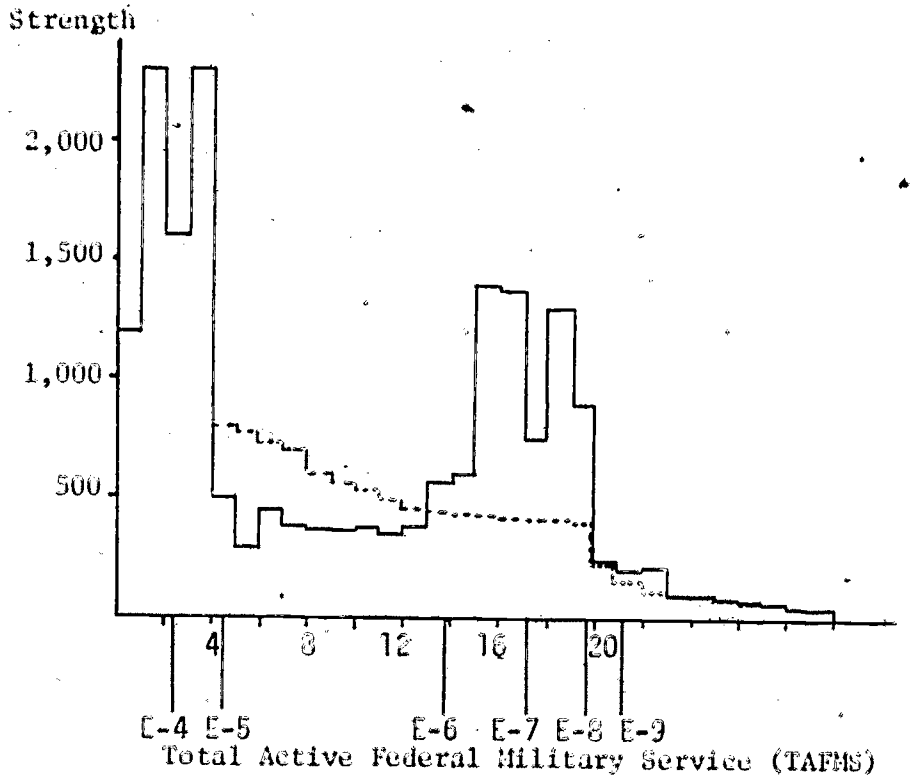
TITLE: Percent Distribution of Skill Levels for Avionics Career Subdivision 322XX - Fire Control and Weapon Control Systems

COMMENTS: Requirements projected to 1981[1] for Group A systems (see Chart I.3-2.1) show that future needs will be approximately the same as those for 1966, 1969, and 1972.

IMPLICATIONS: Since the manpower pool of Skill Level 5 is predicated primarily on a successful buildup of the Skill Level 3 pool, attrited rates reported for 1968 and 1971 (see Chart II.2-8.2) signify possible problems in meeting the projected requirements. Reevaluation and restructuring of technical training as well as job responsibilities represent two positive courses of action that might avert an imminent problem.

DATA SOURCES: 1. United States Department of the Air Force, Manpower Data Systems Branch, AFPRM, Pentagon, Washington, D.C., Document No. PCN-RRA-00035, April 3, 1973.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Percent Distribution of Skill Levels for Avionics Career Subdivision 322XX	**INDEX:** 2-8 **CROSS INDEX:** I.3-2.1 II.2-8.2



TITLE: Avionics Career Field 32 - Manpower Inventory as of 30 June 1970

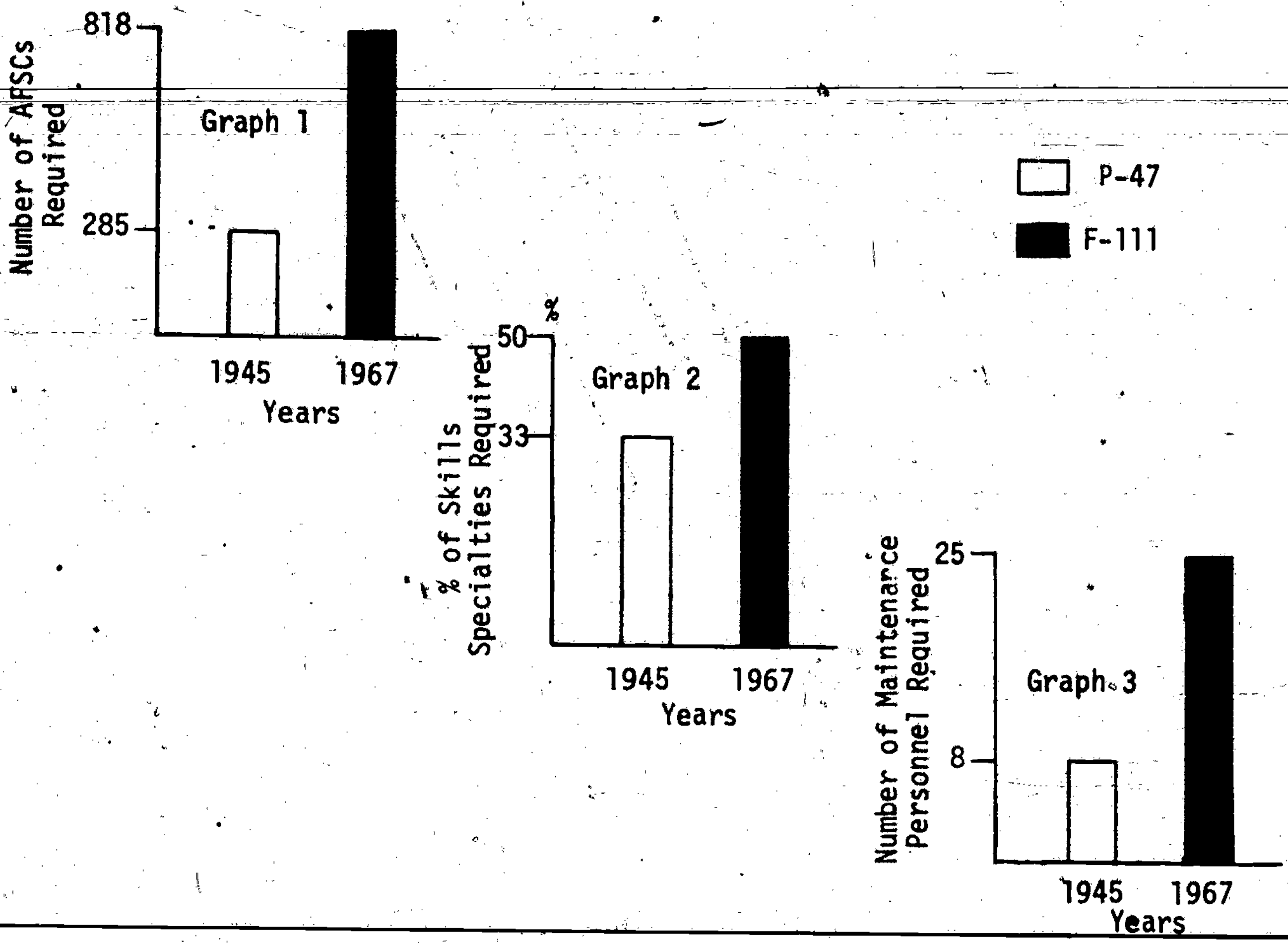
COMMENTS: This career field provides the manpower to support United States Air Force avionics systems. Different types of avionics systems have different manpower requirements. Charts II.2-8.2, II.2-8.3 and II.2-8.4 discussed past inventories and projected requirements for six different career subdivisions, most of them concerned with fire control and weapon control systems. However, since the career field provides a policy of lateral transfer, an overall examination of manpower strength may yield information whether it would be possible to redistribute human resources if deficits become an acute reality; 1970 data were used for this purpose. The total inventory is displayed in TAFMS Groups 1 to 30. TAFMS stands for Total Active Federal Military service, or number of years of military service. The lines extending downward from the X axis indicate the average years of total service at promotion to the grades E-4, E-5, etc. These grade identifications are approximate indicators of the skill level of the airmen. E-4s are generally Skill Level 3, E-5s through E-7s are primarily Skill Level 5s and 7s, and from E-8 and up, the skill level is expected to be 9. The broken line indicates the requirements. Therefore, this chart provides a comparison of actual requirements vs. available human resources as of 30 June 1970. The shortage was in Groups 5 to 12, i.e., airmen with 5 to 12 years of experience. The requirements for first-termers were not stated; however, it can be observed that the numbers required for the beginning point of strength buildup would be predicated on the successful processing of lower skilled airmen into the higher skill ranks.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Avionics Career Field 32 - Manpower Inventory as of 30 June 1970 178	**INDEX:** 2-31 **CROSS-INDEX:** II.2-8.2 II.2-8.3 II.2-8.4

IMPLICATIONS: Despite the fact that there was an E-4 to E-5 ratio of 20:1, it appeared that the E-4s were not being advanced rapidly enough to compensate for the attrition of E-5 through E-7s. These findings substantiated those reported on individual charts cited above. It is predicted that the demands of different skills for advanced design concepts will perpetuate the problem of shortages of skilled airmen. Reevaluation and restructuring of technical training as well as job functions represent two positive courses of action that might ameliorate this problem in the 70s and 80s.

