DOCUMENT RESUME

ED 106 329		TM 004 444
AUTHOR	Shriver, Edgar L.; And Others	
TITLE	Evaluating Maintenance Performance: A Video Approach to Symbolic Testing of Electronics Maintenance Tasks. Final Report.	
INSTITUTION	URS Systems Corp., Falls Church, Va. Matrix Research Div.	
SPONS AGENCY	Air Force Human Resources Lab., Wright-Patterson AFB, Ohio. Advanced Systems Div.	
REPORT NO	AFHRL-TR-74-57-IV	
PUB DATE	Jul 74	
NOTE	21p.; For related documents, see TM 004 522 and 643-645	
EDRS PRICE	MF-$0.76 HC-$1.58 PLUS POSTAGE	
DESCRIPTORS	Cost Effectiveness; Criterion Referenced Tests; Electrical Stimuli; *Electronic Technicians; Job Skills; *Performance Tests; Personnel Selection; Simulation; *Task Performance; Testing; Test Validity; *Video Tape Recordings; Visual Measures	
IDENTIFIERS	*Job Task Performance Tests	

ABSTRACT

This volume reports an effort to use the video media as an approach for the preparation of a battery of symbolic tests that would be empirically valid substitutes for criterion referenced Job Task Performance Tests. The graphic symbolic tests require the storage of a large amount of pictorial information which must be searched rapidly for display. At the time this video effort was started, no completely satisfactory way had been found for rapidly searching and displaying such information. The anticipated results that the video media would provide satisfactory and economical solutions to these problems did not materialize. From a testing point of view, video symbolic tests place the test subject in a passive evaluative role of watching someone else perform each task. Success in this passive role does not ensure his success in the active role of performing the same task. Also, the development costs of the video tests proved to be very high in terms of video equipment and test development time. To obtain video materials of acceptable quality, would require both quality video equipment and studio production facilities. As a result, it was recommended that video should not be further considered as a testing medium for performance analogues and that future efforts should be aimed at improving and refining graphic symbolic substitute tests. (Author/DEP)

AFHRL-TR-74-57 (IV)

AIR FORCE

HUMAN RESOURCES

ED106329

EVALUATING MAINTENANCE PERFORMANCE:
A VIDEO APPROACH TO SYMBOLIC TESTING OF ELECTRONICS MAINTENANCE TASKS

By

Edgar L. Shriver
John F. Hayes
William R. Hufhand
URS/Matrix Research Company
Falls Church, Virginia 22042

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

July 1974

Final Report for Period 30 April 1971 – 30 June 1973

Approved for public release; distribution unlimited.

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by URS/Matrix Research Company, 7245 Arlington Blvd, Falls Church, Virginia 22042, under contract F33615-71C-1505, project 1710, with the Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433. Mr John K. Klesch, Advanced Systems Division, was the contract monitor.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-74-57 (IV)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATING MAINTENANCE PERFORMANCE: A VIDEO APPROACH TO SYMBOLIC TESTING OF ELECTRONICS MAINTENANCE TASKS		5. TYPE OF REPORT & PERIOD COVERED Final Report 30 April 1971 – 30 June 1973 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edgar L. Shriver John F. Hayes William R. Hufhand		8. CONTRACT OR GRANT NUMBER(s) F33615-71-C-1505
9. PERFORMING ORGANIZATION NAME AND ADDRESS URS/Matrix Research Company 7245 Arlington Boulevard Falls Church, Virginia 22042		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62703F 17101005
11. CONTROLLING OFFICE NAME AND ADDRESS Hq Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE July 1974 13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Advanced Systems Division Air Force Human Resources Laboratory Wright-Patterson Air Force Base, Ohio 45433		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for publication; distribution unlimited.

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

18. SUPPLEMENTARY NOTES

Volumes I, II, and III of this report are in press.

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

symbolic substitute job tests
Job Task Performance Tests
criterion referenced tests
video testing
maintenance effectiveness
Personnel selection
psychology – individual and group
measurement & evaluation technical training
measurement & evaluation maintenance training
measurement & evaluation electronics training
measurement & evaluation
vocational education

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

This volume reports an effort to use the video media as an approach for the preparation of a battery of symbolic tests that would be empirically valid substitutes for criterion referenced Job Task Performance Tests. The development and tryout of such criterion referenced tests and promising graphic symbolic substitute tests are reported in previous volumes. The graphic symbolic tests require the storage of a large amount of pictorial information which must be searched rapidly for display. At the time this video effort was started, no completely satisfactory way had been found for rapidly searching and displaying such information. In addition, some dynamic displays would have been desirable for those graphic symbolics where as all of the original graphic pictorials are static. The anticipated results that the video media would provide satisfactory and economical solutions to these

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

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20. (Continued)

problems, did not materialize. From a testing point of view, video symbolic tests place the test subject in a passive, evaluative role of watching someone else perform each task. Success in this passive role does not insure his success in the active role of performing the same task. Also, the development costs of the video tests proved to be very high in terms of video equipment and test development time. To obtain video materials of acceptable quality, would require both quality video equipment and studio production facilities. As a result, it was recommended that video should not be further considered as a testing medium for performance analogues and that future efforts should be aimed at improving and refining graphic symbolic substitute tests.

SUMMARY

Problem

In previous studies, reported in Volumes II and III of this report, both criterion-referenced Job Task Performance Tests (JTPT) and matching graphic symbolic substitute tests were developed for measuring technicians' ability to perform electronic maintenance tasks. The symbolic substitute tests, as developed, employed numerous and cumbersome paper displays of equipment, test point readings and schematics as the mechanism for simulating the actual equipment conditions. While promising results were generally obtained, the tests were expensive and required considerable preparation time. In addition, the trouble-shooting tests were the least satisfactory, in always requiring a highly skilled test administrator. This effort was an attempt to "short circuit" these problems that must be solved for graphic type symbolic tests by using a video media.

Approach

The feasibility of using video tape recordings was considered as a method for developing and administering symbolic performance tests for electronic technicians. Video tape recordings were used to document and analyze various types of job performance on an electronic subsystem. These included component removal and replacement, system checkout, special and general test equipment usage, adjustment and alignment, general tool usage, and troubleshooting. Video taped symbolic tests were then produced taking particular advantage of the media's capability to capture dynamic displays such as flashing lights and oscillating needles.

