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Technical Report 69-25

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Development of a Procedure-Oriented Training Program for HAWK Radar Mechanics

AD 868139

HumRRO Division No. 5

December 1969

Prepared for:

Office, Chief of Research and Development Department of the Army

Contract DAHC 19-70-C-0012

HumRRO

HUMAN RESOURCES RESEARCH ORGANIZATION

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Development of a Procedure-Oriented Training Program for HAWK Radar Mechanics

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HumRRO Division No. 5
Fort Bliss, Texas
HUMAN RESOURCES RESEARCH ORGANIZATION

Technical Report 69-25
Work Unit HAWKEYE
Sub-Unit I

The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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FOREWORD

This report describes the development and evaluation of an experimental program for training HAWK Continuous Wave Radar Mechanics. The study was done by the Human Resources Research Organization under Work Unit HAWKEYE, Sub-Unit I, A Functional Context Course for Radar Technician Training. The research described and the major portion of report preparation was performed while HumRRO was part of The George Washington University.

The HAWKEYE research was conducted at HumRRO Division No. 5, Fort Bliss, Texas. The study was performed under Dr. Robert D. Baldwin, Director of the Division.

Military support for the research was provided by the U.S. Army Air Defense School and the U.S. Army Air Defense Human Research Unit. The Military Chief of the Human Research Unit was LTC Leo M. Blanchett, Jr. at the inception of the research effort, and MAJ Alexander D. Bell at the time it was completed.

The HumRRO research team consisted of Dr. James P. Rogers (Work Unit Leader), Mrs. Julia Harris (Research Scientist), Mr. William Kuza (Equipment Specialist), and Mr. Wayne Burkett (Equipment Specialist). Dr. Albert L. Kubala, assisted by SP4 George Nelson, U.S. Army, was responsible for the field follow-up portion of the study. Mr. Dave Francis and Mr. R.C. Montgomery played major roles in the development of the training devices. Dr. Rogers and Mrs. Harris terminated employment with HumRRO prior to completion of reporting on the research. This report was prepared by the Staff of HumRRO Division No. 5 and of the Office of the Director for Research Design and Reporting; it is based upon information existing within research files and information provided by technical people at Fort Bliss who were associated with the research.

The HumRRO team was augmented by two civilian staff members of the Air Defense School, Mr. Walter Lee and Mr. Ernest Toaso, who participated as fulltime members of the staff and prepared considerable amounts of the training literature used in the experimental course.

The continued support provided by Mr. Peter J. Baker, the Project Officer of the Low Altitude Missile Department, U.S. Air Defense School, was a valuable factor in the conduct of the research. Appreciation is also expressed to the many other individuals at the School who contributed in great measure to this project. In particular, the support of the late COL Maxwell Kallman is acknowledged. COL Kallman was successively the Director of Instruction and the Deputy Assistant Commandant of the School during the earlier phases of this work. His high level of interest in training innovations was the stimulus for the substantial support provided this study by the Air Defense School.

HumRRO research for the Department of the Army is conducted under Contract DAHC 19-70-C-0012, with training studies conducted under Army Project 2Q062107A712, Training, Motivation, Leadership Research.

Meredith P. Crawford
President
Human Resources Research Organization

MILITARY PROBLEM

It is not unusual for a substantial number of students who enter electronics maintenance courses to fail to complete their instruction. Although some students are relieved for administrative reasons or illness, the major cause of attrition is academic deficiency. While attrition in any course is expensive, in electronics maintenance courses the development of practical techniques for reducing such losses would be particularly desirable in order to improve personnel utilization and training efficiency in a military activity of critical importance.

BACKGROUND AND OBJECTIVES OF RESEARCH

Previous HumRRO research concerning functional context and procedure-oriented training has indicated that attrition in electronics maintenance courses could be lessened by reducing training emphasis on abstractions such as electronics theory, and concentrating instead on explicit, pre-developed, standardized procedures for troubleshooting. At the request and with the cooperation of the U.S. Army Air Defense School (USAADS), this study was undertaken to determine whether attrition could be reduced and adequate performance obtained in complex radar maintenance courses developed by applying functional context and procedure-oriented training concepts.

All the previous studies successfully applying procedure-oriented instruction included use in the field of the special job aids presenting the procedures. In contrast, in this study, while the procedures were to be developed and prepared in job aid form for use in instruction, special job aids were not to be available for use by graduates in the field. Thus, equipment analysis was to be directed toward producing a smaller number of simpler procedures than is typical, and training was to be heavily directed towards trainees learning and remembering the procedures, in contrast to emphasis on how to use the job aids.

A supplementary objective would be an attempt to develop "how-to-do-it" guidance documents that could be used in converting other technical training programs to the procedure-oriented approach, should this approach prove to be promising.

METHOD

Personnel from USAADS worked with personnel from HumRRO to develop a 24-week training program for HAWK Continuous Wave Radar maintenance men (MOS 23R) as a prototype for procedure oriented maintenance instruction. This involved (a) the specification, based on equipment analysis, of the complete procedures for doing the job, and (b) the development of instruction to teach these procedures, including the development of symptom-collection manuals—this material to be available to the student during training but not available as job aids in the field—and all other necessary training literature and devices. The experimental course was designed to be the same length as the conventional course and to make comparable use of training facilities.

The research staff trained military instructors in the new procedure-oriented type of instruction. These instructors. under research staff supervision, then taught an experimental class of 30 students who were typical of the input for this MOS. Instruction and materials were revised on the basis of this experience, and the course was administered to a second experimental class; this experiment included a separate test of the proficiency of the experimental students in troubleshooting with and without the use of the symptom-collection manual as a job aid.

Subsequently, a third class of students was managed and taught by the USAADS without researcher participation; this experiment included the development by USAADS personnel of procedures and instruction on an additional piece of equipment that had been assigned to the MOS.

In each experiment, end-of-course job-sample proficiency tests (covering the major maintenance activities of checks and adjustments, and troubleshooting) were administered to both the experimental classes and to control classes that were conventionally trained at approximately the same time. These tests were used in each of the three experiments to establish a pass-fail criterion for the new instruction being given the experimental group, on the basis of the performance by the graduates from the control group. During the tests, the experimental students were not permitted to use their training manuals (except in the separate test in the second experiment, obtaining data on performance with these manuals used as job aids); both experimental and conventional students used the Department of the Army Technical Manuals (DA TMs) that list procedures for checks and adjustments along with technical information on the equipment. The performance and attrition of the experimental classes were compared, in each case, both with their control classes and with the record of all conventionally trained classes during the academic fiscal year of the particular experimental class.

To obtain follow-up information on the performance in the field of the experimentally trained personnel, approximately one year after graduation a questionnaire survey was made of the graduates of the first experimental class and their conventional counterparts. The battery commander and technical supervisor of each man who had been assigned to an overseas tactical unit were asked to work together in evaluation aspects of his technical proficiency.

RESULTS

Attrition Levels

One student from the first experimental class was failed because he did not meet the minimum performance standards specified. This represented an attrition of 3.3% compared with an average of 26% in the nine conventional classes for this MOS during the immediately preceding fiscal year (1965).

In the second experimental class all students met the performance standards. However, attrition for conventional classes during that fiscal year (1966) averaged only 5.1%, and two of the eight conventional classes that year also had no attrition. In the third experimental class, in which the training was completely managed by USAADS, four of the 29 students failed the training program, producing an attrition level of 14% compared with an average of 31.6% for the 10 conventional classes graduating in FY 1967.

Proficiency Levels

In job-sample proficiency tests at the end of training, in all three comparisons the average proficiency of the experimental students equalled or exceeded the average performance levels of the conventional students.

Supplementary analyses suggested that the higher proficiency levels of the experimentally trained students were most evident on those malfunctions that were more difficult for the conventionally trained graduates.

The results of the additional test in which experimental students used their symptom-collection manuals as job aids showed that their performance was substantially better with the special manuals; their troubleshooting proficiency was greatly enhanced on the most difficult malfunctions. Results of this test were of especial interest in view of the fact that the proficiency of the experimental students, even when tested without the manual as a job aid, had been equal to or better than that of the conventionally trained men.

Field Performance Ratings

In the field follow-up survey of graduates of the first experimental class and their conventional counterparts who had been assigned to overseas tactical units, analyses of the proficiency ratings given the graduates by their supervisors did not reveal any differences between the on-the-job performance levels of the two groups.

CONCLUSIONS

The major objective of the study was to develop a prototype training program that was both efficient, in terms of being characterized by low student attrition, and effective, in terms of the proficiency levels of the graduates. The results of the three experimental applications indicated that the study did achieve this objective. The degree of success experienced by USAADS when it had sole responsibility for management of the third class was particularly significant.

Although competent technicians and research personnel were able to develop a successful prototype course, they did not succeed in specifying generalized methods that technical schools could successfully employ for accomplishing the electronic systems task analyses. The crux of the developmental problem lies in the systematic analyses of the equipment and procedures that must be made in order to explicitly state—especially in learnable and rememberable form—the troubleshooting symptom-collection and signal-tracing procedures that constitute most of the procedure-oriented technical training. Since complex military electronics systems possess a large number of unique design characteristics, no single model for developing complete troubleshooting procedures can be applied.

The results also suggest that it is an inefficient use of students' and schools' time and resources to require students to memorize troubleshooting procedures for complex equipment. A more efficient and effective approach would involve using manuals containing complete, accurate troubleshooting procedures for both overall symptom-collection and detailed signal tracing, as job aids in schools and on the job.[1]

The types and amounts of specialized personnel resources required to develop such manuals for all technical training programs are typically not available in service schools. However, it is likely that electronics equipment manufacturers would develop such resources if a military need for such manuals were stated as a part of system development requirement.

[1] At the time the final draft of this report was prepared, the U.S. Army Materiel Command had concurred in a proposal by the U.S. Army Air Defense School that symptom-collection procedures be included in the organizational maintenance manuals for the complete Hawk system. In addition, the U.S. Army Air Defense School had received USCONARC approval to conduct abbreviated programs of instruction for entry-level (or first enlistment) students for all of the Hawk maintenance MOSs. These non-theory courses evolved from the HAWKEYE experimental program and make extensive use of the training aids, devices, and texts developed during this research and development.

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Chapter 1

BACKGROUND AND APPROACH

THE PROBLEM

During the 1963-1965 fiscal years, a number of Army service schools were experiencing high student failure rates in electronics training programs (1). Information gathered in Exploratory Study 32, which was conducted by HumRRO in FY 1964, suggested that this rising attrition was due in part to a decline in average student aptitudes during the previous 10 years and to an increase in the number of students lacking motivation for learning technical subject matter.

It is usual practice in military service schools, as well as civilian technical schools, to require students to satisfactorily complete a prerequisite course dealing with electrical and electronic fundamentals before they begin instruction concerning the maintenance of more complex electronic equipment. Because these basic subcourses emphasize the learning of abstract concepts, definitions, rules, and relationships, their difficulty level usually is high. Consequently, such courses may have high failure rates, particularly among students who are not, at the outset, well motivated to acquire this type of knowledge.

All students must meet minimum intelligence and special aptitude requirements for admittance to electronics training programs in the military service. From time to time, the Army service schools are faced with the fact that the military need for electronics technicians frequently exceeds the number of men who volunteer for such training. When this situation arises, a relatively high proportion of the student input may consist of men who have not volunteered for electronics training—that is, enlisted personnel who are assigned to this training because they satisfy the aptitude requirements, but who may not have any desire to acquire such knowledge and skills. These men are likely to have trouble learning the inherently difficult abstract concepts in conventional courses, especially so because the *utility* of such abstractions for practical application to maintenance is often unclear to the student studying the prerequisite, basic electronics portion of a maintenance training course.

Approaches to performing maintenance, and approaches to training maintenance technicians that would lessen the difficulty of learning and, consequently, lower the attrition rates, may offer promise for solving these problems.

BACKGROUND

A number of new approaches to electronics maintenance and training for electronics maintenance have evolved during the past decade or so. These new approaches, although differing in many respects from one another, share to at least some degree certain common elements. These elements have the effect of both moderating the degree or amount of emphasis on abstract content in a maintenance course and increasing the orientation to direct utility of all training content for actual maintenance job performance. These common elements derive from the implicit or explicit view that troubleshooting (by far the major training and job performance aspect of electronics maintenance) is best performed by carrying out a series of particular procedures that effectively and efficiently isolate the defective part or parts in a complex electronics system.

The common elements for the several approaches are:

(1) Equipment analysis by experts to devise particular troubleshooting procedures for the equipment. This is in contrast to the conventional approach of attempting to provide the maintenance technician with skills and knowledges and general information (e.g., schematics) from which he develops a strategy (i.e., set of procedures) for each maintenance job.

(2) Job aids presenting the procedures derived from equipment analysis for use by the maintenance student and technician. This is in contrast to the conventional approach of providing only the basic general information on the electronics of a system.

(3) Training emphasis on using and learning the procedures and job aids in training, with training focus on practical exercises. This is in contrast to preliminary sole concentration on the purely abstract concepts, definitions, rules, and relationships typifying basic electronics prerequisite portions of conventional maintenance courses.

The precise distinctions among the new approaches to electronics maintenance sharing the above common elements are not easy to discern. Each has been developed for one or more particular electronics systems, and it is not clear what portion of their particular characteristics derives from the equipment used and what is intrinsic to that approach to electronics maintenance. In addition, there are many differences in terminology and emphasis used in describing the several approaches that may tend to suggest wider differences than, in fact, exist.

For purposes of providing general background, the term "Functional Context Training" is used in this report in a general way, to characterize the major, "big" features of the approach to electronics maintenance training; the term "Procedure-Oriented Training" or proceduralized troubleshooting will be used to characterize more specifically aspects of what was done to develop the HAWKEYE experimental course.

Functional Context Training

Under previous HumRRO Work Units REPAIR and LIMIT, an approach to teaching was developed which appeared to stimulate students to higher levels of achievement (2, 3, 4). This approach, which became known as "Functional Context Training" (FCT), is based upon a hypothesis that students learn best and remember more when they can see a real need for the facts they are learning, and when they have a meaningful framework in which to organize these facts.

A discussion of Functional Context Training which compares the method with conventional approaches to technical instruction has been provided by Shoemaker (4). According to this analysis, conventional training in electronics usually involves a part-to-whole or deductive approach to learning; that is, instruction concerning basic principles of electricity and electronics precedes training on intact equipment. Frequently the part-to-whole sequence of instruction parallels the building up of a radio set, beginning with single circuits which are combined into progressively more complex assemblies. Training on maintenance techniques and knowledges follows instruction concerning principles and component functioning.

This deductive approach, which has traditionally been employed in both military and civilian schools, is regarded as having several shortcomings:

(1) The student frequently is not provided with a meaningful, job-oriented context for the learning of abstract material. In conventional training programs, novel concepts may be defined or explained by recourse to even more general or abstract levels of analysis, such as explaining current flow in terms of the movement of free electrons in a conductor.

(2) Abstract and unfamiliar concepts, when taught out of the maintenance context, are not stimulating to many students, and the result is low motivation for learning. This characteristic is especially critical for those students who have not volunteered for such training.

(3) Students are supposed to remember difficult basic electronics concepts until some later period in the course when they are to be applied. The result is that instructors who subsequently give maintenance training often have to repeat instruction on basics in the context of learning maintenance skills.

(4) The procedures involved in actual maintenance work use a whole-to-part approach, in which detailed circuit analysis and piece-part (or component) testing is not begun until the trouble has been localized by progressive sectionalization to a few possible alternative malfunctioning components. Initial training emphasis on a part-to-whole approach which involves analysis of component functioning may result in later attempts by the technician to engage in premature circuit analysis before sectionalization has been accomplished.

In contrast to the conventional training sequence, Shoemaker describes the FCT method as an inductive or whole-to-part approach. Two major characteristics distinguish this approach from the conventional one:

(1) A meaningful job-oriented context is established for the student at the outset of training. Students begin by learning how to energize and operate equipment and to perform the more simple and routine checks and adjustments which require little theoretical background.

(2) In the sequencing of subsequent topics, concepts and principles are taught as they are needed in the context of learning maintenance skills and knowledge. For example, the concepts of voltage and current may be taught in the context of learning how to use test equipment to measure such phenomena. In some conventional electronics courses, the electrical properties of voltage, current (electron flow), and resistance are taught following prefatory instruction concerning the atomic structure of matter. In contrast, in an FCT course these electrical properties might be taught as those properties that are measured by various types of electrical test equipment—that is, voltage is what a voltmeter indicates!

Proceduralized Troubleshooting and Training

Concurrent with studies concerning improved approaches to training in general, considerable research has been done that can be viewed as a version of these general training concepts as applied to training for troubleshooting an electronics system. These procedure-oriented approaches—that is, approaches in which specific procedures for accomplishing all or part of the troubleshooting process on an electronics system are developed and provided in job aids presenting them in systematic form—are reflected in HumRRO Work Units MAINTRAIN (5), FORECAST (6), NICORD (7), and JOBTRAIN,[1] in addition to the work done by military and industrial organizations.

