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PROJECT PROGRESS REPORT

FINAL REPORT SUMMARY

PREPARED BY
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MAY 1964

Prepared for:
SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
MONTGOMERY AIR FORCE BASE, CALIFORNIA



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Volume I

Project PIMO Final Report

PIMO FINAL REPORT SUMMARY



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PROJECT PIMC FINAL REPORT

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FOREWORD

This report (Volume I through Volume VIII) represents the final phase of a study and test which was initiated in September 1964 to explore newly developed techniques and devices for presenting T.O. (Technical Order) type instructions and information. The eight volumes of data contain the result of a test conducted in an operational environment using concepts developed during an earlier phase under Contract AF(694)-729 and documented in BSD-TR-65-456. Both the early and final phases which were accomplished under Contract AF(694)-984, Project 1316, "Presentation of Information for Maintenance and Operation (PIMO)", were started in June 1966 and completed in April 1969.

The original program documentation was prepared by Mr. C. L. Schaffer in 1964. He subsequently functioned as the Air Force Program Director and Chairman of a Working Group which monitored all development throughout the life of the Project. This group was composed of individuals from various Air Force Commands (AFLC, MAC, ATC, ADC, AFSC) and the Army Command (AMCPM, AXMLE), knowledgeable in the maintenance disciplines and all facets of the T.O. system. Capt. Don Tetemeyer, Project Scientist during the formative stages of the Program, was largely responsible for the basic test structure. Mr. John Saunders was the Monitor for all contractual aspects until his reassignment in 1968.

Any success one may attribute to the project must be shared by numerous individuals; however, major credit and appreciation are due General Howell M. Estes, Jr., Commander of the Military Airlift Command, who provided the C-141 aircraft and the bases at Charleston, Dover and Norton for the operational test. Sharing in the credit for the MAC contributions are Lt. Col. Don Watt and his staff at Hq. MAC, and Col. Foreman, Col. Henzi, W/O Van Riper and all the personnel at Charleston Air Force Base and at Dover and Norton who participated in the test. The hardships imposed on their organizations are recognized, and we sincerely appreciate the special efforts put forth to overcome all obstacles. The test could never have been conducted without the cooperation and competent performance of these individuals.

We are especially indebted to the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base for their financial contributions at a critical point in the project; and to the Army Materiel Command, who believed the test potential of sufficient magnitude to warrant the expenditure of their funds. We are most grateful for their confidence and assistance, and it is most assuredly the primary factor that permitted completion of the test.

This report has been reviewed and is approved.

D. A. Cook

D. A. Cook, Lt. Col. USAF
Hq. AFSC (SCS-2)

I. INTRODUCTION

PIMO is one line of a three-pronged attack the Air Force has been using to meet the maintenance challenge created by the new complex Air Force systems. The second line is represented by AIDS and MADAR and is concerned with increased use of automation techniques to reduce the complexity of troubleshooting. The third prong is represented by MMICS and the ground processing portion of MADAR, and is concerned with improving maintenance management by making available relevant resource and historical information. PIMO concentrates on the man-data interface to improve the technician's performance capability by providing information available for use on the job.

These three efforts are supported by many related research activities, such as those sponsored by the Human Resources Laboratory at Wright-Patterson Air Force Base, Air Training Command, and the AFSC Aeronautical Systems Division at Wright-Patterson Air Force Base. Of special significance is the research on proceduralized troubleshooting being conducted under the sponsorship of Dr. John Foley at the Human Resources Laboratory. This research could result in additional improvements of the type evidenced in Project PIMO.

PIMO was not a research project. Rather, it was an advanced development project which applied available research results to resolve a current problem. The positive results indicate that the proper combination of behavioral sciences and system engineering can result in significant improvements of human performance aids.

The Phase II Program was initiated because the preliminary studies revealed a potential for significantly improving maintenance effectiveness. At the program's conclusion, we found that some of the improvements were considerably better than anticipated. For example, the preliminary studies indicated a potential for a 45 percent reduction of errors. The test resulted in a 92 to 100 percent reduction of errors. We had expected that the inexperienced technicians would compare favorably

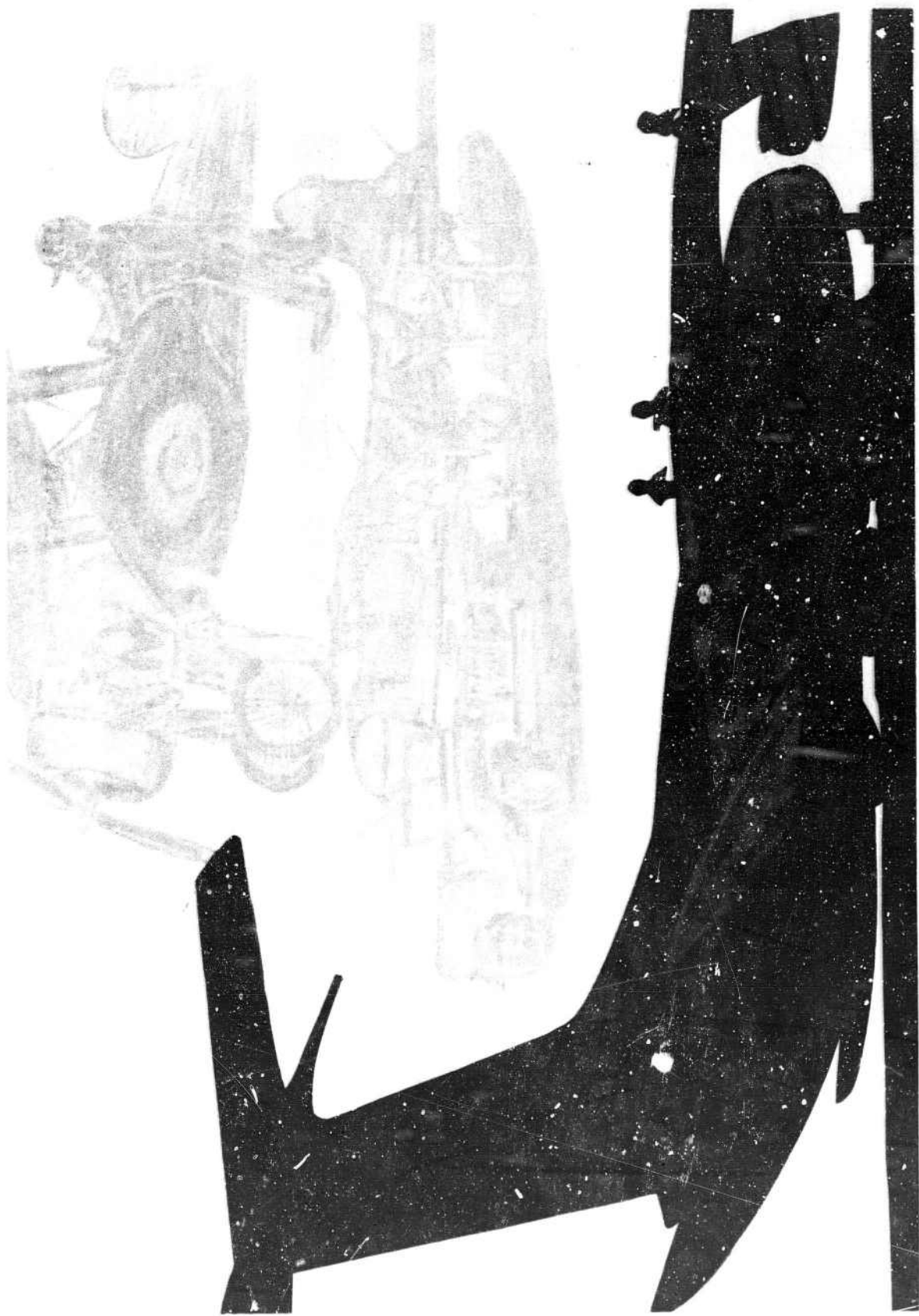
with the experienced specialists when both were using the PIMO Job Guides. We found the performance of both groups to be about the same. More important, the inexperienced technicians using the PIMO Job Guides outperformed the experienced specialists following the conventional T.O.'s.

The improvement in performance time was not as astounding on the surface. However, close examination showed the performance time data to be the most astounding of all the results. The average time of performance with PIMO appears to be longer than when experienced specialists perform without any data. However, a plot of the data revealed that as the technicians continued to use the guides, the time decreased to at least the same level as the technicians performing without data. Moreover, technicians using the guides committed no measurable error, a performance not equaled by technicians performing without data.

The test results have significant implications for the Air Force, especially in reducing the impact of manpower shortages. For one, the usable maintenance manpower can be increased from 25 percent to 50 percent in selected areas. This can be accomplished while improving the effectiveness of the system by 30 percent to 65 percent, depending on the parameter of concern. Concurrently, training costs can be reduced by at least eliminating the need for on-the-job training.

The improvements would be cost-effective for existing systems as well as new systems. However, the effectiveness potential cannot be realized unless the maintenance managers actually utilize the inexperienced technicians and non-specialists for jobs covered by the job guides.

The transition to the job guides will not be a simple process, especially since it represents a significant break from tradition. Whether the Air Force will be able to make a successful transition to the job guide approach remains to be seen. The basic technical problem has been resolved. The Air Force must now resolve the "people" problem associated with any innovation.



II. PROBLEM STATEMENT

The basic problem addressed by PIMO is in reality a series of related problems, each having a direct effect on the complex relationship between qualified maintenance manpower and technical data.

The complexity of recent Air Force systems has resulted in tremendous increases in maintenance demands. In order to meet these increased demands, the Air Force -- along with the other services -- has been steadily increasing both specializations in maintenance and depth of training. In certain cases, some technicians go so far as to specialize on specific aircraft. The extensiveness of training has reached the point where many technicians spend a larger percentage of their first enlistment term in training than in productive labor. Unfortunately, most of these men do not re-enlist.

When the sources of maintenance complexity are examined carefully, we find that they hinge primarily on information. That is, the proliferation of new equipment has resulted in a proliferation of information, the total amount of which, relevant to any maintenance job, is extremely high. Currently, the bulk of this information must be memorized by the technician. This was an efficient approach in the past when the systems were relatively simple and qualified technicians were plentiful. Now, the total quantity of relevant information has reached the point where it is impossible for any individual to retain all the relevant information.

The concept of technical orders developed during the time when one could rely on the technician's memory. They were designed, therefore, to be used primarily as reference materials away from the job by experienced technicians. As equipment became more complex, some attempt was made to provide information usable on the job. However, the basic orientation was still toward reference materials, with the consequence

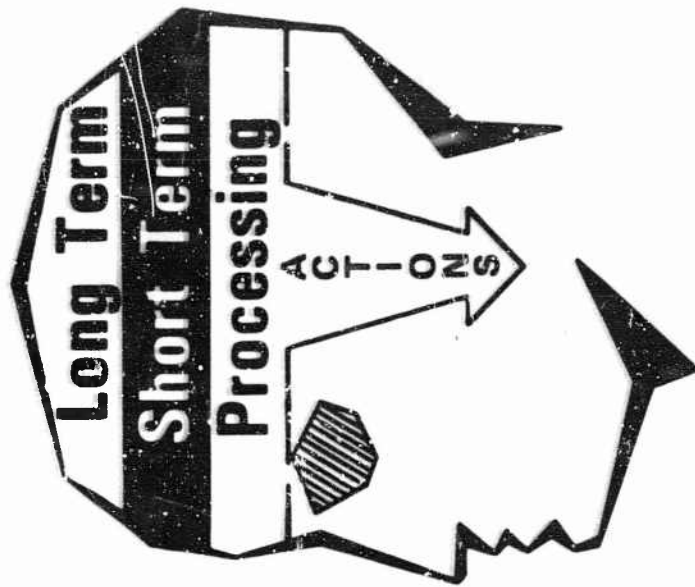
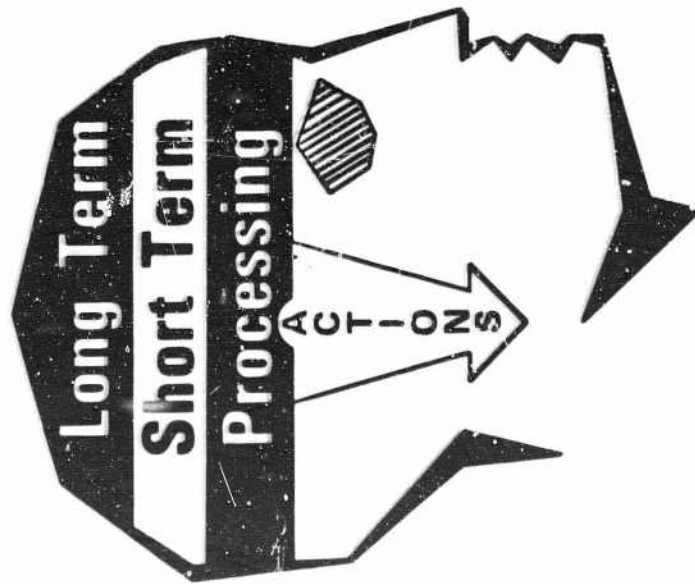
that technicians continued to rely on memory. Since the total amount of information exceeded what the technicians could retain accurately, maintenance errors began to occur with greater regularity.