Results

A validation study was performed at Altus AFB, Oklahoma, using both graphic and video tape versions of performance tests. The video tape tests did not provide any increase in efficiency over the paper and pencil tests and appeared to have many technical problems associated with use of the video equipment itself. Video tests place the test subject in a passive, evaluative role – that of watching someone else perform the job task. Success in this passive role does not ensure his success in the active role of performing the task. This is not an appropriate role for an electronic technician. The cost of developing video symbolic tests is very high in terms of video equipment and test development personnel time. The development of video tests in an operational environment presents production problems that limit the quality of the resolution to an unacceptable level. As a result, the development and administration of these video symbolic tests never advanced to the point of a systematic comparison with job task performance criterion tests using electronic technicians as subjects.

Conclusions

This effort surfaced the above-mentioned and other expensive developmental and administrative problems and solved few if any of the problems associated with the graphic type symbolic substitute tests. It was concluded that the video medium did not show sufficient promise to warrant further development at this time. Future efforts concerning symbolic substitute testing should be aimed at improving and refining graphic symbolic substitute tests in keeping with the recommendations presented in Volume III of this series of reports.

PREFACE

This report represents a portion of the Exploratory Development program of the Advanced Systems Division of the Air Force Human Resources Laboratory. This report was prepared by URS/Matrix Research Company, Falls Church, Virginia 22042 under Contract F33615-71C-1505. Dr Edgar L. Shriver was the principal Investigator of the Matrix work.

This document is the fourth of four volumes to be published concerning the evaluation of maintenance performance. Volumes I, II, and III are:

1. Evaluating Maintenance Performance: An Analysis. AFHRL-TR-74-57 (I), in press.

2. Evaluating Maintenance Performance: The Development and Tryout of Criterion Referenced Job Task Performance Tests for Electronic Maintenance, AFHRL-TR-74-57 (II) Part I, in press.

3. Evaluating Maintenance Performance: Test Administrator's Manual and Test Subject's Instructions for Criterion Referenced Job Task Performance Tests for Electronic Maintenance. AFHRL-TR-74-57 (II) Part II, in press.

4. Evaluating Maintenance Performance: The Development of Graphic Symbolic Substitutes for Criterion Referenced Job Task Performance Tests of Electronic Maintenance. AFHRL-TR-74-57 (III), in press.

The preparation of these volumes has been documented under Task 1710 10, Evaluating the performance of Air Force Operators and Technicians of Project 1710, Training for Advanced Air Force Systems. The effort represented by this volume was identified as work unit 1710-10-05. Dr John P. Foley was task scientist. Mr John K. Klesch of the Advanced Systems Division was the contractor monitor. Dr Ross L. Morgan was the project scientist.

TABLE OF CONTENTS

		Page
I.	Background and Rationale	5
II.	Video Technique Description	6
	Approach	6
	Description of the Video Test Materials	9
III.	Results	11
	Test Material Evaluation	11
	Evaluation of Video as a Performance Testing Medium	14
IV.	Conclusions and Recommendations	16
	Conclusions	16
	Recommendations	16
Reference		17

LIST OF TABLES

Table		Page
1	Video Test Development Rationale	7

EVALUATING MAINTENANCE PERFORMANCE:

A VIDEO APPROACH TO SYMBOLIC TESTING OF ELECTRONICS MAINTENANCE TASKS

I. BACKGROUND AND RATIONALE

The purpose of this study was to continue the examination of methods for simulating the electronics maintenance task as a means of measuring the proficiency of individual technicians. In previous studies, reported in Volumes II and III of this series of reports, a standard set of performance tests was developed for a typical electronic subsystem, a doppler radar, the AN/APN–147 and its computer, the AN/ASN–35. These tests were developed in two formats: actual criterion referenced job task performance tests (JTPT), and graphic symbolic representations of those tests so that performance capability could be measured without requiring extensive electronic equipment support. The latter employed numerous paper displays of equipment, test point readings, and schematics as the mechanism for simulating the actual equipment conditions. While a positive relationship was obtained between individual performances on the two forms of the tests, the area of troubleshooting testing, which is the heart of the electronic technician's job, to date, has been the least satisfactory from an administrative standpoint. These symbolic troubleshooting tests provided a display of the test point reading (e.g., a waveform, or voltmeter display) for a wide range of equipment test points. These readings were those actually present in the set when a particular malfunction was inserted into the system. Two main difficulties were encountered in utilizing this technique. First, there was a requirement for a highly knowledgeable Test Administrator who could quickly find the display for a given test point when specified by the test subject; who could recognize when a requested item of information was outside the boundaries of relevance to the problem and give a standard reply (i.e., "Those values are within tolerance"); and who could change symptom displays when an action had been specified that would cause a change in system values. In effect, the electronic equipment was replaced by the Test Administrator who had to respond just as the equipment would respond.

A more general shortcoming affecting all the symbolic tests was the lack of dynamic response of the graphic displays. Many electronic indicators consist of movement of dials or needles, or other dynamic indicators such as flashing lights. Events such as these that occur across a temporal span could only be approximated or described in verbal terms to the technician when employing graphic techniques.

To attempt to overcome these difficulties and shortcomings, an examination of the utility of other media as the display mechanism was undertaken. While there are a variety of such media that could be employed, video tape recording was selected since it offered the most apparent flexibility for capturing and viewing data in the most expeditious manner for research purposes. This flexibility meant that it could also simulate other media such as filmstrips or still slides without involving the reproduction time and expense associated with those media.

The primary tasks of electronic maintenance that had been selected for study in this series of projects were:

1. *Component Removal and Replacement*, dealing with all levels of mechanical assembly and disassembly from dust covers to plug-in components.

2. *System Checkout*, which covers the standard checkout procedures used to verify system functioning at a gross level.

3. *Special and General Test Equipment Usage*, dealing with the employment of the various types of testing equipment used in electronic maintenance.

4. *Alignment and Adjustment*, dealing with the specified routines required to bring the electronic parameters of a system to the correct operating levels.

5. *General Tool Usage*, dealing with the principle hand tools of the electronic trade, primarily the *soldering tools*.

