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A FIELD SURVEY OF ELECTRONIC MAINTENANCE TECHNICAL DATA

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FOREWORD

This study was initiated by the Behavioral Sciences Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. It represents a portion of the exploratory development program conducted under Task 171004, "Techniques for Training, Aiding and Evaluating the Performance of Technical Tasks," of Project 1710, "Human Factors in the Design of Training Systems." Dr. Gordon A. Eckstrand was project scientist. Dr. Ross L. Morgan was task scientist. This research began in April 1966 and was completed in April 1967.

This report covers part of the research conducted under Contract AF 33(615)3966 by Applied Science Associates, Inc. Dr. John D. Folley, Jr. was the principal investigator. Mr. John P. Foley, Jr. of the Technical Training Research Division, Behavioral Sciences Laboratory, was the technical contract monitor.

This technical report has been reviewed and is approved.

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ABSTRACT

A survey, using interview and observation, was made in five subject areas to determine current and anticipated problems associated with development and use of performance aids in the Air Force, and to identify implications of those problems for relevant research. The five areas surveyed are: job-task content and current performance aids for electronic technicians at typical Air Force sites, unique problems of performance aids in limited war operations, current requirements for optimum performance aids, the nature of future electronic technology as it may affect performance aids, and current and future developments in performance aids technology.

Visits were made to 12 different Air Force bases, nine equipment development firms and laboratories, one commercial airline maintenance facility, one commercial communications firm, and conversations with ten researchers working in technical data and job performance. About 800 man-hours were spent in collecting information.

The survey indicated that a wide range of maintenance concepts are found in the field (from complete modular replacement to replacement of piece parts such as resistors and capacitors); that limited war operations do not change the job-tasks and the performance aid requirements of the electronic technician; that a number of job performance aids systems based on advanced technology have been tested and found to be effective; but that advanced training and performance aids technologies have not been generally applied to operational situations although the vocabulary associated with these technologies is often used.

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SECTION I

INTRODUCTION

The objective of this study is to determine current and anticipated problems associated with development and use of performance aids in the Air Force and identify implications of those problems for relevant research. It was thought that this objective could be achieved through obtaining information in the following five areas:

1. Determine the job task content and current performance aids in at least 5 typical sites in the Continental United States.

2. Identify unique problems associated with the development and use of performance aids in limited war and counterinsurgency operations.

3. Determine current requirements for optimum performance aids based on electronic technology presently found in the field as well as on the technology being used in new equipments currently being programmed into the Air Force.

4. Gather information as to future electronic technology and its input to performance aids requirements.

5. Gather information on current and future performance aids developments and electronic trouble location systems, including related research.

The information collected in this survey was obtained through observation and interviews cutting across these five areas (sections III thru VII herein) of the survey. Each area with its procedure and findings, however, represents a substudy in itself. They are therefore reported individually, in the order listed above.

SECTION II

METHOD

Because the kind of information to be gathered in this study is qualitative in nature, qualitative methods were used to collect the information. Nonetheless, the methods were applied by individuals knowledgeable in the areas of electronic maintenance, training, and performance aids.

Information was gathered by direct observation of technicians performing their jobs, by interviews of technicians, and by interviews with a variety of individuals with information pertinent to the various aspects of the study.

The major emphasis was on observing technicians at work, primarily troubleshooting or repairing rather than modifying, checking, or aligning equipment.

The usual method of investigation at operational sites was as follows. After an introduction to the organization, its mission, physical plant, and equipment, a malfunction was chosen and followed through all the steps leading to restoration of the defective equipment. The steps which were usually seen in association with avionics, for example, were:

Maintenance debriefing

Origination of work order and notification of appropriate shop

Verification of symptom on the aircraft

Identification of suspect defective box

Verification of malfunction produced by suspect box on mockup in shop. (Item may be sent off base at this point as "Not Repairable This Station")

Identification of defective piece part in box

Repair or replacement of part

Verification of repair on mockup

Verification of repair on aircraft or return of box to supply

After following the first problem to its conclusion, selected portions (one or more of the above steps) of other problems were observed, often with participation of the observer in the solution of the problem and repair of the equipment. Many hypothetical problems (What would be the first thing you would do if .... Why?) were also posed for solution by individual technicians.

The above activities were interspersed with examinations of Technical Orders (T. O.'s) prime equipment and test equipment. Related topics such as training, morale, work schedules, etc., were discussed with technicians and supervisors.

Early in the investigation, a four-page questionnaire was administered on a tryout basis to selected individuals. This method of investigation proved unsatisfactory for a number of reasons, most important of which is that technicians do not attend, as they work, to the aspects of their performance which were of interest to the investigators. For example, they were unable to report the strategy they were using in troubleshooting, the number of checks required to solve a problem, the frequency with which they referred to a T.O. or even the total time in interaction with it. The result is that information obtained in this manner is highly unreliable. Nor is it possible to estimate through questionnaires the extent to which errors or missing information in T.O.'s degrade performance.

In the other areas of inquiry, information was gathered mainly by interview, although some examples of advanced electronic technology were examined.

The survey included visits to 12 different operational Air Force Bases, 9 equipment development firms and laboratories, 1 commercial airline maintenance facility, 1 commercial communications firm, and conversations with about 10 other researchers interested and working in the area of technical data and technical job performance. Approximately 800 man-hours were spent specifically in observing and interviewing to obtain information on which the report is based. The information thus gathered is supplemented by related experiences at Air Force technical schools and other sites. These related experiences, obtained in connection with other projects in electronic maintenance, occurred both previous to, and concurrent with, this study.

SECTION III

AREA I. JOB-TASK CONTENT AND CURRENT PERFORMANCE AIDS AT TYPICAL SITES

The job-task content of Air Force electronic technicians covers a fairly broad range. In the Air Force Communications Service, where much of the equipment is permanent-installation transmitters and receivers, the job is much the same as it was 20 years ago. Although some modular packaging and self-test features have crept in, most of the equipment appears to consist of standard chassis with hard-wired components. The technician may do his troubleshooting by replacing tubes, or by signal tracing with scope or meter, or with resistance checks.

Although equipment has changed over the years, and maintenance concepts have been modified to simplify the technician's job, adequate performance of this job still requires the technician to use a troubleshooting strategy. Repair consists mainly of replacing circuit components--resistors, capacitors, etc.--using a soldering iron.

There is also some solid state equipment and some with modular packaging. The solid state devices require the technician to perform the slightly more difficult soldering tasks associated with replacing these devices. Modular packaging makes it possible for the technician to isolate troubles to the module and replace the module in order to get the equipment back on the air. He can then troubleshoot within the module to identify the defective circuit component.

The performance aids available to this technician are the standard Air Force Technical Orders, familiar to all who have been involved with Air Force electronic maintenance.