Ten new concepts—describing work by both HumRRO and others—for electronics maintenance are summarized by Shriver in HumRRO TR 66-23 (8). As has been indicated in this report, by providing the symptom-collection and sectionalization procedures in job aids such as manuals, the requirement that an electronics technician develop such procedures himself is virtually eliminated or substantially reduced (the degree depending on the extent to which the job aid contains the complete set of explicit procedures for progressing from fault indications to defective components or piece-parts).

[1] See "JOBTRAIN" in Section II, HumRRO TR 66-23 (8); a HumRRO report based on this work is in preparation.

If the symptom collection and sectionalizing strategies are provided to the technician in the form of job aids, the need for heavy emphasis on electronics theory during training is greatly reduced. It follows that if the training given is concerned with practice in using these job aids, the training time may also be substantially reduced.

However, such reduction would be contingent upon having the explicit job procedures for performing troubleshooting provided the technician, in a job aid, after he leaves school; if he will not have such a job aid, then it does not necessarily follow that training time can be saved. Indeed, the requirement for student technicians to memorize sets of specific troubleshooting procedures while in school might result in a need for longer programs of instruction than are characteristic of conventional training.

In summary, previous research on electronics maintenance, applying Functional Context and Procedure-Oriented concepts, offered a promising solution to the problem of reducing the difficulty of technical training and increasing the proportion of students who learn to perform at a satisfactory level. The accumulated evidence indicates that procedure-oriented training together with procedure-oriented job aids (usually in the form of special manuals) not only reduce training difficulty and time, but also result in increased job proficiency.

The approach and problem in Work Unit HAWKEYE differ from previous experience along these lines in two ways. First, very little has occurred in the way of research experience in applying procedure-oriented approach to *long* training programs on complex electronics equipment. Second, for this research, it was not possible to arrange that the special job aids (presenting the specific troubleshooting procedures) would be available for use in the field by graduates of the course. Consequently, and in contrast to earlier applications of procedure-oriented training, procedures had to be "condensed", that is, devised to be comparatively few in number and with comparatively few steps for each; at the same time, training was oriented to students not only learning how to use the job aids but especially to their *remembering* the details of the procedure for use both at the end of training and in subsequent job performance in the field, without the use of job aids.

OBJECTIVES AND PLAN OF STUDY

The impetus for this study was a request from the U.S. Army Air Defense School (USAADS), which was experiencing high attrition rates in a number of its technical training programs, to develop a prototype program of instruction for radar technicians which would reduce attrition rates markedly without a concomitant reduction in proficiency. The HAWK Continuous Wave Radar Maintenance Mechanic (MOS 23R) was the course used in the research.

From the research perspective this Work Unit may be viewed as using the development effort as a vehicle to also serve a more general purpose—evaluation of procedure-oriented training as an approach to long electronics maintenance courses, especially the effectiveness of such a course when the special job aids normally associated with them are available only for instruction and not for job performance. Thus, Work Unit HAWKEYE was undertaken to approach three research objectives:

(1) A prototype of a course for MOS 23R would be developed, to reduce attrition and attain at least the end-of-course proficiency levels of conventional courses, and to be practical for adaptation to be the standard course for MOS 23R.

(2) Should the first objective be achieved, the prototype course (or that adapted from it as a standard course) would serve as a model for development of similar courses for other electronics maintenance MOSs.

(3) Should the first objective be achieved, "how-to-do-it" guidance documents which would aid subsequent efforts by schools to develop similar courses for other MOSs would be developed.

Deriving from the objectives of the study, the major ingredients of evaluation involve comparing attrition rates and proficiency levels for the conventional and experimental course. However, since the two courses differed markedly in instructional content and sequencing, achievement tests during training could not be made comparable between the two to serve as a common basis for evaluation (and attrition). Further, since the HAWKEYE achievement tests were new, there was no experience base that would permit prediction of eventual proficiency for the experimental students.

As a solution to the lack of a common standard during training, the HAWKEYE course was conducted under a "no turn-back" policy. Graduation (and hence attrition rate) was determined after training was completed and on the basis of proficiency testing.

The HAWKEYE "no turn-back" policy and end-of-course performance criterion for graduation represent, in part, application of results of RADAR IX (9) research, in which it was found that many of the students who would have failed because of academic deficiencies early in a maintenance course were eligible to graduate on an overall academic-performance basis by the end of course.

The comparison of attrition rates between conventional and HAWKEYE students is best understood as comparative evaluation of the compound of training-student evaluation systems with respect to attrition rates, and with the requirement that job performance capabilities of graduates of the two systems be comparable. This approach required that end-of-course proficiency data on a performance test be gathered for *both* conventional and HAWKEYE students and that the pass-fail performance scores applied to determine graduation for HAWKEYE students be based on proficiency of conventional graduates.

The HAWKEYE research effort included the following phases:

(1) Development of procedures and other training course content, and preparation of procedure-oriented training literature (described in Chapters 2 and 3).

(2) The first administration of the experimental course, and comparison with conventionally trained students (Chapter 4).

(3) Revision of the course and training materials on the basis of experience in the first class, and a second course administration and evaluation that included a separate study of experimental students' end-of-course proficiency with and without using the proceduralized job aids (Chapter 5).

(4) A third administration of the course under the supervision of the Air Defense School, including USAADS development of procedures and training materials for an additional piece of equipment (Chapter 6).

(5) A follow-up study, using a questionnaire survey, of performance in the field of graduates of the first experimental course (Chapter 7).

Chapter 2

COURSE DEVELOPMENT AND CONTENT

SPECIFICATIONS FOR COURSE DESIGN

To ensure that the characteristics of the experimental course would make it practical for USAADS use if it proved successful, the School and the research staff mutually established several specifications for the course. It was to be comparable with the existing "conventional" training program in the following respects:

(1) The total length of the programs of instruction (24 weeks) would be the same.[1]

(2) The requirements for radar equipment and time in the radar laboratories would be the same.

(3) The student-instructor ratio would be approximately equal.

(4) The quality of the instructors used would be representative of instructors at the Air Defense School.

(5) Any training devices employed in the experimental program would be reasonable in cost.

(6) Using existing Department of the Army Technical Manuals (DA TMs), graduates would be able to perform job duties as well as conventionally trained personnel; that is, the experimentally trained graduates would have to be able to perform satisfactorily without new or revised job aids.

OVERALL COURSE OBJECTIVES

Since the experimental course was to be evaluated by comparison with conventional instruction for this military occupational specialty (MOS 23R), it was essential that the *overall* objectives for the experimental course be the same as those for the conventional course. In the broadest sense, the general objective of instruction for this MOS is that graduates should be able to perform second echelon maintenance on the two HAWK radars for which they are responsible—the Continuous Wave Acquisition Radar (CWAR) and the High Power Illuminator Radar (HPIR).

During discussions between USAADS and HumRRO personnel, it became evident that the more specific objectives of the conventional course could be divided into two types—those related to clear, measurable end-of-course performance requirements, and those related to aspects of the job that could not be economically measured in performance terms at the end of the course.

The course objectives relating to measurable end-of-course performance were divided into three areas. First, the graduate was to be able to perform correctly all the checks

[1] The conventional course for MOS 23R is divided into three major segments: nine weeks on basic electronics, not uniquely related to the MOS; six weeks on the CWAR; nine weeks on the HPIR. With few exceptions, four hours of each day are spent in the conference sessions and four hours working on the equipment in the laboratory.

and adjustments specified in appropriate DA TMs, following procedures given in those manuals. Second, the graduate was to be able to isolate any malfunction—that is, to troubleshoot—to the smallest unit that he is authorized to replace, or to the smallest unit to which the malfunction can be isolated using the tools, test equipment, spare parts, and job aids normally provided on the job. Third, the graduate was to be able to repair any malfunction that can be repaired using the tools, test equipment, and spare parts available on the job.

Since there is wide variation in the time required by experienced maintenance personnel to perform each of the tasks involved in the above objectives, and since there was no general agreement as to the time each task should require, no attempt was made to specify precise time limits for each task. Rather, it was agreed that graduates should be able to perform each task within some "reasonable" time.

A small proportion (about 5%) of the content of the conventional course was concerned with varied topics that could not be measured in end-of-course performance (e.g., the HAWK maintenance concept, rigging for helicopter transportation, electronic countermeasures, probable enemy air threat). Since it was obvious that some familiarity with these subjects was desirable, it was decided that the experimental course training devoted to these subjects would be identical with that in the conventional course, and that these topics would not be included in the content of the end-of-course proficiency test.

DETERMINING GRADUATION STANDARDS

In conventional instruction, graduation is based upon scores obtained on a number of written and performance tests administered during the course. These same tests could not be used for determining graduation in the experimental course for two reasons: (a) information would not be presented in the same sequence in the experimental course as in the conventional course, and (b) written examinations used in the conventional course are concerned primarily with facts and theory, rather than with performance.

Stating the problem somewhat differently, the conventional examinations could not be used for the experimental class because the detailed learning objectives for each week of instruction would not be the same for the two courses; more importantly, the approaches to evaluation of students in the two courses are from different perspectives—academic achievement in the conventional course and job proficiency capability in HAWKEYE.

Since the end-of-course objectives of the experimental course were the same as those of the conventional course, the Air Defense School agreed to base graduation for the experimental classes on an end-of-course test. A test was constructed to measure performance on the two major aspects of the job—performance of periodic checks and adjustments, and troubleshooting.

Because the primary purpose of the experimental course was to reduce attrition without lowering proficiency standards, the USAADS agreed that any student in the experimental class would be permitted to graduate if he could perform on the end-of-course test as well as *any* graduate of the conventional course. Instruction for the experimental classes was therefore given under a "no turn-back" policy. That is, all entering students were retained in the course, and no students were dropped or recycled for academic or motivational deficiencies.

The final step in determining standards was the administration of the test to conventionally trained graduates to determine a reasonable pass-fail cutoff. It was essential that the test be administered to enough graduates to ensure that the results obtained would be typical of the performance that might be expected if it were possible to test all conventionally trained graduates, and to ensure that an artificially low pass-fail score would not be obtained as a result of one atypical graduate. The experimental students, in order to graduate, had to match the lowest scores obtained by the control groups.

It is of some significance to note that two systems for determining academic attrition were involved in the comparison of academic attrition levels. In the case of conventionally trained students, attrition is determined by their performance levels on achievement tests administered during training. For the experimental students, attrition was determined by end-of-training proficiency, which normally is not evaluated in conventional courses.

TASK ANALYSIS AND PREPARATION OF TRAINING MATERIALS

General Approach

In considering the development of training programs, it is often assumed that task analysis, specification of training objectives, and preparation of training materials are three separate and distinct activities. That is, the task analysis is completed and is then used as a basis for specifying training objectives, which are in turn used as a basis for planning the training itself, as well as for other purposes.

Under some conditions, this approach has definite advantages. If each of these three activities is to be performed by different people, it is necessary that the results of each step be transmitted, often in written form, to the person or persons responsible for the next step. Moreover, the availability of a written report on the results of each step may make it possible for other persons to review each step and evaluate its adequacy.

However, there are some tasks that can be performed in many different ways, which often present very different training problems. In discussing the development of techniques for developing plans (i.e., procedures), Miller, Galanter, and Pribram (10) have pointed out the physical impossibility of specifying all possible means of performing a task, and have emphasized the fact that people are seldom able to follow any systematic approach in choosing among alternatives. The only practical means of specifying procedures for performing such tasks is to select one possible approach on the basis of "experience," "intuition," or whatever is applicable, to try that approach to see whether it will work, and to continue to select and try others until an acceptable approach is found.

In the present experiment, the major problem was to develop *learnable* and *recallable* procedures for performing the tasks of the maintenance job, since special manuals of procedures for performing the troubleshooting aspects of the maintenance job were not authorized for field use. Thus, the acceptability of any given procedure for performing any of the requisite tasks could not be evaluated until an attempt was made to specify the training that would be required to teach that procedure. If it was found that the particular procedure specified would require too much training, it was necessary to return to the task analysis and try to find a simpler procedure for performing the task. Thus, it was impossible to say that the task analysis had been completed until the training materials themselves were completed, at least in draft form.

This requirement for frequently recycling from the preparation of training materials back to task analysis was of major importance in planning the work. Of course, the ideal solution would have been simply to assign total responsibility for a single task to one person, to have that one individual perform all steps in the development of training for that particular task. This approach was followed for some tasks, with success.

Some tasks, however, were so long and/or complex that this approach would have taken a prohibitive amount of time. More importantly, it was impossible to find individuals with enough technical knowledge in *all* aspects required in developing training programs. The persons who had the technical knowledge about the CWAR and HPIR that was required to develop effective procedures for troubleshooting were not the same ones who knew most about the planning and training. This necessitated the use of a team approach, in which two or more persons worked together to develop training materials for a particular task, with each person assuming primary responsibility for certain phases of the work.

The specific objective for any one portion of the experimental course was the set of procedures the student was to learn during that portion of the course. The analysis activities directed toward developing correct and learnable procedures are summarized in the following paragraphs.

Checks and Adjustments. The procedures for performing all of the periodic checks and adjustments are contained in DA TMs available on the job. One equipment specialist assigned to the research staff studied the procedures given in the TMs and wrote more detailed instructions wherever he believed the linguistic complexity of the descriptions of the TM procedures might be confusing to students. Both the TM procedures and their "translations" were presented in adjoining columns in a manual for use by the students during training.

Repair of Malfunctions. Although repair of malfunctions (e.g., chassis replacement, soldering components) is an essential part of maintenance, no detailed task analysis of repair activities was required. Only a small portion of the conventional course is devoted to instruction in repair skills, and observations by the research staff had indicated that this material is usually learned effectively and efficiently by students in conventional classes.

Troubleshooting Procedures. In discussing the problems of learning and remembering, Miller, Galanter, and Pribram (10) suggest that the real problem in learning is not the learning per se but the recall of learned material. Essentially, the problem is not one of *learning* facts, but of *recalling* the right fact at the right time. The time and effort that go into a learning task are devoted to ensuring that there will be some way to get access to the particular fact when it is needed. Bruner (11, p. 31) is expressing essentially the same position when he states that the only known way of reducing the quick rate of loss of human memory is to organize facts in terms of principles and ideas from which the facts may be inferred.

The above discussion suggests that the fundamental problem in getting students to learn and remember troubleshooting procedures is the problem of *organizing* these procedures so that they can be remembered. That is, the procedures must be organized around some general principles and ideas from which specific procedures can be inferred. The development (or discovery) of appropriate principles and ideas and the organization of troubleshooting procedures around these principles and ideas was the major challenge in the present study.

Troubleshooting Procedures

Troubleshooting task analyses performed in previous HumRRO research suggested how this might be accomplished (5, 6, 12, 13). The troubleshooting of any malfunction—that is, any one series of checks—can be divided into three portions according to the test equipment and information used:

(1) **Symptom collection.** The first few steps in troubleshooting any malfunction require the technician to use built-in indicators and controls to partially isolate the malfunction. During this portion of troubleshooting, which is called "symptom collection," the technician is concerned not with individual malfunctions, but with sets or groups of malfunctions that present the same indications on the built-in indicators. Each

of these sets of malfunctions, which may be called "symptom areas," may contain several dozen, or even several hundred, individual malfunctions. Thus during symptom collection, the technician is concerned with a large number of symptom areas in each radar, each with its own series of checks, rather than with the myriad of individual malfunctions and series of checks.

(2) **Signal tracing.** After symptom collection has been completed, the technician, using portable test equipment, begins to isolate within a single symptom area. This process is called "signal tracing," and involves a different series of checks for each of the symptom areas in each radar.

(3) **Troubleshooting within a stage.** After signal tracing has been completed, the technician has usually isolated the malfunction to one or two stages. That is, he has identified the malfunction as being in one or two vacuum tubes (or transistors) and the five to 20 other piece parts (resistors, capacitors, etc.) associated with these tubes. At this point, he should begin "troubleshooting within a stage," systematically checking each of the piece parts within the stage to determine which one is defective.

Dividing troubleshooting into three major portions provides a structure in which to attempt to reduce the problem of preparing and/or learning procedures for troubleshooting. Without this division, the technician would be concerned with literally thousands of possible checks (procedures)—each involving perhaps 15 steps. When this division is made, he is concerned with perhaps several hundred procedures each for symptom collection, signal tracing, and troubleshooting within a stage. Since the scope of each procedure is more limited, it will have a better chance of involving perhaps five steps, rather than 15.

Since even this amount still poses a very difficult learning task for most people, it then becomes necessary to analyze these different procedures in order to find common portions so that further reduction in the learning load might become possible.