Unfortunately, those attending to the problem have focused on the technical orders. And, in a sense, the T.O.'s have become the scapegoat. The basic problem stems from the fact that the growth of technology has made the maintenance approach obsolete by placing too much reliance on highly trained and experienced technicians. Since the quantity of information is the key problem, a change of requirements for T.O.'s will be important to the solution. However, the solution cannot be restricted to just a change of T.O. requirements. The solution must include changes in the 1) manning concept, 2) training, and 3) maintenance management.

In addition, the solution concept must provide more effective use of the Air Force's total maintenance manpower pool -- of which most members are first term enlistees who do not re-enlist. The job guide concept will provide the capability to utilize a large percentage of the first term enlistees. However, this capability will be wasted if the maintenance managers do not employ these personnel. Similarly, potential cost savings will not be realized if training is not also reduced.

To summarize, the basic problem must be viewed as a manpower systems problem. A systems problem, generally, has no single cause, and the current problem is no exception. Although the solution concept concentrates on job guides -- which requires a change of T.O.'s -- it is erroneous to "blame" the T.O.'s for the problem. Similarly, the solution cannot be restricted to changing the T.O.'s from reference materials to job guide materials, since one portion of a system cannot be changed without changes of interfacing portions.

EXTENSIVE TRAINING JOB GUIDE



Training Job Guides

III. HISTORY OF PIMO

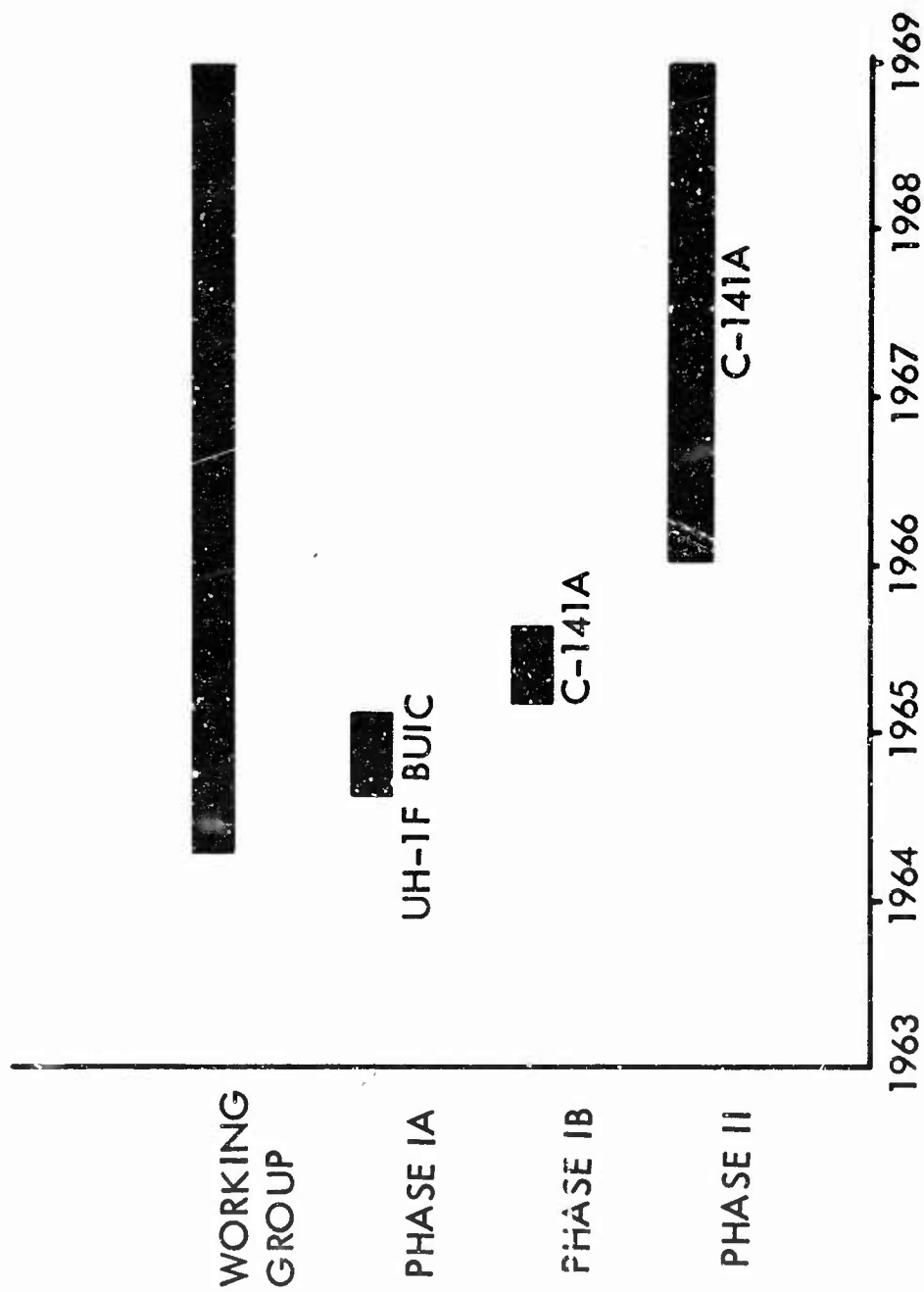
In 1964, the United States Air Force formally recognized the severity of the problem discussed above. Once it became apparent that the Air Force recognized that some major change in data concept was required, the Air Force became "deluged" with proposed "solutions" from the industrial community. The Air Force recognized that the problem was not sufficiently defined to allow selection of a solution.

The Air Force also recognized that a change of the technical order system would affect all commands, if not all services. This meant that all affected agencies should be involved from the outset. It was for this reason that Lieutenant General W. A. Davis, Vice Commander AFSC, initiated a working group in 1964 to plan a program to investigate the problem and to develop a cost-effective solution. This group was comprised of members from all major Air Force agencies, plus invited members from the other services. Some of the basic tasks of the group were to: 1) develop a work statement, 2) issue an RFP, and 3) monitor the contractors.

Two contracts were let in 1965; one to Serendipity, Inc. to study the problem on the UH-1F helicopter system, and the second to R. M. Parsons Company to study the problem on the BUIC (Back-Up Interceptor

Control) System. Both contractors emphasized the need for applying the job guide concept and the importance of the format in improving technician performance. Serendipity, Inc. further concluded that additional improvements were possible by using an audio-visual mode of presentation. The potential improvement in system effectiveness appeared so great that the Air Force requested both contractors to determine whether the concept could be applied to a more complex system -- the C-141A.

This short study indicated that the improvement in system effectiveness would be even greater for complex systems. Serendipity, Inc. was selected in June, 1966 to conduct an extensive field study of the concept in an operational setting. The first portion of the program was devoted to developing the guides and presentation means, and preparing for the test. The first phase of the test was initiated in January, 1968 and was conducted at Charleston, Dover and Norton Air Force Bases. A second, more concentrated test was initiated in November, 1968 and was restricted to Charleston Air Force Base. This test was completed in March, 1969. Almost all the important results of the program were obtained during the shorter but more concentrated test at Charleston Air Force Base.



Project History

IV. FORMAT FOR MAINTENANCE INSTRUCTIONS

A new, relatively simple but highly effective format for presenting maintenance instructions was developed during the PIMO Program. This format enables an individual with very little experience or knowledge of aircraft to efficiently perform both simple and complex maintenance activities.

The format was designed to provide all the relevant information for any given task, but no more. A task is defined as a short series of related actions -- no more than three. The format also provides the information necessary to prepare for an activity (input conditions). The frame or page is the basic unit of storage.

Both illustrations and narration are used to present the total information relevant to a given task. The illustration is used to present location information and to allow the user to relate the task instruction to the equipment upon which the action is to be taken. The pages are arranged to allow the user to have all the information relevant to a given activity located within one small book -- or in other modes of presentation, accessible without extensive search. The format is adaptable to many modes of presentation, including audio-visual.

The format itself is based on presentation principles derived from many different types of research. Research on short-term memory was used to determine how much information should be presented in one task.

"Short-term" is defined as a 20-30 second interval, which is about the elapsed time between reading the information and starting the task. Three separate but related steps are about the maximum amount which can be retained without errors. The maximum decreases when numerical information is involved, since it is shown to be more difficult to remember.

Research on scanning was used to determine the amount of information which can be included on one page or frame. Since the user is constantly switching from reading to working, or from the instructions to the illustrations, speed and accuracy of scanning to find the information of concern is important. Research shows scanning time and errors increase considerably when the number of items searched (in an unstructured presentation) exceeds seven.

Multi-sensory presentation studies were examined to help determine what information should be presented in narrative form and what information should be presented in illustration form. The narrative form can be presented in either the audio or visual mode.

Examination of current data presentation problems also had an influence. A fixed syntax (common sentence structure) was used to help overcome the reading problem. A fixed syntax helps reduce the amount of interpretation required on the part of the user because of the inherent redundancy. A preferred verb list was used to assure that the maintenance technician's language was used. This list was compiled from a survey of the users -- both in training and in the field.

The format is relatively simple, and therein lies its value. It presents the information in a clear and concise manner, at a standard level of detail. While certain pages of conventional manuals have characteristics similar to PIMO, the strength of the PIMO format is that all of its pages have the same basic characteristics.

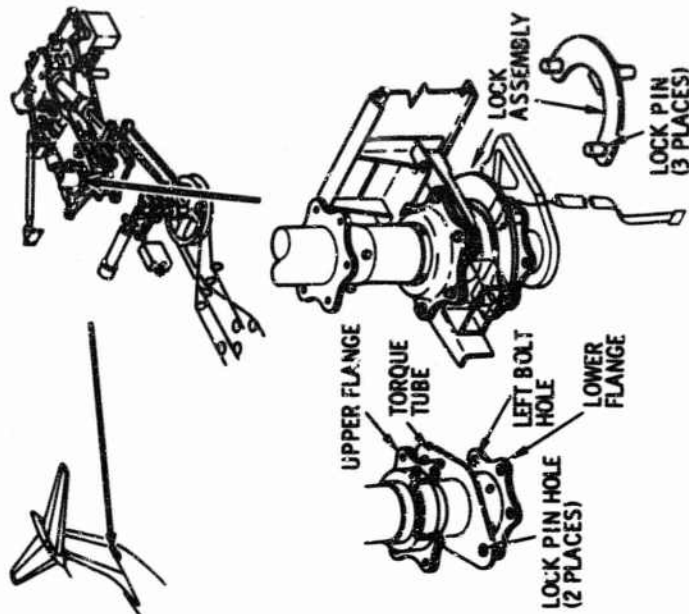
REMOVE RUDDER CONTROL PRESSURE SWITCH

Install rudder lock.