At the other extreme of job-task content for electronic technicians is that of the Minuteman shop technician. His job begins when a unit identified as defective is brought in from a silo. The unit typically consists of a chassis about 2' by 2' by 1', containing from 20 to 100 plug-in circuit boards and associated connectors and wiring.

The shop technician proceeds as follows:

1. From the nomenclature of the unit brought in, look up in a T.O. which adapter cables to use to connect the unit to the tester.

2. Select these adapter cables from the cabinet and connect them to the unit and the tester.

3. Select an adapter plug-in board in the same way.

4. Slip this board into place on the tester and operate the level handle to seat the connections.

5. Select the punched-tape program the same way.

6. Place the tape on the tester much the way a movie film is threaded on to a movie projector.

7. Push the "start" button.

8. The tester first self-checks itself automatically.

9. If a "NOGO" is achieved, the technician calls a group of senior technicians who troubleshoot and repair the tester for him.

10. If a "GO" is achieved, the technician presses the "start" button again, and the testing proceeds automatically, programmed by the punched tape. The tape stops automatically if some change in setting of controls is required on the unit under test. If this occurs, the technician reads the step number from a set of nixies on the tester. He then goes to the T.O., and under that step he is told what control settings to make, and then to press the "start" button again.

11. The entire test goes on this way until the "Test Complete" light comes on on the tester or until a "NOGO" condition is identified by the test equipment.

12. If a "NOGO" condition is encountered, a red light, with the word "NOGO" on it illuminates on the tester.

13. The technician reads the nixies to determine the step number.

14. He then looks under that step number in the T.O., where he is instructed to replace some circuit boards, usually from 1 to 6 in number. The boards to be replaced are precisely identified in the T.O. by their nomenclature code, which also appears in the unit under test, showing which board is which.

15. After replacing the boards, he pushes another button on the tester, and the tape backs up so the failed test can be repeated. He then pushes the "start" button again and the test is repeated. If the test produces a "NOGO" again the T.O. instructs the technician to send the unit under test back to the depot, since the trouble is apparently not in one of the replaced circuit cards. The assumption apparently is that if the trouble cannot be found by the automatic tester, and corrected by replacing aplug-in card, then it is too difficult a problem for this technician.

16. If the unit under test passes the originally-failed test after the specified boards have been replaced, it is considered repaired and may be returned to service, assuming it passes the rest of the tests. It is apparently the technician's option whether he goes back to determine which one of the replaced boards was defective, or whether all the replaced boards are sent to the depot for overhaul.

The jobs of technicians on other equipments represent transitional characteristics between the two extremes. The technician's job on the ASB-4 Bomb-Nav system is a good example. This system contains many line-replaceable units. The technician must determine which contains the malfunction, and should therefore be replaced.

This requires him to have some knowledge of data flow between line replaceable units, and to employ a troubleshooting strategy. To this extent, his job is similar to the technician in the communication service. However, he has available to him some items of automatic and semiautomatic test equipment of a kind not generally available to the communications technician. A considerable amount of the troubleshooting done by the ASB-4 technician can rely upon trial-and-error removal and test of a substantial number of easily-replaced plug-in units. These units are tested on an automatic tester in the shop.

This technician, therefore, while he has to apply a troubleshooting strategy to the data flow of the ASB-4, need not carry his troubleshooting to the level of detail that the communications technician must reach. On the other hand, his job is not nearly so proceduralized as that of the Minuteman technician.

SECTION IV

AREA II. UNIQUE PROBLEMS ASSOCIATED WITH PERFORMANCE AIDS IN LIMITED WAR AND COUNTERINSURGENCY OPERATIONS

Method and Sources of Information

Nine technicians who had recently returned from southeast Asia were interviewed, and discussions were held with responsible persons at Headquarters, Tactical Air Command. Because of the uniformity and nature of the responses obtained, it was judged that further inquiry on this topic would not be worthwhile.

Findings

There appear to be no unique problems with performance aids in limited war and counterinsurgency operations. Tactical Air Command technicians in southeast Asia use the same T.O.'s as are used at bases within the United States. It must be concluded that the same problems that exist with T.O.'s in the United States also exist when those T.O.'s are used in other parts of the world.

The technicians interviewed did not report any additional problems associated with T.O.'s. They did, however, report somewhat different working conditions, with the work week consisting of seven 12-hour days. This was thought by the interviewees to result in significantly more productivity than was typically attained in the United States.

Though it is commonly assumed that the hazard of combat would interfere with maintenance performance, none of the men interviewed had been fired upon, though they were armed at all times during their stay. Maintenance was done for the most part inside a guarded compound.

Few of the men interviewed had seen battle-damaged equipment. When such equipment was brought into their shops it was usually not repaired unless damage was very minor, but was used as a source of spare parts.

The major difference between the combat and non-combat situation appears to be in terms of the consequences of errors in maintenance performance or of lack of speed in maintenance performance. These consequences are likely to be much more severe under combat conditions.

For the most part the dash-six T.O. was observed less rigorously there than here. Cannibalization was more frequent as well. Some ad hoc design modifications were reported by one interviewee.

Usually, if needed parts were available and the technician felt he could repair an out-of-service item, he attempted to do so.

The same maintenance procedures, in general, are used in the combat situation as are used here. For example, defective items are virtually always brought to a mockup for verification of symptoms. However, the practice of flying a maintenance man on the aircraft is more frequent there than here.

Conclusions and Recommendations

No further attention be given to the matter of attempting to identify performance aid problems unique to limited war situations. The problems appear to be the same as performance aid problems elsewhere.

SECTION V

AREA III. CURRENT REQUIREMENTS FOR OPTIMUM PERFORMANCE AIDS

Method and Sources of Information

Findings in this area are based upon the aggregate of all the information collected in this survey, combined with background knowledge of the project staff. The information was sifted, discussed, reviewed, and argued about at great length.

Observation and interview covered equipment ranging from communication gear that is 20 years old, or older, to components of the Apollo Lunar Excursion Module.

Findings

The same findings, conclusions, and recommendations apply to equipment presently found in the field as well as new equipment currently being programmed into the Air Force inventory. While it is possible to use performance aids in an attempt to patch up a poor design of a performance system, the more effective approach is to design aids as an integral part of the system from the beginning phase of system development.

In either case, what constitutes effective performance aids depends upon the needs of the performance system. It is not possible to specify optimum performance aids outside the context in which they are to be used. Performance aids function in a context, environment, a "performance system". The relative effectiveness of performance aids depends greatly upon how well they fill the role designated for them in the performance system. Since this role may be different for each system, the search for optimum performance aids is best focussed on the process by which they are created, rather than upon the objects themselves, or rather, even, than on the characteristics of the objects. A process by which performance aids can be developed as an integral part of a performance system will result in effective performance aids.

This is not to say that certain human engineering principles could not be stated. Information on type size and style for documents, for example, could be given, and is given in specifications. Other rather general principles can be stated and, for the most part, have been stated. For example, if the performance aid contains a variety of information, it should also contain a subject index with entries in the subject-oriented language of the user.