6. *Troubleshooting*, dealing with the ability of the technician to isolate and correct representative faults in the subject electronic system.

In deciding how to employ video techniques to improve the graphic symbolic techniques previously utilized, consideration was given to the deficiencies of the graphic format and how video capabilities could be used to overcome them.

In classic testing theory, elements of a total set of skills or knowledges are selected for measurement. In criterion referenced performance testing, as represented in the previously developed JTPT for electronic maintenance, the totality of skills and knowledges *for producing selected outputs* must be employed to produce the desired output. If the output produced is within tolerance, this is accepted as evidence that a proper set of skills and knowledges has been exhibited in order to produce the output. In fact, by definition, this is an acceptable set of skills and knowledges. It is interesting to note that this "set" represents a "chain" which leads to the production of the correct output. It is a "complete set" for this output. The elements of this "set" do not need to be tested individually to determine that they have been performed correctly. The evidence of a "within tolerance" output is sufficient to indicate that all the elements of the performance were "correct". This would seen to simplify testing procedures. But unfortunately it does not reduce the testing *time* required – or the equipment requirements. The time and equipment required for testing is still high even though the measurement of the product does not require much time.

Is there anything to be gained by sampling a few of the skills and knowledges within a "set" or "chain" which leads to a within tolerance output? It would appear to reduce the time and equipment requirements. But what assumptions would be involved? One assumption is that selected elements from this set would bear a relationship to the total set. That is, failure on an element would be indicative of failure on the total set. This appears to be a reasonable assumption. A second assumption is that elements of a set would be meaningful to the subject outside the context of that set. This assumption appears difficult to meet in some cases. For instance, a pointer on a dial has no absolute meaning outside the context of a "set" leading to some purposeful end product. A subject's ability to read the dial could be measured. But an interpretation as to whether that particular reading was right or wrong cannot be made out of context. So this assumption could be met for the "skill-knowledge" of reading a dial, but not for interpreting that reading. Likewise, the subject would not be able to *select* the proper dials or controls without the context supplied by a *purpose;* the purpose being the product of a certain output. Nor would the sequence of selection of control actions and indicator interpretations be meaningful without a stated purpose.

These things that cannot be measured out of context are the essential elements to be measured to determine if a subject can produce the desired system outputs. The things that can be measured are necessary but not sufficient for producing the outputs. So it seems that in situations where the purpose of a set of skills and knowledges is to produce some output, those skills and knowledges cannot be measured independently of the context provided by that purpose.

How does this analysis impact a test in which the subject would be observing and judging someone performing a "set" intended to produce the desired output? There is an advantage to such a test in that the standard performance can be captured and presented realistically on video. This would eliminate the requirement for equipment for every subject, and groups of subjects could be tested, resulting in time savings using this procedure. The procedure also seems to overcome the problem of context. *But there is a question of whether observing and critiquing someone else's performance taps the same skills and knowledges as does the subject's own performance.* The answer to this must come fron an empirical study, and that, in turn, requires adequate testing materials.

To guide the development of the initial set of video testing materials to examine this question, then, a general rationale was developed for each of the functional testing areas. This rationale is summarized in Table 1.

II. VIDEO TECHNIQUE DESCRIPTION

Approach

The video equipment utilized to develop the testing materials consisted of one camera with viewfinder, a video tape recorder, one monitor, and several types of lenses. An Air Force organizational maintenance shop (electronic) was the setting for filming the maintenance tasks. A number of difficulties were encountered in using such a location. The benefits, however, did outweight the disadvantages. One advantage was direct access to all of the prime and test equipment, and to a sample of experienced technicians. Another advantage was access to a source of technical expertise pertaining to the prime equipment. It was necessary to work during times of relative inactivity, such as during the evening shift, to get adequate uninterrupted access to the equipment. In developing the test materials, typically, a

Table 1. **Video Test Development Rationale**

Test Category	Paper Symbolics Testing Approach	Video Symbolics Testing Approach
Removal and Replacement	S must identify equipment, locate module and component, and indicate fasteners involved in gaining access.	1. S must discriminate from among several removals which was the correct one. OR 2. S must properly identify components as they are removed.
Checkout	S must select from among graphic equipment depictions which are required items, draw connections to correct points and indicate controls to be set to which positions.	S views technician making bench set-up. Indicates on answer sheet erroneous missing connections. S observes technician making checkout and gives his interpretation of whether equipment is functioning properly.
Special and General Equipment Usage	Given a front panel display of an item of test equipment and a specific problem, S must mark the controls and settings, and give the resultant readings.	S views technician using item of test equipment in work context. Must identify any procedural errors, and interpret results obtained.
Alignment/ Adjustment	Give a series of graphic depictions, S must identify correct equipment to be used, location of adjustment point, critical values, and how adjustment is accomplished.	S will be given an adjustment problem and then given time to study his technical data. He will then be shown a series of test equipments from which he must identify that which is to be used. Finally, he will observe a technician performing the adjustment and be required to identify errors made.
General Tool Usage	S must identify correct worksmanship on soldering task. Must also correctly locate and identify piece/parts for replacement according to schematic directions.	S will view a piece/part replacement task being performed. He will be required to note any errors made in performance and evaluate resultant solder connections.
Trouble-shooting	S is told that there is a malfunction that he must find. He then can ask for any information he wants, in terms of test readings and values existing in the system. He must correctly identify the bad component.	S will view a technician conducting a troubleshooting effort. He will be shown the results of each check that is made, up to a given point. He will then be required to define either: a. the next steps to be taken or b. the faulty component or S will be informed as to what problem exists in the equipment. He will then observe the troubleshooting actions of the technician and identify any incorrect actions.

technician was placed at the disposal of the test developers for the length of a shift.

At the outset of the data gathering, a technician was given a general assignment such as "Perform the XYZ adjustment" and an attempt would be made to film his actions. This produced a lot of dead time on the tapes in which nothing was happening as the technician studied his technical documentation, hunted for a piece of equipment, or thought about the problem. While these are all legitimate activities, they are not good video material. In addition, with only one camera, the test developers were seldom properly positioned to catch clearly two successive actions. While they could watch, for example, the technician's actions on top of the equipment, he might then shift to the back or side where his hands would be out of view. This quickly led to the necessity of stopping his actions while the camera was repositioned. The "non-interference" concept soon proved infeasible with limited video equipment. Once the test developers started controlling the technician's actions to the extent of slowing him down or stopping him, it was a short step to "directing" the technician's actions. This ultimately proved to be the most efficient mode of operation.