DATA SOURCES: 1. United States Department of the Air Force, The USAF Personnel Plan, Volume III, Airman Structure Annexes, July 2, 1970.

MODELS FOR DATA APPLICATION:	SUBJECT: Avionics Career Field 32 - Manpower Inventory as of 30 June 1970 179	INDEX: 2-31 CROSS-INDEX: II.2-8.2 II.2-8.3 II.2-8.4



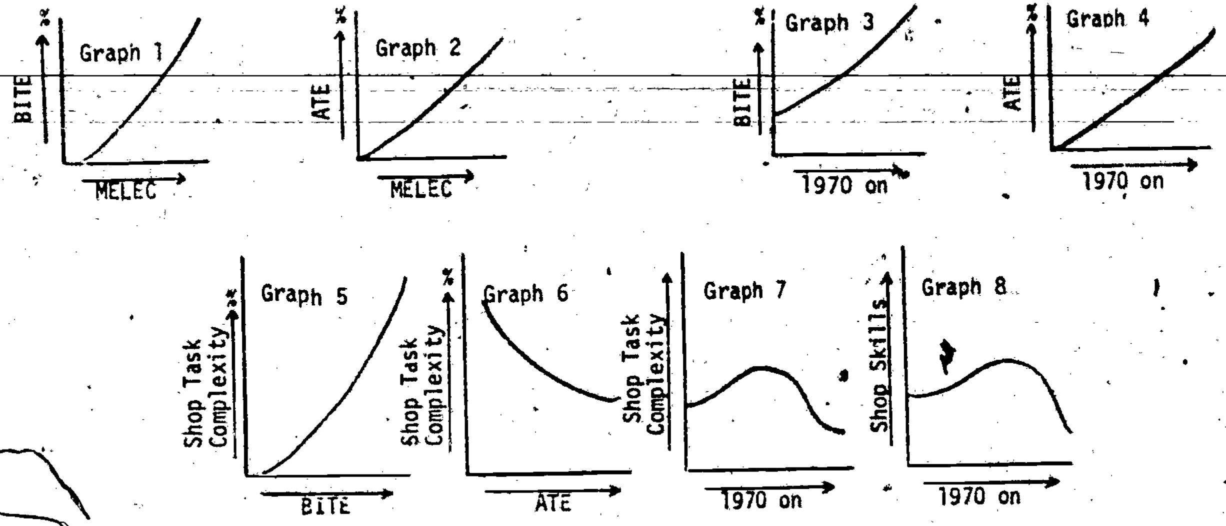
TITLE: Increases over Time of Numbers of AFSCs, High Skill Specialties and Number of Maintenance Personnel Required

COMMENTS: A study conducted in 1967[1] showed that the total number of job specialties had risen from 285 in 1945 to 818 in 1967 (Graph 1). In 1945, one out of three high skill specialties was electronics, mechanical, or technical; in 1967, the proportion was one out of two (Graph 2). In 1945, it took eight men to keep a P-47 flying during World War II; in 1967, the F-111 required three times as many (Graph 3).

IMPLICATIONS: The increased human resources requirements with concomitant effects on training and maintenance costs were due largely to greater complexity of Air Force hardware. As equipment complexity continues to grow, similar effects are expected.

DATA SOURCES: 1. Ferraro, Eugene T., A Look Ahead in USAF Personnel Research. Proceedings Twenty-Fifth Anniversary Symposium, Personnel Research and Systems Advancement, December 1967.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Required Human Resources Quantities vs. Time Period	**INDEX:** 2-31 **CROSS-INDEX:**



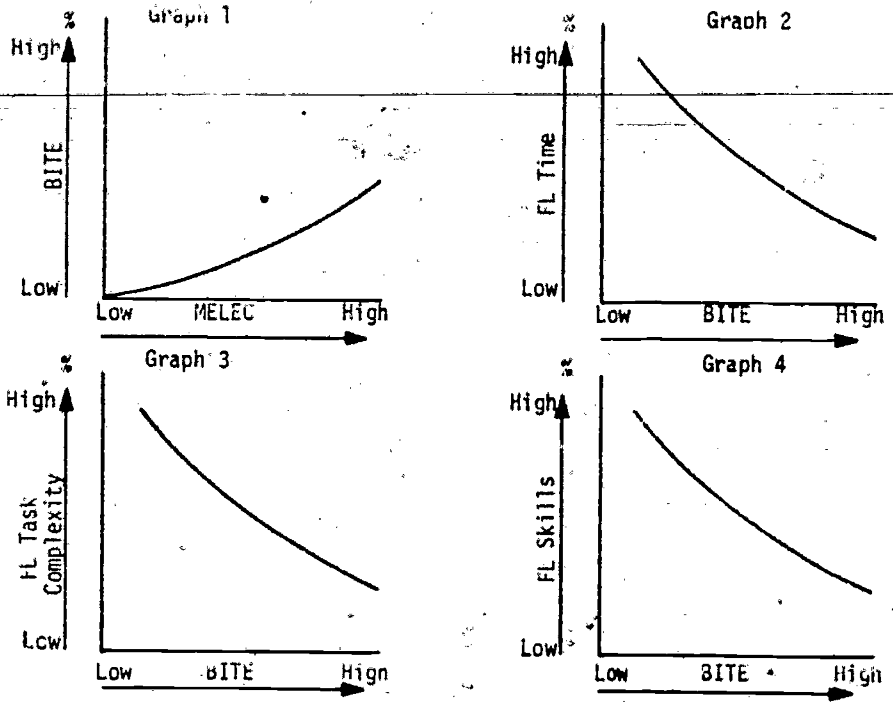
TITLE: Effects of Microelectronics (MELEC) on Required Shop Personnel Skill Levels

COMMENTS: Studies[1] conducted in 1970 described the impact trends of MELEC on testing concepts, shop task complexity, and shop skills. Graphs 1 through 8 explain the nature of the relationships. Graph 1: As MELEC increases, the use of built-in test equipment (BITE) will increase. Graph 2: As MELEC increases, the use of automatic test equipment (ATE) will increase. The rate of increase will be slower for ATE than BITE. Graphs 3 and 4: BITE and ATE development as a function of time show more rapid progress for BITE. Graph 5: As use of BITE increases, shop task complexity will increase. Fault localization is expected to be more difficult on MELEC than on conventional equipment. Graph 6: As use of ATE increases, shop task complexity will decrease. Automated testing was expected to simplify the operator's functional role. Graphs 7 and 8: Because of the lag in time between BITE and ATE, shop task complexity and shop manning of certain skills will tend to increase until it is offset by a corresponding increase in ATE development. A partial assessment of these findings and predictions can be made by referring to the field data on conventional vs. advanced systems, contained in Section I.

IMPLICATIONS: Decreasing task complexity and skill levels required may reduce training requirements and the number of people required (ATE reduces task time). Equally powerful ripple effects can be expected with the advent of other new technologies.

DATA SOURCES: 1. Air Training Command, Ad Hoc Committee, The Impact of Microelectronics and Integrated Systems on Technical Training, April 1970.

MODELS FOR DATA APPLICATION:	SUBJECT: Retention of Airmen vs. Positions (AFSCs)	INDEX: 5-3 CROSS-INDEX:



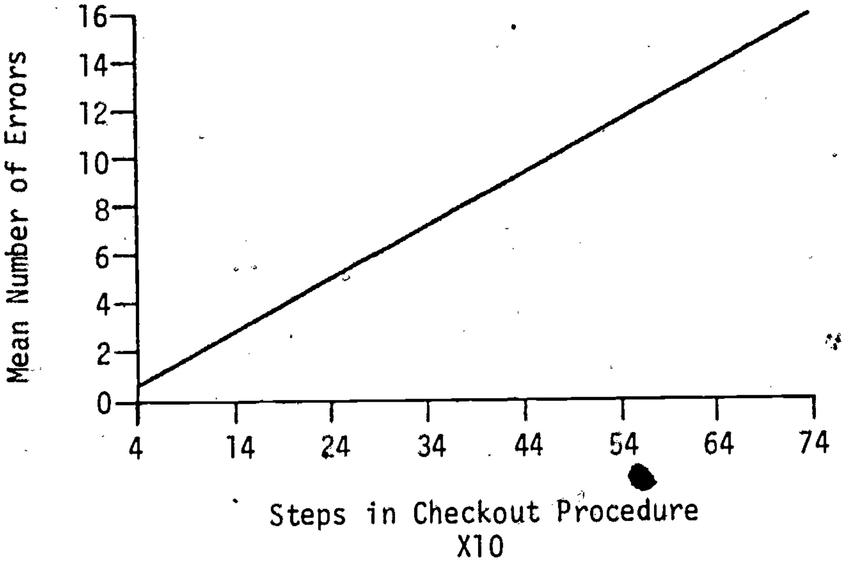
TITLE: Effects of Microelectronics (MELEC) on Built-in Test Equipment (BITE) and Flightline (FL) Maintenance Time, Complexity and Skill Level