But having a generally acceptable type size (which may be too big or too small in certain contexts) will probably make little difference in the effectiveness of the performance aids in some contexts. In others it will be very important to have the proper type size. And what is "proper" depends at least partly on the context or environment in which the aid is to be used. Note, therefore, that even with such a seemingly cut-and-dried matter as type size, a once-and-for-all optimum cannot be specified. What needs to be specified is a suitable way of determining what type size will be satisfactory, and, hopefully, approach optimal, for a particular performance aid that is to be used in a particular performance system. When the more important questions of what information should be in the aid, what form it should take, and how it should be organized are considered, the central problem of how to answer these questions effectively is essentially the same, but considerably more complex.

Development of methods for designing performance aids seems to have reached a point where further gains will be difficult unless some feedback is obtained from attempts to apply the methods.

It is clear that a few individuals who have been working in performance aid development are able to develop good performance aids for particular systems. Rogers and Shriver at HumRRO have done it, and it has been done at Applied Science Associates, Inc., at the Navy Electronics Laboratory, and other places. What is needed is a technology that will work when applied by people not so deeply involved or informed. It is in this area that effective methods are lacking.

Interviews with people who have been involved in research and development on performance aids, and actual participation in the process of developing experimental aids, reveal that the process is truly a creative design process. Those involved can attach labels to what they are doing, but the important operations involve making judgments and weighing alternatives. These activities also are much affected by the interaction with other parts of the performance system, especially training. In every case where a successful study of performance aids development has been done, training has been adjusted in some way to mesh with the performance aids.

These facts about how the researchers design performance aids may suggest that improving the generally-used design process for performance aids will require primarily an educational program.

It would be aimed at teaching those who are usually responsible for the design of performance aids how to make the necessary decisions that the researchers are now able to make.

Conclusions and Recommendations

For the next few years research and development should emphasize development of methods for determining optimum performance aid characteristics for any performance system, rather than trying to specify any "absolutes" of design.

Methods are needed for determining the functional trade-off between performance aids and training, for identifying appropriate information content for the aids, for specifying suitable physical characteristics and information display characteristics, and for designing effective information retrieval systems. On the management side, methods are needed by which the performance aids designer can obtain the information he needs to do his job. It appears that at present in many cases the people responsible for preparing technical orders must obtain their information from the engineering department through informal channels and methods. It would probably be better if a more formalized and officially recognized procedure were available to them.

Development of the needed methods should begin with an attempt to apply the methods now used by advanced researchers. This application should be made to a new system, or a major segment of a new system. Those making the attempt should be selected from among the handful of people in the country who have been deeply involved in performance aids research for the past five or ten years. The reason for this is, as pointed out above, the process as currently practiced is a creative design process. The attempt to reduce this process to practice in the real world should be made with the best talent.

While some efforts generally along these lines are now in effect, they should be supplemented by additional efforts with certain added features. An effort should be started that will begin at the very earliest date in development of a new system. This will have two major features of realism lacking in present efforts:

1. Information needed in development of the performance aids will become available piecemeal, and will be subject to change as the system evolves, as is usually the case.

2. Early entry will permit some inputs into selection of specifications that will apply in the performance aids development.

Another important feature that should be included in the development is interaction with the training establishment. Present efforts generally accept training as given. The evidence is clear that the best systems can be produced when training and performance aid development interact.

A final important reason for additional efforts on performance aid development is that there are many approaches to this development problem. Several should be tried.

In setting up any efforts along these lines, formal contractual arrangements should be made so that the "tryout team" has essentially the same access to technical information about the system as is available to those who normally prepare the Technical Orders. The tryout should be set up so that the "tryout team" prepares a set of performance aids in addition to the normally-prepared Technical Orders.

In attempting to apply their knowledge, judgment, and techniques to development of performance aids in a real system development process, the researchers will presumably identify, firsthand, the real-world constraints and the limitations and shortcomings of their technology. This information can then be used to improve the technology and adapt it for use by the technical writers and others who normally must make the method work.

SECTION VI

AREA IV. IMPACT OF FUTURE ELECTRONIC TECHNOLOGY ON PERFORMANCE AIDS

Method and Sources of Information

Data for this area were collected through interviews with persons associated with advanced electronic developments. An attempt was first made, in these interviews, to obtain the judgments of these experts on the nature of future electronic technology. They were then asked what implications they saw for maintenance activities associated with the new technology.

One problem encountered in this area was that those who know about advanced technology are usually separated from the problems of maintenance, while those who do know about maintenance have relatively little information about advanced technology.

A second problem which permeates the entire field of inquiry about electronic maintenance is that hardly anyone, other than the behaviorally-oriented researcher, thinks or talks in terms of the specific operations or behaviors that are, or will be, required of the maintenance technician. Consequently, much of the judgment and opinion obtained about maintenance is superficial.

The consequence of these two problems is that it is virtually impossible to obtain authoritative judgments on the implications of new technology on job performance aids.

Findings

Miniaturized and Integrated Circuits: The "advanced technology" that was mentioned, almost to the exclusion of any others, was microminiaturization. Associated closely with this technology was the idea of "integrated circuits".

Four main effects are predicted from these technologies:

1. Substantial reduction in size of electronic equipment of a given functional complexity.

2. Functionally more complex equipment, since many more operations or functions can be housed in a given volume and weight.

3. Significantly higher reliability of circuits.

4. Functionally more complex units will be discardable when they malfunction because manufacturing costs will be reduced.

The following implications for maintenance work were suggested.

1. The substantial size reduction (with associated cost reduction) may make it possible to virtually eliminate field and shop maintenance as we now know it. If an entire complex radar set or computer is housed in a single box the size of two or three shoe boxes, such units can be replaced by a "universal electronic box-replacing technician" and sent to the depot for repair.

2. The higher reliability will reduce the maintenance work load so that fewer technicians will be required.

Other implications, not suggested by the interviewees, and a few corollaries to the above, can also be drawn.

1. To the extent that line maintenance truly becomes a remove-and-replace operation, specialization of technicians can be reduced. If technicians need to know nothing about circuitry to do their jobs, they need not be trained on any particular equipment.

2. For the same reason as in 1., technician training can be reduced to training on the manual skills required for remove-and-replace maintenance, thereby cutting the duration and cost of that training.

3. The line maintenance technician may have to be able to replace units of many systems, but may have to replace any given unit very infrequently. This may mean that he will have to rely more heavily on performance aids for instructions on how to replace a given unit when the occasion arises. While most electronic units are quite easy to replace, requiring very little special information or skill, some units may require special procedures. This is especially true of units like antennas, with 3-degree-of freedom gimbal mounts.

   Providing instructions for replacement of these units does not appear to pose any particularly difficult problems in performance aid design. It does pose the problem of getting the technician to <u>use</u> the aids, rather than trying to blunder his way through replacement of a delicate mechanism.