The approach generally used after the initial period of experimentation was to define the test structure and the action sequences required to present the situation, and then to stage the sequences and have the technician perform defined actions.

One of the major factors affecting the development of video tests is the procedure to be used in administering the tests. The format of materials on the tape must be governed by how active a role is to be taken by the Test Administrator (TA). Essentially there are three levels at which the TA can be employed: full control, limited control, and self-administered tests.

Under full TA control, the TA conducts the whole testing operation. He operates the recorder, provides narration, presents the questions, and controls the rate of video material presentation. This means that he must be completely familiar with the video material and the testing concept so that he can properly program the administration. It minimizes the pre-programming required on the video tape.

Alternatively, the TA may be used in a minor role in administration, only to pass out forms, answer questions and start and stop the video tape on cue. In this mode, the narration and test instructions must be on the tape as well as the signals to the TA for recorder starting and stopping. This requires careful production, planning and timing of the video and audio material, which entails considerable editing and transferring of material from tape to tape.

Finally, the goal may be to achieve a totally self-administered test. This may be technically feasible with the advent of cartridge and cassette recorders which a technician could easily load himself. There are two elements, however, which make this mode difficult to achieve. *First*, a technician must be given time to think and analyze a situation once it has been presented to him. Troubleshooting is not a matter of recalling specific answers or bits of information in response to a question. *Secondly*, the technician must be allowed to use his standard technical documentation. No one is expected or even permitted to troubleshoot without referring to the manuals on the equipment. Both of these activities, however, require time. This means that the tape recorder has to be shut down for a given period so that this work can be done. *Further*, each technician being tested would require varying amounts of time for reference and analysis, so that any pre-programmed amount of time would be inappropriate for some percentage of the test subjects. While in a self-administered test the technician could stop the tape (or even reverse it to view again), this would not be appropriate for group administration, which is one of the goals of video testing. A recorder would have to be obtained that could be programmed to start and stop automatically at specified poi: ..

The issue of time necessary for technician review and analysis also impacts the previous alternative of a limited TA role. There is an easier solution available in that case, however, in having the TA control the review time. Since that alternative represented both challenge and feasibility, the video test materials were developed based upon a limited TA role.

In addition to the extent of the TA role in video testing, another consideration affecting test strategy is the choice between providing very structured response possibilities (e.g., multiple choice responses), or requiring constructed responses based on information presented. Since there was no clear rationale available for pre-selecting one approach or the other, both were employed. Under the first approach, questions were constructed that had the technician select, based on what he had been shown on the video tape, the proper component name, fault, or next action required from among four choices. As designed, the technician had a card on which he punched out his selected response number after listening to the question and the response choices given verbally on the tape. An alternative approach to this would be to provide the questions in printed form for him to read. The trade-offs involved are that in the written question format the subject's visual attention is divided between the screen and the paper. In the verbally presented questions, the technician must remember the questions and alternative answers long enough to decide which one he thinks is correct. While the latter approach reduces the amount of reading required, it does impose a different source of variance in the retention requirement.

When video is used as the primary means of test administration, *there are only a limited number of testing strategies available. The most compelling of these,* based on the nature of the medium, is that of having the subject *critique* the performance demonstrated to him. In this, the subject observes the action of the demonstrator and then is asked questions concerning both the appropriateness of the actions shown and the correctness with which they were performed. *The critiquing type activity is not, of course, the standard activity of the electronic technician.* Certainly the question of whether success in such activities corresponds with the capability of performing maintenance activities on one's own would have to be demonstrated, since there is no basis for making such an assumption. *The only case where critiquing activity does correspond to actual job duties is that of the supervisor. It may be that the evaluation of supervisory personnel is the most valid application of video tests using this strategy.*

Another basic testing approach available is that of having the subject state what he considers to be the next required action based on given information. In this, a subject might be shown a series of checkouts and their results and be asked what should be checked or replaced next. A recurrent problem in using this strategy in electronic maintenance is the presence of multiple correct answers. In terms of process, different technicians may proceed in different directions to arrive at a problem solution. Thus, the grading of responses to such questions become difficult.

A third strategy is to use video to present discrete results for direct interpretation. For example, in testing the ability to use a voltmeter or oscilloscope the meter readings or waveforms are shown along with the control settings for the subject to read. The subject is asked specific questions concerning the instrument reading. The video medium does not permit him to operate the dials or, in itself, let him indicate what should be operated or set.

To achieve any flexibility or expansion in the testing strategies available, it is necessary to introduce other media into the testing structure. The use of symbolic answer forms, for example, permit a recall type of response rather than the rec[illegible]e required in the video tests. H[illegible]o[illegible] other media are introduced, the role o[illegible]ideo becomes reduced and the flexible part of the testing system becomes the alternative medium. When this occurs, it is hard to rationalize the use of video as the presentation medium since less expensive alternatives come easily to mind.

Description of the Video Test Materials

Removal and Replacement. The tests in this area consisted of having a demonstrator, being given a specific assignment (e.g., "remove the crystal oscillator") proceed to remove a given component. For each instruction several sequences were taped, consisting of the location and removal of the specified component and several sequences showing the removal of the wrong component. The test subject would be shown any one of the sequences and asked whether it was correct and whether proper tools and procedures had been utilized. The main element of this testing was recognition and identification capability on the part of the test subject.

The video taped materials of the removal/replacement process permitted adaptation to either of the original testing strategies outlined, that of *recognition* or that of *identifying components* as they were encountered in the taped sequence.

System Checkout. The checkout procedures for the AN/APN-147 Radar system involve making equipment connections with a test harness, generally mounted in the workbench, energizing the system, and then observing the response of several indicators as the input signals are varied. In the video testing of this task the procedures for setting up the equipment were taped and were to be tested one time. The checkout procedure itself, however, is an integral part of the troubleshooting process, so that it is essentially tested in every troubleshooting problem. The graded portion of the checkout test, then, was included in the troubleshooting tests.