COMMENTS: Studies[1] conducted in 1970 described the effects of MELEC on testing concepts, flight-line performance time, flight-line task complexity, and flight-line skills. Graphs 1 through 4 explain the nature of the relationships. Graph 1: As the use of MELEC increases, BITE will increase. Graph 2: As the use of BITE increases, performance time will decrease. Graph 3: As the use of BITE increases, task complexity will decrease. Graph 4: As the use of BITE increases, flight-line skills will be less demanding. The relationships shown in Graphs 2 and 3 were predicated on BITE's capacity for rapid and operationally simple fault localization to a line replaceable unit. The relationship shown in Graph 4 was predicated on the reduction of different types of test equipment as well as reduction in repair tasks. A partial corroboration of these findings and predictions can be established by referring to the operational data on conventional vs. advanced systems contained in Section 1.

IMPLICATIONS: Training required for these FL maintenance personnel will be very limited. This concept will no doubt create serious problems in career progression and preclude use of these personnel in the intermediate maintenance area without additional training. Equally powerful ripple effects, with the advent of other new technologies, can be expected.

DATA SOURCES: 1. Air Training Command, Ad Hoc Committee, The Impact of Microelectronics and Integrated Systems on Technical Training, April 1970.

MODELS FOR DATA APPLICATION:	SUBJECT: Hardware Design Variable vs. Future Human Resources Experience	INDEX: 5-3 CROSS-INDEX:



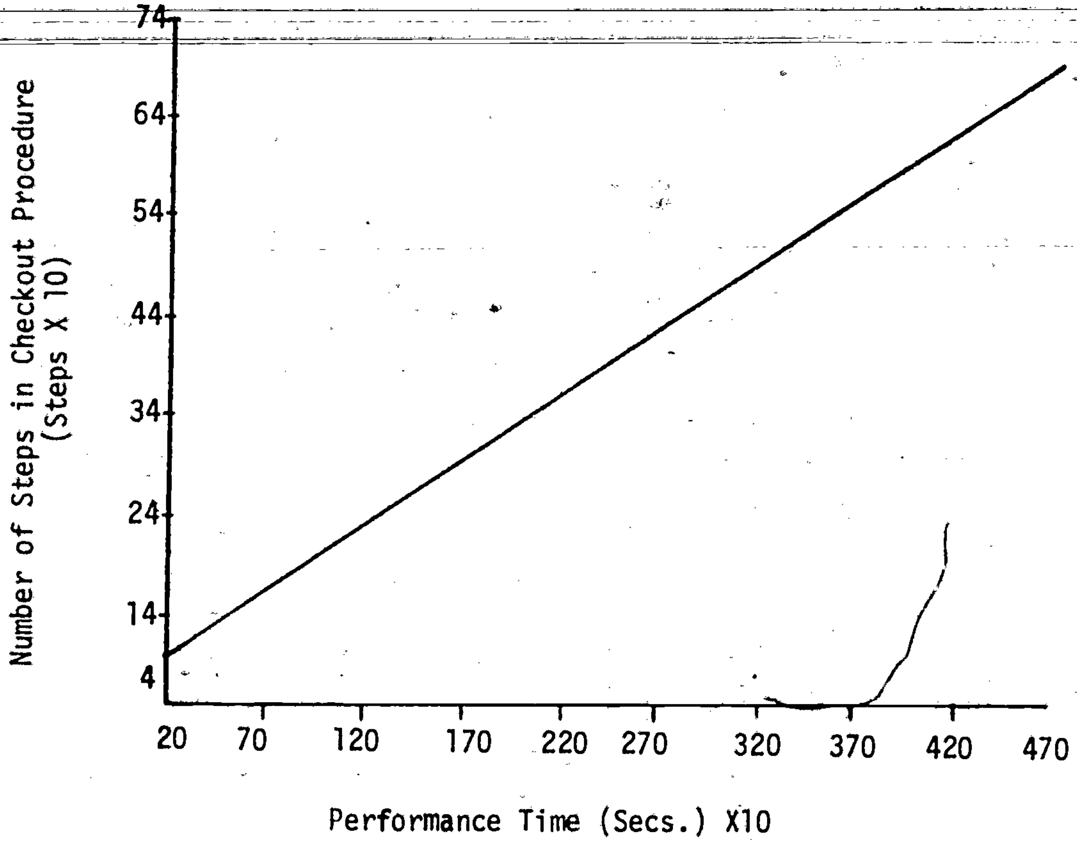
TITLE: Relationship between Number of Steps in Functional Checkout and Mean Number of Errors.

COMMENTS: Data represent 30 components in the following 10 avionics systems: ASN-91; ASG-19; APQ-109; APQ-120; F-111 CADC: F-111 AFCS; F-101; ASN-48; ARC-51; ARC-34.[1]

IMPLICATIONS: In a training environment, the number of steps in checkout is a predictor of the number of errors in performance.

DATA SOURCES: 1. Lintz, L., Loy, S., Hopper, R., and Potempa, K., Relationships between Design Characteristics of Avionics Subsystems and Training Cost, Training Difficulty, and Job Performance. AFHRL-TR-72-70, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, January 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Hardware Design Characteristics 183	INDEX: 5-36 CROSS-INDEX:



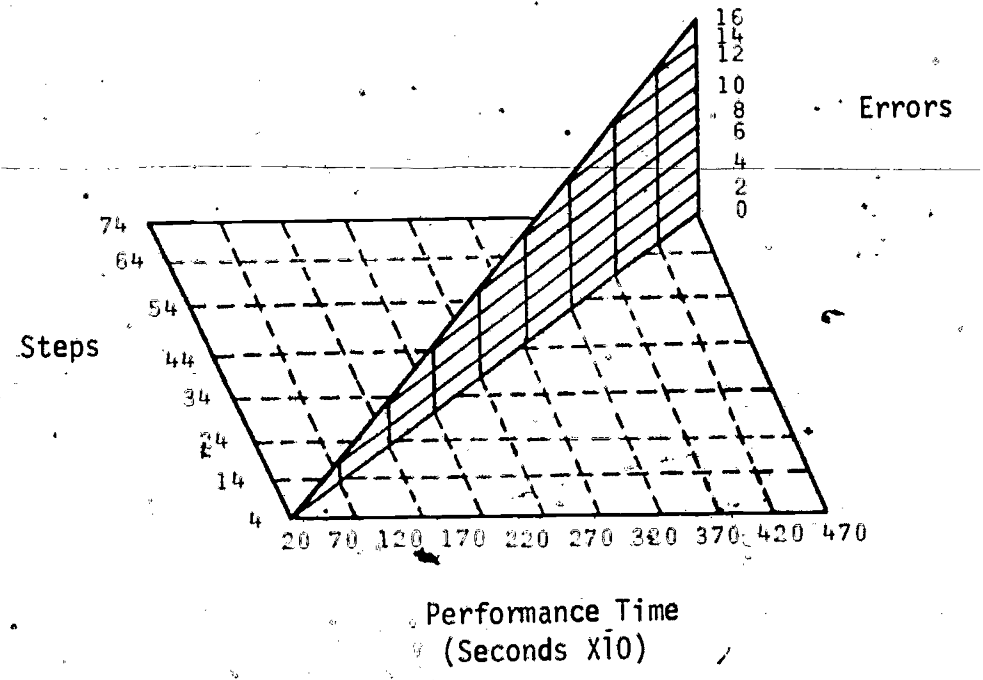
TITLE: Relationship between Number of Steps in Functional Checkout and Performance Time

COMMENTS: Data represent 30 components in the following 10 avionics systems: ASN-91; ASG-19; APQ-109; APQ-120; F-111 CADC; F-111 AFSC, F-101; ASN-48; ARC-51; ARC-34.[1]

IMPLICATIONS: In a training environment, the number of steps is shown to be the single best predictor of performance time for functional checkout tasks.