Since many of the CWAR procedures were similar, it appeared that some combination might be feasible, producing procedures that were effective if not optimally efficient. The process was essentially one of trial and error, but several guidelines were used:

First, any combined procedure must be as effective as the individual procedures for finding any malfunction; that is, two or more procedures could not be combined if the combined procedure would mislead the technician and cause him to be unable to find some malfunctions.

Second, procedures should involve no more than five to seven steps, if at all possible, since increasing the number of steps makes procedures much more difficult to learn.

Third, the combined procedure must be nearly as efficient as the individual procedure—in general, use of the combined procedure should not add more than two to five minutes to the time required for troubleshooting.

CWAR Symptom Collection. In the attempt to develop combined procedures for symptom collection, it was found that, in order to be sufficiently complete to replace more than two or three individual procedures, a combined procedure almost invariably included too many steps to be easy to learn.

In the CWAR, this problem was eventually solved by dividing symptoms collection into three parts: (a) Isolation to a Subsystem, (b) General Symptom Collection Within a Subsystem, and (c) Detailed Symptom Collection. Isolation to a Subsystem involved a single five-step procedure, and resulted in isolation of any malfunction to one of the major subsystems in the radar—Power and Control Circuits, Transmitter, Receiver, Antenna Positioning System, and Display System. For each of these subsystems, a single procedure was developed for isolating malfunctions to one of approximately five portions of the subsystem. Finally, for each portion of a subsystem, there was a procedure for isolating malfunctions as far as it is practicable in symptom collection.

Thus, by dividing symptom collection within the CWAR into three portions, and using combined procedures, the number of procedures was reduced to 31. Although each of these procedures was less than optimally efficient, it was believed that the reduction in the number that had to be learned more than outweighed the slight loss in efficiency of symptom collection. The development of the final process was, however, a time-consuming operation; approximately 50 man-months were required to develop or discover procedures of the type described.

HPIR Symptom Collection. The amount of time consumed in developing the CWAR procedures was not available for development of procedures for the HPIR instruction for the first experimental comparison, so a less painstaking approach was used. Although an attempt was made to follow the same guidelines in developing HPIR symptom-collection procedures, it was necessary to apply them less rigidly. Thus the procedure developed for isolating malfunctions to a subsystem involved 18 steps, rather than the more preferable five to seven.

Signal Tracing Procedures. Examination of the procedures for signal tracing within each of the symptom areas showed that the large number of individual procedures required could be reduced with little loss of efficiency. Most measurements should be made at the grid of each tube, but this is not true for all cases. For example, in the case of a transistor amplifier, consisting of three to four transistors in series, it was found that checking the amplifier input and the output was as effective as checking the outputs of the individual transistors.

Troubleshooting Within a Stage. A single procedure was developed for use in troubleshooting within any stage, replacing 400 to 500 different procedures for individual malfunctions. Although this procedure may have been less than optimally efficient, experienced maintenance personnel (USAADS instructors with field experience in MOS 23R) found that they could actually troubleshoot faster and more accurately using this one procedure than by using their own procedures for each malfunction.

Use of Common Test Equipment. In troubleshooting, it is frequently necessary for the technician to make measurements with portable test equipment. Three multimeters and two oscilloscopes are used by MOS 23R on the job, and one additional oscilloscope is used during training (because of the shortage of appropriate oscilloscopes at USAADS). During previous research projects, detailed procedures for using two of the multimeters and one of the oscilloscopes had been developed.[2] These procedures were used as models in performing task analyses and developing procedures for using the remaining multimeter and one of the two remaining oscilloscopes. Because of lack of time, detailed procedures were not developed for using the third oscilloscope, which is available on the job but seldom used during training.

PRINCIPLES OF SEQUENCING

Practical Considerations. One factor in determining the sequencing of instruction was the time available for developing the course; instruction was scheduled to begin in 10 months. It was clear that the staff would not have time to develop the entire 859-hour course and train the instructors in that period. The course was therefore divided into two subcourses: a 15-week subcourse on the CWAR and a 9-week subcourse on the HPIR. Although the HPIR is a larger and more complicated radar, more time was allocated to

[2] Julia S. Harris and Harold E. Christensen. "Procedural Analysis for the Use of Three Pieces of Test Equipment: OS-8 C/U Oscilloscope, TS-505 A/U VTVM and TS-352 A/U Multimeter," HumRRO Division No. 5, August 1962; Julia S. Harris, James P. Rogers, and David H. Francis. "Procedures for Using AN/USM-24C Oscilloscope," draft prototype manual, HumRRO Division No. 5, January 1965.

the CWAR subcourse to cover instruction on terminology, use of test equipment, reading of schematic diagrams, and other aspects common to both radars. This division of the course permitted the research staff to concentrate on completing the CWAR subcourse, with the assurance that some additional time would be available for completing the HPIR subcourse after instruction on the CWAR had begun.

Another factor affecting the sequencing of instruction was the availability of laboratory facilities, practicularly radar laboratories. Only 122 hours of CWAR radar laboratory time were available although the CWAR subcourse was to involve a total of 513 hours of instruction. There was, however, a total of 104 hours during which other—Basic Electronics (BE)—laboratory facilities could be used for instruction that did not require radars. To make efficient use of facilities, the initial training on the use of common items of test equipment (e.g., multimeters) was presented in the BE laboratory rather than in the radar laboratory.

The laboratory facilities available for use by the experimental class were also used by other classes undergoing conventional instruction. Instruction in these conventional classes is normally scheduled in four-hour blocks, with each class spending four hours each day in the laboratory and four hours in the conference room. Thus, it was considered to be highly desirable that instruction in the experimental course be planned in four-hour blocks, with laboratory and conference instruction alternating. (This alternation is not followed rigidly in the conventional courses, and some flexibility was permitted in the experimental course.)

Massed and Distributed Practice. As was stated earlier, the primary goal of the experimental training was to have the students learn and remember sets of prescribed procedures for troubleshooting. Each procedure for isolating a malfunction to a symptom area may be considered as a fixed sequence or list of equipment checks. Since the students had to remember a large number of such sequences, the training had to be designed to minimize interference in the learning of similar sequences.

Research in the field of verbal learning has shown that the learning and retention of lists is facilitated if (a) each list is practiced to a high level of mastery and (b) practice on successive lists is distributed over time (14). These principles were applied in the design of the experimental training. Since both laboratory and conference instruction were usually scheduled each day, it was sometimes necessary to provide laboratory practice in learning a procedure and to follow this instruction with oral practice on the same procedure during the four-hour conference period. Usually, however, the administrative requirement for four-hour blocks of laboratory and conference instruction each day dictated that no more than four hours be devoted to training on a particular task each day.

It should be noted that provision of an "optimum" schedule for distribution of practice would be less critical if the student were not required to attempt to memorize all the procedures during training. Such a memorization burden would be substantially reduced if a manual of symptom-collection procedures were available to the technician on the job.

Uniform Difficulty. It is probably undesirable to have the difficulty of the students' learning task vary greatly from day to day. Ideally, perhaps, some given difficulty level would be maintained throughout the course, to minimize the extent to which the students might be overworked one day and worked too little the next.

An attempt was made to approach this by considering the knowledges and skills that were required for each type of task. Wherever two tasks had a number of knowledges and skills in common, but each involved some unique knowledges and/or skills, sequencing could affect the relative learning difficulty.

For example, both functional diagrams and schematic diagrams contain electronic symbols the students must learn, with most of the symbols being common to both types of diagrams. Since schematic diagrams also contain additional symbols, the student might be overwhelmed and discouraged if he were required to learn to use schematic diagrams first. By being taught functional diagrams first, he would not have so many new symbols to learn at any one time.

Concreteness. Bruner (11) has indicated that some people have difficulty in thinking about or learning about things that they have not previously experienced. That is, they have difficulty with abstract ideas or facts, but are able to deal very satisfactorily with more concrete events. This hypothesis suggested that students should be provided an opportunity to do, see, or perform *before* they are required to think about or discuss.

Generally speaking, this meant that a student was first *told* (usually by written instructions) what he was to do, then he was shown how to do it (instructor demonstration), then he *did* it under supervision, then he *discussed* it, and finally *practiced* it. This learning sequence is similar to the LOCKON training method which was demonstrated some years ago by HumRRO and which is used at Fort Bliss for training radar operators and launcher crewmen (15).

ORGANIZATION OF THE EXPERIMENTAL COURSE

Development of the Program of Instruction (POI) for the first administration of the experimental course was essentially a matter of estimating time needs, since there was as yet no firm basis for establishing time allocations. For this reason, details on the first version of the POI are not presented in this report; instead, the POI for the second administration of the course, which was based on experience with the first class, is presented in Appendix A.

The major blocks of instruction in the POI, which provided detailed guidance on what the students were to practice during each unit of instruction, are summarized below.

General Orientation. The course began with a demonstration and explanation of the entire HAWK system and its role in air defense. It was thought that this orientation would answer many questions about the purpose and importance of the students' future job.

Daily Checks and Adjustments. The first block of instruction was concerned with Daily Checks and Adjustments on the CWAR, since this could be learned without any prior knowledge of electronics. This instruction was conducted on the actual equipment and was intended to stimulate the student's curiosity about the equipment. It also provided him with some useful terminology for discussing and asking questions about the equipment during later blocks of instruction.

Introduction to Portable Test Equipment. Before the student could go further on the equipment itself, he had to learn to perform some measurements with multimeters and vacuum tube voltmeters (VTVM). Thus there was a need at this time to insert a block of instruction on the use of these items of test equipment. It was conducted in a basic electronics laboratory to conserve valuable radar laboratory time. The instruction at this point covered only those types of measurements that would be required in the instruction to be given in the near future, not all possible uses of the test equipment.

Weekly Checks and Adjustments. As soon as the student had learned to perform certain measurements, laboratory training on the Weekly Checks and Adjustments began. This enabled the student to apply his new skills in using the test equipment, and it familiarized him with most of the remaining controls, indicators, and adjustments on the radar. In addition, the student learned to use the special test sets that were required in the weekly checks.

Symptom-Collection Procedures. The instruction on daily checks, test equipment, and weekly checks was given in laboratory facilities. Since laboratory facilities were available only four hours each day, the remaining four hours were devoted to learning symptom-collection procedures in a classroom. During these conferences the students learned to follow the written procedures contained in a symptom-collection manual and to name the circuits to which hypothetical malfunctions were isolated by these procedures. Essentially, this involved extensive verbal practice, aimed at memorization of these symptom-collection procedures.

Each step in the symptom-collection procedures involved indicators, controls, or adjustments that the student had encountered in the daily or weekly checks. It was possible that the verbal practice would be too abstract for the students to learn the procedures; to minimize this possibility, a four-hour laboratory session on symptom collection was provided once each week. (This necessitated the omission of lab sessions on daily and weekly checks on those days, providing somewhat wider spacing of practice on daily and weekly checks.)

Signal Tracing. When the students had completed their laboratory training on weekly checks, they began laboratory training in signal tracing. Since signal tracing requires the use of schematic diagrams, conference instruction on the use of schematic diagrams for signal tracing began about this time. The fact that the symptom-collection manuals (which had been studied earlier) contained many of the symbols that are used in schematic diagrams, and are drawn by the same general rules, eased the student's transition to schematic diagrams. Thus it was feasible to begin conference instruction on schematic diagrams even if instruction on symptom collection was not completed.

Troubleshooting Within a Stage. Shortly after signal tracing began, the student should have become familiar with essentially all of the schematic symbols that he would ever encounter, and he should have developed some interest in identifying specific piece-parts. At this time, instructions on troubleshooting within a stage began. Most of this instruction was presented in the basic electronics laboratory, even though this necessitated the development of some special training devices (described in Chapter 3).

At least one radar lab session each week was devoted to the entire troubleshooting task—symptom collection, signal tracing, and troubleshooting within a stage. This tended to tie the entire task together in the way it is likely to be encountered on the job, and tended to keep the instruction from being too abstract.

The training sequence described above constituted the 15-week CWAR subcourse. The nine-week HPIR subcourse followed the same general pattern. However, since there was no need for extensive additional instruction on the use of test equipment, nor were there many new schematic symbols to learn, instruction on signal tracing and troubleshooting within a stage began very shortly after symptom-collection practice began. The student began practicing the entire troubleshooting task in its logical sequence very shortly after he had learned to perform the daily checks, and he continued this practice throughout the remainder of the course.

THE TRAINING APPROACH

As has been described in earlier sections, the experimental training was directed toward having the students (a) learn to perform the explicitly stated procedures for making the routine checks and adjustments, and (b) learn and remember the symptom-collection procedures (and signal tracing procedures) required for isolating malfunctions to defective chassis and piece-parts. Standard electronics concepts, rules, and relationships were taught as needed in the context of learning these job procedures.

For example, the concepts of *voltage*, *current*, and *resistance* were introduced in the experimental course during the initial period of instruction concerning procedures for using the VTVM (TS-505). Presented below is an extract of part of the information provided students in a special text for the initial conference concerning the properties of voltages:

The three quantities you will need to measure in electronic circuits are *voltage*, *current*, and *resistance*. *Voltage* is the power or pressure applied to a circuit which causes *current* to flow. *Resistance* limits the amount of current flow in the circuit.

There are two kinds of current. *Alternating current (ac)* flows first in one direction, then the opposite direction, with very rapid alternations. *Ac voltage* is a voltage (or pressure) which causes ac current. Ac voltage is used in home wall outlets in the U.S., and in the HAWK system it is applied from the generator to the radars as their main source of voltage.

Direct current (dc) flows constantly in one direction. *Dc voltage* is a voltage which causes dc current flow. Dc voltages are produced and used in many places in the CW radars.

Voltage must always be measured between two points. One of these points is often called "ground" and may be physically hooked to the earth ground. The other point is usually called the "hot side" because if you touch it and ground (or are standing on the ground!), you may get shocked—or worse (burned—or buried).

With dc voltages, ground is sometimes called the "reference point." Some dc voltages are positive (+) in respect to ground, and some are negative (—) in respect to ground.

Voltages which you will measure at your lab position in these first blocks of instruction on meter use are called "source voltages" or "applied voltages," since they are voltages produced by a power supply (source) to be applied to a circuit. Voltages measured across part or groups of parts within circuits are often called "voltage drops," since they are voltages dropped by or used by individual parts. You will learn to measure these later in the course.

Subsequent blocks of the test equipment instruction provided additional information concerning electrical quantities and components. Following is an extract from the special text discussion of resistance. This training was given in conjunction with instruction concerning use of the Multimeter, TS-352A/U for making resistance checks:

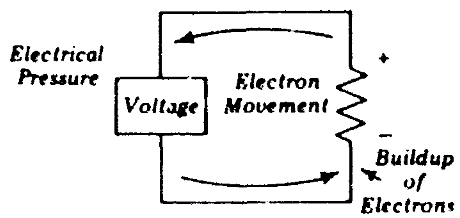
When you were introduced to using meters to measure voltage and current, you learned that there were three important quantities you would need to measure in electronic circuits—voltage, current, and resistance. Voltage, you may remember, is the power or pressure applied to a circuit which causes current to flow. Resistance opposes current flow, and thus limits the amount of current flowing in a circuit.

Various components are used in electronic circuits to provide resistance. Some components provide the same resistance to ac current as to dc current, and some components provide different amounts of resistance to ac current and dc current. The resistor is a very common component used in electronic circuits to provide the same resistance to ac current and dc current. Today you will use resistors to learn to measure the value of resistance. You will learn later about the resistance of other components.

The amount of resistance a component offers to current flow is measured in ohms. When we have large values of resistance, we use the term "kilohm" to represent 1,000 ohms and the term "megohm" to represent 1,000,000 ohms. The symbol for ohm is the Greek letter Ω (omega). The symbol for kilohm is K and the symbol for megohm is M.

In electrical diagrams (schematics), the symbol for the fixed resistor is  The abbreviation for resistor is R.

The resistor, by offering opposition to current flow, will cause a voltage drop across it. There must be current flow in order to have a voltage drop. Current flow is the movement of negative charges (electrons). The resistor, by opposing current flow will cause a difference of potential across it, making one side negative in respect to the other.



This difference in potential is the voltage drop. The larger the resistance value of the resistor, the more opposition, therefore, the larger the voltage drop.

The relationship between current, voltage, and resistance is stated in a mathematical formula known as Ohm's Law. Ohm's Law states that the current (I) is equal to the electrical pressure (voltage) divided by the resistance (R). $I = \frac{E}{R}$.