4. The advent of miniature integrated circuits makes feasible the use of phased array antennas to achieve beam focussing and scanning without mechanical movement. This development may largely invalidate 3. above.

What is not known is the extent to which this remove-and-replace utopia, free of troubleshooting, will really come to pass. As far back as 1951, the Air Force was promoting the remove-and-replace concept of line maintenance that was supposed to virtually eliminate troubleshooting at the line level. It did not achieve that end partly because of confusion between how to correct a malfunction (remove and replace the malfunctioning component), and how to determine which unit had malfunctioned (troubleshoot). The question is, to what extent will the same problem arise with miniaturized circuitry.

As the circuitry becomes more densely packaged, the per-function cost comes down, and the per-circuit reliability goes up, the electronic designers are likely to make their equipment more sophisticated in what it can do, and thus more complex. The net effect may be no net change in system reliability or in the number of line-replaceable units, and no change in the line maintenance job. This turn of events would probably mean that the problems of performance aid development and use would remain essentially the same as they are now.

Another consideration is that, even if miniature integrated circuits comprise most of a system, there will usually be at least one "catch-all" line replaceable unit (LRU), according to one interviewee. The design process is not yet capable of planning for all contingencies in advance of manufacture of the equipment. Furthermore, there probably will continue to be a need for some relatively large-size components for a considerable time in the future. These components are generally collected together into a single catch-all unit.

The effect of this practice is to increase the complexity of the interconnecting wiring between LRU's. This may complicate the troubleshooting process, if troubleshooting is required, and certainly would complicate the interconnecting wiring that would have to be represented in the technical data.

It is sometimes necessary for the designer to add supplementary components to LRU's after they are fabricated and tested. An example of this kind of addition is decoupling capacitors. They sometimes must be added to eliminate cross talk or feedback which did not show up in the designer's breadboard circuit, but occurred after the circuitry was more densely packaged in manufacture. This type of patchwork has about the same effect as the "catch-all" units.

Cryogenics: The use of superconducting materials at extremely low temperatures was mentioned in one of the advanced electronic laboratories as another new technology that might have some implications for the future maintenance job. As best we could determine, the major implication is for personnel hazard in which high pressures and the very low temperatures are present. The tasks associated with this type of equipment will probably be, for the most part, procedural. They may also require greater emphasis on tasks associated with low-temperature refrigeration equipment. More specific information on this matter was not obtained, and it was not mentioned by any other source.

It would appear that this technology would pose no new problems for performance aid design and use.

Automatic Test Equipment: The increased use of automatic test equipment was mentioned as having clear implications for simplifying the maintenance jobs. If this equipment can be designed so it will automatically check and troubleshoot prime equipment, it should have some impact on the maintenance job and on associated performance aids. In fact, this type of equipment has already affected the maintenance job significantly.

Setting aside the fundamental question of whether automatic test equipment is the best cost-effective approach to maintenance, since it is outside the scope of this study, there are few implications for performance aids.

The automatic or semi-automatic test equipment generally produces procedural tasks for the technician. The information required to perform these tasks is quite adequately presented in a conventional book-type performance aid. A good example of this kind of situation is the job, performance aid, and equipment of the maintenance shop technician described elsewhere in this report. The implications for performance aid design and use are no different than those for any other procedural task.

New Testing Technology: Infra-red scanning to identify malfunctioning components and incipient malfunctions has been used successfully for final inspection of manufactured units. The major implications of this technique for the maintenance job are:

a. Reduction or elimination of troubleshooting, in the sense of data-flow analysis.

b. Increased capability in pattern analysis to read the infra-red "signatures" of normal and malfunctioning circuits.

The first implication reduces the need for performance aids designed to aid in data-flow troubleshooting. The requirement for a sensitive interpretation of IR scan patterns may indicate a need for aiding the technician in making the fine discriminations required.

Fluidic Circuits: These circuits use pneumatic or hydraulic devices in the same way that electronic circuits use resistors, capacitors, and other components. Their application appears to be mostly in the digital logic field. While none of the interviewees mentioned fluidics, this technology has begun to receive publicity in the trade and professional journals, and even in a popular magazine.

Just what implications these devices may have for maintenance job performance aids is not known. It seems likely, however, that as a minimum, a need will soon exist for a standardized set of symbols for representing fluidic circuits.

Conclusions and Recommendations

The new technology suggests several implications for design and use of performance aids in the future.

There exist no specifications covering performance aids for these types of equipment. This provides an opportunity for the specifications to be prepared in anticipation of the need in this area.

Miniaturization: Miniaturization, microcircuitry and integrated circuits suggest the following:

1. Within-stage troubleshooting down to the piece part (resistor, capacitor, etc.) will be reduced even more in importance and may largely disappear. This would mean that it would no longer be desirable to include within-stage schematics in Technical Orders.

2. New manufacturing techniques such as thin-film deposition may result in a substantial increase in the cost of Technical Orders if present specifications continue to be imposed. Much of the technical information now required in the Technical Orders is generated as a part of the design process presently used. The newer techniques are not likely to generate that information. This would mean that the amount of special engineering work that would have to be expended to get this information, beyond that required for system design, would be increased, raising the cost.

Work required in this area is development of a model specification that meets the needs arising from this new technology. Questions such as the following should be answered:

1. What should be the nature of the "Theory of Operation" section describing a microcircuit?

2. What kinds of data flow diagrams are needed, if any? What should they be like?

3. Are new symbols needed? What symbols?

4. What kinds of signal state information should be provided?

5. What parts of existing specifications can and should be used in the specifications for performance aids for this new technology?

Infra-red pattern interpretation: An attempt should be made here to identify the critical discriminanda involved. The study should start with examination of a variety of patterns and formulation of hypotheses regarding the elements of the pattern critical to its interpretation. Previous research on photo interpretation should be studied for relevant information. Experimental studies on difference threshholds and "signature" recognition should follow, leading to results that can be used in designing appropriate performance aids and training.

Fluidic Circuit Maintenance: The initial study should be a fact-finding survey focussed on maintenance of this particular type of equipment. Organizations and individuals that are experimenting with and developing this technology should be visited. Structured interviews should be used to obtain the desired information.

The kinds of information sought should include typical maintenance task analysis data.

1. Descriptive information about the equipment.

    a. How will it be packaged

    b. Maintenance concepts

    c. Types of interconnections

2. Behaviors required in

    a. Checking

    b. Adjusting

c. Troubleshooting

d. Replacing

e. Repairing

f. Servicing

3. Test equipment and tools used.

4. Kinds of technical information required and how it is to be presented.

SECTION VII

AREA V. CURRENT AND FUTURE PERFORMANCE AIDS DEVELOPMENTS

Method and Sources of Information

This information was obtained through interviews with persons involved in performance aids research, through a study of published reports on the topic, and from the results of a meeting on performance aids sponsored by the Behavioral Sciences Laboratory. The meeting was attended by persons who have been working in research on performance aids for a number of years.