The checkout procedure was tested by taping the results of the checkout with each of the various faults inserted into the radar system. This produced tapes with varied results to be interpreted during the checkout. There were several possible conclusions that a technician could reach as a result of watching the checkout procedures:

a. The radar system is functioning normally (within tolerances).

b. The radar system is malfunctioning; suspect a problem in the frequency tracker.

c. The radar system is malfunctioning; suspect a problem in the receiver/transmitter.

d. The radar system is malfunctioning; suspect a problem in the computer.

e. The radar system is malfunctioning; suspect a problem in the antenna.

The checkout procedure was considered particularly well adapted to the video approach since the movement of dial and meter indicators had to be observed over a specified time period. The response of those indicators provides the cues to the technician as to the most likely general location of a specific malfunction.

Special and General Test Equipment Usage. In the use of test equipment the prime requisites are selection of the proper equipment, correct hookup of the equipment, proper usage, correct reading of the results, and, finally, correct interpretation of the results.

For the special test equipment these elements were tested in the context of their application to the prime equipment since, by definition, that was their only application. The video tape for these tests showed a technician performing a defined function which required the use of the item of test equipment under test. The test subject had to verify whether the item shown was the required piece of test equipment, observe and note any errors made in connecting the equipment, observe and critique the control settings used by the demonstrator, and observe and interpret the results obtained. In most cases the tapes for testing the use of special test equipment items were lengthy since the set of equipment involves numerous connections and ancillary equipments.

The video test materials for the general test equipment followed the same format, however, this equipment (i.e., voltmeter, oscilloscope, tube tester and transistor tester) was tested on non-prime equipment in the actual performance tests. Special signal generators for the voltmeter and oscilloscope were used to have a complete and standardized set of test responses required. The same input devices were used in the video test so that a comparison of results could be made. In addition, however, it was necessary for the test subject to interpret results obtained on these items of test equipment during the course of the troubleshooting problems. That is, voltage readings and oscilloscope displays had to be read and interpreted as part of these problems. The test subjects were not evaluated on the basis of that interpretation, per se, however, in the troubleshooting test. Therefore, separate test equipment usage tests were developed as a basis for dignosing specific individual skill areas.

Alignment and Adjustment Tests. The video materials to test this functional area were developed on the basis of depicting correct and incorrect procedures for accomplishing specific adjustments on the equipment. A specific named adjustment was announced as the subject of the test. The video material then showed a technician proceeding to accomplish that routine. He first selected the equipment he would need, made the equipment interconnections, demonstrated that the subject test value is out of tolerance, manipulated the controls on the prime equipment that affected that parameter (e.g., coils, trim pots, etc.) and then rechecked the output values. The test subject observed the actions of the technician-demonstrator and was asked specific questions about the events on the screen as the action progresses. He was required to indicate whether proper equipment connections were made, whether tolerance values were correct, whether correct controls were adjusted, and whether the equipment was properly adjusted.

General Tool Usage. In electronics maintenance the most commonly used hand tools and the most critical are those associated with soldering. The tool usage test, therefore concentr es on this skill. The other hand tools employed (screwdriver, wrenches, etc.) are represented in the removal and replacement task and are considered too rudimentary to be covered in separate usage tests. Soldering, however, is a complex skill made up of many separate sub-skills. The individual must have physical dexterity and be able to locate the proper components, select proper replacements, select proper soldering tools, remove components without heat damage to adjacent components, and install a replacement properly, again without heat damage.

The video tape materials for this test consisted of two parts. The first presented the array of soldering tools and quizzed the subject on their proper employment. The second part showed a series of piece/part removals and replacements illustrating common errors in tool selection, installation and component selection. The test subject is to observe the procedure used and answer specific questions about what was done correctly and incorrectly.

Troubleshooting. The video tests for troubleshooting incorporate all of the previously covered skills into an integrated performance directed at finding and correcting a system malfunction. In the performance tests of troubleshooting the individual was simply told that the radar set was inoperative and he was to fix it. This meant he had to start at the beginning of the checkout routine and track down through the system to the defective part. He was permitted to use any techniques or procedures he chose without penalty, being graded only on whether he found the problem.

The video materials had to incorporate some troubleshooting strategy, however. Therefore, the test subject was shown the demonstrator carrying an action to a decision point and then the test subject was queried about his interpretation and decision based on what he had seen. He was then shown what the demonstrator had decided to do which could either be right, wrong or neutral (i.e., different but not incorrect). Whenever the test subject felt he had enough information to reach a conclusion about the fault he could indicate his answer. The video tape material proceeded to show the demonstrators actions as he made his decisions and attempted various corrective actions. After each attempted corrective action it would be checked out and the test subject would indicate whether or not the fault had been corrected, and, if not, what should be done next.

III. RESULTS

Test Material Evaluation

The video materials developed in this project were subjected to several forms of evaluation at various stages in the project. These consisted of evaluations by psychologists viewing the materials and critiquing the test strategies employed and by administering the test materials to both novice and experienced electronic technicians. *These test administrations, however, never advanced to the point of giving both the video and actual performance tests to any of the technicians for comparison purposes.* This was due to the difficulties encountered in getting a satisfactory version of the video tests to warrant such a comparison. The results reported herein, then, are what was found in administering just the video materials, observing and questioning the test subjects on their reactions to the materials, and their relative success in the tests themselves.

General Test Equipment Tests (GE). The following items of equipment made up the GE category of tests:

- VTVM
- Oscilloscope
- TV–2 Tube Check
- 1890M Transistor Tester

In transitioning the general equipment usage tests to the video format, the hypothesis was that the added fidelity of the displays, with actual meter movement where appropriate, would result in more valid tests or equally valid but more interesting tests. The actual result, however, was that the video versions of these tests remove at least one degree of freedom from the graphic versions – that of allowing the subject to adjust the control settings – while not significantly improving the display fidelity. Neither were advantages of interest or production efficiency achieved. As a matter of fact, both were at a disadvantage when compared with the graphic versions. Since video must be paced for the slowest individual in a group, it tends to be boring for the average and faster subjects. In terms of production, the cost in time and labor is much higher than for the graphic versions, so no advantages are gained in that respect.