1. Request that assistant hold rudder in faired neutral position.
2. Remove left bolt.
3. Place lock assembly around torque tube from left side. Engage lock pins through forward and aft holes of upper flange.
4. Lower and engage center lock pin through lower flange left bolt hole.
5. Request that rudder be released.
6. Place streamer outside of aircraft through open tail cone or tail cone access door.

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Format for Maintenance Instructions

V. FORMAT FOR TROUBLESHOOTING AIDS

An entirely different format was selected for presenting troubleshooting information. One major decision made during the early portions of the program was whether to proceduralize troubleshooting, or to provide "system representation" information which would allow the technician to derive his own strategy. A review of the state-of-the-art of proceduralized troubleshooting indicated problems of flexibility, development cost, and user acceptance. * Therefore, it was decided to adopt the MDC (Maintenance Dependency Chart) portion of the SIMM's (Symbolic Integrated Maintenance Manuals) package. This technique has the advantage of being flexible, as well as being structured by checkout tasks themselves, thus limiting the user's search to only the information relevant to the task at hand.

The MDC displays the dependency of equipment items for each checkout task. When the user notes an out-of-tolerance condition, his troubleshooting task is limited to the equipment items shown to be on-line for that task. In this way, the user employs noted dependency information to determine the specific strategy for malfunction isolation.

Although MDC's have been tested by others on different types of electronics systems, this was the first application to general aircraft systems. Integrated (electrical/mechanical) schematics were used in lieu of precise access block diagrams and block text schematics which are usually contained in the SIMM's troubleshooting package. In addition, the MDC's for each subsystem were supported by:

- 1) Preliminary information sheets which provided aircraft effectiveness information and input conditions,
- 2) Parts location diagrams,
- 3) Functional descriptions -- primarily to make up in part for the lack of blocked text diagrams,
- 4) User instruction sheets, and
- 5) Index sheets.

The pages were packaged in eight volumes, each 11" x 17", with each volume covering several systems. Due to budget limitations, MDC's were not developed for all systems. In these cases, symptom-cause charts from the T.O.'s were substituted in order to assure that all troubleshooting information was covered.

A smaller index volume (8-1/2" x 5") allowed rapid access to the proper volume and section. This volume was designed in such a way as to allow the user to relate any given "squawk" to the proper troubleshooting data. One portion provided a schematic representation of indicators which allowed the user to find the proper data. Thus, a need to know indicator names was obviated. The indicators were arranged both alphabetically and by systems.

* Subsequent research efforts sponsored by the Human Resources Laboratory at Wright-Patterson Air Force Base show promise of resolving these problems. Continued improvements will probably result in a wide application of proceduralized troubleshooting. The proceduralized troubleshooting approach is in no way incompatible with the FMO Job Guide approach for maintenance instructions.

VI. TEST OBJECTIVES

The basic objective of the Phase II field test was to determine the extent to which maintenance effectiveness could be improved by the PIMO Job Guide format. Current maintenance practices were used as the reference or baseline for comparison.

This somewhat general objective can be stated in more specific terms by expressing it as a set of hypotheses to be tested. The hypotheses were expressed in positive terms as follows:

- A 10 percent reduction in maintenance time will be realized by reformatting technical order data to serve as job guides.
- A 45 percent reduction of maintenance errors will be possible when the technicians use the PIMO Job Guides.
- Presenting the reformatting data by audio-visual techniques will allow an additional 10 percent decrease in maintenance performance time.

- On approximately 80 percent of the maintenance activities, the reformatting data will allow a 3-level technician (apprentice) to perform as well as a 5-level technician (experienced specialist) using conventional T.O.'s.

- Application of the PIMO Job Guide concept will result in a significant lesser number of maintenance spares required, less maintenance demands on forward support bases, and a substantial improvement in operational effectiveness.

The over-all program had additional objectives, including the following:

- Provide specifications for an operational PIMO System which will allow the Air Force to procure the job guides and presentation means without undertaking additional testing.
- Provide job guides for selected C-141A aircraft.
- Specify Air Force systems (aircraft, missiles, etc.) to which the PIMO Job Guide System will be applicable and recommend presentation means for other Air Force systems.

- DETERMINE EFFECTIVENESS OF PIMO ON MAINTENANCE BY EXPERIENCED TECHNICIANS
- DETERMINE EFFECTIVENESS OF PIMO ON MAINTENANCE BY INEXPERIENCED TECHNICIANS
- DETERMINE EFFECTIVENESS OF TSA ON TROUBLESHOOTING
- DETERMINE DIFFERENTIAL EFFECTIVENESS OF DATA PRESENTATION MODES---A/V vs. VISUAL ONLY

Field Test Objectives

VII. BOOKLETS FOR FIELD TEST

The reformatted pages were packaged into fifty-eight 6-1/2" x 5" booklets, plus an index volume of the same size. Each booklet contained a maximum of 250 pages and could fit easily in the pocket of the technician's fatigues. No more than one booklet was required for any maintenance activity.

Generally, the booklets were packaged by systems. Wherever possible, all maintenance activities relevant to a given system were placed in the same booklet. Obviously, this was not possible for the more complex systems. In these cases, the system was further divided into segments or equipment groupings, and the data for all maintenance activities relevant to a given equipment item or grouping were located in one booklet. This was accomplished to assure that the user would not have to use more than one booklet once he was assigned to a specific repair job.

The following approach was used to ease data retrieval. Each booklet was assigned a unique number (1 through 58) and a dual numbering scheme was used to number pages within each booklet. Each activity was assigned a unique number, depending on the relative location of the data for the activity in the booklet. The pages for the activity were numbered consecutively, starting from 1 and ending with the last page for the activity. Thus, the first page for the first activity in a booklet was numbered 1-1. The first page in the second activity was numbered 2-1.

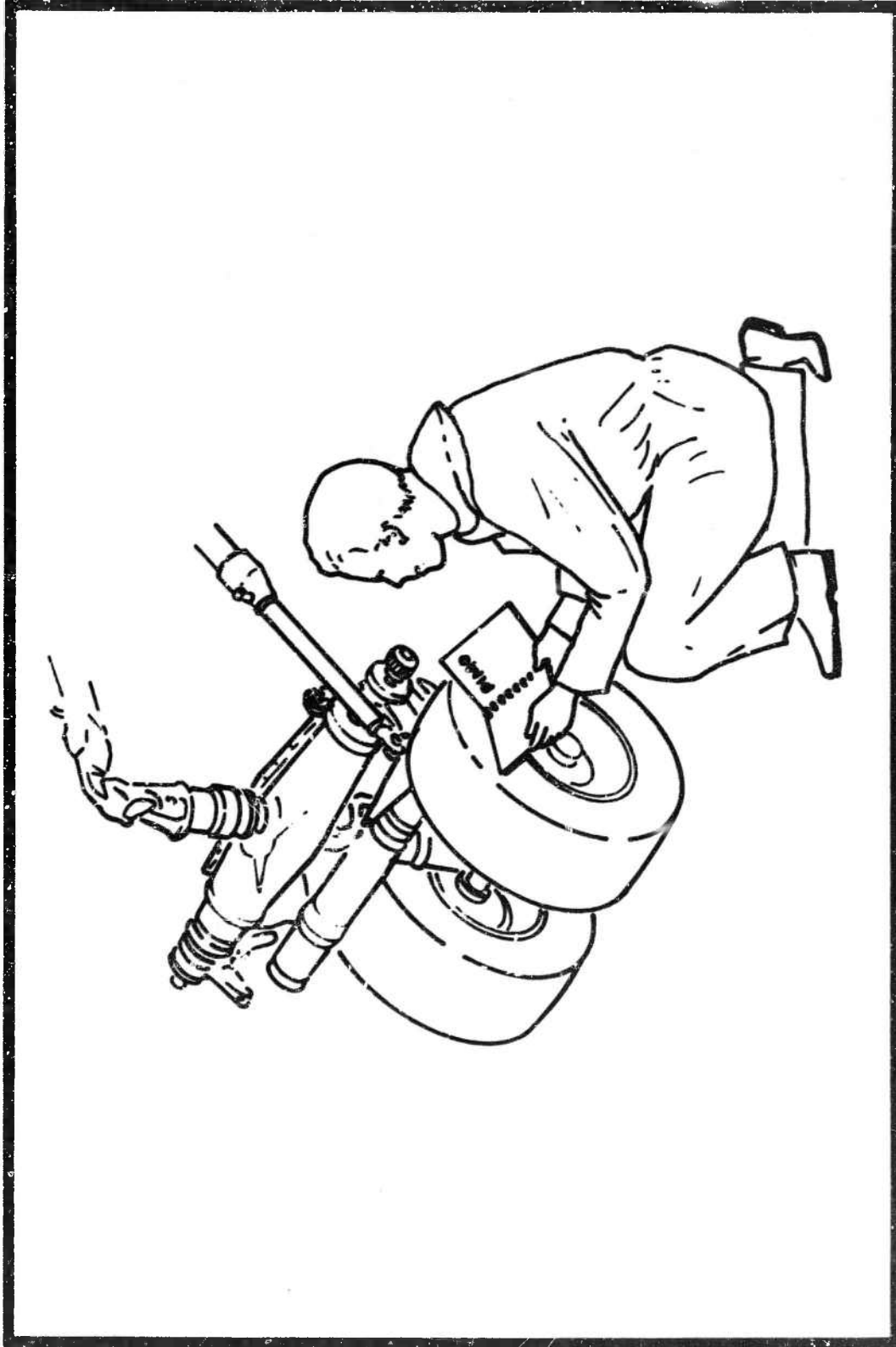
The numbering scheme took into account the manner in which a user would normally search for the data. His initial search is for a booklet and this search is limited to 58 numbers. The index volume identifies

the volume number for any specific maintenance activity. Once he locates the specific volume, he has to locate only the first page of the activity. The activity number is provided in an index page in each volume. The user then searches the pages but looking only for the first set of digits of the page numbers. Thus, if he is searching for an activity assigned the number 3, he knows any page with a 2- number precedes the activity of concern and any page larger than 3-1 is past the page of concern.

The Master Index Volume presented the index information in two forms, alphabetically by equipment items and by systems, since normally a technician knows the equipment item (for Remove and Install) or the system (for Checkout and Adjust). Only the volume number is identified in the Master Index.

An entire set of booklets can be placed in a small suitcase. In the main, a given shop will require only a small number of booklets. Some shops will require the same booklets, due to the overlap of assignments. The OMS would require a complete set since it is not specialized.

During one phase of the field test, one complete set (in a small suitcase) was dispatched to the aircraft. This set was used as a backup in the event a specialist forgot to bring a booklet from the shop. This approach was not necessary during the second phase of the test since the PIMO technicians were dispatched from a central location.