DATA SOURCES: 1. Lintz, L., Loy, S., Hopper, R., and Potempa, K., Relationships between Design Characteristics of Avionics Subsystems and Training Cost, Training Difficulty, and Job Performance. AFHRL-TR-72-70, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, January 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Design Characteristics vs. Job Performance Time 184	INDEX: 5-36 CROSS-INDEX:



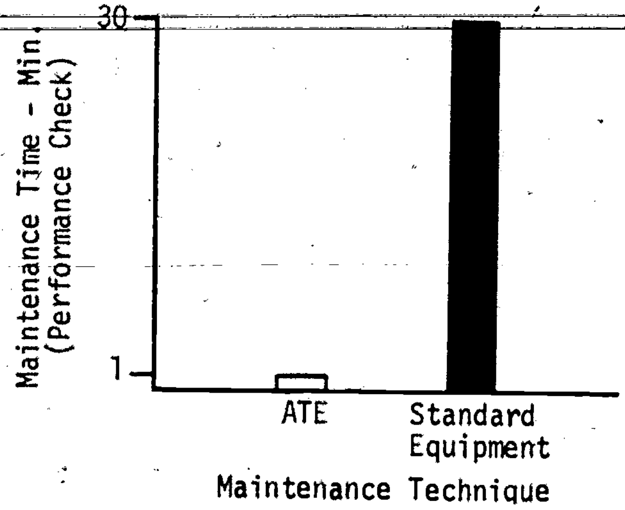
TITLE: Performance Time and Errors as a Function of Number of Steps in Checkout Procedures.

COMMENTS: Data represent 30 components in the following avionics systems: ASN-91, ASG-19; APQ-109; APQ-120; F-111 CADC; F-111 AFCS; ASN-48; F-101; ARC-51; ARC-34.[1]

IMPLICATIONS: As the number of steps increase, so do the number of errors. Also, as the number of steps increase, performance time increases. Errors and performance time in checkout procedures may be reduced by decreasing the number of required steps.

DATA SOURCES: 1. Lintz, L., Loy, S., Hopper, R., and Potempa, K., Relationships between Design Characteristics of Avionics Subsystems and Training Cost, Training Difficulty, and Job Performance. AFHRL-TR-72-70, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, January 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Hardware Design Characteristics	INDEX: 5-36 CROSS-INDEX:



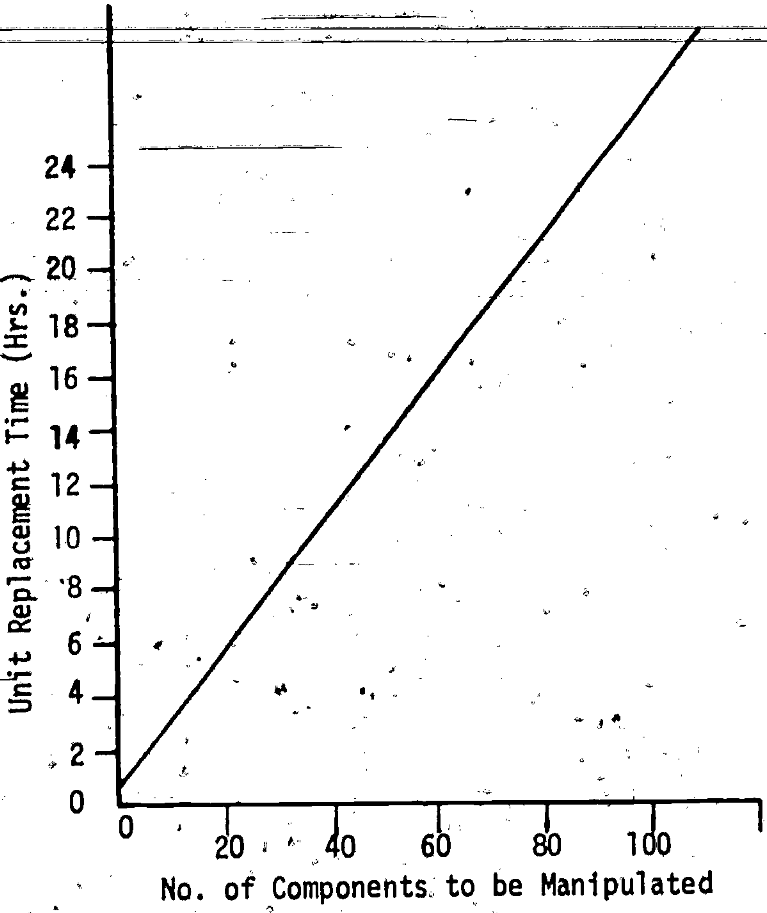
TITLE: Time Difference on a Performance Check Task between Two Maintenance Techniques - Automatic Test Equipment (ATE) Used or Standard Test Equipment Used.

COMMENTS: This performance check was performed on a military FM transceiver. Prior to automation it took a skilled technician with standard test equipment about 30 minutes to check the performance of a military transceiver. With ATE it takes about one minute to do the same test.[1]

IMPLICATIONS: As more and more ATE enter the inventory, shop maintenance time reductions, similar to that shown above, should result. Since the time required for maintenance is reduced, the number of maintenance personnel required may be reduced or shifted to other maintenance activities.

DATA SOURCES: 1. Air Training Command, Ad Hoc Committee, The Impact of Microelectronics and Integrated Systems on Technical Training, April 1970.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance (Performance Time) vs. Hardware Design Variables	INDEX: 5-36 CROSS-INDEX:



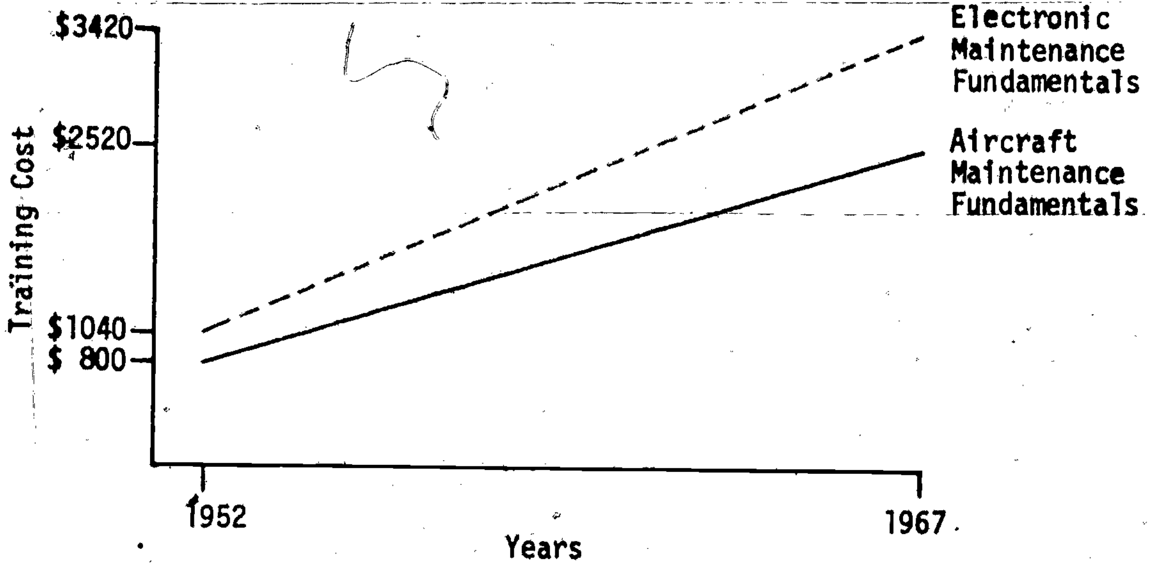
TITLE: Unit Replacement Time as Influenced by the Number of Components that Need to be Manipulated

COMMENTS: The number of components to be manipulated refers to the number of separate major parts that must be handled in order to effect repair.[1]

IMPLICATIONS: These data can be used as a hasty estimate of the effects on maintenance time of the number of components that must be manipulated. If there is a requirement to reduce maintenance time, a reduction in the number of manipulated components will help effect the reduction.

DATA SOURCES: 1. Tillman, S., Benson, N., Clausen, H., Development of Criteria and Quantitative Predictors of Maintainability of Air Force Equipment. ASD-TR-61-502, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, September 1961.