The most serious disadvantage found with the use of video to measure test equipment usage ability was the need for lock-step presentation of information. Typically, each individual will examine the piece of test equipment in a random and unique fashion, therefore, he will operate best when having a fixed, static display (either real or simulated), given that he can inspect, consider, and reconsider, using the display as an aid to recall. A video display, due to limitations of lenses, must focus on one control position at a time. The subject has to accept or reject the relevance of that control and its value setting when it is shown. He cannot come back to it at will. Thus, the individual with less than highly-developed usage skills is penalized by lack of observation control while the proficient individual must view much more information than he needs. Since the video testing techniques for general equipment usage have multiple disadvantages while offering virtually no advantages, it is concluded that performance on this type of task is not best tested via the video medium.

Removal and Replacement Tests. The primary limitation in testing these types of tasks via video is in the lack of wrong alternative procedures that can be presented. About all that can be shown incorrectly is the removal of the wrong element, which is primarily testing component identification skills. This skill is readily tested with printed graphic materials. The elements of the removal and replacement task for electronics are basically very simple once location is known. For the most part, they consist of manipulating screw fasteners and plug-in units, such as tubes and circuit boards. Therefore, the physical demands are limited, and, due to the size of the equipment, there are few critical sequential aspects that can be portrayed. Video testing of these tasks has not been found to offer any advantages over the graphic symbolic media.

Special Test Equipment Usage Tests. The only way to employ the items of test equipment covered in this category (UPM-10, Signal Generator, URM-25, and Audio Oscillator) is in the process of performing a specific alignment or adjustment on the prime radar equipment. The video materials developed for the tests on these items of special test equipment, then, overlap with that portion of the larger alignment/adjustment test. They duplicate that portion dealing with the use of the particular item of test equipment, but are presented and evaluated differently.

In the test equipment usage test, the elements of the task are evaluated in greater detail than in the adjustment task. The elements of this task that are evaluated are identification of the test equipment, connecting the test equipment for use, correct manipulation and setting of the controls, both on the prime and test equipment, and reading and interpreting results.

While the degree of overlap of these tests with the associated adjustment tests varied, in most cases it constituted a significant and critical portion of the adjustment task. This is particularly true of the video tests, more so than the performance tests. In performance tests of adjustments, the individual has to demonstrate that a radar set has been put back into tolerance on the subject parameters. This is all the Test Administrator has to grade. The test subject can use any equipment he wants, although there are not generally workable alternatives available. In the video version of the adjustment task, however, since the final result cannot be controlled by the test subject, *he must evaluate processes* in order for the examiner to know whether he has an understanding of the correct procedures and outcomes sought.

In the performance test for test equipment usage, the test subject is given the same general assignment as in the corresponding adjustment task only he is instructed that he must use the particular item of special test equipment under test, even if he would normally employ other equipment or techniques in its place. In the performance tests, there was the possibility of a difference between the way the same task was performed in the above two tests and the grading system was set up accordingly. In the video version, however, the two were by definition the same, since it was considered legitimate only to present approved methods of task performance with the label "correct" on them. Local variations, procedures, and short-cuts were tolerable in the performance tests but could not be promulgated via the video tests. Due to this situation, then, the evaluation of special test equipment usage capability was integrated into the appropriate alignment/adjustment test.

System Checkout Tests. A somewhat similar situation existed with the system checkout procedures. The basic connections necessary to make a radar system checkout are lengthy and involved, so that in actual practice a "bench set-up", once established, is maintained intact even though it may be used only occasionally. The checkout portion of the task, however, is employed repeatedly as the initial part of the troubleshooting process. The bench set-up capability was tested once in the performance tests as a specific skill, but was not required each time a checkout was made. In the video tests a comparable division of the task was made. The checkout was tested separately in the performance test to provide a separate measure of that skill since, while it is part of the troubleshooting process, it was not separately evaluated. In the video tests, however, it is measurable each time a troubleshooting test is taken, since the checkout process is performed in standard fashion each time. Therefore, a separate test of checkout procedures was redundant in the video tests, whereas it was necessary in the performance tests.

General Tool Usage Tests. The ability to solder properly is a skill that has thus far defied satisfactory testing via symbolic techniques. It is a combination of technique and individual physical dexterity and only the technique portion is ultimately testable in symbolic format. Recognizing this limitation, graphic symbolic tests were developed which dealt with the individual ability to recognize proper soldering jobs, to identify correct and incorrect part replacements, and to translate from schematics to actual parts location. All of these were considered as ancillary soldering skills. To test these skills, however, it was necessary to segment them considerably. Judging completed solder joints was one segment, selecting proper tools another, and correct parts installation a third.

In the first area, video did not offer any significant advantage since sufficient resolution could not be achieved to permit accurate discrimination of good and bad solder joints. In the latter two areas, however, video does permit a much more realistic problem to be formed. The soldering process can be shown combining the elements of equipment usage and parts replacement in a manner closely resembling the actual job. A number of questions can be asked concerning these aspects of the job as they are being performed on the screen, which is more realistic than the graphic exercise which requires interpretation of a representational line drawing. Thus, while the evaluation of physical dexterity related to soldering is still not measured, the related skills measurement appears to be improved with the controlled video presentation.

Alignment/Adjustment Tests. Alignments and adjustments on electronic gear involve the use of numerous items of test equipment and specific processes to check and set the various operational parameters of the equipment. The elements of the task are: knowledge of appropriate test equipment, proper hook-up of equipment; checkout procedures; location of adjustment control; application of tolerance limits, and interpretation of readings so that proper adjustment is made.

In converting to graphic symbolics for these tests, the elements retained were equipment connections (drawing lines between equipments), location of adjustment control (by marking pictures), identification of test equipment to be used, and results interpretation (by interpreting display pictures). The evaluation of the subject's performance is made in terms of the correctness of each of his responses to these test items, since the test materials are not responsive to his actions. The evaluation scheme shifts, then, from the product-oriented type to the process-oriented type.