Visual Only (Booklets) Presentation of Maintenance Data

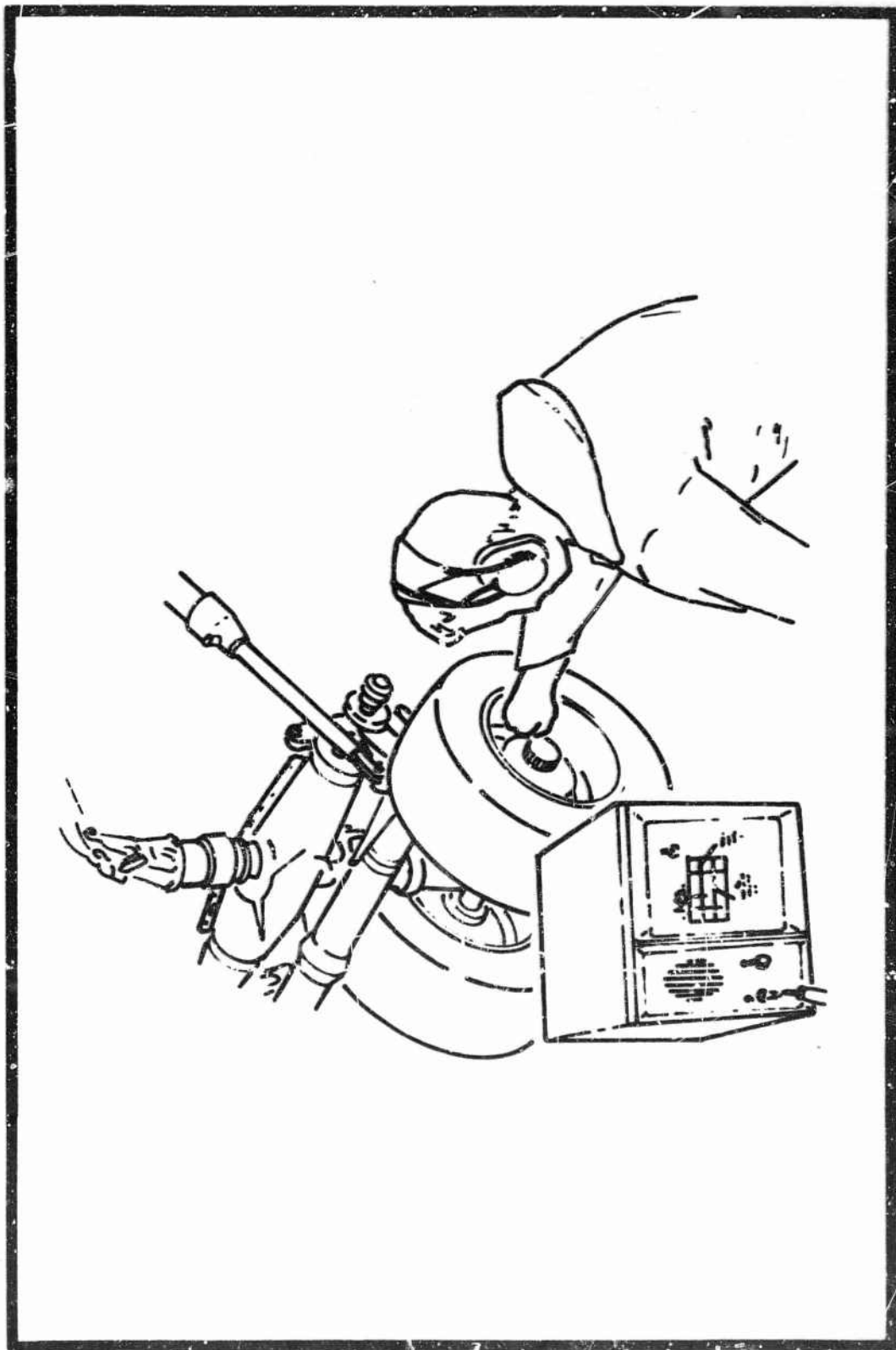
VIII. PIMO FIELD TEST AUDIO-VISUAL PRESENTATION MODE

A highly reliable, light-weight audio-visual device was used to test the concept of audio-visual presentation of maintenance instructions. The audio-visual device selected, Audiscan, was off-the-shelf equipment that allowed for an objective test of this concept, despite some of its compromises.

The maintenance data were exactly the same data presented in the booklet form with instructions given one task at a time. The maintenance technician commanded each task, thereby allowing him to work at a comfortable pace. Because the device did not have automatic repeat capability, repeats were provided by the observer upon demand.

The audio-visual "system" was comprised of two major parts: the Audiscan projector/playback and a cartridge which contained the maintenance information. The cartridge included a 16-mm film strip and a self-looping, two-track audio tape reel. To operate the device, the cartridge was inserted into the device and the advance button was depressed. An audio burst containing one maintenance task would be played. Then, the device would automatically stop. The machine would give no further instructions until the advance button was again activated. The visual presentation would advance automatically as dictated by the programmed instructions -- always in synchrony.

For test purposes and in order to reduce search and access time, only one activity was included in a cartridge. Each cartridge has a total capability of 225 frames and 30 minutes of continuous audio instructions. The Audiscan device was in continuous operation for approximately three months, during which time no equipment failure occurred.



Audio-Visual Presentation of Maintenance Data

IX. FIELD TEST DESIGN

The field test was carefully designed to permit an objective test of the hypotheses stated earlier. Particular care was paid to the design since a field test is the most difficult of all test situations. In fact, an approach calling for simultaneous testing at several Air Force bases had to be abandoned because of implementation problems. Since stringent controls were required to assure proper test implementation and data collection, multi-base testing appeared to be impractical.

The group of test subjects was composed of both experienced and inexperienced maintenance technicians, and was so divided into separate subgroups. Test Group A consisted of the qualified, experienced specialists from the CEMS and FMS; Test Group B was comprised of the unqualified (3-level) inexperienced technicians from the OMS, CEMS, and FMS.

The control group consisted of qualified 5-level maintenance technicians. The members of this group were assigned maintenance activities for which they employed standard Air Force procedures.

Half of Group A and half of Group B were assigned to do maintenance following the formatted procedures in the PIMO booklets. The other half of these groups was assigned to employ the audio-visual procedures. At the halfway point of the test, each group was assigned the opposite mode of presentation, thereby allowing each test subject to perform

maintenance employing the audio-visual and booklet procedure and to act as his own control.

Troubleshooting with the PIMO aids was performed by Group A (experienced personnel). Since troubleshooting data were not presented in the audio-visual mode, the comparison was designed to be limited to Group A with PIMO aids, with the control group troubleshooting in the normal manner.

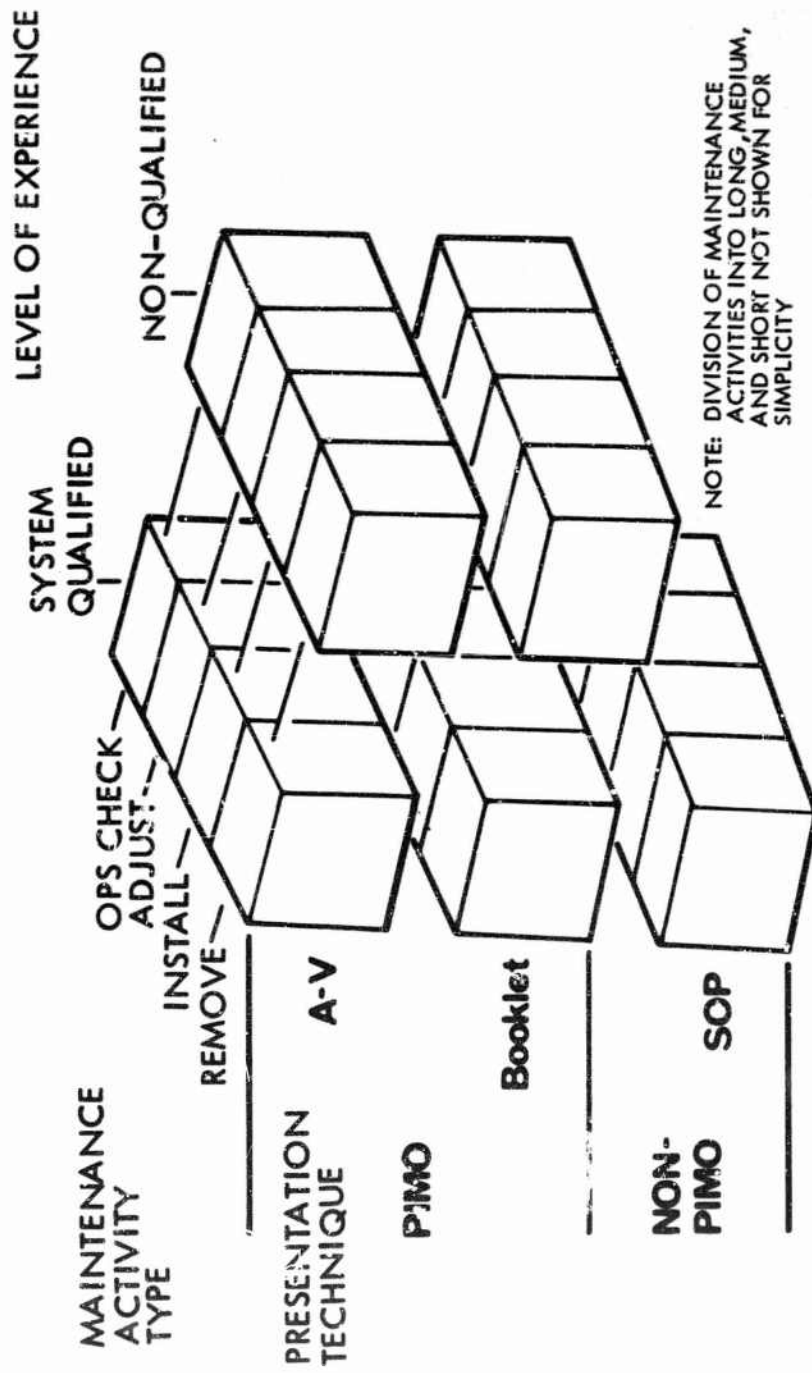
The design allows an objective test of both the main and interaction effects. The main effects of concern are:

1. The effect of PIMO Job Guides,
2. The effect of activity length, * and
3. The effect of experience (3-levels versus 5-levels).

The interaction of primary concern is the differential effect of presentation modes -- including format -- for different levels of experience and different types of maintenance activities.

(See Volume II for details concerning field test design).

* Activity length was treated as a main variable primarily for the purpose of increasing the sensitivity of the test for the other two main effects.



PIMO Field Test Experimental Design

X. FIELD TEST IMPLEMENTATION

The test was conducted over a four-month period at Charleston Air Force Base.* The test was administered by Serendipity personnel but direct subject participation (including data collection) was limited to Air Force personnel from the Military Airlift Command (MAC). Although care was taken to minimize interference, lessons learned from the earlier phase of the test indicated some interference had to be accepted in order to conduct a valid test. The interference was limited primarily to assignment of apprentices (3-level technicians) to complex maintenance activities, using the PIMO Job Guides.

Personnel participating in the test were selected by the Air Force at Charleston from CEMS, FMS, and OMS, in accordance with the field test design requirements. The personnel assigned to the PIMO test attended five days of classroom instruction devoted to the PIMO concept, and the use of the PIMO materials. There were a total of 36 PIMO test personnel, divided equally between Groups A and B. Both groups performed maintenance using the PIMO Job Guides.