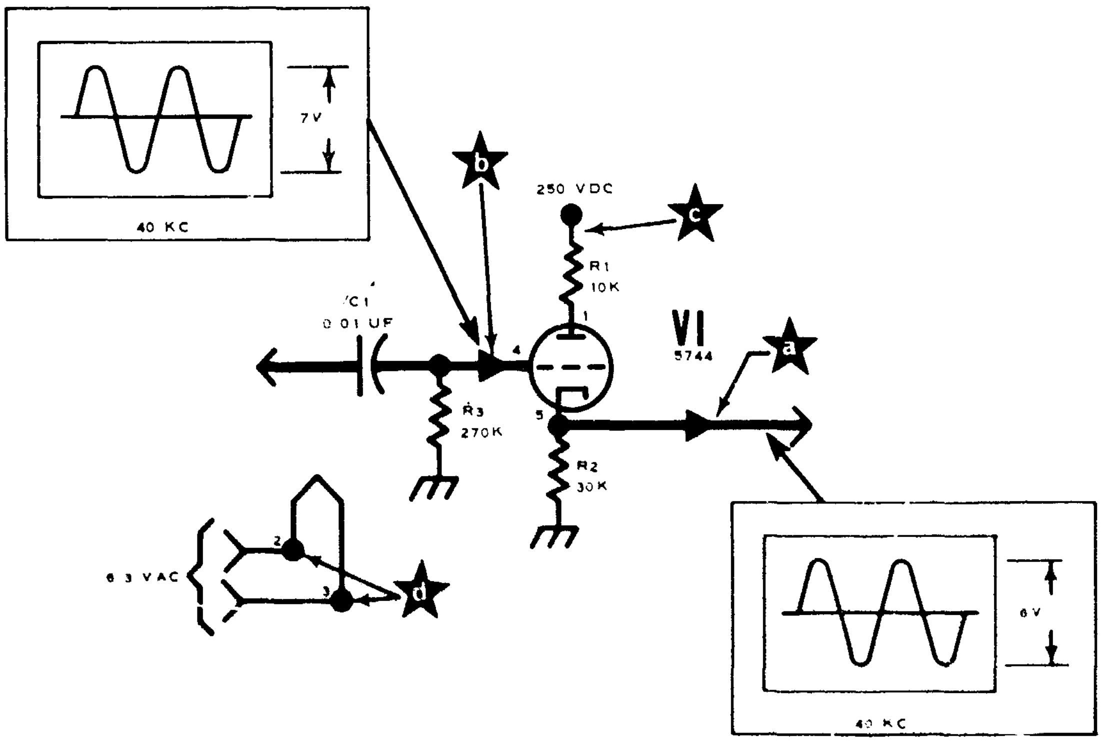
In many cases resistors are used to reduce the voltage, that is, to drop a large voltage to a small voltage. This can be done by using a combination of resistors known as a voltage divider. By doing this, the same power supply can be used to supply circuits requiring different amounts of voltage.

The resistive value for some resistors is printed on the resistor. Others have colored bands around them. By knowing the color code of the bands, the value of the resistor can be determined. The use of resistor color codes will be covered in a later class.

Throughout the preparation of the experimental training program a distinction was made between "need-to-know" and "nice-to-know" information. The distinction between "need" and "nice" was made on the basis of judgments of the research staff concerning the types and depth of understanding of fundamental concepts required by student technicians in order to perform the various job procedures. The quoted presentation that follows illustrates this distinction. This discussion is extracted from instructor materials for the initial conference session for experimental students concerning troubleshooting within a stage. The instructor was discussing the first circuit presented in this portion of the training. The "nice-to-know" information for the instructor's use in his presentation or in answering questions is shown in italics.

a. Schematic diagram. The schematic diagram is of greatest importance in determining the preliminary steps of repair functions. In effect, the schematic diagram provides the electrical picture of the circuit being tested. This electrical picture provides specific information by which a troubleshooting procedure may be derived.

Circuit 1



(1) Signal path—As the signal progresses from the input to the output, the path it follows is indicated by the heavy dark line. The heavy dark line is used to facilitate the collection of symptoms during the signal tracing. At any point along the signal path the signal may be monitored and changes noted. Of primary importance is determining the point at which the output and the input signal of the stage must be monitored. For circuit board #1, with only one stage of circuit present, the monitor points can be easily identified.

(a) Output signal—The circuit that uses the output of circuit board #1 is not physically shown on the board itself. Under this condition, the monitor point for output signal may be at any connection from the cathode of V6 to the output plug connector. Usually the connector is not an accessible point, therefore, the most accessible point will be the junction between the cathode, R2 and the connector as indicated by ★a.

(b) Input signal—The input signal is always monitored at the control grid of the vacuum tube of the stage. This point is indicated by ★b. The wire connecting C1, R3, and the control grid (pin 4 of V1) are electrically the same point. The most accessible point will be where soldered connections are used between any two of these components.

By observing the schematic of circuit board #1, it is apparent, with the input applied to the control grid and output taken from the cathode, that cathode follower action is present. This is a special type of an amplifier called a cathode follower. When monitoring the input and output signals it will be noted that there is no increase in the amplitude of the output as compared to the input. As a matter of fact, the output will always be of lesser amplitude. This condition is expressed as having a gain factor of less than one or unity. Any time this configuration is used in electronic circuits the same conditions will apply.

The reason for using this type of a circuit is to provide isolation between two electronic circuits whose internal characteristic of opposition, called impedance, are very different, preventing direct connection. The cathode follower is used as an impedance-matching circuit so that electrically the two circuits are connected signal-wise but interaction is prevented. This isolation principle is also used where one signal source must be applied to more than one chassis or using circuit. Some manner of isolation must be present between the two circuits so that each may operate even if one contains a malfunction. By preceding each circuit with a cathode follower, the isolation is obtained. Interaction of the two using circuits is prevented by the cathode follower.

(2) Applied voltages—In order to allow V6 to operate properly requires the application of two voltages; B+, used by the plate, and filament voltage, used by filaments or heaters of the tube. When measuring the voltage applied to the stage, it is necessary to locate the point at which the voltage first touches a component considered a part of the stage.

(a) B+ voltage—Circuit board #1 shows only one stage present on the board, therefore, the point at which the voltage is measured can be readily identified. The 250v dc is first applied to the top of R1 and must be measured at this point as indicated by ★c. The voltage at the top of R1 must be the same as the voltage at the external source. In effect, the wire connecting the voltage from the plug connector P1 to the top of R1 is considered to be a part of the voltage distribution.

(b) Filament voltage—Normally the filaments are not shown in the immediate vicinity of the stage under test. Where more than one stage is present in a chassis, the filaments are shown separately and are called a filament string. Each filament in the string of filaments will show the pin connection and the tube number it applies to. The 6.3v ac filament voltage is measured at pins 2 and 3 of V6 as indicated by ★d.

Vacuum tubes require the application of voltage in order to operate. V6 is a triode vacuum tube whose purpose it is to provide an automatic method of control on the rate of electron movement (current flow) in the circuit. It acts as a valve to increase or decrease the rate of flow.

The filament voltage applied to the vacuum tube is necessary to produce thermionic emission within the tube. By using voltage on the filaments, heat is radiated to the cathode and electrons may move from the cathode to any other element which will attract the electrons. This principle of heat causing electronic movement is called thermionic emission.

The electrons in the tube are caused to move from the cathode to the plate due to the application of the B+ voltage. When this high positive voltage is applied to the plate an attracting force is exerted on the electrons. This force is sufficient to cause the electrons to leave the cathode and attach themselves to the plate. The number of electrons that move is controlled by the signal on the control grid.

(3) Circuit components—Before the final phase of the maintenance problem can be solved, the components that make up the stage must be known. To determine the components that must be checked in the stage where the malfunction is suspected, the basic rule previously established must be applied. After the signal path has been established and signal tracing accomplished, any component through which the signal must pass must be checked. That is, any component that is in the path from input monitor point to the output monitor point. In addition, any component that can be reached from this signal path without going through another capacitor must be checked. The circuit is considered to be terminated when a known voltage is reached (whether applied voltage or divided voltages) or when ground is reached.

While the instructors were provided with a number of documents that were intended to guide their instruction, they were not provided with detailed lesson plans for use in class. It was believed by the research staff that the availability of scripts or detailed outlines would tend to force the instruction into a fixed pattern, with specific items of information being introduced when the course builder thought they were appropriate, rather than when the student needed them. By insuring that the procedures to be learned were specified clearly and the instructors and students understood the principles of procedure-oriented training, and by providing an abundance of practice problems, it was anticipated that instruction would be more nearly suited to the students' needs as the course progressed.

Perhaps it should be pointed out here that one of the primary purposes of class outlines or scripts in conventional courses is to control the instructor's *lecturing;* that is, to tell him what terms to introduce and what to say about each of them. In the present course, it was desired that lecturing be kept to a minimum and that terms be introduced as they were needed rather than according to a planned schedule that would have to be created without knowledge of the students' information needs at any given point. It was also felt that attempts to exercise close control over what the instructor was saying might keep the instructors from using their own ingenuity in trying to find solutions to problems that arise during instruction.

The plan, in general, was to have some 10 to 20% of each classroom period devoted to statements by the instructor concerning the objectives for the period, and the remainder of the time devoted to practice and questions by the students.

Chapter 3

TRAINING LITERATURE AND DEVICES

Several types of documents portraying the procedures and related training materials were developed for use during the experimental course. These documents provided guidance for the instructors in teaching and advising the students; their content was planned to ensure that the students had an opportunity during their training to encounter most of the problems they would later encounter on the job.

The documents, especially the symptom-collection manuals, were extensively revised on the basis of the experience gained as instructors and students used the materials during the first two administrations of the experimental course. Several training devices were also developed as teaching aids to enhance the ability of the students to perform in the field.

DAILY AND WEEKLY CHECKS

A manual was prepared for the CWAR which presented the daily and weekly check procedures, as specified in the DA TM, and an equivalent statement of these procedures written in a less technical manner. The manual also contained illustrations of the radar with all major components labeled to show their location. This manual was issued to all instructors and students for the first experimental comparison. On the basis of the results of the first experiment, it did not appear that this manual facilitated instruction. Therefore, it was not included as part of the training literature provided subsequent experimental classes.

USE OF TEST EQUIPMENT

Three multimeters (TS-352A/U, TS-505A/U VTVM, and PSM 6) and two oscilloscopes (AN/USM-50C and AN/USM-32C) are used by MOS 23R on the job, and one additional oscilloscope (AN/USM-24C) is used during training.

Training Manuals

For each item of test equipment that the students were required to use, a manual was prepared to present all the necessary information. The manuals contained definitions of electrical terms, descriptions of the test equipment, and detailed procedures for using the equipment for any measurements that would be required of the students.

These procedures were organized in outline form to facilitate learning. For each meter a summary chart of the procedure was provided; the summary chart for the Multimeter TS-352A/U is illustrated in Figure 1.

The manuals also presented a selected series of practice problems in which the students would encounter essentially all the problems that would be encountered in using the equipment on the job.

TS-352A/U Meter Guide

STEPS		TYPE OF MEASUREMENT			
		AC VOLTS	DC VOLTS	DC CURRENT	OHMS
SET UP	Connect black lead	−DC ± AC OHMS	−DC ± AC OHMS	−DC ± AC OHMS	−DC ± AC OHMS
	Connect red lead	1000 OHMS PER VOLT AC DC. 1000V (largest)	20000 OHMS PER VOLT DC.* 1000V (largest)	*DC CURRENT (up to 2.5 amp)**	OHMS
	Set FUNCTION switch	AC VOLTS	2000 Ω V DC* DIRECT (pos.) or REV (neg.)	DC CURRENT	OHMS
	Set Range switch	Not used	Not used	2.5 AMP (largest)**	R X 1
	Adjust needle to zero	Not necessary	Not necessary	Not necessary	OHMS ZERO ADJ knob
CONNECT	Plan meter placement	In parallel	In parallel Observe polarity	In series Observe polarity	Across resistor
	Prepare circuit	Power on	Power on	Power off, open circuit	Power off (may need to isolate)
	Attach	Black to ground, red to hot	Black to −, red to +	Black to −, red to +, power on	Across resistor. Hold 3 seconds before reading.
READ	Select scale	AC (blue lower). Check row	DC (black middle). Check row	DC (black middle). Check row	OHMS (green upper)
	Check range	Smallest without pegging	Smallest without pegging	Smallest without pegging (remove probe to adjust range)	10 ⟶ 100 Over 100, increase range. Readjust needle
	Read value	Convert scale	Convert scale Note polarity	Convert scale	Multiply by range switch setting
DETERMINE IF GOOD	Compare with expected value	Schematic value ± 10%	Schematic value ± 10%	Schematic value ± tolerance	Schematic value ± tolerance

* For specified DC voltage readings the FUNCTION switch may be set at 1000 Ω V DC and the red lead placed in the 1000 OHMS PER VOLT AC DC column, largest jack.

** If current could be more than 2.5 amp (but less than 10 amp), use +10 AMPS ONLY jack and position range switch to 10 AMP position.

Figure 1

The manuals were issued to all students and instructors; however, the answers to the practice problems were presented only in the instructors' copies.

Training Devices

To provide adequate opportunity for students to practice using the test equipment, it was necessary to produce several training devices. Special test panels (Figure 2) were designed for use with multimeters and VTVMs. These presented all the voltages that the students would encounter in the radars, and all the types of terminals at which these voltages would have to be measured. In addition, these panels were so designed that the voltage at any particular terminal could be readily changed by specified amounts without the students' knowledge.

Test Panel for Multimeter Training

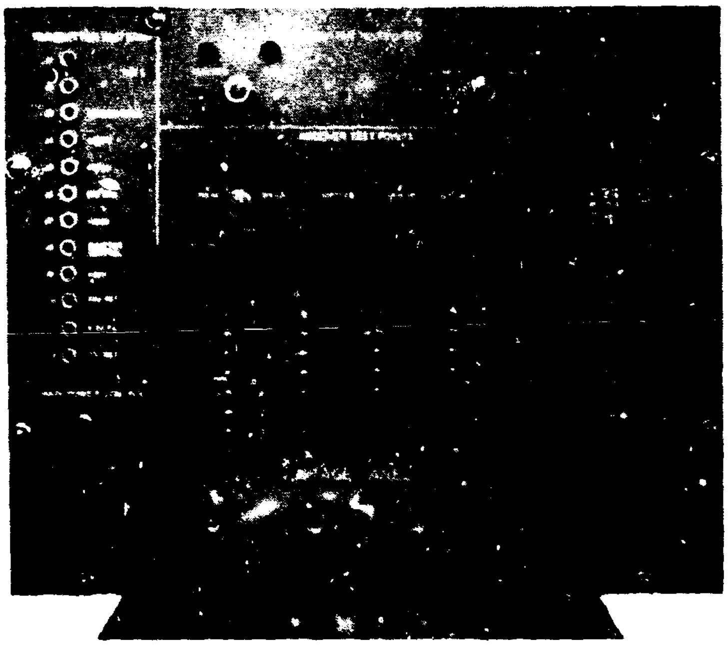


Figure 2

For use in oscilloscope training, signal generators were developed to produce all the types of signals that the students would encounter in the radars (Figure 3). A series of multiposition switches controlled the display of these various signals and were identified

USM-50C Oscilloscope and Signal Generator

Figure 3

by a numbering system. By operating these switches, students could select the required signal for a particular practice problem. However, the numbering system for the switches was deliberately made complex, so that the students would be unable to memorize the signal resulting from any given combination of numbers.

SYMPTOM COLLECTION

A symptom-collection manual was provided for each of the two radars. Each manual presented the symptom-collection procedures and showed in schematic and/or functional diagram symbols the circuits that related to each check.[1]

For each of the specified checks, an attempt was made to develop complete instructions for performing the check. These instructions were written in sufficient detail so that instructors could readily be trained to follow them. In each diagram, enough detail was provided to ensure that the instructors would have no difficulty in identifying the corresponding circuit in the DA TMs.

It was not possible to prepare the instructions or diagrams in sufficient detail to ensure that untrained students could use them. Rather, it was intended that the instructors train the students to use these materials, largely by verbally guiding the students in repeated attempts to use them.

To enable them to select practice problems, the instructors were provided with a set of cards that listed each possible symptom and each portion of the radar that could cause that symptom. These cards constituted a complete set of all problems that could be solved by symptom collection, thereby permitting the instructors to provide as much practice in symptom collection as time would permit, without having to generate new problems for each class.

SIGNAL TRACING

The research staff was unable to develop an explicit procedure that would always work for selecting "the best" signal tracing points for checking within a given symptom area. It was therefore not possible to present such procedures to the students in written form. However, some members of the research staff and some of the instructors learned to correctly select signal tracing points, and were able to prepare written procedures for the instructors.

A signal tracing sheet was prepared for each of the equipment areas to which a malfunction could be isolated by symptom collection. These signal tracing sheets listed every part on the signal path and identified the places at which signal tracing checks should be made. In addition, the sheets specified the signal that should be present at each point, and the test equipment that should be used in measuring the signal. Each instructor was provided with a complete set of these sheets, giving him complete signal tracing information for the radars. A sample of an instructor's signal tracing sheet is shown in Figure 4.