The following persons were interviewed or attended the meeting:

Mr. Robert Atchley, Tracor, Inc.
Mr. Albert Chalupsky, Western Development Lab
Mr. Gerald Chubb, Aerospace Medical Research Lab
Dr. Joseph Dorton, Research and Technology Division, WPAFB
Dr. Gordon Eskstrand, Aerospace Medical Research Lab
Mr. Thomas K. Elliott, Applied Science Associates, Inc.
Mr. John P. Foley, Jr., Aerospace Medical Research Lab
Dr. John D. Folley, Jr., Applied Science Associates, Inc.
Miss Julia Harris, HumRRO
Miss Ruth Herman, Propulsion Lab, WPAFB
Dr. K. Inaba, Serendipity Associates
Dr. Earl Jones, Navy Electronics Facility, San Diego
Miss Edna Jones, American Institutes for Research
Mr. Reid P. Joyce, Applied Science Associates, Inc.
Dr. Robert B. Miller, IBM
Dr. Joseph Rigney, University of Southern California
Mr. James Rogers, HumRRO
Dr. Edgar Shriver, HumRRO
Mr. Horace Valverde, Aerospace Medical Research Lab

Findings

The findings in this area are probably best presented by giving brief descriptions of various research and development efforts.

Earlier Studies: The procedures and techniques of MAINTRAIN and FORECAST are still very much with us. Since these projects have been reported in detail in other publications, (References 5 and 6) they will not be described here. It is noteworthy, though, that both of these projects combined the modification of training and the development of new performance aids to produce an effective performance system. This is a further indication of the close interrelationship of these two parts of the performance system.

SIMMS: This acronym stands for Symbolic Integrated Maintenance Manual System. This system incorporates many features of technical data that have been suggested by researchers in the field of performance aids. The essential feature is that it is designed to aid performance of a job, rather than being simply a repository for various items of technical information.

The core of SIMMS is the Maintenance Dependency Chart. This chart shows, in symbolic form, what elements in the system depend upon what other elements. The chart is coordinated with checking procedure steps. When the technician finds an out-of-tolerance condition during checking, he enters the maintenance dependency chart at the point, or unit, at which the unacceptable signal was found. The chart indicates all of the units or functions that contribute to the signal at that point. It also shows roughly the amount of work involved in making checks at the various points in the system. By means of background shading, the SIMMS diagram also shows what units and subunits are involved in the particular data flow chain the technician is concerned with. Associated textual material presents information on theory of operation of the elements involved.

It appears to us that, properly implemented, the SIMMS concept adequately meets the needs for diagrams and related information required for decision-type troubleshooting. Sample SIMMS materials are currently being evaluated by the Air Force Logistics Command.

PIMO: This acronym stands for Presentation of Information for Maintenance and Operation . The PIMO project is a fairly large-scale attempt to bring about a breakthrough in performance aids technology. The emphasis in this project has been to correct as many as possible of the omissions and errors found in the technical data previously prepared for the systems under study. Since a large number of discrepancies were found, correcting these, in itself should result in a significant improvement.

The emphasis in presentation of the information to the technician has been on projecting diagrams and drawings with microfilm, and providing audio instructions to him with a walkie-talkie or telephone headset.

PIMO seems not to be innovative in the sense of using new types of diagrams, or kinds of information not heretofore used. Materials developed in this project are currently being evaluated.

XFL Fault Location Device: The XFL, developed by Dr. Joseph Rigney at UCLA, is a small, circular, plastic job-aid which incorporates circuit front panel relationships essential for fault localization. It is used by checking out the five receive and transmit modes of the AN/URC-32 transceiver and a number of other sub-functions, noting symptoms of malfunction during the checkout, entering these symptoms in the XFL, and looking up the possible malfunction(s) in an accompanying manual.

An evaluation of the device by Dr. Rigney and his associates showed that the XFL produced dramatic gains in the ability of experienced electronics technicians to troubleshoot the AN/URC-32. The device takes over and performs part of the cognitive function otherwise left to the technician. In effect, it proceduralizes the process of symptom pattern analysis.

Computerized Troubleshooting: Two efforts appear to provide substantial potential for making feasible completely proceduralized troubleshooting performance aids for moderately complex systems. One of these efforts has focussed on within-stage troubleshooting, and the other on between-stage.

These developments are of interest because the available evidence indicates quite clearly that inexperienced personnel troubleshoot significantly better with proceduralized aids than without.

One of these efforts (Reference 7) developed detailed procedures for component fault diagnosis of linear and nonlinear circuits. Employing a FORTRAN-IV computer program, the procedures are based upon the analysis and measurement of various network transfer functions of the circuit under test. While the method of analysis of the electronics is sophisticated, it appears to ignore the question of the efficiency of the troubleshooting sequence to the technician.

The other effort uses a computer program in ALGOL language to develop between-stage troubleshooting trees. (Reference 1). This program produces decision trees based upon maximizing information gain per unit of cost at each step.

Implementation: The meeting held at the Behavioral Sciences Laboratory was intended to be a discussion of research issues and problems in performance aid development and use. It was thought that this direct approach would yield information on current and planned research, and on research needs in performance aids design.

The outcome of the meeting was a very clear picture, from the researchers, that the most important activity that could be undertaken is implementation of existing technology. It was also clear that this technology has not been developed to the point where it can be merely handed to technical writers for their use. It was thought that a considerable education program is needed so that persons who now routinely prepare performance aids would be able to apply the techniques and ideas that the researchers have successfully used on an experimental basis.

The method suggested for bringing about this implementation was a succession of tutorial programs. In these programs the researchers who had developed the performance aid technology would work along with technical information people, coaching and assisting them in applying the new technology. It was thought that this approach would lead to a gradual infusion of these new ideas into the ongoing process of performance aid development.

Implications for Research

It is apparent to us that, although all technical problems in design of performance aids are not solved, the primary need is to reduce to practice the technologies presently within the capabilities of prominent researchers in this field. These technologies have been experimentally tested and found to be effective as they were applied in the experimental situations. What is needed now is to try them in the context of system development as a first step toward making them generally usable.

SECTION VIII

GENERAL FINDINGS AND RECOMMENDATIONS

Introduction

In the process of collecting the information needed for the five objectives of this study, important observations were made, impressions obtained, and insights revealed. Many of these broader findings provide a backdrop against which the more specific matters can be viewed in a realistic context. It appears to us that these broader matters, partly because they are so broad, and partly because they are so severe, may have greater implications for Air Force action than many of the specifics. Furthermore, the implications may reach not only into the realm of research direction but may also have some application to management actions.

These findings and recommendations are presented in accidental order. The first is not necessarily the most important, nor is the last necessarily the least important.