In applying video technique to the alignment/adjustment test area, attempts were made to utilize the dynamic aspects of video to increase the realism of the task. A demonstration of the specific alignment procedure was staged to illustrate both correct and incorrect procedures being used at various points in the performance. During the showing of the tape, subjects are quizzed about what is being done. They must "critique" the demonstrated performance by answering questions about it. The topics covered are equipment set up, results interpretation, tolerance limits, and test equipment usage.

While video offers some advantages in the testing of alignment and adjustment capabilities (in terms of displaying for the test subject the myriad of connections to be considered and the dynamic response of the output indicators), this is one of the areas where integration of documentation usage is most difficult and important. These procedures are seldom performed without constant reference to the technical documentation. The technician uses it for checking on procedure and confirming tolerances. When attending to the video presentation and verifying the procedures being used therein, it is impossible to shift attention to the documentation unless the videotape is stopped to permit this. In addition, the lengthy checkout routines become even longer when each step has to be carefully and distinctly demonstrated.

Troubleshooting Tests. The tryout of the troubleshooting materials indicated the difficulty of having to impose an arbitrary strategy on a technician and have him evaluate it. It appears that one of the critical links required to do this is a description of the rationale being employed by the demonstrator. That is, when the technician taking the test sees a symptom or malfunction indication, he may make assumptions based upon logic, experience, or hunch any of which may lead to a different successive action. When the demonstrator in the film takes a follow-up step it may or may not correspond to that which the test subject would have taken. Whether either is "incorrect" is a moot point. In terms of the performance tests the procedures taken would not have been evaluated per se, only whether or not the malfunction was fixed. To have the test subject view a 30 - 45 minute tape sequence and then describe what was done incorrectly was, of course, unreasonable. The initial approach used was to have him view each discreet operation, (e.g., system checkout, power supply check, etc.) and then answer several questions about the procedures used, the results obtained, and the recommended next action. The test subjects became bored even when the tape was broken into viewing and testing segments of 5-10 minutes. It was simply tedious to sit and watch a very methodical depiction of all the actions. The actions had to be methodically portrayed, of course, otherwise there was no way to make sense out of them. One had to know precisely which test point was being checked or which trim pot was being adjusted to evaluate what was happening. To display such information required careful camera positioning and then, because of the cramped location of such items and their similarity in appearance, it was necessary to provide the viewer with sufficient overview so that he could identify exactly where the demonstrater was working. The amount of such referencing data that was necessary for the viewer varied with the level of experience. Since no assumption of high experience could be made, a high level of reference views had to be included. This contributed to the slow pace of the action on the film and the length of the time required to present sufficient information to frame the problem.

Evaluation of Video as a Performance Testing Medium

Based upon the results obtained in the individual test areas, *it was concluded that video has several inherent characteristics that makes it undesirable as a medium for administering performance tests in electronics maintenance.* These characteristics affected all of the individual test areas, and were found to outweigh the originally sought advantages of prime equipment reduction, group administration, and dynamic display characteristics. Specific deficiencies identified are summerized as follows:

Presentation Time Required. In order to solve problems in electronic maintenance it is necessary for the technician to have access to a large amount of data about equipment conditions. He must then be able to select the relevant and necessary data from that information. If the symptoms of a malfunctioning radar are to be interpreted, for example, it is necessary for the student to see how they were obtained, where any readings or measurements were taken and what the exact results were. *To portray this in meaningful context via video takes about as long as for the technician to do it himself,* less, of course, the normal time required to find equipment, gather up *tools,* connectors, etc., and the other time consuming side activities associated with performance in a shop environment. While actually performing the test tasks keeps the subject occupied and perhaps interested, watching someone else do it does not. While all that is needed is to know what the results of such checks are, results given out of context are confusing. Further, to boil down results to a series of displays removes the main function of video, which is to show the details of process.

Passive Nature of Tests. Video requires the test subject to observe and react to the actions shown on the screen, and he cannot control or alter what is presented. Since the video must be presented in a fixed sequence, that sequence must be prescribed. The information on tape cannot readily be randomly accessed with present equipment. Therefore, it cannot give him a result based upon his action. The video suffers, therefore, from the lack of responsiveness just as do the graphic symbolic forms of the test.

The passiveness of the video, combined with the extended presentation time required, creates a problem in that it is boring to watch someone else perform for an extended period. Yet the observer must remain attentive for if he misses a critical item, what follows can become meaningless. This is not as true when the subject is performing himself. He may make a mistake but he goes on with hypotheses and beliefs that are meaningful *to him.* That is, he may be wrong, he may be performing meaningless steps so far as the "real" problem is concerned. But if he doesn't know that, it has some meaning for him - even though it's the wrong meaning. The point is that he doesn't become bored or distracted so long as it seems meaningful to him.

Conflict with Documentation Usage. Since video has, by definition, high visual demands, it presented a basic conflict with a dominant visual demand of electronics maintenance for the use of documentation. To be realistic, the problems presented in the performance tests require that the subject be permitted to refer to his technical documentation. The technician must use such information on the job and he is not supposed to rely on his memory for technical data. In video testing, however, the situation is encountered where the subject must attend to two information sources – the video and the technical documentation. To produce video tests that can be validated against performance tests, the use of such documentation must be an integral part of the test design. This introduces the need to predict both the points at which the subjects will have to refer to their documentation and the amount of time that will be required. Such requirements will, of course, vary with individuals and allowance has to be made for slower individuals. Alternative methods for accomplishing this are available based upon the administrative techniques employed. If the tests are to be strictly standardized in terms of administration, then the frequency and duration of time allowed for documentation usage can be controlled by the voice-over on the tape, along with the regular narration. Alternatively, if less control is possible, then the Test Administrator could control the use of the documentation. In this approach the Test Administrator would observe the subjects and when he judged that sufficient time for documentation usage had been allowed, he would re-start the video tape. Doing this would mean that the frequency and time allowed for documentation usage would vary from administration to administration. If this variation can be tolerated it would permit the test to continue when everyone is ready to continue, rather than waiting for a fixed interval.

The question of documentation usage is further complicated when the video tests are administered to personnel using Proceduralized Job Performance Aids (Foley, 1973). Using such aids, the subjects are to perform every maintenance action according to specific written instructions. Theoretically all decisions about what actions to take have been accounted for in these instructions. Use of such materials has two major impacts on video tests. *First,* time for documentation reference has to be provided more frequently. The test subject would have to check each step against the documentation to know whether it had been performed correctly since much less information is supposed to be in the JPA user's head than for conventionally trained personnel. *Second,* questioning the subject as to the most appropriate next step would not be meaningful since the next step is directed by the JPA. JPA users do not generate their own troubleshooting strategy.