It was apparent that the students could not memorize the mass of signal tracing information for the two radars, so it was not given to them in printed form. Rather, they were provided with laboratory worksheets which were blank forms to be filled out in class. Because of (a) the practice in filling out the laboratory worksheets as the students performed signal tracing and (b) the discussions with the instructors that would result

[1] Presentation of materials in the symptom-collection manuals in the initial and revised versions is discussed in more detail and illustrated in Chapters 5 and 6.

Sample Signal Tracing Sheet

J1-1

SIGNAL TRACING: DOPPLER (Name of Subsystem)

Name of Circuit: Lock + Recycle (LOCK) Radar Condition: RAD., Lock sw: Lock Hold

Indicator: Lock lamp

1. Use Detailed Data Flow Diagram to identify subassemblies for signal tracing. (Trace from indicator back to source.) (List subassemblies below.)
   a. C.I.P. (1) e. C.I.P. (2)
   b. D.T.U. (1) f.
   c. D.T.U. (2) g.
   d. D.T.U. (3) h.

2. Use Detailed Data Flow Diagram to list KEY POINTS in each subassembly, tracing from the source back to the indicator. (List subassembly and key point below.)
   a. *1st Subassy:* D.T.U. (1) *Key point:* K1 CONTACTS
   b. *2d Subassy:* C.I.P. (1) *Key point:* Lock lamp
   c. *3d Subassy:* D.T.U. (2) *Key point:* V20
   d. *4th Subassy:* D.T.U. (3) *Key point:* K2
   e. *5th Subassy:* C.I.P. (2) *Key point:* Lock Hold sw.
   f. *6th Subassy:* *Key point:*
   g. *7th Subassy:* *Key point:*
   h. *8th Subassy:* *Key point:*

3. Signal Tracing in Functional Schematics
   a. Index page number of subsystem: 43
   b. Identify complete signal path by tracing from indicator back to the source.
   c. Tracing from source back to indicator, list all information required under column headings below.

	Page	*Chassis*	*Check Point*	*Grd/Ret*	*Signal/Voltage*		*T.E.*
PATH-1	45	D.T.U.	K1-9	28 V RET	28 VDC		505
	"	"	K1-11	"	"		"
	47	R.S.G.	A12TB1-2	"	"		"
	"	C.I.P.	DS1-2	DS1-1	"		"
					NORMAL	LOCK-HOLD	
PATH-2	45	D.T.U.	K2-5	GRD	250 DC	250 DC	"
		"	K2-3	"	0.0 DC	250 DC	"
		"	Y20-7	"	-21 "	+5 "	"
		"	K1-1	K1-2	0.0 "	+100 "	"

(Continue on reverse side of form)

Page of

Figure 4 (continued)

	Page	Chassis	Check Point	Grd/Ret	Signal/Voltage	T.E.
PATH-3	44	D.T.U.	K2-8	GRD	+250 VDC	505
			K2-6	"	+3v to +250	"
PATH-4	44	C.I.P.	S3-1	28 V RET	28 VDC	"
			S3-2	"	"	"
			K1-2	"	"	"
			K1-3	"	"	"
			K2-1	K2-2	"	"

d. Signal trace from source to indicator using selected test equipment and check points listed above.

e. Indicate point of:

(1) Last good check: ______________ Chassis: ______________

(2) First bad check: ______________ Chassis: ______________

4. Troubleshooting in Detailed Schematics

a. Identify chassis in which first bad check and last good check was obtained:

______________ (First bad check) ______________ (Last good check)

b. Index page number of above listed chassis: ______ and ______

c. To continue from this point in troubleshooting, use the form titled: "Troubleshooting Within Stage."

Page ____ of ____

Figure 4

from this work, it was hoped that some students would be able to learn how to select signal tracing points even though no explicit procedure was available.

TROUBLESHOOTING WITHIN A STAGE

Worksheets

The first step in troubleshooting within a stage is to identify the parts that constitute the stage. This can be done easily if the signal tracing points have been properly selected. The students were provided with worksheets for use in listing the parts within each stage. For troubleshooting purposes a "stage" was defined during the experimental training in the following manner:

> A stage consists of all the components between the first bad signal tracing check and the last good check. A stage consists of not only the components on the main signal path, but also all the components that can be reached from the components on the main signal path without going through power supplies, past ground, or through any component that blocks dc (tube, capacitors, transformer cores, or open switches).

Once the parts that compose a stage have been identified, it is necessary to check them. The worksheets required the student to list the parts in the order in which they should be checked. A procedure was developed for checking the parts within a stage, and this procedure was supplied to the students in written form (see Appendix B). This procedure was not written in sufficient detail for a new student to consistently use it correctly, since the research staff was unable to write such an unambiguous document. Rather, it was intended that the students learn to follow the procedure by applying it, under supervision, to a number of stages.

Devices

Training for troubleshooting within a stage necessitated the development of some 90 circuit boards (Figure 5), each of which contained one stage similar to one found in the

Sample Circuit Boards and Mounting Base

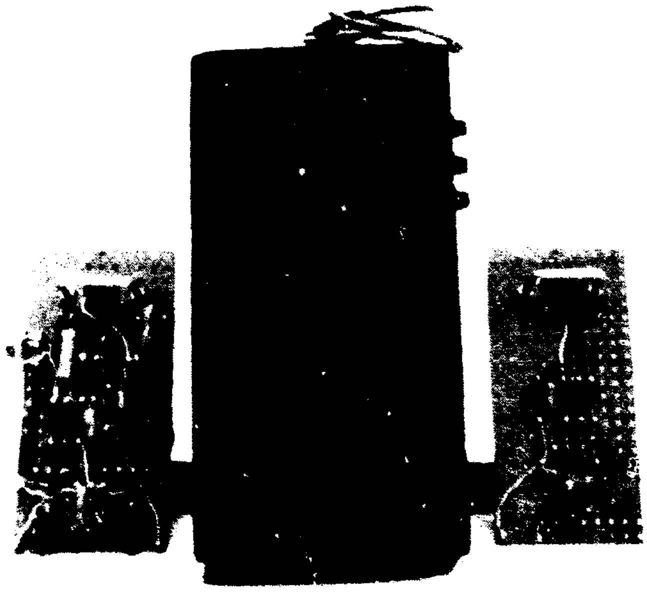
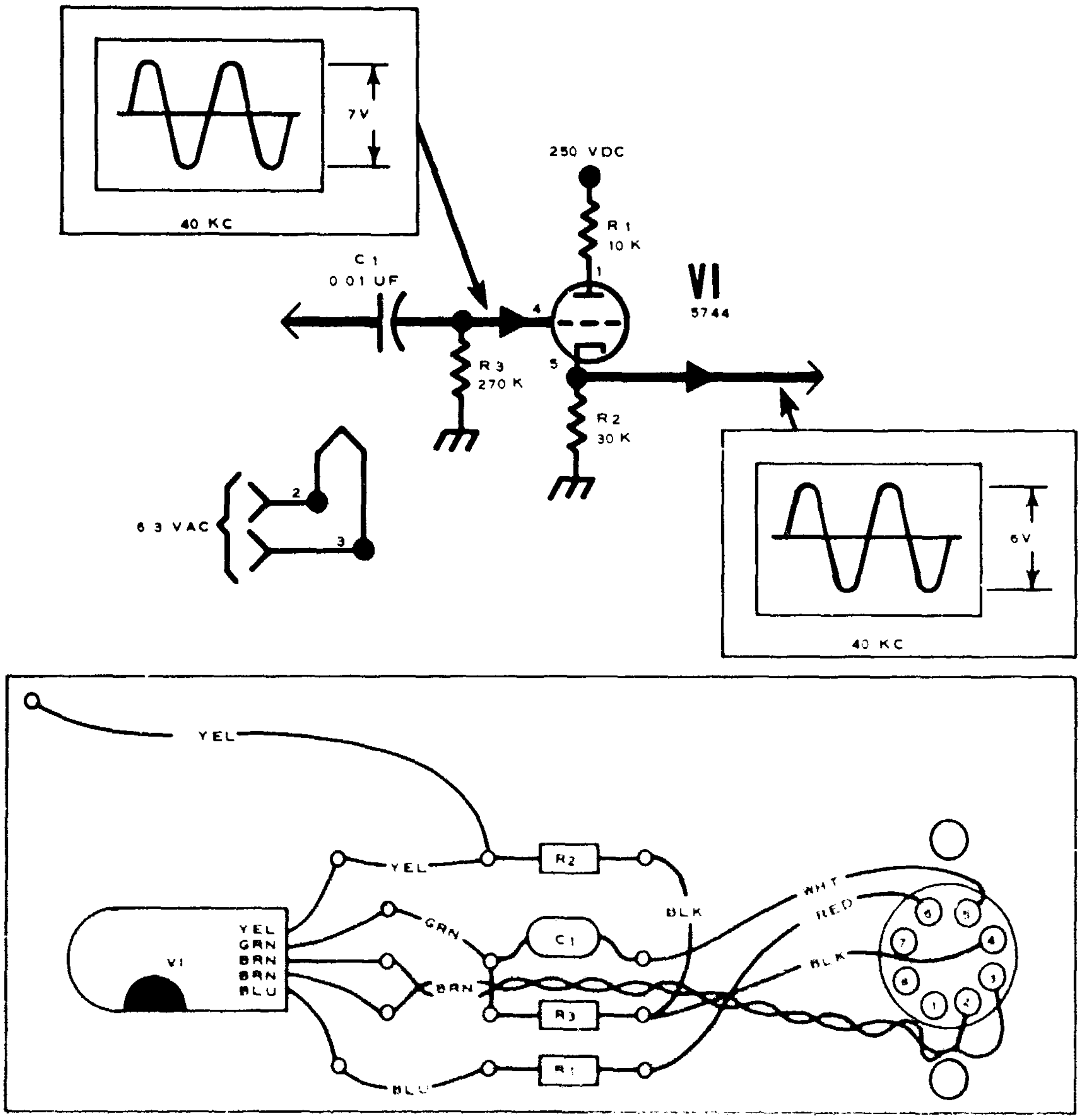


Figure 5

radar. Each of these circuit boards contained a realistic malfunction, which the students were required to locate.

To teach students the relationship between schematic diagrams and actual hardware, schematic and wiring diagrams for each circuit board were prepared according to the rules governing preparation of diagrams for the HAWK system (Figure 6). These schematic diagrams were bound in a manual along with the procedures for troubleshooting within a stage.

Sample Schematic and Wiring Diagram for Troubleshooting Within a Stage



Reference Designation	Nomenclature
C1	CAPACITOR, FIXED, PAPER DIELECTRIC: 400v, 0.01μf ($\pm$10% tol)
V1	ELECTRON TUBE: JAN 5744
R1	RESISTOR, FIXED, COMPOSITION: ½w, 10K ($\pm$5% tol)
R2	RESISTOR, FIXED, COMPOSITION: ½w, 30K ($\pm$5% tol)
R3	RESISTOR, FIXED, COMPOSITION: ½w, 270K ($\pm$5% tol)

Figure 6

Chapter 4

THE FIRST COMPARISON

The first experimental course was given early in FY 1966 to a regularly scheduled class of 30 students at USAADS. The two preceding classes were used as a control group to establish standards for graduation of the experimental students. This trial of the initial version of the course and of the training literature and devices provided the basis for revising the procedures and materials that made up the course content for subsequent versions of the course.

SELECTION OF INSTRUCTORS

The course was taught by a team of 10 Air Defense School instructors under the supervision of a warrant officer. All the instructors were selected from available personnel by the School, in fulfillment of the specification that the course be taught by persons representative of instructors at the School.

Two of the instructors were civilians with prior experience in the conventional course for MOS 23R. The other eight instructors were enlisted technicians who held the MOS. Some of these had field experience with the Hawk system, some had previously taught the conventional course, some had both field experience and teaching experience, and some had neither.

TRAINING OF INSTRUCTORS

Instructor training began four weeks before the first experimental class began. It was designed to help the instructors learn the purposes of the experimental course, and to let them see how it could be effective. Since experienced personnel are likely to have difficulty in adjusting to innovations, the emphasis was placed on teaching the characteristics of the new approach to maintenance training. Comparatively little attention was given to teaching specific instructional techniques, or to having the instructors actually learn all the procedures they were to teach.

During the first week of the training period, the future instructors served as students for sample classes presented by the research staff. These sample classes had been selected to represent the different types of classes involved in the course, and the research staff tried to present the material as they thought it should be presented to students in the experimental course.

These presentations were interrupted by frequent and extended discussions between the future instructors and the research staff as to why material was being presented as it was. These discussions were encouraged by the research staff because they provided an excellent opportunity to explain the instructional philosophy underlying the experimental course.

During the second week of training, the instructors began to specialize in the particular portions of the course that they would teach. Two instructors concentrated on symptom collection, which they would teach in conference. A third instructor studied signal tracing, and a fourth focused his attention on troubleshooting within a stage. The remaining six assistant instructors studied the materials to be taught in laboratories. Overall supervision of the instructors was provided by the warrant officer.

The third and fourth weeks that had been allocated for instructor training were used to present a sample course to some 15 senior staff officers from USAADS. This sample course lasted 40 hours, and consisted of materials selected to illustrate the use of procedure-oriented training in a radar maintenance course. The instruction started with daily checks of the radar, proceeded through symptom collection, use of test equipment, signal tracing, and troubleshooting within a stage. During the last four hours of this course, the "students" (i.e., USAADS staff officers) troubleshot malfunctions in the CWAR to the piece-part. This course was conducted by the instruction team assigned to the project two weeks earlier, and constituted the only real opportunity for these instructors to practice procedure-oriented training before the beginning of the first experimental course.

WRITTEN GUIDANCE

As indicated in the earlier discussion of training literature, the instructors were provided with a number of documents that were intended to guide their instruction, as well as with a copy of the POI that indicated what the students were to practice during each block of instruction.[1]

Scripts or detailed outlines were not provided for use in class, to promote the likelihood that lecturing would be kept to a minimum and that specific items of information would be introduced whenever the student needed them. The students would, in part, guide the instruction themselves by the mistakes they made and the questions they asked. The process of presenting instruction suited to the students' needs was furthered by clearly specifying the procedures to be learned, helping instructors and students to understand the principles of procedure-oriented training, and providing an abundance of practice problems.

CHARACTERISTICS OF THE STUDENTS

The 30 students in the first experimental class were not specially selected. Rather, they were typical students in that they were the ones who happened to be scheduled to begin instruction at the time the experimental course was ready to begin. An examination of available aptitude and experience data (Table 1) failed to show any particular differences from other groups of students being trained for the same MOS. Classes vary considerably in their proportions of volunteers; this class was in the higher range in this respect.

MONITORING OF CLASSES

Attempts to obtain information on the progress of the experimental instruction through direct monitoring of classes proved to be unsatisfactory. Very early in the course it was found that the presence of a member of the research staff in the classroom

[1] A copy of the POI used for the second comparison is presented as Appendix A. Except for some minor modifications in time allotments, it is similar to the POI used for the first experimental class.

Table 1

Input Student Background Data for the First Comparison

Class	Student Input	Age	Education	Percent Volunteers	Aptitude Scores[a]			EPT[b]
					GT	EL	VE	
65-1	24	25.1	11.6	76	117.9	118.0	121.5	66.0
2	26	19.9	11.8	20	105.4	114.6	105.0	52.2
3	27	20.0	12.1	40	110.7	117.3	112.0	59.0
4	32	21.4	11.5	41	110.1	115.0	110.3	53.6
5	31	24.5	11.9	63	112.4	117.2	111.8	61.9
6	26	26.7	11.7	23	114.3	116.2	115.4	58.9
7	20	18.6	11.8	8	113.2	113.4	113.7	56.6
8[c]	28	22.8	11.1	12	113.0	112.4	115.9	60.4
9[c]	24	22.8	11.5	39	111.7	117.5	112.6	59.0
66-1[d]	30	23.8	11.1	60	114.7	116.8	114.9	60.5

[a]GT, General Technical; EL, Electronics; VE, Verbal.
[b]EPT is the Electronics Placement Test developed by the U.S. Army Air Defense School.
[c]Conventional classes which were tested.
[d]First experimental class.

appreciably altered instruction. When a research staff member was present, the instructor focused his attention on this individual and tried to "teach" him rather than the students. As a result, the instructors tended to lecture much more than was desirable. Later discussions with the instructors indicated that, because of their previous experience, they tended to feel that monitors were there to evaluate their instruction, rather than for the purpose of helping and learning; thus, they tended to present material in ways that had brought favorable evaluations during conventional courses.

To reduce this interference with instruction while still maintaining some contact with class activities, the research staff adopted an indirect monitoring technique. The instructors' office was so located that instruction in the classroom could be heard and even observed from the office. During the CWAR portion of the course (i.e., the first 15 weeks) a member of the research staff spent several hours each day in the instructors' office. Most of this time was spent in discussions with the instructors, who had numerous questions about the instructional approach and about the procedures that were being presented. However, a few minutes each day were spent in observation of the class.