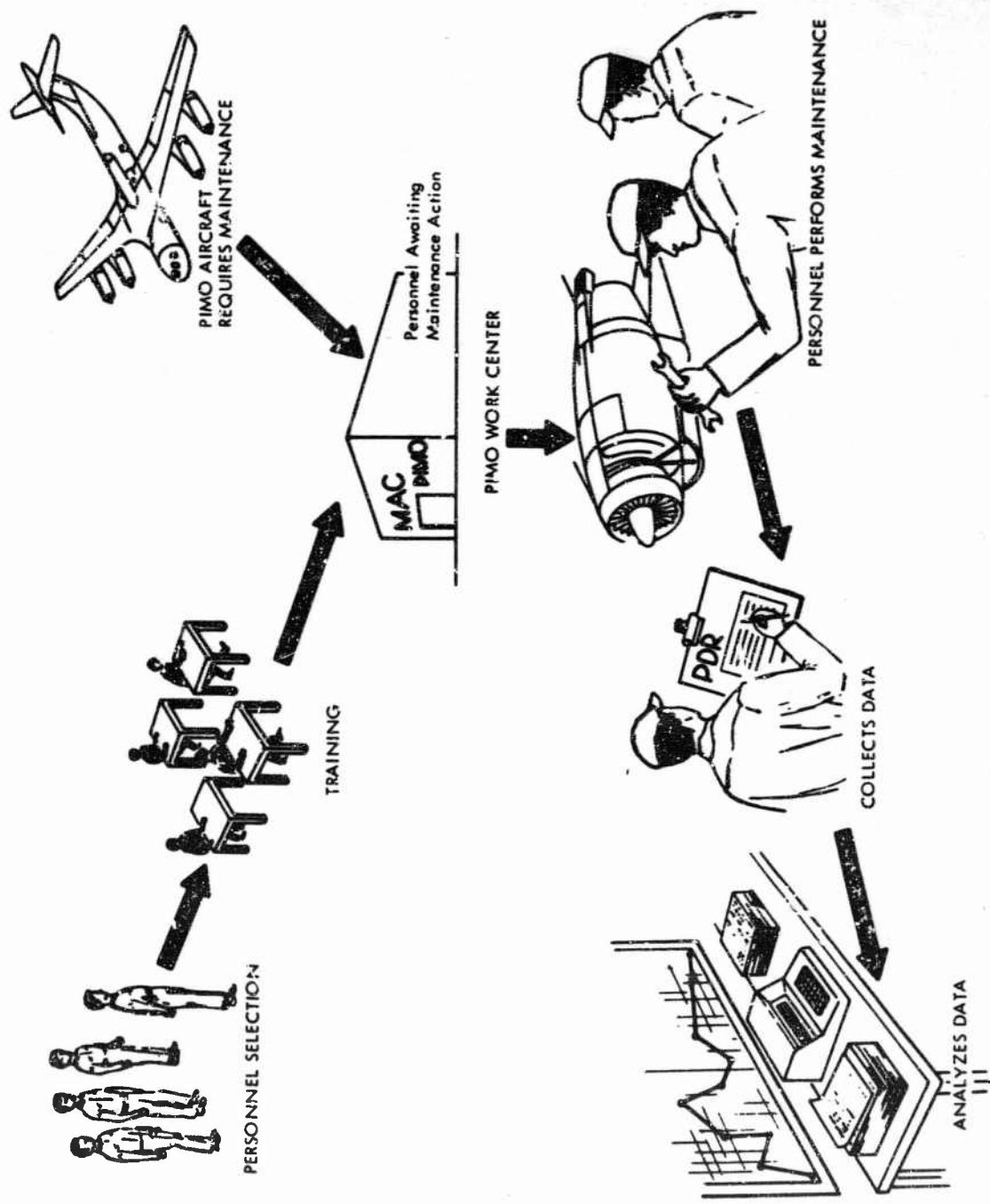
Twelve Air Force personnel "observers" were trained in the PIMO maintenance system and in data collection procedures; then they were assigned to their respective tasks.

Originally, forty C-141A's were assigned to Charleston as designated PIMO aircraft. Later, as a supplement to the assigned aircraft, PIMO maintenance procedures were performed on aircraft assigned to IRAN and NORB.

When an aircraft required maintenance, the PIMO work center was notified. Upon receiving this notice, the required maintenance task was assigned to applicable test personnel. Maintenance was then performed following the procedures dictated by PIMO. While maintenance was performed, data were collected by members of the observer group. The specific parameters monitored were job time and errors.

Analysis was performed continuously during the test period to facilitate identification and isolation of possible problem areas within the test structure. This analysis also permitted the observance of certain behavior trends which began to form, with the serendipitous discovery of additional areas of interest for testing. At the conclusion of the PIMO field test, a special test was conducted to compare performance aided by Air Force Technical Orders with the performance aided by PIMO Job Guides. During this special test, selected members of both groups (A and B) were assigned to perform maintenance following the instructions in the T.O.'s. A group of apprentices naive to the PIMO Job Guides were assigned to perform maintenance following just the instructions in the T.O.'s. Data were collected by monitoring the same parameters as were monitored during the "normal" PIMO field test.

* PIMO field tests for the booklet presentation only were conducted at Norton Air Force Base, Dover Air Force Base, and at Charleston Air Force Base. For information concerning these tests, see Volume II.



PIMO Field Test Implementation

XI. DATA COLLECTION PROCEDURES

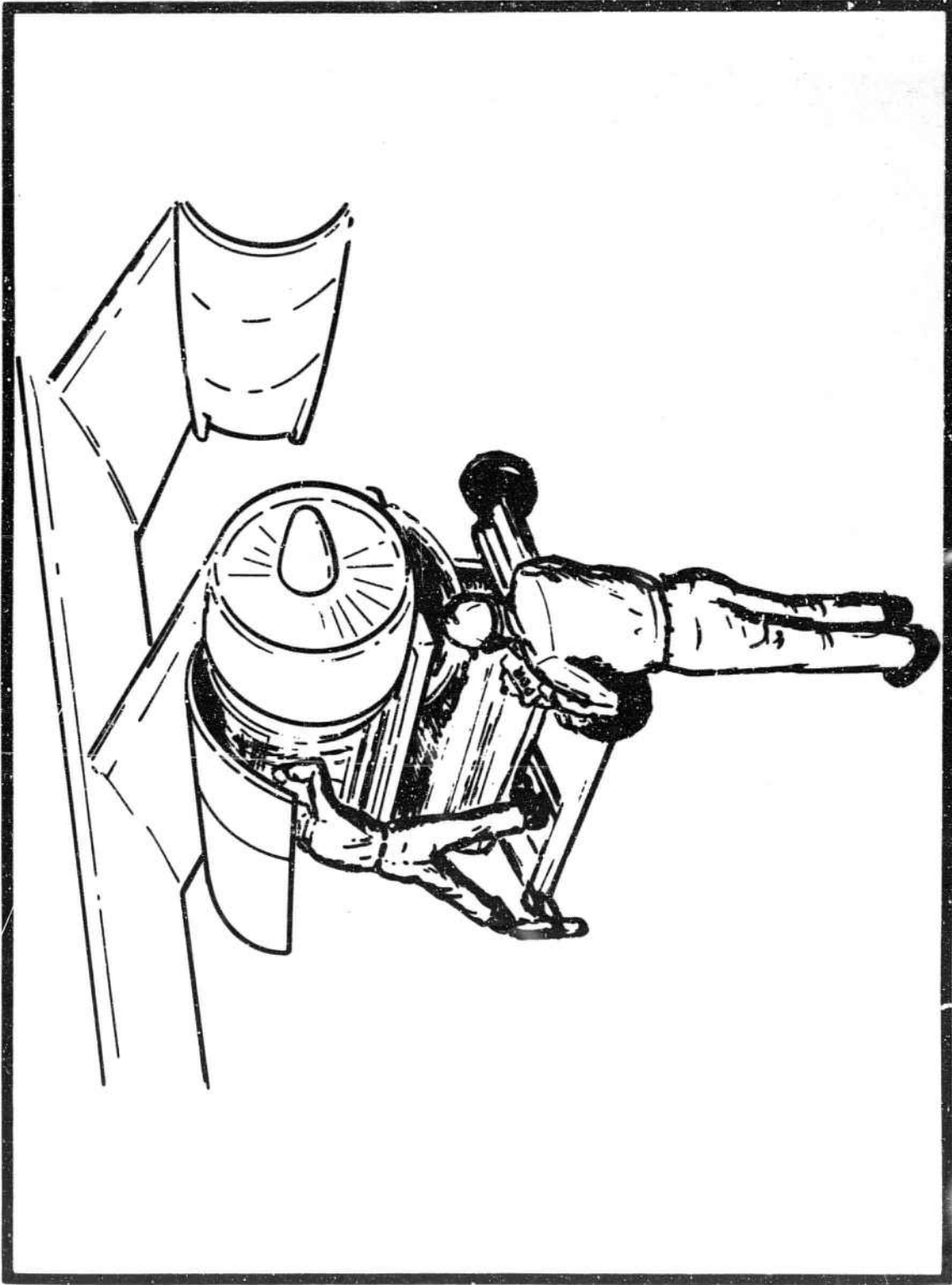
The data collection procedures used in the test were designed to minimize data contamination and maximize data reliability. The earlier phase of the field test indicated that sufficient measurement precision and data reliability could not be obtained with self-recorded data. Thus, the observer technique was adopted for the final phase of the test.

The data collection personnel -- known as observers -- were selected by Serendipity and the Air Force at Charleston, from the various maintenance squadrons. The nature of their job required these observers to have a complete understanding of the PIMO concept, purpose of test, and use of PIMO equipment and materials. The observers attended one week of classroom instruction where they were introduced to the PIMO concept and were allowed to develop their data collection skills.

The observers were present during all PIMO maintenance actions, where proper recording of performance time and procedural errors was their prime responsibility. The observer, following a script identical to the PIMO maintenance procedures, monitored the maintenance performed. Use of the script helped the observer to identify errors that might not have been identified otherwise. Performance time was limited to actual time on the job and did not include other contributors to maintenance man hours, such as travel, set-up, and waiting time.

All data were recorded on PIMO Data Records (PDR's). Upon completion of an activity, the observer checked all data on the card for completeness and accuracy, and then entered both the function performed and presentation mode employed. A matrix of completed maintenance was used as an aid in updating the data collection requirements. The data were taken from storage and organized for analyses every week.

Twice during the test period -- at the halfway point, and again at the completion -- questionnaires were the vehicle for obtaining the acceptance attitudes of the Air Force personnel using the various PIMO aids.



PIMO Field Test Data Collection

XII. DATA ANALYSIS

The analysis was generally guided by the experimental design. However, the richness of the data warranted additional analyses not initially planned. A significant portion of the analysis was devoted to conducting statistical tests for inferential purposes -- to allow generalizations to a wider population of Air Force personnel and situations. Both parametric and non-parametric tests of significance were used: Analysis of Variance, t tests, the Mann-Whitney U test, Chi-square test, and the Fisher Exact Probability test.

The Analysis of Variance was used to test the effect of presentation mode (audio-visual vs. booklet), experience (specialists vs. apprentices), and the interaction of presentation modes for different levels of experience. The Analysis of Variance was also used to test the difference between performance with FIMO Guides and normal performance by experienced specialists. The t test was used to compare specific means (e.g., mean performance times of specialists vs. apprentices for lengthy checkouts). Because of some suspected anomalies, the Mann-Whitney U tests were used to support the conclusions drawn with the t tests.

The Chi-square and Fisher Exact Probability tests were used to test the difference in error rates when comparing performance with FIMO Guides with performance with T.O.'s.

Descriptive statistics were developed for defining the acceptance of the PIMO Job Guides, obtained with questionnaires. Other descriptive statistics developed included curves showing the learning effect and relative changes when the same subject switched from one mode of presentation to another.