Video Material Development Costs. A major consideration with respect to the use of video test materials is the expense involved in their production. This expense is incurred in several ways. Equipment is required that will produce an acceptable product and facilities are required for the production of the materials. These will likely be operational facilities rather than studios since that is where the equipment and personnel are located. Working in these environments is less than maximally efficient since operational priorities can intrude at any time. Further, videotaping requires sufficient control of conditions so that usable material will be obtained, which involves setting up shots, controlling the actions of the demonstrator, and insuring minimum essential environmental conditions. In doing those things, expense is incurred either in video equipment and accessories or in increased time and personnel costs to compensate for equipment shortcomings. In the latter case limits of such compensation are reached where increased production time cannot make up for equipment deficiencies.

The approach taken in this study was to start with limited equipment on an experimental basis to determine whether a greater investment was warranted. In some respects, this guarantees marginal results. To obtain video pictures with sufficient resolution for any degree of detailed observation, it is necessary to have good equipment at each critical point in the system - camera, recorder, and monitor. Next there must be a minimum of two cameras (and probably more) to provide proper viewing angles, and this requires some switching equipment, as well as multiple monitors for the cameras. An adequate assortment of lenses is required to provide flexibility, and supplemental lighting will likely be required. If any editing of tape is required (and it almost certainly will be), then a second recorder compatible with the first must be available. In this project, with one camera, recorder and monitor, a minimum of two people were required to operate the equipment and control the action of the technician-demonstrator. The recording was, of course, conducted in a nonstudio environment. However, it seems that this would very often be the case, if one were dealing with operational prime equipment that could not be readily made available in a studio.

As the basic system and operational conditions get more complex, the requirements for operator personnel may increase, with resulting increase in costs. In this project, approximately 15 hours of video tape material was recorded. Over 700 manhours were required to obtain this material. While this included some excess time as various alternatives were tried out, and certain other experimenting, it also included down time spent while repairing the prime radar equipment, yielding to higher priority work requirements at the site, and waiting for test equipment to become available. These are typical costs that have to be paid when the video taping mission is secondary. This, too, is a high probability condition. The total time required could likely have been reduced by more equipment. As it was, considerable time was required to shift the camera, lights, and human subject when a different view was necessary. If pre-positioned cameras were installed, then such shifts could be accomplished by a switching device.

Once the desired material is on tape the next step is to edit it. This consists of selecting the specific sequences desired, eliminating unwanted material and adding the desired narration. This process is not easily accomplished and can best be facilitated by having a complete and accurate log of the location of each specific action sequence. The desired final tape should then be programmed on paper first to define the desired sequence such as spacing and tape source. This will greatly facilitate the actual manipulations of the videotape, which is desirable since the resolution quality and durability of the tape decrease rapidly with frequent stopping, starting, and re-winding.

To accomplish the editing functions requires a second recorder so that tape material can be transferred onto a second tape at the desired location. This process requires equipment with electronic editing capability to produce satisfactory results. Without it, the junctures at which materials are inserted produce considerable visual noise caused by the start up of the recorder mechanism.

The value of the equipment used in this project was about $2,500. A minimum of equipment estimated as required to produce tapes of sufficient quality for viewing and reproduction would be $7,500 to $10,000. This would provide two to three cameras, assorted lenses, two 1/2-inch video tape recorders with electronic editing and remote control, three monitors, a switching network, auxillary lighting, tapes, and associated hardware for interconnection. A minimum amount would also have to be invested in carts, stands, etc., in lieu of a console. This is estimated to comprise a minimum system to produce adequate video tapes under nonstudio conditions.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The testing strategies available for video application are not very appropriate to the nature of the electronic technician's job. They are limited in permitting a technician to pursue alternative courses of action, cannot conveniently permit use and study of technical documentation, and require a lock-step presentation that is not efficient for this type of work.

2. For the most part, these testing strategies violate a major ground rule of criterion referenced tests for electronic maintenance (as discussed in Vol II of this series of reports) which places the measurement emphasis on an acceptable product. In most cases, video test strategies must place the measurement emphasis on process.

3. Video symbolic tests place the test subject in a passive, evaluative role of watching someone else perform the job task. Success in this passive role does not ensure his success in the active role of performing the task. The passive, evaluative role is an appropriate one for a job supervisor, a test administrator, or an instructor - not for an electronic technician whose job is to perform the task.

4. This effort indicated that the cost of development of video symbolic tests is very high in terms of video equipment and test development personnel time.

5. Development of video tests in an operational environment presents production problems that limit the resolution of the taped information to a less than adequate level for testing purposes.

6. The use of quality video equipment and studio production conditions is the only way that video materials of acceptable quality can be produced for testing purposes.

7. Due to development and administrative cost and the other shortcomings indicated above, the administration of these video symbolic tests never advanced to the point of giving both the video and the job task performance criterion tests to any technicians for systematic comparison purposes.

8. This video effort was an attempt to "short circuit" some of the administrative problems that must be solved for graphic type symbolic substitute tests. The attempt to use video for this purpose surfaced expensive developmental and administrative problems and solved few if any of the graphic type symbolic substitute test problems.

Recommendations

Based upon the foregoing conclusions and upon the results of the preceding efforts in this program reported in the first three volumes of this series of reports, the following recommendations are made regarding future development and use of symbolic testing materials for electronics maintenance.

1. The method of video presentation described in this document should not be considered as a testing medium for performance analogues. The method of presentation described places the test subject in an observational rather than a performance mode.

2. Future efforts should be aimed at improving and refining graphic symbolic substitute tests in keeping with the recommendations presented in Volume III of this series of reports.

REFERENCE

Foley, J.P., Jr. *Description and results of the Air Force research and development program for the improvement of maintenance efficiency.* AFHRL-TR-72-72, AD 771 000. Wright-Patterson AFB, Ohio: Advanced Systems Division, Air Force Human Resources Laboratory, November 1973.