In general, the instruction during the CWAR portion of the course appeared to be proceeding as planned. A small part of each classroom period was devoted to statements by the instructor concerning the objectives for the period, and the remainder of the time to practice and questions by the students. The students soon learned that their questions would be answered clearly and directly if the questions related to what they were to do or how they were to do it. The instructors learned that they would get complaints from the students if they lectured too much, gave answers the students couldn't understand, or digressed too much.

Since the instructors appeared to be receiving adequate guidance in the form of feedback from the students, the research staff avoided offering comments or suggestions about the classroom presentations. When, as occasionally happened, an instructor realized that the students were not learning some of the material as they should, he usually asked for advice on how to handle the problem differently for the next class. These requests resulted in informal conferences between the staff and several of the instructors, in which a number of suggestions were offered and discussed.

The monitorship of instruction during the first experimental comparison was thus quite informal, and no attempt was made to supervise instruction very closely. Essentially, it was felt that closer monitoring of instruction would do more harm than good.

DEVELOPMENT OF THE CRITERION TEST

The end-of-course proficiency test was constructed to measure performance on the two major aspects of the job—periodic tests and adjustments, and troubleshooting.

It was decided that the students' ability to perform periodic checks and adjustments could be determined adequately by observing and scoring performance on the weekly check procedures. Since the entire weekly check procedure for both radars requires some 12 hours to perform, it was impractical to test each student on the entire procedure. Therefore, USAADS personnel who were not familiar with the experimental instruction, but who were familiar with HAWK maintenance, selected portions of the weekly check procedure for the test. The portions they selected were among the most difficult and provided a maximum opportunity for errors to occur. This portion of the test required approximately one hour for each student.

The troubleshooting test for the first experiment consisted of 24 troubles: 12 in the CWAR and 12 in the HPIR. Within each radar, there was at least one trouble in each subsystem. The 24 troubles were selected to provide the following types of malfunctions: tube, 7; resistor, 4; capacitor, 4; wiring, 4; troubles in chassis not authorized for repair at second echelon, 2; adjustment, 2; defective crystal, 1.

Within these category restrictions, the actual troubles were selected by USAADS personnel to provide difficulty levels ranging from very easy to very difficult, the average difficulty being such that an "average" student should be able to identify the correct chassis for approximately half of the troubles. A list of these troubles is given in Appendix C.

For administrative reasons, it was decided to impose an arbitrary time limit of 30 minutes for each trouble. Although this time limit was somewhat severe, there was little indication during the testing that more time would have changed the results significantly.

Also for administrative reasons, the students were not provided with spare chassis or other spare parts, and they were not permitted to unsolder any connections. These restrictions, while administratively necessary, were undesirable in that they almost certainly resulted in lowered performance scores. Chassis substitution is an efficient and effective technique for troubleshooting in the field, and in some cases it is the only available technique for identifying the defective chassis.

The final step in test development was the administration of the test to conventionally trained graduates to determine a reasonable pass-fail cutoff for the experimental students. Because of the limited time available for testing the conventionally trained graduates, it was decided to divide the troubleshooting portion of the test into two subtests of 12 troubles each—Form A and Form B.

In the first experiment, each form of the test was administered to 23 graduates representing two successive classes of the conventional training program. Thus the standardization of the test involved the testing of 46 conventionally trained graduates, each of whom was tested on 12 troubleshooting problems and on performance of weekly check procedures.

TEST ADMINISTRATION

The test on weekly check procedures was administered by USAADS instructors, who used prepared forms to record errors made by students. Since the performance of check procedures is normally done by two technicians, one reading the DA TM procedures and the other performing the actual checks, the instructors read the procedures to the student if he so requested.

The troubleshooting portion of the test was administered by 10 experienced HAWK warrant officers working under the joint supervision of the USAADS Project Officers and the senior member of the research staff. For each problem, the warrant officers read the initial instructions to the student. There was no further conversation between the student and the examiner until the student reported that he had found the trouble or the examiner called time. At this time, the examiner asked the student to name the chassis containing the malfunction, and the specific part that was defective. If a student said that he didn't know, he was encouraged to guess.

ESTABLISHMENT OF GRADUATION STANDARDS

Control Group Test Performance

Weekly checks. The errors made by the control groups in performing the weekly checks were very few, and they appeared to be unrelated to the troubleshooting ability of the students. Because of the guidance supplied by the DA TM—that is, step-by-step procedures for the checks—all students who made errors were able to detect and correct their own errors. Consequently, there was no meaningful variability among the students in performance on this portion of the test.

Since this turned out to be true not only for the conventionally trained graduates but also for the students in the experimental class, this portion of the test provided no information concerning the students' ability. Thus, in actuality, it did not have any effect in determining graduation.

Troubleshooting. The troubleshooting portion of the test was much more revealing. In the first experiment, no student had a perfect score, none missed all of the items, and there was considerable variability in performance.

On Form A, two students in the control group in effect tied for low score, one finding three troubles to the chassis and the other finding two to the chassis and one of these to the piece-part. Since it was unclear which of these represented better performance, it was agreed that any experimental student who matched either of these performances would be considered as having passed this form of the test.

On Form B, one of the 23 conventionally trained students found only three troubles to the chassis, and none to the piece-part. However, the next lowest student found six troubles to the chassis. It was agreed that the student who found only three troubles was atypical and that his score should not be used in setting graduation standards. Therefore, it was necessary for experimental students to find six troubles to the chassis to receive credit for passing Form B of the test.

Graduation Standards

In summary, the standards for graduation for a student in the first experimental class were as follows: (a) He had to perform selected portions of the weekly check without making any errors, or he must recognize and correct any errors that he made; (b) he had to isolate 6 of the 12 malfunctions on Form B of the test to the chassis, *and* he had to isolate 3 malfunctions to the chassis (or 2 to the chassis and 1 to the piece-part) on Form A of the test.

In effect, he was required to equal or excel the performance level of the two lowest-scoring men in each class of the conventionally trained graduates.

RESULTS FOR THE EXPERIMENTAL CLASS

Attrition

Of the 30 students who started in the first experimental class, one was dropped because he missed more than 20% of the instruction while on emergency leave. Thus there were 29 students who completed the course. Twenty-eight of these students met or exceeded the standards for graduation. The one remaining student failed *both* parts of the troubleshooting test. Failure of one student out of 29 constitutes an academic attrition of about 3%.

During the year immediately preceding the first experimental class, there were nine classes for MOS23R. Attrition in these classes averaged 26%, the lowest attrition being 12.5%, and the highest being 50%. The difference between the attrition rates for the experimental class and the average of the previous nine conventional classes was statistically reliable ($p < .01$). Attrition in the first experimental class was only one-eighth of the average attrition for the year, and less than one-fourth of the lowest attrition obtained in that year. The attrition rates for the 10 classes are compared in Table 2.

Table 2

Academic Attrition in Course 23R (221) for the First Comparison

Class	Input	Academic Loss	Percent Attrition
65-1	24	3	12.5
2	26	13	50.0
3	27	9	33.3
4	32	10	31.2
5	31	5	16.1
6	26	6	23.0
7	20	8	40.0
8[a]	28	5	17.8
9[a]	24	3	12.5
66-1[b]	30	1	3.3

[a]Control groups that were tested.
[b]First experimental class.

Performance

As indicated earlier, there was no difference among the students in their performance of weekly checks. Errors among all students were so few and so minor as to be meaningless. This was to be expected because of the nature of the task and the DA manuals, and the training devoted to the task.

A comparison of performance in isolating malfunctions to the chassis in the first experiment is presented in Figure 7. It will be noted that the average score for graduates of the experimental class in identifying the malfunctioning chassis was 60% (SD = 16.4) on Form A and 70% (SD = 13.6) on Form B of the test. For graduates of the conventional course, the respective average percentage for Form A was 48 (SD = 13.7) and for Form B was 67 (SD = 18.7). For Form A, the superiority of the graduates of the experimental course is statistically reliable ($p < .05$, Mann-Whitney test).

Figure 8 presents results for isolation of malfunctions to the piece-part. Graduates of the experimental course were successful in identifying the defective piece-part 17% of the time on Form A and 26% on Form B of the test. The conventional students were successful 12% and 15% of the time on Forms A and B, respectively. The difference between the performance of graduates of the experimental and conventional courses is statistically reliable for Form B ($p < .05$, Mann-Whitney test).

Since isolating the defective piece-part is dependent on finding the correct chassis, success to the piece-part is contingent on success in getting to the chassis. To determine whether improvement in getting to the piece-part was all a matter of having found the chassis more often, the results were analyzed to determine the percentage of success in

Test Results, First Class, Chassis

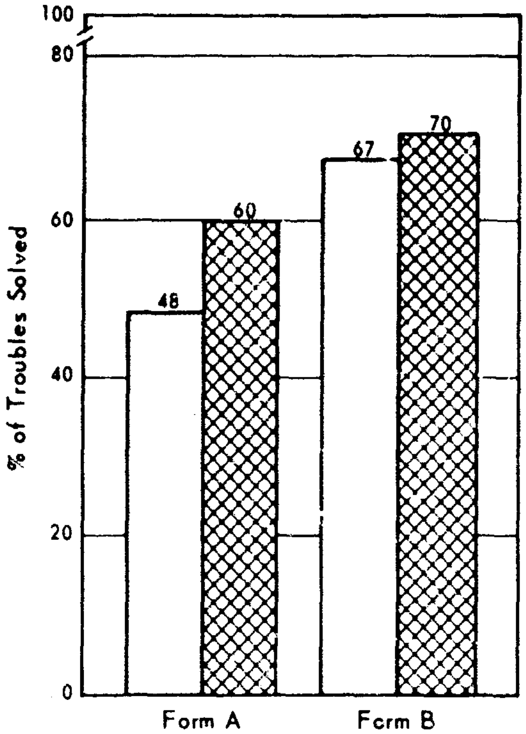


Figure 7

getting to the piece-part when the chassis was found. These results for the first experiment are shown in Figure 9. The experimental class was successful in finding the piece-part once they had found the chassis 27% of the time on Form A and 34% on Form B, compared with 23% and 21%, respectively, for the control classes. This difference is statistically reliable for Form B ($p < .05$, Mann-Whitney test).

Test Results, First Class, Piece-Parts

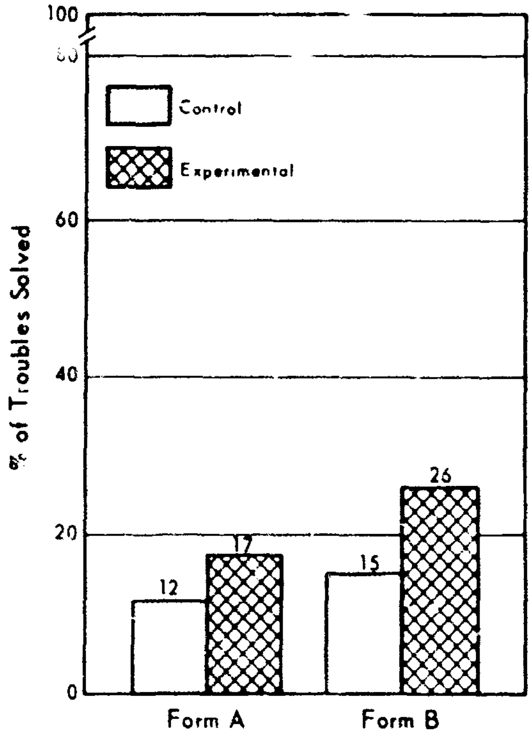


Figure 8

**Test Results, First Class—
To Piece-Part When Chassis Found**

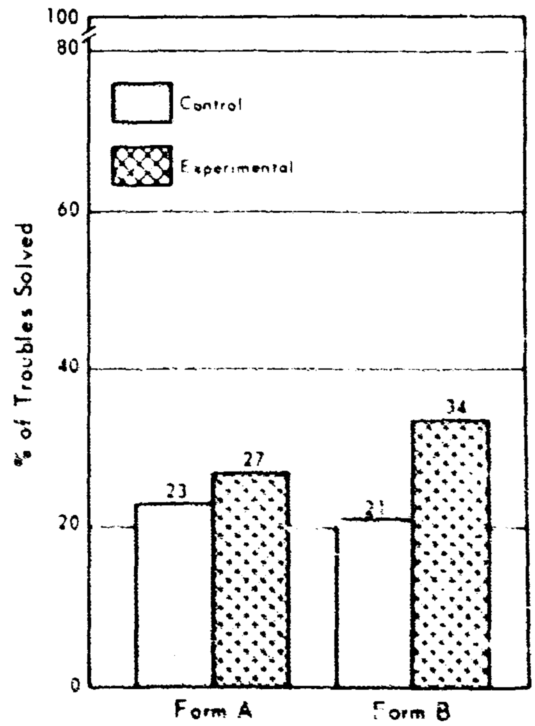


Figure 9

Chapter 5

THE SECOND COMPARISON

As a result of experience in the first administration of the course, several changes were made in the POI, the training materials for instructors and students, and the selection of instructors before the beginning of the second experimental class. This class was a regularly scheduled USAADS class of 30 students toward the end of FY 19[illegible]

PROGRAM CHANGES

The POI for the first experimental class was largely a matter of "best estimate," since there was no firm basis for allocating the relative amounts of time to be devoted to various topics, nor a pretest of the experimental training materials. The experience with the first experimental class provided such a basis for use in planning the second class, both for time allocations and for structure of procedures, sequence of course content, and format of training materials. The POI prepared for the second comparison is shown in Appendix A, and a detailed training schedule is presented in Appendix D.

Daily and Weekly Checks. The time devoted to daily checks was reduced from 16 hours to eight hours, since experience in the first class made it apparent that this amount of time would be sufficient.

The block of instruction on [illegible]ekly checks was reduced from 40 hours to eight hours, with the 32 hours transferred [illegible]dditional practice on symptom collection and signal tracing. This change was made because all of the individual actions involved in weekly checks were included in symptom collection, and it was decided they could be better practiced in that context. An eight-hour block of instruction on weekly checks was presented at the end of the CWAR subcourse.

Troubleshooting Within a Stage. The time devoted to laboratory practice in troubleshooting within a stage on circuit boards was reduced by approximately 25%, since the students in the first class appeared to be bored and complained about the extensive laboratory practice.

A four-hour review of test equipment was added late in the course This review emphasized the detection of malfunctions within the test equipment itself, since this had proved to be somewhat of a problem during the proficiency testing that followed in the first class.

Signal Tracing. Perhaps the greatest change in the POI involved the portion of the course when signal tracing was introduced. During the first experiment, signal tracing was delayed until quite late in the course to ensure that the students had an adequate opportunity to become familiar with schematic symbols (which are used in the symptom-collection manuals as well as in the schematic diagrams) before trying to use schematic diagrams for signal tracing. Between the first and second classes new DA TMs became available. These new manuals contained functional diagrams that could be used for signal tracing, and were much easier to use than were the previous schematic diagrams (that are still required for troubleshooting within a stage). It thus became feasible to introduce signal tracing earlier in the course, providing much better distribution of practice on both symptom collection and signal tracing, during both conference and laboratory instruction.

The radar lab time that was no longer required for weekly checks was used for combined symptom collection and signal tracing practice.

SYMPTOM-COLLECTION MANUALS

The symptom-collection manuals for the CWAR and the HPIR were revised for the second comparison. The only changes made in the CWAR manual were to correct errors and inaccuracies that became apparent during the first administration of the experimental training.

For the HPIR manual, further development work was done to structure the procedures, and format modifications were made in an attempt to reduce student and instructor difficulty in making the transition from the CWAR training to the more complex HPIR equipment. The HPIR manual was changed in the following ways:

(1) A table of contents was added, organized in terms of the HPIR subsystems and their built-in indicators. Written instructions explaining how to use the manuals were added.

(2) The Index to Indicators was expanded and a compendium of the indicators used in the weekly checks was added. The weekly checks index was keyed to the sequence in which built-in indicators are monitored during performance of the weekly checks. This addition was intended to facilitate symptom collection for malfunctions detected while performing these checks.

(3) The ECCM circuits, which in the original manual appeared on one diagram, were separated into a series of 12 sets of diagrams and instructions, each set being keyed to individual steps in the weekly checks. This change also corrected technical inaccuracies and reduced the complexity of the circuit diagrams.

(4) The original set of 16 major circuit checks used for isolating a fault to a symptom area were reduced to six major checks which evaluated the status of six subsystems: Power, Antenna Position, Computer, Transmitter, Receiver, and Doppler.

(5) A series of check procedures was specified for each subsystem. These procedures partitioned each subsystem into its constituent circuit areas.