General Finding I

In its attempt to achieve acceptable maintenance capability the Air Force is paying several times for redundancy that is not necessary and is not really effective. That the maintenance is getting done, in some sense, must be admitted; but by any reasonable standards it is getting done poorly and at an extremely high cost.

An outstanding example is the Minuteman system, which was described earlier. Semiautomatic test equipment with explicit procedural instructions is used. The technician needs to follow an extremely simple procedure to do his part of the job of troubleshooting the units brought in from the field. If the semiautomatic test equipment and the procedure do not solve the problem, the work load is passed on to the depot. The technician is not required, and is prevented from, doing any additional troubleshooting. The procedure he must follow in using the semiautomatic tester was learned in a few hours by the authors. The Air Force technicians in this job are given about 40 weeks of training.

The Air Force is apparently paying for this maintenance capability through extensive training, through very elaborate and expensive test equipment, and through depot facilities that must be large enough to handle the work that the technician is unable to do even with his extensive training and elaborate equipment, in addition to the work that legitimately should go to the depot.

If the training were more valid for job performance, or if the performance aids carried the troubleshooting procedure a bit further, the technician could do more maintenance on site, reducing the load on the depot. Training costs could be lowered and, possibly, the complexity and therefore the cost, of the test equipment could be reduced.

General Finding II

No current problem situation needs additional technological development before improvements could be made. The problems all appear to be attributable to failure to implement in an effective manner, the technology already available.

Task analysis, the concept of validated training and demonstrated effectiveness of task simulators, have all been available for years. While a form of task analysis has been used in Qualitative and Quantitative Personnel Requirements Information (QQPRI), it has not eliminated the problem of irrelevant training because of defective and incomplete application of the concepts and techniques.

General Finding III

Some people at all levels in the Air Force appear to be fooling themselves, either consciously or unknowingly, into thinking that the best technologies for training, performance aids, and maintenance capability are being used.

People in high places, who presumably would have the authority to improve the quality of training and related activities that so heavily affect maintenance, normally reply "We're already doing that" when suggestions are made or questions asked. The fact is that a lot of "OK words" are being effectively applied. An incredible discrepancy exists between what the fine-sounding labels imply is being done, and the operations that are actually being performed. For example, although "task analysis" and "training objectives" are said to be in use the central problem of determining valid training content is far from solution. An analysis of the composition of four electronic maintenance courses shows the following distribution of time devoted to the various topics, as specified in the Plan of Instruction (POI).

Theory and Principles	55.8%
Procedures	21.0
Troubleshooting	2.6
Use of Test Eq. and Tools	5.2
Tech Order famil.; records	1.6
Remove and Replace	1.4
Tests and Orientation	12.0

It can be seen from the results of this analysis that over half of the course is clearly spent on theory and principles. At the most, 31.8% of course time is spent on what could be clearly considered job-relevant matters. The extent to which this proportion of the time is devoted to actual job practice is not known, and not really knowable. It depends to a great extent upon the instructor. Observation of classes on this and other projects, however, suggests that effective "hands on" practice is relatively rare. It seems likely that much of the time designated for "procedures, troubleshooting, use of test equipment and tools, Technical Order familiarization and records, and remove and replace" is spent in the classroom with the students listening to the instructors lecture on these topics.

This heavy orientation toward theory could not occur if the content of the course were validly based on the behavioral requirements of the job. It would also become apparent that different training equipment would be needed to provide the opportunity for adequate practice.

General Finding IV

Some reasons given for the continuation of principles-centered training are based upon unverified assumptions that sometimes contradict the facts. Examples of these are:

1. It is not possible to know where technicians will be assigned - they may be assigned to an equipment not covered in training, so training must be principle-centered so the technician can transfer what he learns on one equipment into work on another.

Fallacies:

a. No evidence is presented that training on circuit functioning of one equipment results in significant positive transfer to performing maintenance on a different equipment, or, for that matter, on the first equipment.

b. A set of "principles", different from the ones presently given may provide much more positive transfer from training to job performance and from one equipment to another. Analysis of a sample of technicians' jobs suggests that principles of troubleshooting, use of test equipment, and techniques to use in making replacements would be useful, valid training content that would transfer from one equipment to another.

c. No data has been presented that shows what proportion of electronic technicians are assigned to equipment not covered by their training. Maybe it is only 1 or 2 per cent, in which case broad training for all could not be defended.

2. The fundamentals and other "principles" are required for the career development of the technician.

Fallacies:

a. Reenlistment rate for 2nd enlistment is below 20%, which means that 80% of money and time spent for "career development" of 1st enlistment technicians is wasted. Therefore, it would be more cost-effective to train all first enlistment men to do a job and train for a career only those who reenlist.

b. 7-level courses often begin with several weeks on fundamentals. If the fudnamentals were necessary for effective career performance, wouldn't you expect that these technicians would already know them well?

c. If they are not part of his job, should they be involved in his career development?

3. Fundamentals and principles are needed to provide motivation. Technicians will not be motivated if they are "cookbook" technicians who do not understand what they are doing.

Fallacies:

a. That the material presented in typical training helps the technicians understand what they are doing. Frequently much of the content is behaviorally unrelated to what the technician must do.

b. There are no data to support this assertion. It can, on the contrary, be argued that one of the greatest producers of poor motivation and attitude is to put a man on a job he has not been trained to perform.

General Finding V

Air Force technical training spends vastly too much time to train electronic technicians who, when they arrive on the job, are unable to perform many of the simplest tasks that might reasonably be expected of them. This condition is of such long standing that supervisory personnel typically do not expect newly graduated technicians to work independently until after a substantial period (several weeks to as much as 6 months) of additional formal (FTD) and on-the-job training coupled with self-study course work (CDC). For example, the maintenance supervisor at a communications switching center did not expect new technicians (after 38 weeks of technical training) to be able to solder in a transistor in such a way that the leads were connected to the proper terminals. (A transistor had been installed with the collector and emitter leads reversed). It was later discovered that, although the trainees had spent a substantial amount of training time on semiconductor theory, none had actually seen a transistor. Yet, the equipment on which they were working contained literally hundreds of them.

Even allowing for the loose wording of job training standards, there is strong justification for the conclusion that there exists a substantial gap between a reasonable interpretation of the wording and what the technicians are actually able to do when they finish school.

The long-standing inadequacy of technical school output contributes to two corollary problems.

1. From 40 to 60% of the total monthly man-hours of units having primary responsibility for maintenance are reportedly spent on the training function.

2. Technical school output has been inadequate for so long (in terms of actual job preparation) that the supervisors interviewed apparently no longer complain to the school, thus eliminating a potential source of feedback.

General Finding VI

It was apparent during field observation of troubleshooting and repair that many technicians frequently proceed on unverified assumptions, use incorrect logic, and come to (erroneous) conclusions on the basis of patently incomplete evidence. Often information about the state of signals inside the equipment obtained early in a troubleshooting sequence is forgotten before the end of the sequence--leading to a faulty conclusion about the location of the malfunction. Not once was a technician <u>ever</u> observed to write down what information he had obtained from his troubleshooting checks.