- I PIMO EFFECTIVENESS:
P x Q x R FACTORIAL DESIGN - ANALYSIS OF VARIANCE
MANN-WHITNEY U TEST
- II TSA EFFECTIVENESS:
STUDENTS t
- III USER ACCEPTANCE
 χ^2
FISHERS EXACT PROBABILITY

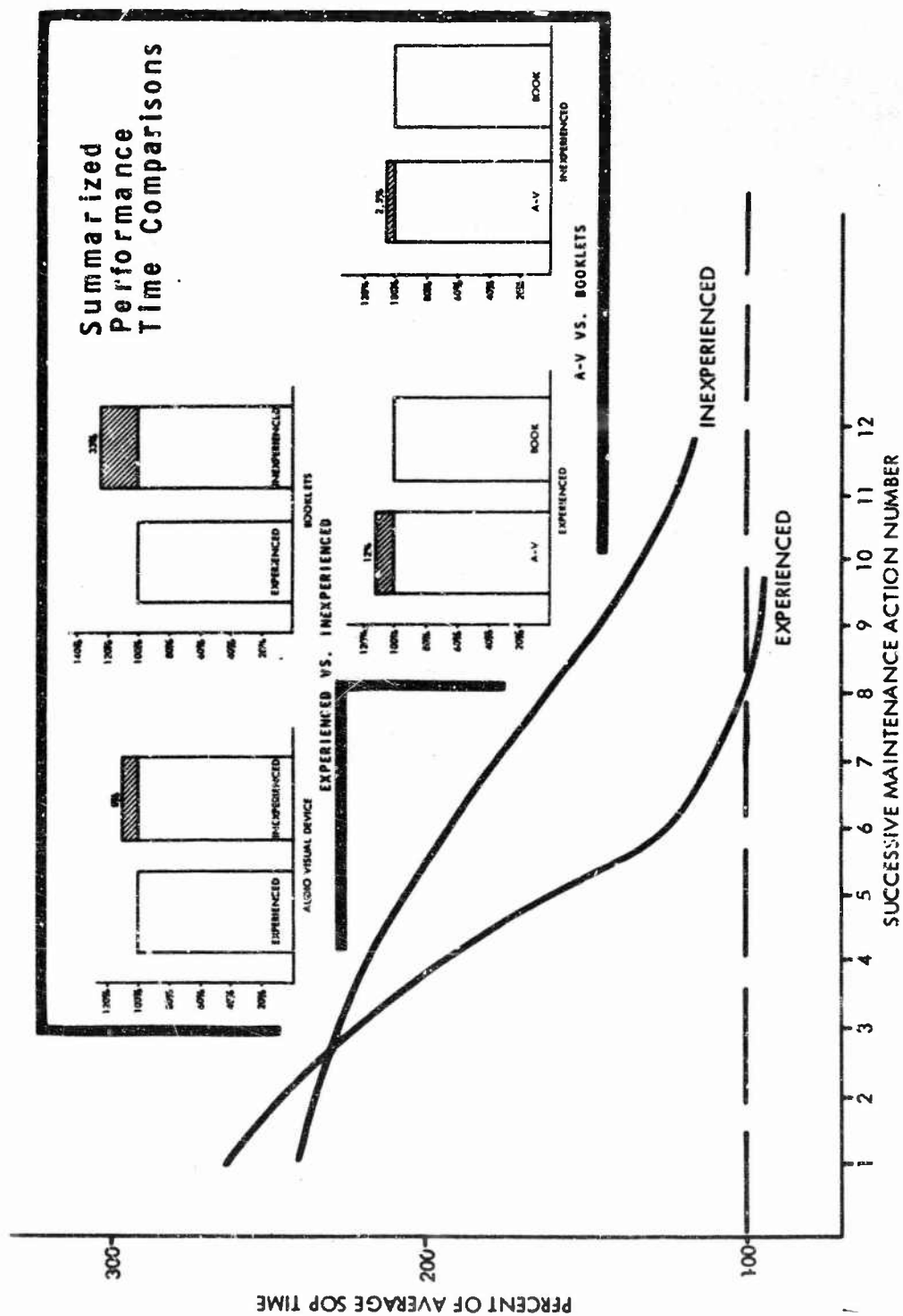
XIII. TEST RESULTS

The results of the field test indicate that the PIMO Job Guide concept provides an extremely effective means of improving maintenance while reducing support costs. Many of the findings are quite dramatic, especially in terms of manpower factors which currently plague all services. The results may be summarized as follows:

- Apprentices can perform as well as experienced specialists when both groups use the PIMO Job Guides. Whereas current maintenance practices result in a significant number of errors, no measurable error was noted for either group using the PIMO Job Guides.
- Both experienced specialists and apprentices showed strong evidence of learning while performing with the PIMO Job Guides. Generally, their performance times reduced (after about seven or eight trials) to approximately the same level as the very experienced specialist performing under "normal" conditions. During this learning period, all performance was error-free. This is not the case when technicians perform in their regular fashion.
- Although based on a small sample, the special test indicated that both experienced specialists and apprentices do commit errors when conventional technical orders are used as guides. It was noted that apprentices using PIMO Job Guides outperformed specialists using technical orders as guides.
- When apprentices attempted to follow the technical orders they committed numerous errors. Often, (two out of three activities used for the special test) they could not even complete the activity. When these same apprentices had learned

the activity with the PIMO Job Guides -- and then were required to follow the technical orders -- they performed as well as specialists using technical orders.

- The PIMO troubleshooting aids resulted in an 11 percent reduction of performance time and 92 percent reduction of maintenance errors.
- The effectiveness of the PIMO Job Guides depends on what is used as the point of reference. If experienced specialists performing in the normal manner (usually without data) are used as the reference for all PIMO groups, there is:
1) a 100 percent reduction of errors; and 2) an initial increase of time diminishing until about the seventh or eighth trial where it approaches the "normal" time as an asymptote.
- If experienced specialists using T.O.'s are used as reference for all PIMO groups, there is: 1) still a 100 percent reduction of error, and 2) no initial reduction of time, but a 50 percent reduction after learning takes place. If inexperienced apprentices using technical orders are used as reference, the comparison is meaningless, since: 1) the apprentices cannot perform adequately with the T.O.'s, and 2) when using the PIMO Job Guides, they can perform as well as the experienced specialists. There is no practical difference between the visual-only (booklet) mode of presentation and the audio-visual mode of presentation. There was some indication of faster learning at the outset with audio-visual, but there was not enough time to substantiate this effect.



PIMO Field Test Results

XIV. PIMO FIELD QUESTIONNAIRE RESULTS

The purpose of Project PIMO was to test an improved method of information presentation for maintenance technicians. However, it was recognized early that unless the users accepted the PIMO guides, usage would be severely limited, and the improvement potentials would not be realized. Therefore, a questionnaire was designed to obtain an indication of the acceptance of the PIMO Job Guides by those using them during the test. The questionnaire and results are discussed in detail in Volume II, Sections Five and Six.

In summary, the attitude of the users was highly positive, both for the experienced and inexperienced technicians. Both technician groups indicated intent to use the guides (if available) for jobs which occur relatively infrequently. Surprisingly, about half of the technicians indicated intent to use the guides even for jobs occurring frequently.

Although both groups showed a highly favorable attitude, the inexperienced technicians showed a slightly more favorable attitude. Both groups were unanimous in their feeling that the PIMO Job Guides would be good training aids.

Both groups evidenced a preference for booklets over the audio-visual device. However, as the frequency of occurrence of the specific job being performed decreased, the difference in the preference for booklets over the audio-visual device also decreased. The main objection to the audio-visual device seemed to be the size and its inability to repeat individual maintenance steps. Both of these objections undoubtedly could be corrected in a more advanced device.

- HIGH DEGREE OF ACCEPTANCE OF PIMO FORMAT
- 80% EXPERIENCED & 100% INEXPERIENCED BELIEVE AIR FORCE IS "HEADING IN RIGHT DIRECTION"
- TECHNICIANS AGREE PIMO :
PROVIDES GOOD REFERENCE MATERIAL
PROVIDES GOOD TRAINING AIDS
ARE EASY TO USE
SHOULD BE MADE AVAILABLE FOR OTHER AIRCRAFT

XV. SYSTEM EFFECTIVENESS IMPLICATIONS

The system effectiveness implications of the PIMO Job Guide system are quite astounding. There are very good indications that by applying cost and production control techniques, the cost of developing the PIMO Job Guide materials can be kept within the same general cost regime as the conventional technical orders. Thus the difference in system or cost effectiveness arises primarily from an increase of value. Translating the increased value to dollar terms is not always meaningful, since generally it is not measured in dollar terms. It is more meaningful to translate the improved values into system terms.

As indicated previously, the job guides will allow essentially immediate utilization of maintenance personnel assigned to a squadron. This relatively simple process of using personnel normally on O.J.T. (on-the-job training) will reduce the time a one-term enlistee spends in training by approximately 25 percent, and increase the maintenance manpower available for productive maintenance labor by as much as 50 - 100 percent. However, this saving will be possible only if the inexperienced technicians are assigned to the jobs covered by the PIMO Job Guides.

If the inexperienced technicians (both in the shops as well as the Organizational Maintenance Squadron) are assigned the meaningful jobs covered by the job guides, other system level improvements are possible. The improvements will depend on the scope of coverage with the job guides, and the extent to which the job guides are used religiously. It is unreasonable to expect the same level of improvement (92 percent - 100 percent reduction of errors) noted on the test. Without the necessary operational experience, an estimation of improvement potential can only be a guess. We are therefore conservatively estimating that the improvements in the operational setting will range between 50 - 100 percent of the improvements noted in the test.

Departure reliability (including reduction of flights with deferred maintenance) can increase somewhere between 50 and 65 percent. The time an

aircraft spends in unscheduled maintenance at the home base only can be reduced 37 to 44 percent. The percent of time an aircraft is operationally ready can be increased 38 to 40 percent. The improvement potentials will be even greater after the job guides have been in use for a few months due to the reduction of performance time as learning takes place.

If the number of missions is kept constant, there is a significant reduction in both demands for personnel and spares. Since reduction of personnel for an existing system is difficult, the reduction of personnel demands will probably have an impact primarily on new systems. The results show that if the Air Force is willing to keep departure reliability, time in maintenance, and operational readiness at the current level, they can reduce the manpower pool for a large segment of unscheduled maintenance by 30 to 39 percent. This also means that even for existing systems, the Air Force will be less vulnerable to manpower shortages.

The results also show that the improvement in cargo-carrying capability for just the C-141A will be equivalent to adding 16.44 more C-141A's to the fleet. However, this only represents an increase in capability. Whether the capability is applied will depend on many other factors, such as mission demands and air crew availability.

More extensive system effectiveness analyses were not conducted since the potential gains already identified far outweigh the cost involved. For example, the reduction of O.J.T. for only the 431X1E technician would probably save 22 times more money than it would cost to expand the job guides to cover the entire C-141A fleet. If the operational life of the C-141A extends another five years, the multiple will increase to over 100. The cost of converting the data for any existing aircraft system is expected to range from \$500,000 to \$1,000,000, depending on the complexity of the system and adequacy of the existing data. The cost of expanding the current PIMO Job Guides to the entire C-141A fleet is expected to be far less.

PERCENTAGE IMPROVEMENT

	25%	50%	75%	100%
TIME IN TRAINING (DECREASE)	25%			
ERRORS (DECREASE)			50%-100%	
DEPARTURE RELIABILITY (INCREASE)		50%-65%		
HOME BASE MAINTENANCE (DECREASE)	37%-44%			
OPERATIONAL READINESS (INCREASE)	38%-40%			
MANPOWER DEMANDS (DECREASE)	30%-39%			
CARGO CARRYING CAPABILITY (INCREASE)	6%			

System Effectiveness Implications

XVI. TRAINING IMPLICATIONS AND APPLICATIONS

There is almost overwhelming evidence that the technicians learn while performing with the FIMO Job Guides. Both the experienced (generally 5-level) and inexperienced (generally 3-level) specialists as well as the inexperienced non-specialists (e.g., 431X1E) showed the same type of learning. Furthermore, their performance times reduced within a very short time to the same level as the very experienced specialist who knows the job well enough to perform without data. Even more importantly, their error rates were essentially zero.

These results have considerable implications and applications for training. For one, the results indicate that the job guides provide the method for putting newly trained technicians immediately to productive maintenance work. Through the use of FIMO, within a very short time technicians will be performing maintenance that is essentially error-free and expending about the same time at it as the very experienced specialists.

The job guides also provide a method whereby technicians can be assigned to squadrons without specialist training -- and probably with lesser training than is currently being given to non-specialists assigned to Organizational Maintenance Squadrons. These technicians subsequently can be assigned to specialist schools if they intend to remain in the Air Force. The on-the-job experience with the job guides should be excellent background for the school. In the meantime, the Air Force will be able to realize productive maintenance from the technicians without the investment of expensive specialist training.