(6) As a result of this reorganization of the structure of the fault isolation procedures, a considerable number of the symptom-collection diagrams were redesigned and additional written procedures were provided. Whereas the original HPIR manual contained approximately 40 symptom-collection diagrams, the revised manual contained 60 diagrams and associated written procedures.

(7) Each page that presented a symptom-collection diagram also presented a reduced-scale block diagram of the checks that should have been performed prior to beginning the procedures on that page. These "reminder diagrams" were added as an aid in remembering the complete series of symptom-collection procedures and to inhibit the initiation of checks on component circuits prior to performing the more general isolation checks. For example, each subsystem diagram was referenced to the complete HPIR system checks, and each circuit diagram was referenced to the appropriate subsystem check.

(8) The procedures in the original HPIR manual were written in a condensed and abbreviated language form and used color-coded references to the corresponding diagram to indicate the "good" and "bad" circuits. An example of the original format for the low-voltage power supply circuits is presented in Figure 10. During the first comparison, it was reported that this format for the procedures frequently confused both the students and the instructors, and may have adversely influenced the students' learning the procedures.

The procedures in the revised manual were presented in outline form, and each was organized in terms of: (a) The circuit being checked; (b) the radar controls that are involved in the procedure; (c) the built-in indicator to be monitored; and (d) the correct indication if no malfunction is involved in the circuits being monitored by the check. An example of the revised format of the written procedures for the low-voltage power supply is shown in Figure 11.

(9) The revised manual also contained location diagrams of the subassemblies and major components of the radar, and a Repair and Replacement Information Table.

SELECTION OF INSTRUCTORS

It was noted during the first experimental class that several of the instructors had difficulty in adapting to and teaching by the new procedure-oriented maintenance approach. Their own conventional course training, and perhaps field and/or instructional experience, sometimes interfered with their attempts to use the experimental procedures, materials, or instructional approach as had been intended by the research staff. These problems on the part of the instructors had, in some instances, some unfavorable effects on the learning by the students.

It was therefore decided that, for the second experimental class, graduates of the first class would be used as the laboratory instructors since they would already be able to follow the new procedures themselves, and should find it easier to teach them to others.

STUDENT CHARACTERISTICS

The student characteristics are summarized in Table 3. The graduates of Classes 6 and 7 were tested as controls to determine the graduation standards for the experimental class, which was Class 8. Some general student changes had occurred since the first experimental class graduated in early FY 1966. Apparently as a result of the Vietnam build-up, this MOS program tended to receive a much larger percentage of volunteers during FY 1966 than during prior months and the average aptitude levels of the students also tended to be higher. However, the second experimental class was in the lower range of classes in proportion of volunteers (45%).

Table 3

Input Student Background Data for the Second Comparison

Class	Student Input	Age	Education	Percent Volunteers	Aptitude Scores			EPT
					GT	EL	VE	
104	34	21.8	11.8	45	106.4	111.2	109.9	53.1
66-2	25	22.2	11.0	60	110.4	113.9	110.6	57.6
3	26	21.0	12.4	18	105.1	112.5	107.2	54.8
4	31	20.1	12.1	79	114.1	115.5	115.1	60.1
5	41	20.8	12.2	98	111.6	119.7	112.5	61.9
6[a]	21	21.8	12.6	43	115.8	119.7	118.4	61.2
7[a]	29	21.2	12.4	89	118.5	119.1	121.7	65.4
8[b]	30	20.1	12.6	45	123.4	121.9	125.1	67.6
9	46	20.0	12.7	91	114.5	118.5	116.4	65.7

[a]Control groups that were tested.
[b]Second experimental group.

Sample of the Format Used in the Original HPIR Symptom-Collection Manual

★1 Check LV PWR SUPPLIES meter in 6.3V position.
If OK, GOOD

★2 Check LV PWR SUPPLIES meter in both 250V positions
If both OK, GOOD, GOOD, and GOOD

★3 Check LV PWR SUPPLIES meter in 100V position.
If OK, GOOD and GOOD

★4 Check LV PWR SUPPLIES meter in 150V position.
If OK, GOOD and GOOD

★5 Check LV PWR SUPPLIES meter in both −100 positions.
If both OK, GOOD, GOOD, and GOOD

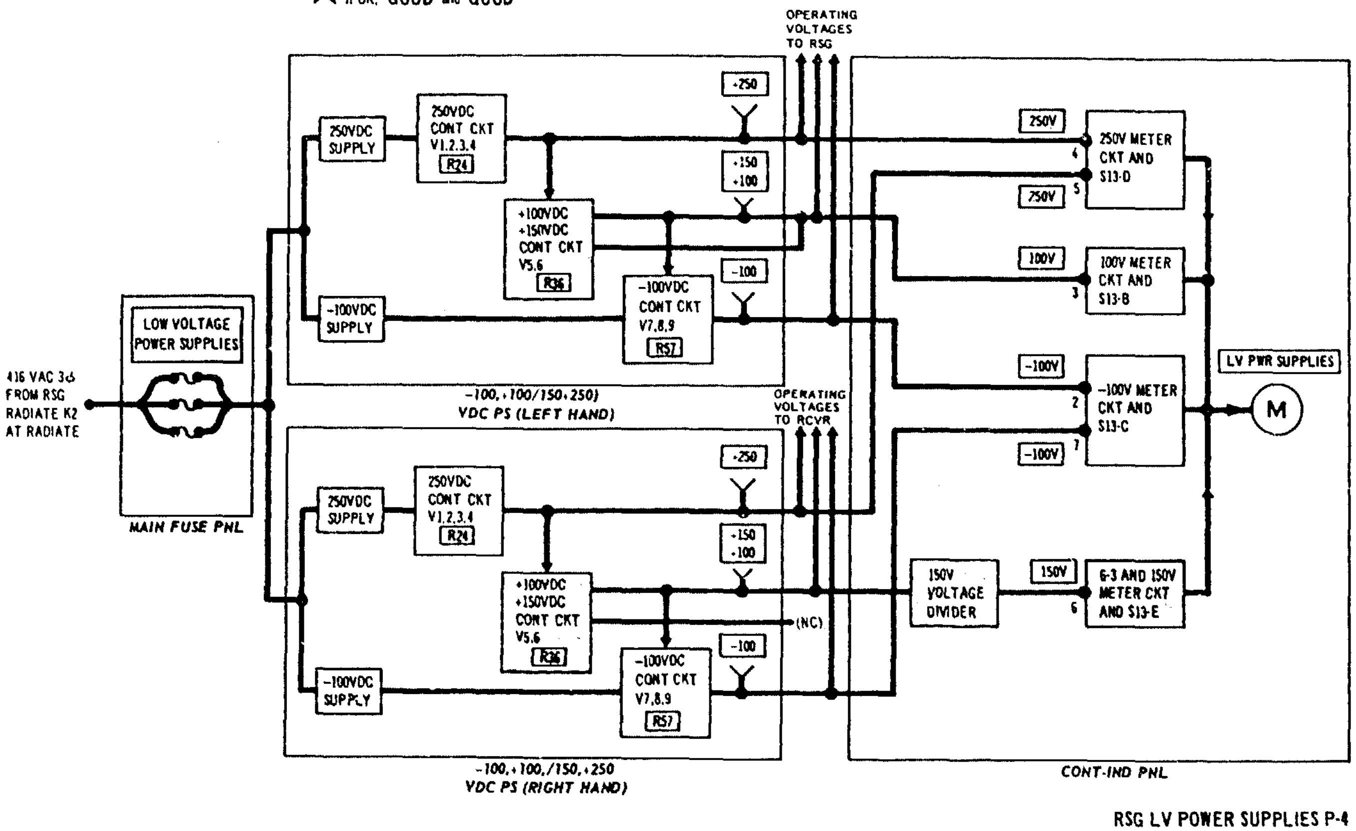


Figure 10

Sample of the Revised Format Used in the Second Version of the HPIR Symptom-Collection Manual

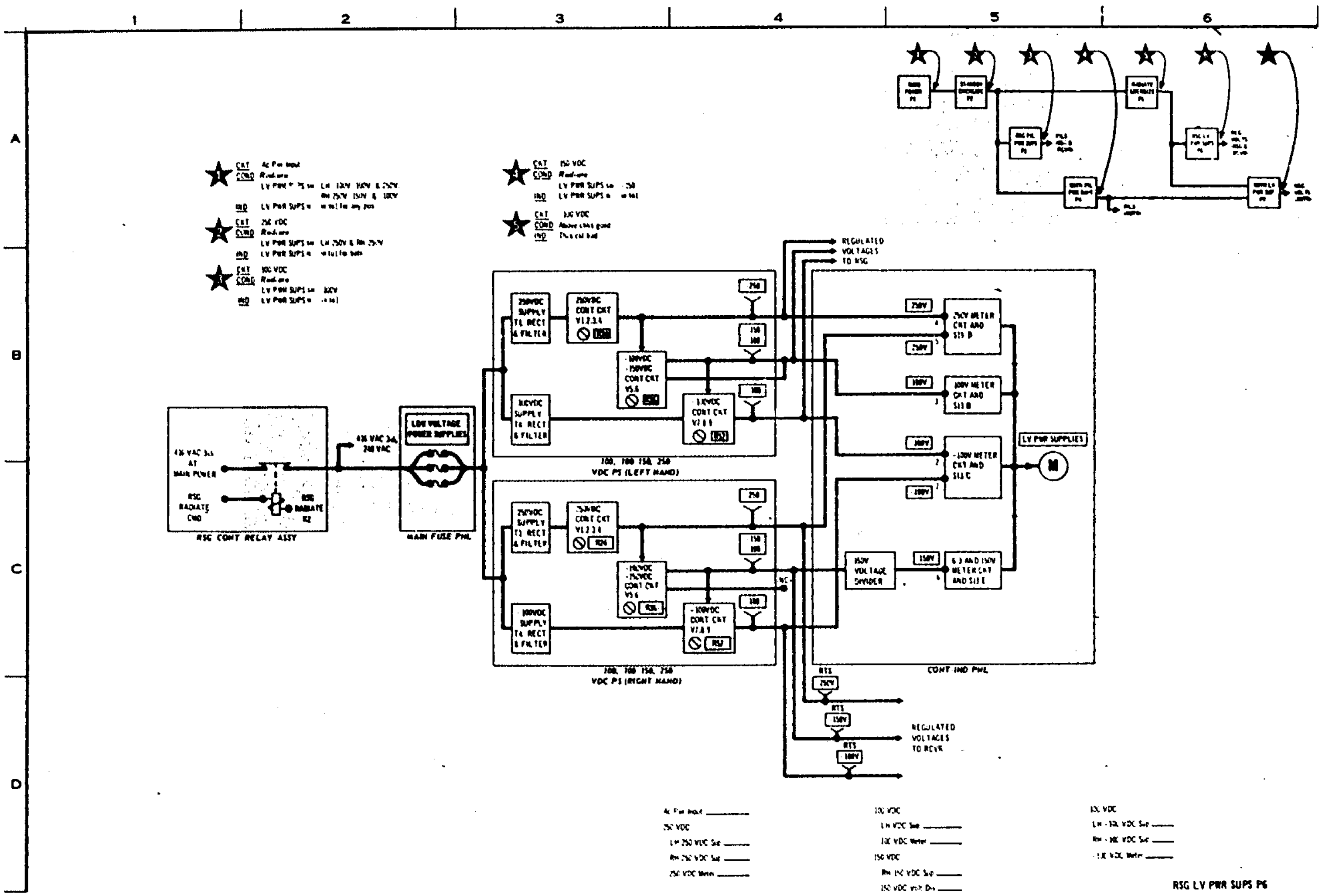


Figure 11

END-OF-COURSE TESTING

The criterion test for the second experimental class was developed and administered in essentially the same manner as for the first experimental class. For the periodic checks portion of the test, USAADS personnel selected different portions of the weekly check procedures. The troubleshooting portion of the test consisted of 16 troubles, eight on the CWAR and eight on the HPIR. The items were selected in the same manner and with the same restrictions as for the first experiment.[1]

The 16 troubles consisted of the following types: Tube, 4; resistor, 4; wiring, 3; capacitor, 1; defective crystal, 1; defective chopper, 1; adjustment, 1; trouble in a chassis not authorized for repair, 1. No items were identical with those on the first test, because graduates of the first experiment were instructing the second class and might have tended to emphasize those items.

These 16 troubles were also divided into two subtests—Form C and Form D. To provide the basis for graduation standards for the experimental class, Form C was administered to one class of 26 conventionally trained students, and Form D was administered to another such class of 28. A list of these troubles is given in Appendix E.

Administration of this test was identical with the first experiment except that there were not enough warrant officers to serve as examiners. The warrant officer group was supplemented by several NCOs who were maintenance men or instructors in USAADS, with no previous contact with the experimental or control classes.

GRADUATION STANDARDS

In the second experiment, on Form C the lowest man in the control class found three chassis and no piece-parts. He was not considered atypical, since the next lowest man found only four chassis and no piece-parts. On Form D, the lowest man in the control class found two chassis and no piece-parts. He was also not considered atypical, since the next lowest man found only three chassis and no piece-parts.

Thus standards for graduation for the experimental students in the second experiment were based on correctly performing selected portions of the weekly check procedures, plus isolating three of the eight malfunctions on the C Form to the chassis, *and* two of the eight malfunctions on the D Form to the chassis.

RESULTS FOR THE EXPERIMENTAL CLASS

Attrition

Of the 30 students who started in the second experimental class, all completed the course and all met or exceeded the standards for graduation. Consequently, academic attrition in the second experimental class was zero.

After the first experimental class had graduated, attrition in conventional courses for this occupational specialty dropped sharply. The highest attrition for 1966 was only 16% and the lowest was zero. The average for the year, not including the second experimental class, was only 5.1%. This low average attrition level could hardly be improved upon.

[1] Six additional troubles (Appendix E) were selected for use in a special test to provide an indication of how well the experimental students could perform if allowed to use their symptom-collection training manuals during testing (they were not, of course, allowed to use their training manuals during that part of the test upon which graduation was based). The results of this part of the study are reported later in this chapter.

Performance

A comparison of the performance of the conventionally and experimentally trained students in isolating malfunctions to the chassis is shown in Figure 12. The experimental students were successful 75% of the time (SD = 15.8) on Form C and 80% of the time (SD = 13.8) on Form D. The conventionally trained students averaged 72% on Form C (SD = 14.8) and 62% on Form D (SD = 23.6). The difference in the percentages for Form D is statistically reliable ($p<.05$, Mann-Whitney test).

A comparison of the experimentally and conventionally trained students in isolating malfunctions to the piece-part is shown in Figure 13. The experimental students were successful 38% of the time in finding the defective piece-part on Form C and 42% of the time on Form D. For the conventionally trained students, the respective percentages were 32 and 25. The difference for Form D is statistically reliable ($p<.05$, Mann-Whitney test).

A comparison of performance in finding the piece-part when the chassis was found is given in Figure 14. The experimentally trained students were successful 51% of the time on Form C and 52% of the time on Form D. Conventionally trained students were successful 44% and 36%, respectively, on Forms C and D. The difference between the groups was statistically reliable for Form D ($p<.05$, Mann-Whitney test).