The consequences of such thinking are frequently slight, causing, in some cases, an additional test reading to be made or an additional $5.00 tube to be replaced with a consequent delay of a few seconds or minutes. However, if it requires 2 hours or more for the technician to find the Federal Stock Number of a component, as it too frequently does, the time consequences are more serious. Further, an error may result in the replacement of an item costing thousands of dollars with time consequences which result in an entire airplane's failure to go on alert status as scheduled. One such situation was described by a technician. Another such situation was averted on the A3A system of the B-52. In the latter case, a major assembly was erroneously identified as containing the malfunction. When coauthor Elliott was told that approximately 8 hours would be required to change the assembly, he told the team of technicians (one seven and two five levels) that the evidence pointed to a different unit. On restatement of the evidence and reexamination of the logic, they revised their conclusion and replaced the unit indicated by the author. This cleared the trouble.

Related to the problem of sloppy thinking is the problem of sloppy workmanship in repair. Wires and components burned by soldering irons were observed frequently, as were many electrically sound (at least temporarily) but physically poor solder joints. On one occasion, the authors detected nuts and bolts loose in the bottom of a radar modulator unit ready for installation in the aircraft. Though the shops themselves are typically kept clean by the technicians, repaired items leave the shop containing dirt and debris.

General Finding VII

Adequate standards for evaluating training, Technical Orders, and technician performance are almost completely lacking. The inadequacies of the job training standards are well-known, with their use of such words as "familiar with", "limited knowledge of", "understand", etc. The same level of looseness appears to exist in the field, where promotion and responsibility are heavily dependent upon the subjective feelings of the technician's superior, i.e., another technician with more "experience". Though tests are also used, their criteria are highly questionable and there appears to be nowhere an objective, scored, job-task performance test of technician capability. Regarding the technical data system, the lack of adequate standards in this area was well documented in a 1962 report (Ref. 3), which recommended that "Specific, valid and accepted standards of adequacy, technical sufficiency, and accuracy be established and published . . . ."

Inadequacy of standards is basic to all aspects of the problem of costly and ineffective maintenance. To the extent that standards are not unambiguous, valid, and enforced, training and Technical Order development can be maximally successful only by accident. Without adequate performance standards, it is not possible to know in general whether maintenance is being done well or poorly, or to distinguish between mediocre and poor performance of individual technicians. In the absence of adequate standards it becomes difficult to separate the effects of equipment design, personnel, training, and performance aids in order to identify the cause of high system maintenance man-hours. Even when it is known that one of the above causes is operating, the lack of standards makes it difficult to identify the needed remedial action. Finally, the lack of adequate standards increases the difficulty for managers, at all levels of maintenance support functions, to insure the quality of their product.

With all of its inadequacies, the Job Training Standard (JTS) is, however, the only training document now available that relates training to the job. A document such as the training standard is necessary, and should be strengthened. A good training standard does have a listing of job activities. Efforts should be made to make this listing much more realistic and accurate. The code key presently used is weak, with too much emphasis placed on knowledge. The performance part of the code key is stated in terms of adjectives; it should be revised to reflect performance in terms of demonstrated accomplishment, which can be specified in terms of time and errors.

General Finding VIII

Provisions are generally inadequate for retrieval of information from Technical Orders. Examinations of tech orders in use by technicians, and of others related but not viewed in use, clearly bear out the existence of this problem area. In most of the T.O.'s examined, indexes were lacking altogether. Those indexes which were found were observed to be short (1 or 2 pages for a 300 - 400 page tech order) and lacking in entry words likely to be used by technicians seeking information about particular aspects of trouble-shooting problems. The indexes seemed to be designed for the purpose of locating broad classes of information or general discussions of topics frequently of little direct value in troubleshooting.

The following paragraphs are quoted in their entirety from MIL-H-25095(USAF): Handbooks: Field Maintenance Instructions (for Airborne Electronic Equipment).

> "3.20 1. 3 Index of diagrams. Within each applicable section of the handbook, the titles of all diagrams in the section shall be listed in numerical order by the figure number of each diagram."

This paragraph reveals that in order to find a diagram, the technician must know in which section of the handbook to look. Then he must either know the number of the diagram, since they are listed in numerical order, or he must scan the list of diagrams until he finds the title of the one he is looking for.

> "3.26. Index - An alphabetical index, by paragraph numbers, of the topics discussed in the text of the handbook shall be

included. Eliminate the index if the brevity of the handbook does not warrant its insertion."

While this paragraph calls for an alphabetical index, it gives no guidance on the types of descriptors to use, or how detailed the index should be.

The location of important information in the T.O.'s must, as a consequence of the above situations, be learned during On-Job-Training (O.J.T.) or through asking another technician or supervisor. If this has not been or cannot be done, the technician has a strong tendency to proceed with the information he needs, usually in an ineffective (at best inefficient) manner. This is in spite of the fact that the information is (with important exceptions - most notably Federal Stock Numbers), in all probability, in the tech order in one form or another. Further, after a series of unsuccessful searches for information of a particular type, technicians tend to stop trying to find that type of information.

In an extreme example (actually observed), a team of five-and seven-level technicians refused to open a manual when faced with a malfunction in a system and began immediately to troubleshoot by substitution. When questioned, they said it would take longer to find the information they needed than it would to put the system back in operation, and the information would probably be in error anyway. After replacement of 6 relays and an undetermined number of tubes, the trouble was found to be an open fuse--clearly indicated in the manual as a possible cause of the symptom.

SECTION IX

OVERALL CONCLUSIONS AND RECOMMENDATIONS

The general conclusion that must be drawn from virtually any aspect of this study is that the most pressing need for advancement of the technology of maintenance training and performance aids is to reduce to practice those concepts and techniques presently within the capability of research and development people in the areas of training and performance aids. This is not to say that further research efforts should be stopped or suspended. Final answers have not been achieved. But the great gap at present exists between what we know how to do experimentally and what is being done operationally. It is in closing this gap the greatest gains can be made in the technology.

Attempting to apply what is known will also provide a sounder basis for identifying the most productive research avenues of the future. Until the attempt is made to fit the heretofore experimental processes into the operational environment, it is difficult to determine what additional information, obtainable through research, is needed to complete these processes.

There are, however, some matters that could productively be the subject of research studies immediately:

1. Obtain factual information on personnel assignment. Determine the probability, based on past experience, that a technician will be assigned at the end of training, to the particular equipment or class of equipment on which he was trained. Determine the extent to which technicians are transferred or assigned in the field to maintain equipment on which they have had no training.

   This information could possibly be obtained through a computer analysis of personnel records normally kept by the Air Force. If it was suspected that these records might not include the level of detail necessary, a simple questionnaire mailed to a large sample of technicians could provide the needed data.