There are approximately 5,700 431X1E's assigned to the C-141A. Assuming a conservative figure of 1,000 new 431X1E's per year due to turnover, a significant savings can be realized simply by reducing training. Assuming a cost of about \$4,500 per man for on-the-job training (OJT), elimination of OJT for the 431X1E should result in a savings of approximately \$4,500,000 per year. Assuming about \$3,500/man in formal training, another \$3,000,000 to \$3,500,000 can be saved by reducing formal training of the 431X1E's to a minimum.

Specialists and specialist training will still be needed, especially for troubleshooting and jobs not covered by the guides. However, the training can be restricted to those electing to remain in the Air Force.

The test results also indicate that the job guides represent an excellent training tool. If a goal is to produce technicians sufficiently proficient that they can perform without data, the job guides would be an excellent way to train such technicians, either on the job or in a training situation. The job guides would not be useful for "educating" the technician but have, with certainty, proven themselves effective for training a technician to perform a given activity.

Lastly, there is some indication that the audio-visual presentation mode, using the same job guide format, can further facilitate training. This may be an effective method to train technicians for activities which occur with such a high frequency that development of job guide data would not be cost effective. The high frequency would assure sufficient retention from one occurrence to the next. However, training must assure that replacement personnel on their first assignment will have sufficient skill to complete it satisfactorily.

- **POTENTIAL TRAINING SAVINGS**
(\$4,500,000 FOR 431X1E)

- **LEARNING ON-THE-JOB**

- **REDUCED SPECIALIST TRAINING**

Training Implications and Applications

XVII. PIMO OPERATIONAL SYSTEM

The recommended PIMO operational system is a visual-only system, using booklets as the presentation mode at least for the C-141A. An integral part of this system is a computerized data management and production control subsystem. The job guides represent a system, regardless of the mode of presentation. Thus, the booklets will be described as a system, using parameters which will have to be considered if any other mode of presentation (e.g., viewer) is to be considered in the future.

There are three basic units within the system -- the basic presentation unit, the basic storage unit, and the basic package unit. All the information required for a task represents the basic presentation unit. A task is comprised of no more than three steps or separate actions and generally represents no more than two minutes of action. Each task represents a presentation. A page or frame represents the basic unit for storage. Information for a group of tasks is stored on a given page and is retrieved as a set. An activity represents the basic packaging unit in that all pages relevant to a given activity are packaged together. In the case of the booklets, two or more activities are packaged together in one booklet. However, the basic requirement is to keep all pages for an activity together.

There are four presentation parameters which help make the booklet system an effective one. Search time for the task information is kept to within three seconds by the arrangement on a page and the limitation of tasks and identifiers on a given page. Access accuracy is maintained at a very high level by the use of a fixed syntax and a preferred verb list. User retention is facilitated by limiting the quantity of information per presentation unit to the quantity adequately handled (three items) within the limitation of short-term memory (20-30 seconds). User flexibility is facilitated by allowing any task on a page to be available to the user without extensive effort. If devices are used, care should be taken to prevent degradation of these four parameters.

A technician can only use one page at a time. Therefore, he need only retrieve one page at a time. However, he will tolerate less time in moving from one page to the next when he is within an activity (e.g., Remove) than when he is between activities (e.g., switching from Install to Checkout). The retrieval time for the next page or frame is simply the time to turn a

page (which should not be exceeded significantly by a device). The time to retrieve the first page of an activity is longer, but probably within 10 seconds.

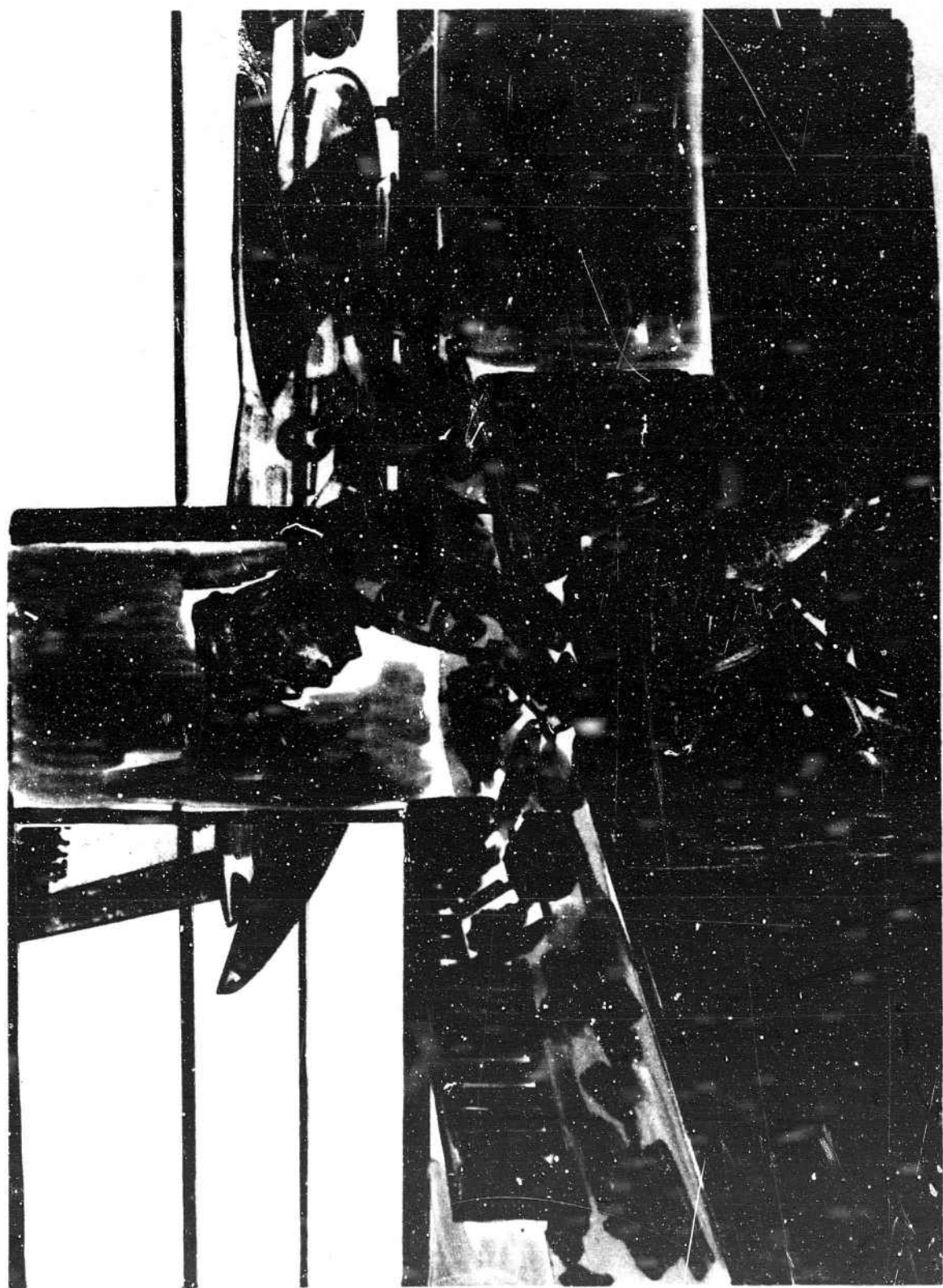
The booklets and TSA's are highly portable and take very little space in any given work area. Resolution and visibility are excellent in daylight and high ambient lighting conditions. Any device will tend to degrade resolution but would improve visibility when the ambient illumination is low.

The critical aspect of data configuration control is to assure that the data required for a given activity are up to date. This does not mean all the data have to be up to date all the time. If only 40 percent of the data account for 90 percent of the maintenance actions, assuring that the 40 percent is kept up to date at all times will assure that 90 percent of the actions will be covered with up-to-date data. This will mean a fast turnaround for the data in the 40 percent category -- probably close to a 24-hour turnaround for those pages which are critical. Due to the high expected usage, the turnaround time should be short (two to three days) even for the "non-critical" data. For the remaining 60 percent of the data base, a more leisurely time can be established for the "non-critical". However, the time should be based on use expectancy.

The computerized data management system will allow an update scheme as described above. Page changes can be handled in the field (as with conventional T.O.'s) or can be handled like microfilm cassettes, i.e., new booklets sent to the field with the proper pages.

Reliability for the booklet system refers essentially to the durability of the paper. This could become a problem at offshore bases. More durable materials can be used but will weigh and cost more. If visual devices are to be considered, reliability must be quite high or it will tend to outweigh the advantages in configuration control, visibility, and data accessibility.

The booklets should have essentially no maintenance problems except for changing pages.



XVIII. DEVELOPMENT AND PRODUCTION OF MAINTENANCE INSTRUCTIONS

The PIMO Job Guide format for maintenance instructions is deceptively simple. Indeed, the format appears so simple at first glance that:

1) little credence is given to its power; and 2) development of the format appears straightforward. This is unfortunate since one breakthrough in PIMO was the fact that many different people with different backgrounds were able to produce thousands of pages with identical format characteristics.

Six important factors contributed to the successful development of the formats. These factors were:

1. Measurable specifications -- The specifications are defined in explicit and measurable terms to allow ready identification of deviations. The critical specification items included: level of detail, quantity of information, sentence structure, verbs and illustrations.
2. Job Guides -- Detailed job guides were provided to eliminate by standardization the need for creative writing. Specific guidelines were provided for syntax (sentence structure), verbs, nouns, arrangement, acquisition of additional information, selection of illustrations, and standard procedures.
3. Equipment indenture -- A common equipment indenture scheme was developed to assure complete coverage as well as elimination of voids. The indentures were based on a functional partition of systems which provided a measurable criterion for assigning equipment items to subsystems or other equipment groupings.

4. Flow analysis -- A detailed functional flow analysis at the outset helped determine the necessary work and flow for all data items. The input-output relationships were clearly defined which allowed establishment of standards and flow control processes.

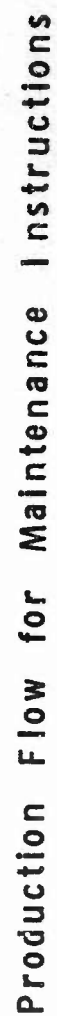
5. Production control -- A production control process similar to those used for hardware production was developed and used. The process allowed measurement of both time and error rates for each function.

6. Quality control -- Every page was inspected for quality by specially trained human factors specialists.

All data for a maintenance activity* were packaged together and processed as a single package. Relevant pages of the T.O.'s served as the basic input data. However, every T.O. page had to be supplemented with additional details. These details were obtained from MAC technicians by Serendipity analysts. Each package was then given to the formatter group which was comprised of high school graduates. The formatted data were reviewed by the analysts for technical content and by the Quality Control personnel for adequacy of presentation. All major changes of procedures were sent to the field for validation/verification.

Once the review was completed, duplicate copies were made. One copy was sent to typing. A second copy was sent to the illustrators. Both copies were returned with the final product to Quality Control for final review. Actual production was not initiated until all the formats for a given system were completed.

* A maintenance activity is defined as a maintenance function (e.g., Checkout, Remove, Install, Adjust) applied to an equipment item (e.g., ADF system, input quadrant).



XIX. DEVELOPMENT AND PRODUCTION OF TROUBLESHOOTING AIDS

As in the case of the development of job guides, development of Troubleshooting Aids (TSA's) of standard quality and of the same basic characteristics makes the difference between useful and non-useful aids. Unless different people can produce to the same basic quality, the usefulness of the aids will become dissipated.