MODELS FOR DATA APPLICATION:	SUBJECT: Hardware Design Variable vs. Maintenance Time	INDEX: 5-36 CROSS-INDEX:



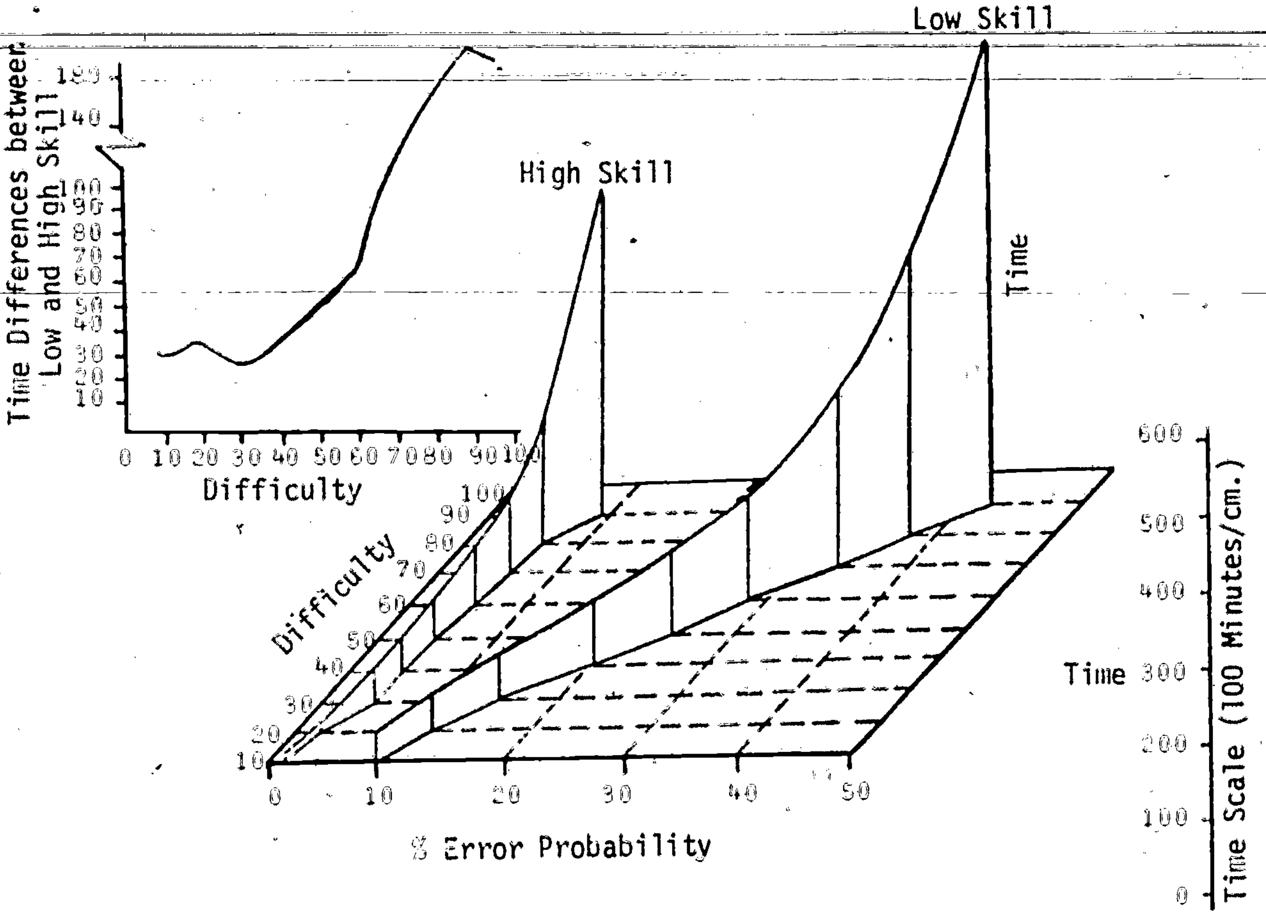
TITLE: Cost Increases over Time of Electronic and Aircraft Maintenance Fundamentals Training

COMMENTS: In 1952, the cost for training in aircraft maintenance fundamentals was $800. In 1967, the same course cost $2,520. For the same years, the cost of training in electronic maintenance fundamentals rose from $1,040 to $3,420. The ratio of increase in both instances was 1:3.2.[1]

IMPLICATIONS: Part of the cost increase stemmed from the general rise in cost of living, but a large part was due to the increasing complexity of the hardware used in the Air Force. As time goes on, equipment complexity will continue to increase resulting in a corresponding increase in training cost.

DATA SOURCES: 1. Ferraro, Eugene T., A Look Ahead in USAF Personnal Research, Proceedings Twenty-Fifth Anniversary Symposium Personnel Research and Systems Advancement, December 1967.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Training Cost vs. Time Period	**INDEX:** 5-38 **CROSS-INDEX:**



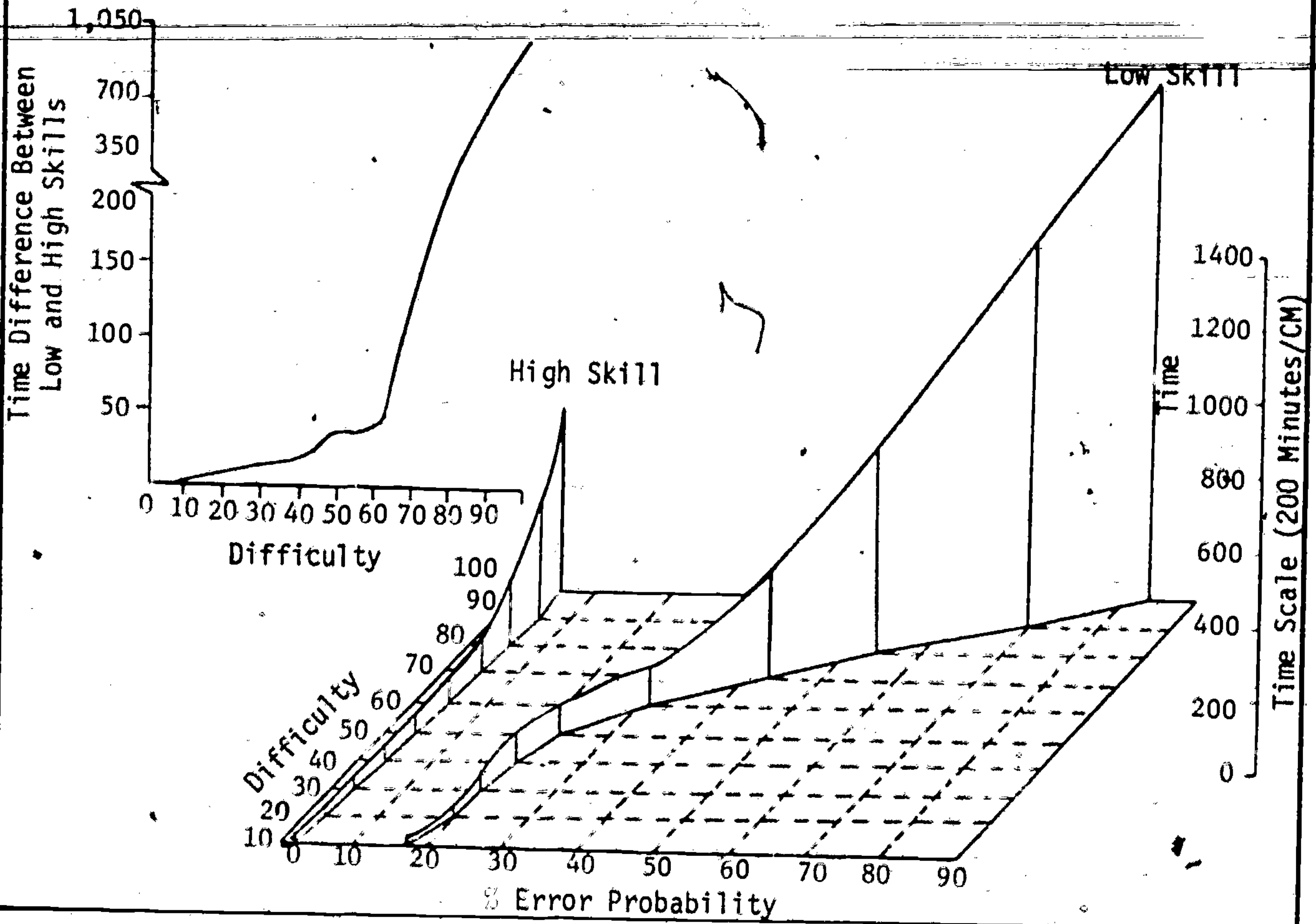
TITLE: Performance Time and Percent of Error Probability as a Function of Task Difficulty - Organizational Maintenance

COMMENTS: The functions represent organizational level maintenance data collected on 27 functional loops from 10 avionics subsystems.[1]

IMPLICATIONS: As task difficulty increases, the number of errors increase, but more so for low skills. Also, time to perform increases with difficulty, but more so for low skills. The inserted figure shows that for tasks of up to medium difficulty (50), time to perform for both high and low skills remains relatively constant. There is a large difference in time to perform, between high and low skill, as tasks become more difficult.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionic Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Skill Level (High and Low)	INDEX: 6-40 CROSS-INDEX:



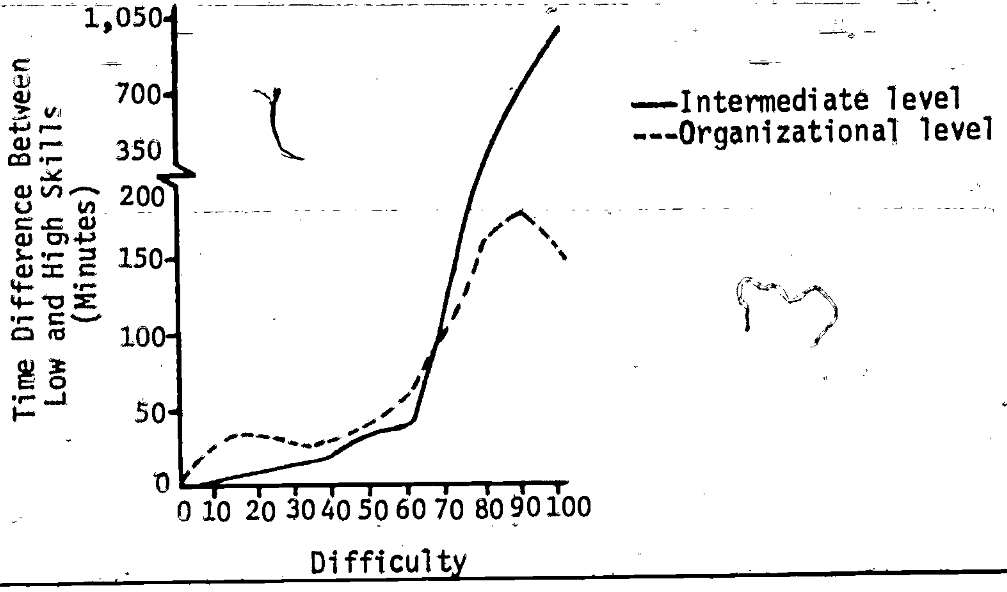
TITLE: Performance Time and Percent Error Probability as a Function of Task Difficulty - Intermediate Maintenance

COMMENTS: The functions represent intermediate level maintenance on 23 line replaceable units (LRUs) from ten avionics systems.[1]

IMPLICATIONS: As task difficulty increases, the number of errors increase, but more so for low skills. Also, time to perform increases with difficulty, but more so for low skills. The inserted figure shows that for tasks of up to medium difficulty (50), time to perform for both high and low skills remains relatively constant. There is a large difference in time to perform, between high and low skills, as tasks become more difficult.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionic Subsystems, AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Skill Level (High and Low)	INDEX: 6-40 CROSS-INDEX:



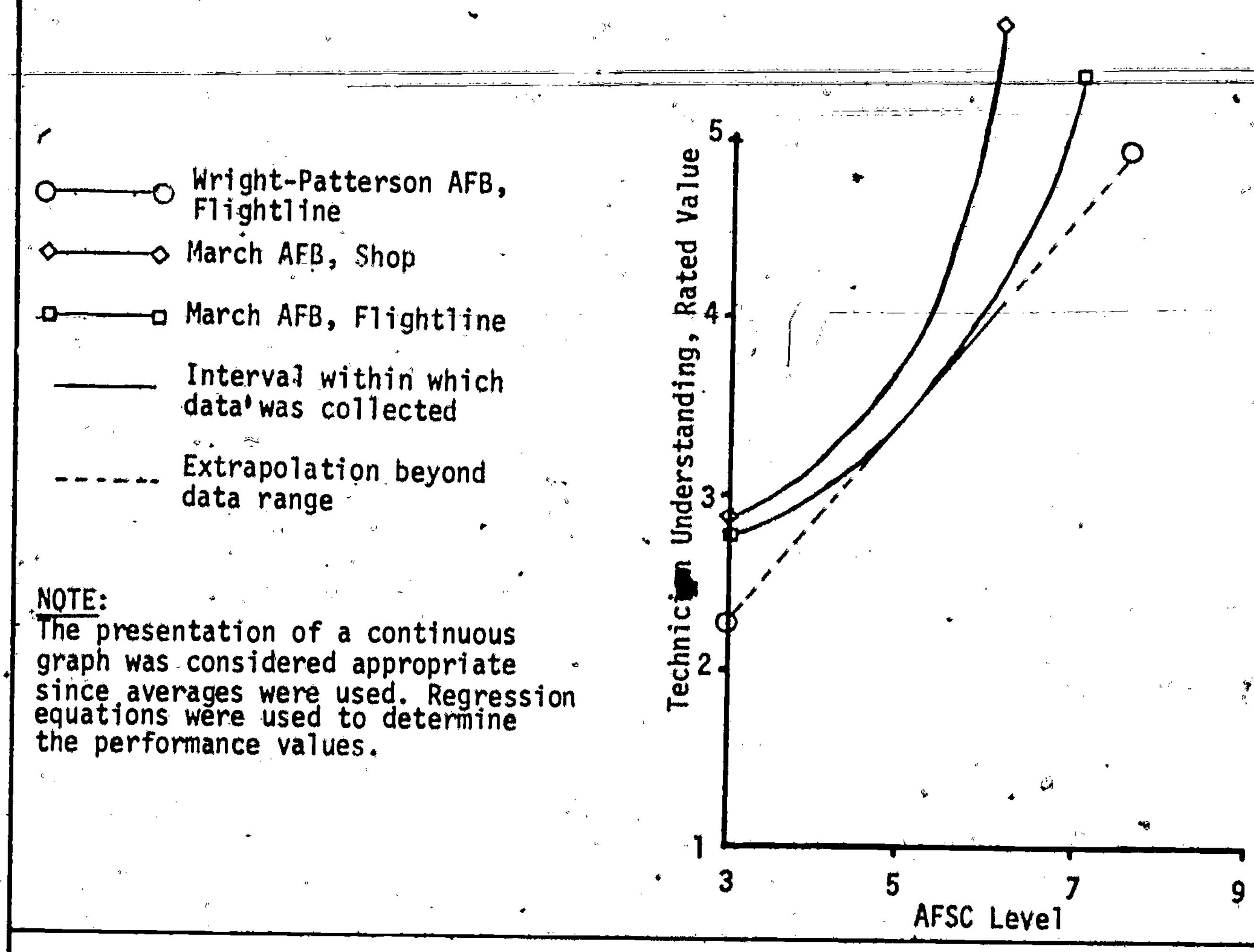
TITLE: Performance Time Differences for High and Low Skills as a Function of Task Difficulty

COMMENTS: The functions represent intermediate level maintenance (on 28 line replaceable units from ten avionics systems) and organizational level maintenance (on 27 functional loops from ten avionics systems). The ordinate is based on time differences for performing tasks of varying difficulty level by low and high skills (low minus high). The difficulty levels range from 0 to 100, the latter being the most difficult. Low skills are generally related to first term airmen, while high skills refer to second term airmen.

IMPLICATIONS: Performance time differences between high and low skills remain level for tasks of up to medium difficulty. Beyond this level, performance time climbs radically for low skills. This large difference suggests that task assignments for both organizational and intermediate level maintenance should be dependent on work experience. Airmen with low experience levels should not be assigned to tasks of above medium difficulty. For efficient manpower utilization, airmen with greater experience (e.g., second term airmen) should be assigned tasks of greater difficulty.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionic Subsystems, AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Skill Level (High and Low)	INDEX: 6-40 CROSS-INDEX:



NOTE:
The presentation of a continuous graph was considered appropriate since averages were used. Regression equations were used to determine the performance values.

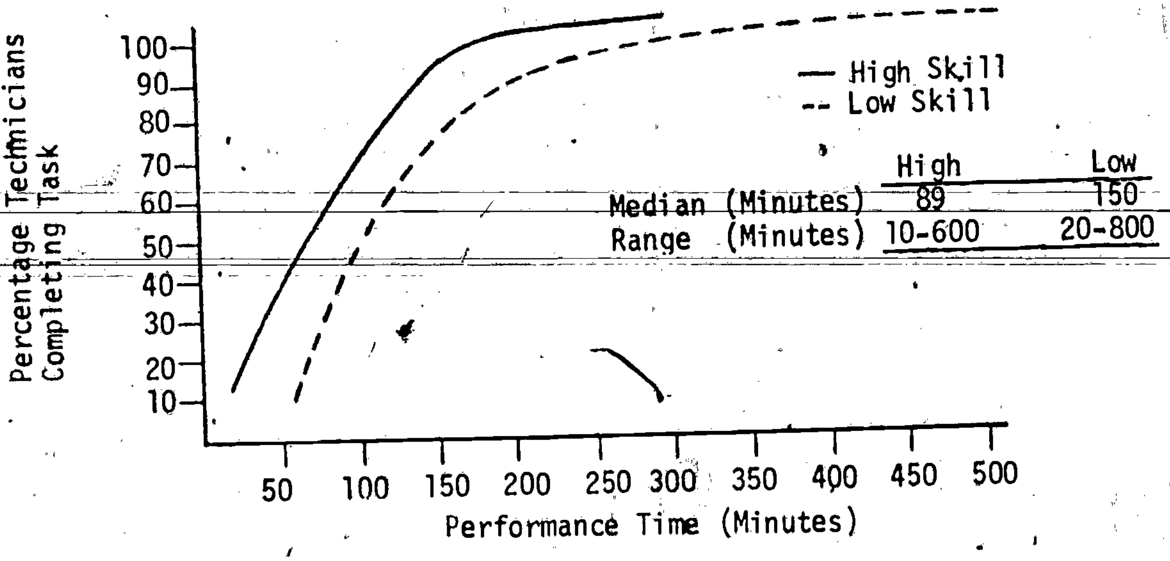
TITLE: Technician Understanding of Problems as a Function of AFSC Level

COMMENTS: Technician understanding of malfunctions and procedures for solving the problem is related to AFSC level.[1] Surprisingly this relationship is significant only for the flight line.[1]

IMPLICATIONS: Equipment characteristics appear to play a larger role in the shop (arrangement of internal components is significant in both shop locations). The reason for this may be simply that the amount of contact the technician has with equipment characteristics at the flight line is so restricted that other factors (e.g., experience level) overshadow these. Also, the more frequent use of the TO in the shop may compensate to some extent for inexperience.