2. Attach the problem of transfer of training on cognitive tasks. Determine the relative effectiveness of various kinds of principles or concepts in bringing about transfer of training or performance from one equipment to another.

One problem here is to choose the "kinds" of concepts or principles to be studied. The number of kinds is virtually unlimited, depending only on the imagination of the person setting up the categories. It would be worthwhile, however, to start with two particular categories, namely, those commonly used in present Air Force electronic maintenance training and those that would be derived from an analysis of a sample of electronic maintenance jobs. A study comparing the relative effectiveness of these two sets of principles could provide a factual base for decisions on training content for electronic technicians in the event that other investigation revealed that transfer from one equipment to another without cross training was a frequent enough occurrence.

3. Devise and test more adequate performance standards. This problem area has two important aspects. One of these is in performance standards for personnel. How can they best be stated; how can personnel be assessed to determine the extent to which they meet the standards?

The manner in which the standards are stated may imply the manner in which the degree of achievement of those standards should be measured. Since many electronic technician jobs contain the same kinds of functions (checking, adjusting, etc.) and consist largely of procedural tasks, perhaps a generally applicable test development specification could be developed. This general specification could then be adapted to each individual job or equipment system. The specification could include a method for sampling from the job and for setting up performance problems. It could contain an explicit scoring procedure and method for establishing achievement standards for the various skill levels on the tasks in the job.

Related to development of standards and suitable means of measuring achievement of those standards is the matter of periodic checking for the extent to which proficiency is being sustained at an acceptable level. A study should be undertaken to explore the possibility of establishing a workable procedure for effective periodic evaluation of technician proficiency in the field. Consideration should be given to the use of a Standardization Board Crew for this periodic evaluation, analoguous to that used for periodic evaluation of pilot proficiency.

The other aspect of this problem is in performance standards for technical orders or other performance aids. Clear, operation, quantitative statements are needed to specify just what these items are supposed to do in assisting the technician in performing his job. Suitable methods are needed to determine the extent to which the aids meet those standards.

Effectiveness of job performance aids is, of course, closely tied in with training. Consideration should therefore be given to whether secondary measures of performance aid effectiveness could be developed that would permit evaluation of the aids independent of training. This sounds very much like it would lead to descriptive specifications of the kind now in existence. It is hoped that whatever such specifications might result from this effort would be oriented more toward the functional rather than the physical characteristics of the aids.

4. Studies of methods for effective and prompt implementation of the results of research and development. The gap between products and processes used successfully to develop training and performance aids in experimental studies and those used in ongoing operations is very large. Factors contributing to the existence of this gap probably include:

   a. Inadequate dissemination of the research and development results.

   b. Negative attitudes toward acceptance and utilization of the results.

   c. Inapplicability of some research and development results to operational problems.

   d. Lack of capability of the operational people to apply the new facts and methods to their activities.

   The first phase of the suggested studies should include an effort to determine the extent to which each of these, and other factors, operate to inhibit the use of the research and development results more promptly and more adequately than at present. Subsequent work could then be directed toward obtaining the needed facts or developing the procedures required to reduce the gap.

5. Studies of technician attitudes and motivation. The effects of attitudes and motivation are strong both in training and job performance, and probably also have a significant effect on re-enlistment rate. Great improvements in training technology and in job performance aids will be minimized in their effect on performance unless the technicians are motivated to learn and to perform their jobs.

Vital as these matters are, they appear to have received little attention in the context of electronic maintenance training and performance.

It is clear that what is not needed is a survey of technicians' attitudes. The evidence is fairly clear that present attitudes do not foster careful attention to detail on the job. What is needed are studies to determine what factors have what kinds of effects on the attitudes and motivations of the technicians. The results of such studies could provide a factual basis for management decisions designed to produce positive attitudes in the technicians toward their work. An extensive interviewing program is suggested in which the attitudes of a large sample of technicians and technician trainees be examined in some depth. Later studies could then be designed to provide the means by which attitudes toward the job of technician could be influenced in appropriate ways to produce a more effective maintenance capability.

6. Studies associated with new electronic technology. Suggestions for these studies were outlined in an earlier section of the report.

REFERENCES

1. Folley, John D., Jr. & Pieper, William J. Development of a method for generating troubleshooting decision trees. Applied Science Associates, Inc., Valencia, Pennsylvania, 1964.

2. Goldbeck, R. A.; Tibbitts, R. H. & Buchaca, N. J. Deriving maintainability design requirements, fault diagnosis data, and procedures with a computer program. Western Development Laboratories, Philco, May 1964.

3. Losee, J. E.; Allen, R. H.; Stroud, J. W. & Ver Hulst, J. A study of the Air Force maintenance technical data system Technical Report No. AMRL-TDR-62-85, Wright-Patterson Air Force Base, Ohio, August 1962.

4. Rigney, Joseph W.; Fromer, R.; Langston, Edward T. & Adams, Harry C. Evaluation of an experimental fault location device. II. Fault location and isolation by experienced electronics technicians. Department of Psychology, University of Southern California, September 1965.

5. Rogers, James P. & Harris, Julia S. Preparation of MAINTRAIN Troubleshooting Manuals. HumRRO, October 1964.

6. Shriver, Edgar L.; Fink, C. Dennis & Texler, Robert C. FORECAST Systems Analysis and Training Methods for Electronics Maintenance Training, Research Report 13. HumRRO, May 1964.

7. Stahl, W. J.; Maenpaa, J. H. & Stehman, C. J. Development of advanced dynamic fault diagnosis techniques. Technical Report AFAPL-TR-67-44, Wright-Patterson Air Force Base, Ohio, May 1967.

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13. ABSTRACT

A survey, using interview and observation, was made in five subject areas to determine current and anticipated problems associated with development and use of performance aids in the Air Force, and to identify implications of those problems for relevant research. The five areas surveyed are: job-task content and current performance aids for electronic technicians at typical Air Force sites, unique problems of performance aids in limited war operations, current requirements for optimum performance aids, the nature of future electronic technology as it may affect performance aids, and current and future developments in performance aids technology. Visits were made to 12 different Air Force bases, nine equipment development firms and laboratories, one commercial airline maintenance facility, one commercial communications firm, and conversations with ten researchers working in technical data and job performance. About 800 man-hours were spent in collecting information. The survey indicated that a wide range of maintenance concepts are found in the field (from complete modular replacement to replacement of piece parts such as resistors and capacitors); that limited war operations do not change the job-tasks and the performance aid requirements of the electronic technician; that a number of job performance aids systems based on advanced technology have been tested and found to be effective; but that advanced training and performance aids technologies have not been generally applied to operational situations although the vocabulary associated with these technologies is often used.

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	ROLE	WT	ROLE	WT	ROLE	WT
Job Performance Aids						
Technical Order Content						
Technical Data						
Electronic Equipment Maintenance						
Counter Insurgency Maintenance Data						
Microcircuitry Data Requirements						

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