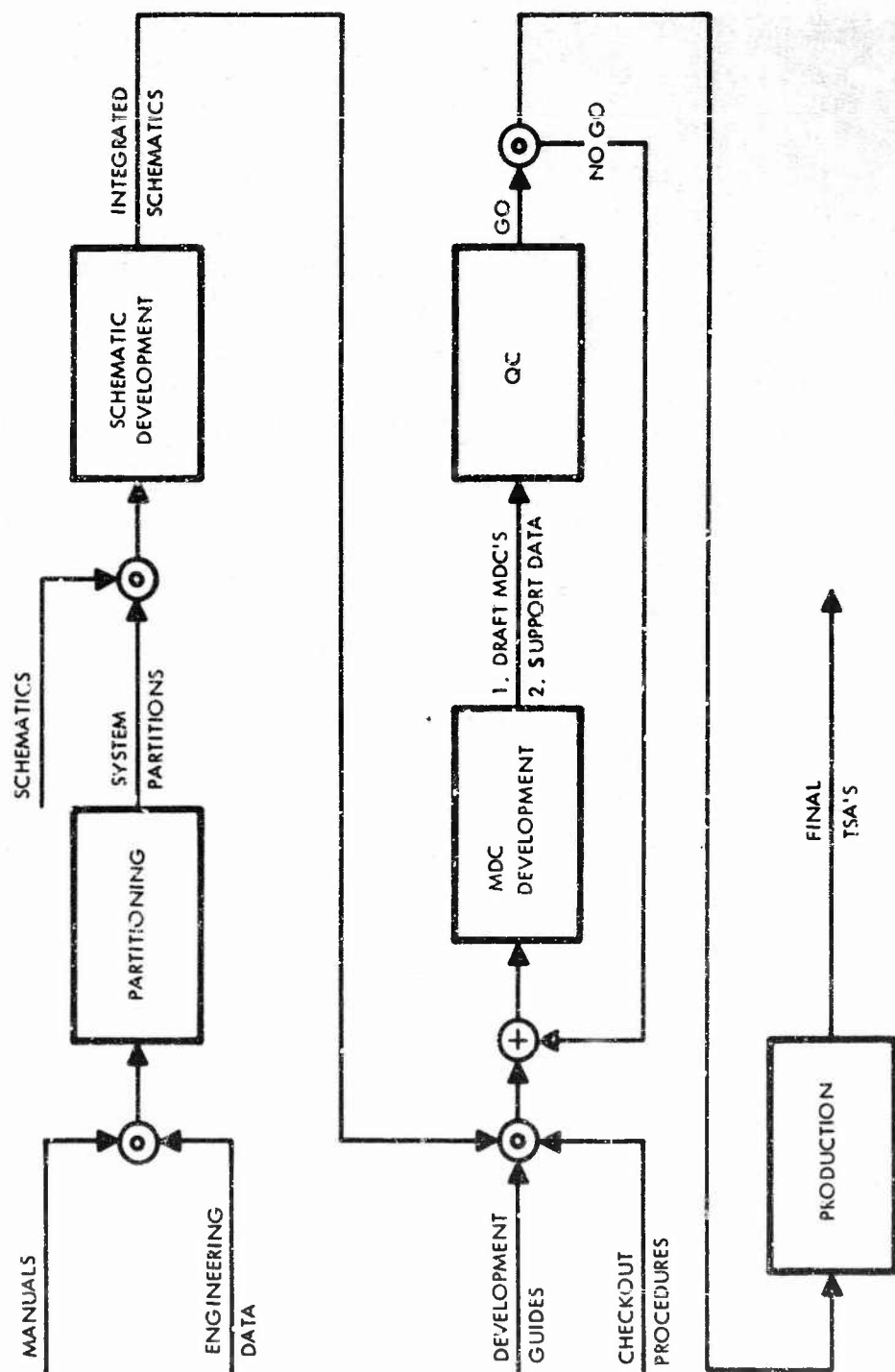
Four important factors contributed to the successful development of the TSA's.

1. System partitioning -- The C-141A aircraft system was partitioned into functional segments. The partitioning was carried to the point where "troubleshooting units" were defined. Inputs and outputs (both functional and signals) were used to define the boundaries of each unit. Each unit served as the basis for a troubleshooting package. Proper system partitioning to a "troubleshooting" unit level is important not only for packaging the final product but also for work assignment, coordination and control.
2. Integrated schematics -- Troubleshooting data cannot be developed without a thorough understanding of the system. This understanding was obtained through the construction

of an integrated schematic for each system. These schematics were used to develop the MDC's and were included in the package as backup for the MDC's.

3. Job Guides -- Detailed guides were developed both to aid the individual analyst and to assure standard quality. The guide required frequent revision during the development phase as a function of feedback from the effort itself. The guide covered such factors as level of detail, arrangement of entities, identification of outputs and points of measurement, and how to handle feedback circuits.
4. Quality Control -- Each TSA package was carefully reviewed for Q.C. purposes by an experienced analyst. Approximately 25 to 50 percent of the original development effort was spent in Q.C. Valid quality control was not possible without a certain degree of redundant analysis.

Higher level people were required to develop the troubleshooting aids as compared to those required to develop maintenance instructions. However, proper application of computer technology and partitioning the total effort into smaller segments can result in significant decreases in cost and personnel capability requirements.



Development and Production of TSA's

XX. BTDS DATA MANAGEMENT SYSTEM

Such complex military and commercial systems as aircraft, communications centers, and traffic control centers, require thousands of pages of maintenance information. The management and control of the data itself present major problems, and Project PIMO was no exception. Thus, as an integral part of the project, a group of computer programs was developed to aid in the management, configuration, and production control of the voluminous maintenance data. The Basic Technical Data Storage (BTDS) programs were used as the major configuration and production control tool during the preparation and use of the PIMO Job Guides for the C-141A aircraft system.

The BTDS Configuration Management Program is an inventory control program specifically designed for the storage of all information pertinent to system maintenance. Such data include identification of end items, special tools, test equipment, and source data -- e.g., engineering drawings and reports, maintainability data, reliability data, checkout procedures. As changes occur to the prime system, the BTDS' rapid access query system provides specific information regarding the effect on the maintenance data system.

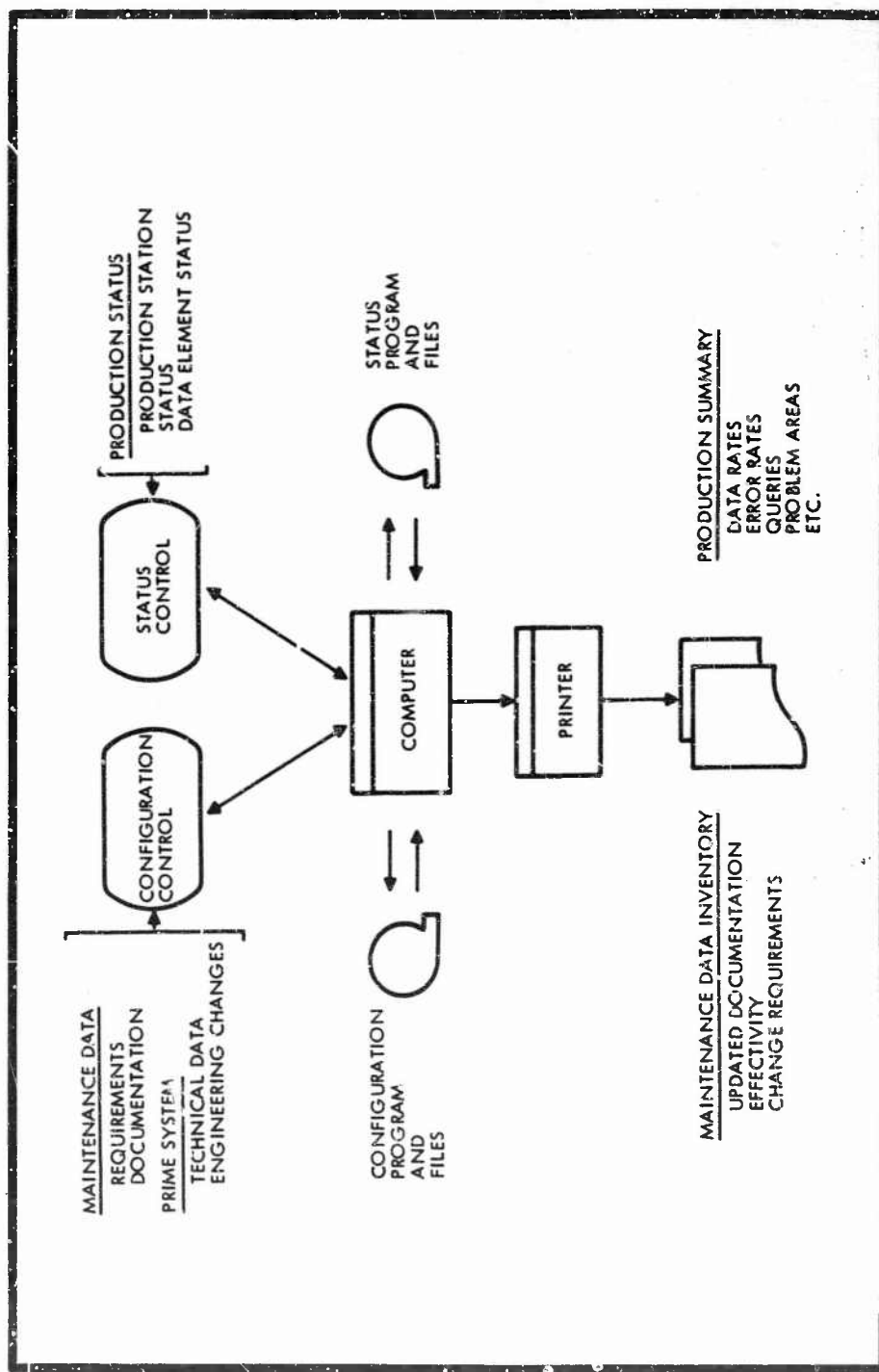
Additionally, the BTDS includes a production status program to simplify the process of controlling the production of the data. During the development of the job guides, significant points in the production process are monitored. Surveillance is maintained over any specific breakdown of functions or equipment. System, equipment group, and maintenance functions, for example, were common levels of surveillance. The pro-

gram also provided status of the loads and queues at individual points in the production cycle, thus allowing management to evaluate the overall production status and make adjustments accordingly.

Both the configuration control and production control programs of the BTDS were tested during the PIMO Program -- June 1968 through March 1969 -- where approximately 1,300 pages of maintenance data were produced for the PIMO field test. These data represented approximately six hundred maintenance segments. A segment was a package of data representing one action (Troubleshoot, Adjust, or Remove, Install) against an end item or end item group (system). As the maintenance segments were formatted, the BTDS provided weekly status reports as to the over-all data preparation, production loop status and status (location within the production cycle) of any required data package. At the same time, these data segments were documented -- material covered, source data used, etc. -- to provide a data base for query as changes were made in the system hardware and/or system technical data.

These programs proved their worth in control over the production of the materials and facilitated a fast and efficient update to the maintenance data.

The programs are written in COBOL for the IBM 7094 and are applicable for any technical data management system. In fact, they are suitable for many other inventory and production control applications.



BTDS Data Management System Flow Diagram

UNCLASSIFIED

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3. REPORT TITLE		2b. SUPP
Project PIMO Final Report - PIMO Final Report Summary		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)		
Technical Report -- June 1966 - April 1969		
5. AUTHOR(7) (Last name, first name, initial)		
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13. ABSTRACT		
This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guide presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Maintenance Aids, Improved Job-oriented Guides Aircraft Maintenance Troubleshooting Aids Field Test of Maintenance Aids Audio-visual Presentation, Maintenance Data Maintenance Dependency Charts, Preparation of PIMO, Programmed Information for Maintenance Technical Data, Reformatting of Technical Data, Specifications for Technical Orders, Comparison of (with PIMO) PIMO, Project Final Report						

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