DATA SOURCES: 1. Meister, D., Finley, D. and Thompson, E., Relationship between System Design, Technician Training and Maintenance Job Performance on Two Autopilot Subsystems. AFHRL-TR-70-20, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, September 1971.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Technician Understanding vs. AFSC Level	**INDEX:** 6-40 **CROSS INDEX:**



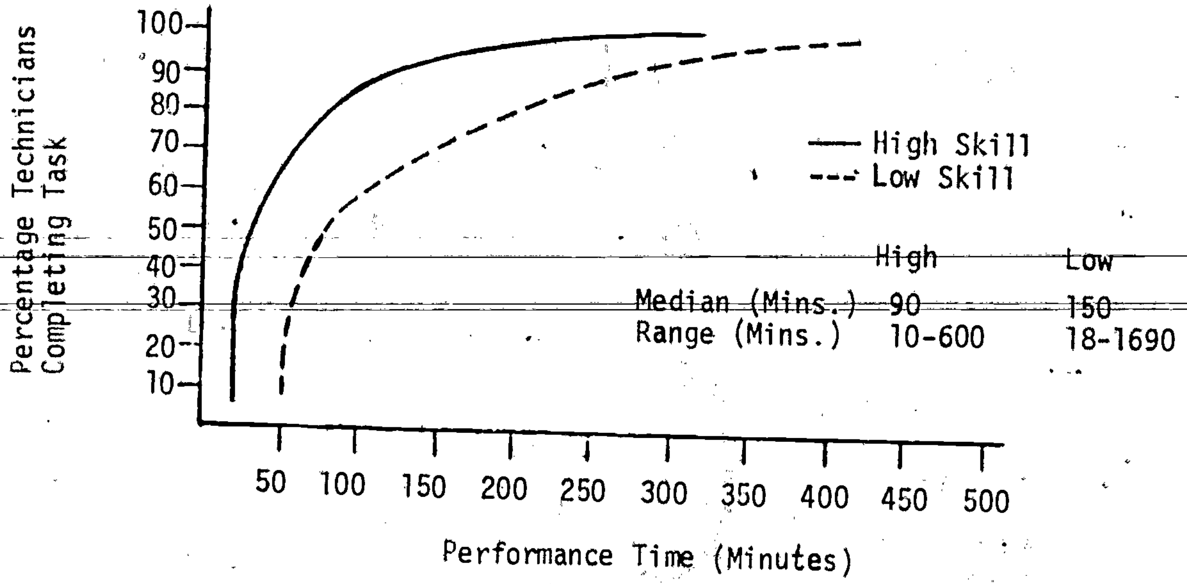
TITLE: Organizational Maintenance - Functional Checkout of Ten Avionics Subsystems

COMMENTS: The functions represent organizational level maintenance data collected on 27 functional loops from ten avionics subsystems. A functional loop is defined as a network of circuits and equipment units within an avionics subsystem through which signals are processed to perform a specific function.

IMPLICATIONS: A large difference in time to perform exists between high skill and low. At a median time of 89 minutes, 65% of the high skills would have completed the task by that time as compared to 40% for low skills. At a median time of 150 minutes for low skill technicians, 70% would have completed the task as compared to 95% for high skills. The difference between the medians of the two groups is 61 minutes.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionic Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Skill Level (High and Low) 193	INDEX: 6-40 CROSS-INDEX:



	High	Low
Median (Mins.)	90	150
Range (Mins.)	10-600	18-1690

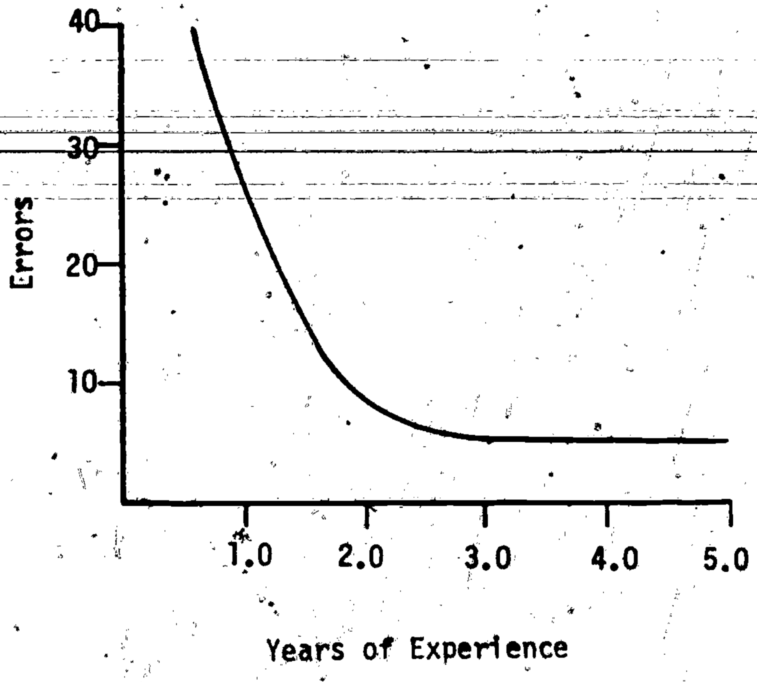
<u>TITLE</u>: Intermediate Level Maintenance - Functional Checkout on Ten Avionics Subsystems

<u>COMMENTS</u>: The functions represent intermediate level maintenance data collected on 28 line replaceable units (LRUs) from ten avionics subsystems.

<u>IMPLICATIONS</u>: A large difference in time to perform exists between high skill and low. At a median time of 90 minutes, 85% of the high skills would have completed the task by that time as compared to 55% for low skills. The difference between the medians of the two groups is 60 minutes.

<u>DATA SOURCES</u>: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionic Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	SUBJECT: Occupational Performance vs. Skill Level (High and Low)	INDEX: 6-40 CROSS-INDEX:



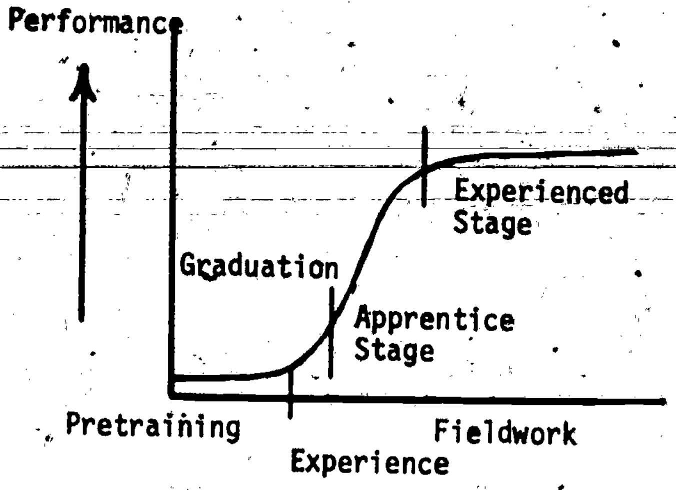
TITLE: Relationship Between Errors in Functional Checkout and the Number of Years of Experience on the Subsystems

COMMENTS: The function represents organizational-level maintenance data collected on 27 functional loops from 10 avionic subsystems, and from intermediate level maintenance data collected on 28 lines replaceable units (LRUs) from 10 avionics subsystems.[1] A functional loop is defined as a network of circuits and equipment units within an avionics subsystem through which signals are processed to perform a specific function.

IMPLICATIONS: The relationship shown here represents a typical learning curve. The relative complexity of the avionics systems requires about two years of experience on the subsystems before errors asymptote at a low level.

DATA SOURCES: 1. Lintz, L., Loy, S., Brock, G., and Potempa, K., Predicting Maintenance Task Difficulty and Personnel Skill Requirements Based on Design Parameters of Avionics Subsystems. AFHRL-TR-72-75, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, August 1973.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Occupational Performance vs. Skill Level (Experience) 195	**INDEX:** 6-40 **CROSS-INDEX:** III.6-40.12



TITLE: Job Performance as a Function of Experience Level

COMMENTS: Experience seems to play little role in influencing maintenance performance of technicians who are already fairly well experienced. The experience factor becomes an important predictor of performance when different experience groups are compared. Chart III.6-40.8, for example, shows that errors in functional checkout decrease radically with experience

IMPLICATIONS: As the novice technician is exposed to a certain amount of on-the-job training, the experience factor tends to become less of a discriminant factor. The contribution of experience to performance is represented by the hypothetical graph.

DATA SOURCES: 1. Meister, D., Finley, D. and Thompson, E., Relationship between System Design, Technician Training and Maintenance Job Performance on two Autopilot Subsystems. AFHRL-TR-70-20, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, September 1971.

MODELS FOR DATA APPLICATION:	**SUBJECT:** Occupational Performance vs. Experience Level	**INDEX:** 6-40 **CROSS-INDEX:** III.6-40.8

The following list of models were selected or adapted from references because of their potential practical application in deriving weapon system life cycle cost estimates which consider the functions of design, operations, training, logistics, and human resources. An examination of these models will show that in many cases, the level at which a model parameter is defined is too gross to permit direct application of data currently contained in Sections I, II and III. Successive iterative refinements of the Handbook will yield a series of matching models and input values considered to be the most valid estimators of weapon system life cycle cost.

Ident.	Models	Source
A	$T = A + S$ T = Total Cost of System A = Acquisition Cost of System S = Total System Lifetime Operation and Support Costs	1
B	$Ict = \frac{Cct}{Hct/L_T}$ Ict = Inflation Costs of Capital Resource Cct = Current Replacement Cost Hct = Historical, Original or Acquisition Cost of Capital Resources L_T = Average Life of Capital Resource.	2
C	$A = CD + CI - (M_{CD} + M_{CI})$ A = Acquisition Cost of System CD = Total Cost of Research, Design and Development CI = Total Equipment Initial Investment Cost M_{CD} = Maintainability Research, Design and Development Cost M_{CI} = Maintainability Initial Investment Cost	1
D	$S = CP_i + CC_i + CS_i + CT_i$ S = Total System Lifetime Operation and Support Costs CP_i = Cost of Personnel at all Levels CC_i = Cost of Consumables at all Levels CS_i = Cost of Spares at all Levels CT_i = Cost of Transportation at all Levels	1
E	$A = \frac{MTBF}{MTBF + MTTR}$ A = Availability MTBF = Mean Time Between Failures MTTR = Mean Time to Restore	5

MODELS FOR DATA APPLICATION:	SUBJECT: Models of Processes for Weapon System Life Cycle Costing	INDEX: 7-42 CROSS-INDEX:

Ident.	Models	Source
F	$C_o = C_{om} + C_{of} + C_{os} + C_{ot}$ C_o = Cost Incurred at Organization C_{om} = Cost of Personnel C_{of} = Cost of Consumables C_{os} = Cost of Spares C_{ot} = Cost of Transportation (Round-Trip)	1
G	$C_f = C_{fm} + C_{ff} + C_{fs} + C_{ft}$ C_f = Cost Incurred in the Field C_{fm} = Cost of Personnel C_{ff} = Cost of Consumables C_{fs} = Cost of Spares C_{ft} = Cost of Transportation (Round-Trip)	1
H	$ST = X + Y + Z$ ST = Stock Level (or Demand Level) X = (Daily Demand Rate or Total Maintenance Actions per Item) x (% Base Repair) x (Repair Cycle Time) Y = (Daily Demand Rate or Total Maintenance Actions per Item) x (% NRTS - Not Repairable this Station) x (Pipeline Time or Order and Shipping Time) $Z = \sqrt{3(X+Y)}$, Which is the Safety Level Quantity	6
I	$TR = A + BD + E + F$ TR = Training per AFSC A = Direct Training Cost (Instructions Plus Equipment) B = Average Training Time (Months) C = Average Grade at Time of Training D = Average Monthly Pay for Grade while Training E = Average Travel Pay and Allowances to Trainees F = Miscellaneous Costs Connected with Training	2
J	$L_{if} = D_{ij} + R_{ij} + T_{ij} + P_{ij}$ L_{ij} = Personnel Attrition in Skill Field i and Skill Level j where ij = skill designation D_{ij} = Personnel Discharged in Skill Field i and Skill level j R_{ij} = Personnel Retired in Skill Field i and Skill Level j T_{ij} = Personnel Transferred out of Skill Field i and Skill Level j P_{ij} = Personnel Exited from Skill Field i and Skill Level j through Promotion	7

MODELS FOR DATA APPLICATION:	**SUBJECT:** Models of Processes for Weapon System Life Cycle Costing	**INDEX:** 7-42 **CROSS-INDEX:**

Ident.	Weapons	Source
K	$M_T = M_{US} + M_S + M_{SV}$ M_T = Total Maintenance Load per System M_{US} = Unscheduled Maintenance Load M_S = Scheduled Maintenance Load M_{SV} = Servicing Operations Maintenance Load	3
L	$MP = \frac{MMH}{OH}$ MP = Manpower Burden MMH = Maintenance Manhours OH = Operating Hours	1
M	$M_s = \frac{\sum_t F_t MH_{st}}{a_s}$ M_s = Manning Requirements for Skill s per Unit Operational Time F_t = Total Frequency of Duty or Task t MH_{st} = Required Manhours per Portion of Duty or Task t requiring Skill a a_s = Personnel Skill s Availability	2
N	$M_S = \sum_i^N F_i M_i$ M_S = MMH/OH for System S F_i = Failure Rates of Component i M_i = Mean Manhours Required to Restore the System when Component i Fails	1
O	$M_i = \frac{W_i}{E_i}$ M_i = Mean Number of Personnel at Level i W_i = Workload for Level i E_i = Repairman Efficiency or Units of Maintenance per Unit of Time	2
P	$PH = \frac{1}{T} \times AP \times N$ PH = Productive Hours Expended on Duty $\frac{1}{T}$ = Proportion or Percentage of Time Spent on Duty AP = Available Productive Manhours N = Number of Personnel of a Particular Skill Level Performing Duty	3

MODELS FOR DATA APPLICATION:	SUBJECT: Models of Processes for Weapon System Life Cycle Costing	**INDEX:** 7-42 **CROSS-INDEX:**

Ident.	Models	Source
Q	$Y = \sum_{i}^{N} a_i\ X_i$ Y = Estimated Time Required to Perform a Major Task on Unit j a_i = Coefficients Required to Translate the X_i into Time Elements X_i = Equipment Design Characteristics	4
R	$W_i = T_i\ T_i$ W_i = Workload for Level i T_i = Mean Performance Time for all Maintenance Tasks at Level i G_i = Arrival Rate of Units at Level i for Maintenance, or Failure Rate	4
S	$WL_D = (F)\ (N)\ (T)$ WL_D = Workload for Duty D F = Frequency of Duty Performance per Unit of Equipment N = Number of Units of Equipment T = Mean Performance Time per Action	3
T	$R = \frac{1}{1 + D/U}$ R = Operational Readiness D = Effective System Downtime or Effective System Failure Rate U = Effective System Uptime or Effective System Repair Rate	1

MODELS FOR DATA APPLICATION:

SUBJECT: Models of Processes for Weapon System Life Cycle Costing

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CROSS-INDEX:

DATA SOURCES:

1. Harrison, Jr., G.T. Maintainability Engineering Design Notebook. RADC-TR-69-286, Rome Air Development Center, New York, January 1970. AD 866 818.
2. Losee, J.E. Maintainability and Supportability Evaluation Techniques. WADD T.N. 60-82, Wright-Patterson AFB, Ohio, March 1960.
3. Losee, J.E., Payfer, G.E., Fraham, W.F., and Eisenberg, B. Methods for Computing Manpower Requirements for Weapon System Under Development. ASD TR-61-361, Wright-Patterson AFB, Ohio, August 1961. AD 264 435.
4. Purvis, R.E., Mallory, W.K., and McLaughlin, R.L. Validation of Queuing Techniques for Determining System Manning and Related Support Requirements. AMRL-TR-65-32, Wright-Patterson AFB, Ohio, March 1965. AD 615 436.
5. Smith, R.L. and Westland, R.A. Status of Maintainability Models: A Critical Review. AMRL-TR-70-97, Wright-Patterson AFB, Ohio, March 1971.
6. Weifenback, A. Base Maintenance Activity and Repair Cycle Times. Rand Corporation, RM-5027-PR, September 1966.

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(See INTERMEDIATE MAINTENANCE)
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