Test Results, Second Class, Chassis

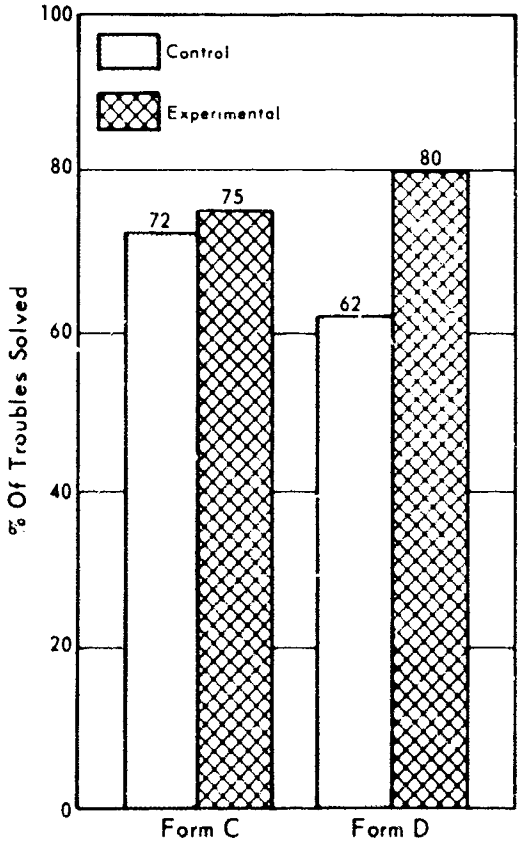


Figure 12

Test Results, Second Class, Piece-Parts

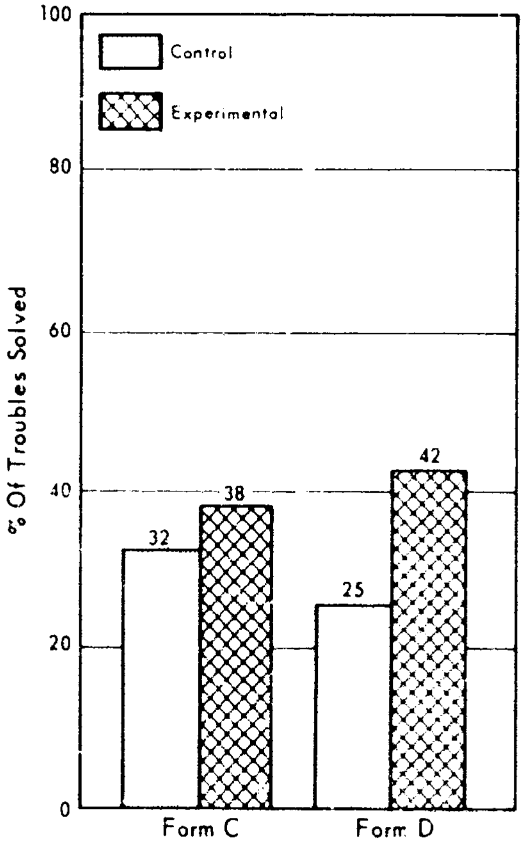


Figure 13

Test Results, Second Class—
To Piece-Part When Chassis Found

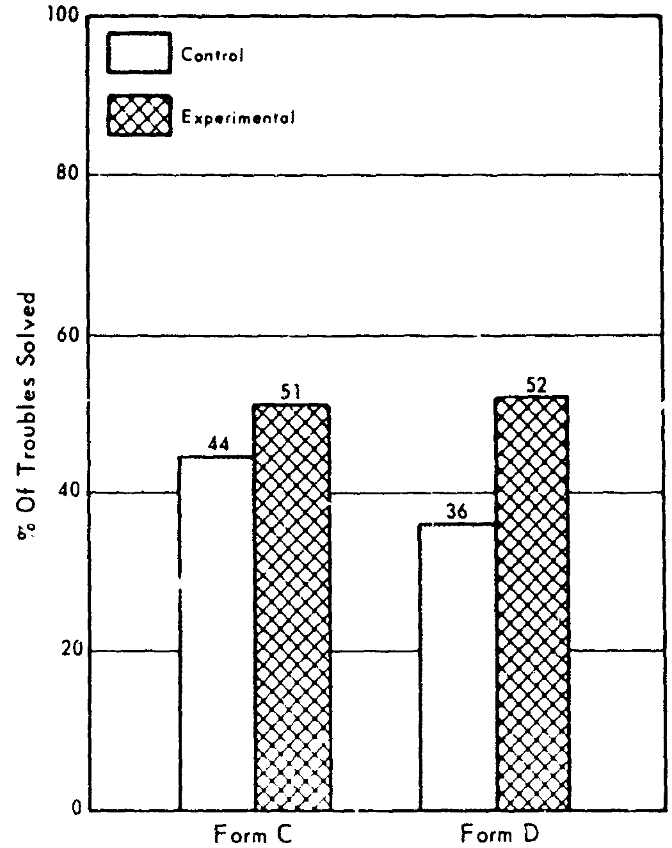


Figure 14

TEST USING SYMPTOM-COLLECTION MANUALS

Purposes of Test

At various times during the course students were required to troubleshoot with their symptom-collection manuals, and at other times without them. It was the general impression of the research staff and the instructors that performance with the symptom-collection manuals was noticeably superior to performance without them, particularly on review items, and that performance with the manuals on practical exams during training was superior to that obtained on the end-of-course proficiency test.

Of course, the observations made during the course were not under controlled conditions, and it was seldom possible to obtain information on the same malfunctions both with and without the use of special manuals. Thus the apparent difference between performance with and without the manuals during training may have been less than was generally believed.

To obtain data on the difference between performance with and without the symptom-collection manuals, a supplementary test was conducted at the end of the course. In addition to providing information on performance levels, such a test gives some indication of the extent to which the procedures were being forgotten. During training on each subsystem, the students were required to demonstrate that they could perform the procedures from memory. Thus it was known that they had learned the procedures at least moderately well. If it were true that there was a marked difference in performance with or without the manuals at some later date, it could be assumed that forgetting was occurring.

The time available for testing the second experimental class was two days longer than the time required to administer the items on which graduation would be based. For each of the two control classes, one additional day was available. This time was utilized to obtain data on troubleshooting performance with the symptom-collection manuals.

Three additional items were administered to students in each of the two control classes during their normal testing, and the students were not informed that these items were in any way different from their previous eight items. The administration and scoring on these six special items was identical with that for the previous items.

At the end of the fourth day of testing the experimental class, the students were divided into two matched groups on the basis of their performance on the first 16 test items. During the next two days, each of these groups was tested on three of the six special items. The testing procedures were identical with those for the first 16 items except that the students were permitted to use symptom-collection manuals in addition to the DA TMs (DA TMs were required since they contained the schematic diagrams needed for troubleshooting within a stage).

Results for Special Manuals

The overall results of the special testing are presented in Figure 15. The experimental students using the symptom-collection manuals correctly isolated 80% of the defective chassis. In comparison, the conventionally trained graduates using the DA TMs correctly isolated 40% of the defective chassis. This difference was statistically reliable (Mann-Whitney test, $p<.05$). The percentages of piece parts correctly located by both groups are also shown in Figure 15.

It will be noted that the difference in the percentages of defective chassis located by the experimentally and the conventionally trained students was larger when the experimental group used the symptom-collection manual than when both groups used only the DA TMs.

Comparison of the chassis results for the conventionally trained group on Test Forms C and D and the special items provides a means of estimating the difficulty of the tests. Results suggested that the difficulty level of the test items was not constant over the three tests. The percentage of chassis located by the control classes was 72% on Form C, 62% on Form D, and 40% on the special items as shown in Figure 12).

The performance levels of the experimentally trained students were 75% and 80% on Forms C and D, requiring use of DA TMs, and 80% on the special items test, involving use of the symptom-collection manuals. These results suggested that the troubleshooting abilities of the experimentally trained men, both with and without symptom manuals, were relatively uniform despite the varying difficulty levels of the malfunctions.

Additional item-by-item comparisons were made for the two groups of students on Forms C and D and the special items. The percentages of students in each group which correctly isolated each defective chassis on Forms C and D and the special items are shown in Figure 16.

Inspection of the results for Form C indicates that seven of the eight items on this test were relatively easy (percentage correct was 50% or more) for both groups of students and the differences between the percentage correct for the experimental and control students were small. In contrast, on Form D, three of the eight problems were correctly solved by less than 50% of the control students, and the magnitudes of the

Test Results for Symptom-Collection Manuals

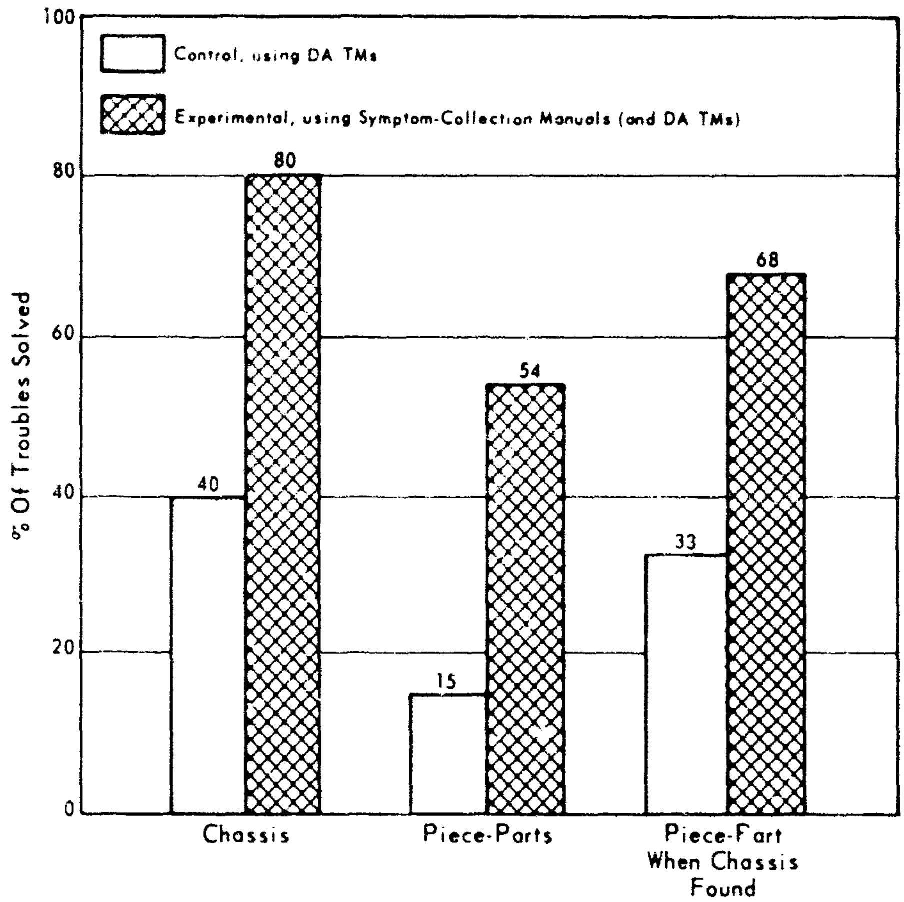


Figure 15

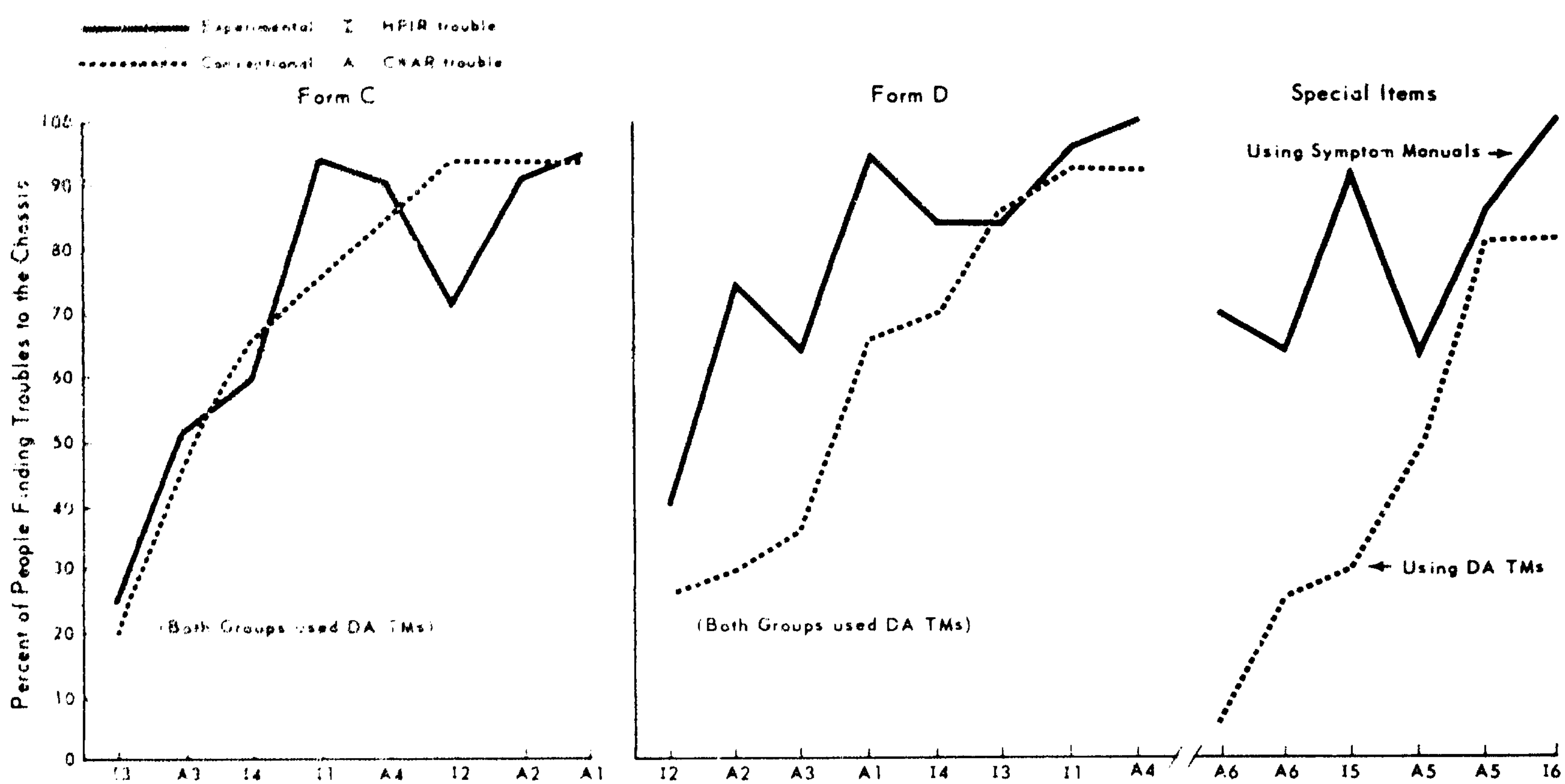
performance differences between control and experimental students tended to be large. These results suggest that the experimental training program tended to produce graduates who had relatively uniform capabilities to locate malfunctions of different degrees of difficulty.

Inspection of the item-by-item differences shown in Figure 16 for the special test items quite dramatically illustrates the value of the symptom-collection manuals in troubleshooting performance. Whereas the conventional students using DA TMs were quite variable in their performance levels on the set of troubles, the experimental students using the symptom-collection manuals were relatively consistent. The utility of the symptom manuals is especially evident for the most difficult malfunctions (that is, for those items on which the control students had the lowest success rate).

Comparison of the performance levels of the two groups on the three tests also suggests that the experimentally trained men were unable to remember all the symptom-collection procedures that were required for the problems of Forms C and D. Taking the level of success of the control students as an indicator of comparative difficulty of items, it is apparent that the experimental students performed no better than the controls on the difficult troubles on Form C (when both groups were using only DA TMs).

Results for Test D are less clearcut but seem more similar to those for Test C than for the special items. Since performance of the experimental students was markedly superior to the controls on the special items, the usefulness of the symptom-collection manuals as job aids seems evident.

Item-by-Item Results for Forms C and D, and Special Items



NOTE: Items in each test arranged in order of difficulty for the conventionally trained.

Figure 16

Chapter 6

THE THIRD COMPARISON

OBJECTIVES AND APPROACH

As originally planned, the HAWKEYE research was to consist of two runs of the experimental training However, the study was continued for a third class to obtain data on the ability of USAADS personnel to conduct this type of training without guidance or supervision by the research staff. This third comparison also provided an opportunity for the School to use their personnel in applying to another item of equipment the experimental procedure analysis techniques for developing symptom-collection manuals.

A group of 56 students was divided into two groups on the basis of previous experience, rank, GT, EL, age, and volunteer status. One of these two matched groups was then selected to receive conventional training while the other received the experimental training, the selection being based on the flip of a coin.

The control class received training according to the standard POI used for the previous control classes, with one exception. The duties of MOS 23R had been increased to include maintenance on the AFCC, and the course had been lengthened by one week to provide time for this additional training.

The experimental class received training according to the POI that had been used for the second experimental class, with the addition of one week on the AFCC. The experimental training for the AFCC, including the troubleshooting procedures and manuals and a 33-hour training program, was developed by one of the USAADS instructors, who had worked with the research staff in the development of the experimental training for the first two classes. His work on the AFCC program was done without supervision or guidance by the research staff.

SYMPTOM-COLLECTION MANUALS

While the second experiment was being conducted, the research staff had converted the format of the procedures in the CWAR symptom manual to that developed for the revised HPIR manual. This conversion was desired to reduce transitioning problems that were experienced by the students when they progressed from the CWAR to the HPIR instruction. In the original CWAR manual the check procedures for each indicator were presented in charts, and each chart had a corresponding color-coded symptom-collection diagram. Figure 17 presents an example of one of the original charts, and Figure 18 shows the presentation of the corresponding procedures in the revised manual.

The change in format necessarily required a modification to the approach used for organizing the symptom collection procedures. In the original CWAR manual, all the circuits that could produce an incorrect indication on each built-in meter, display, and so forth, were keyed to each meter, and so forth. This permitted the student to begin fault isolation procedures using any incorrect indication as a starting point. This approach is exemplified in Figure 17.

Sample of Format for Original CWAR Symptom-Collection Manual

WARNING: The Antenna SAFETY SWITCH should be t SAFE for all checks, unless otherwise specified.

POWER AND CONTROL CIRCUITS

INDICATOR & CONDITIONS	SYMPTOMS	CIRCUITS USED	SWITCHES & CHECKS	COMMENTS
LINE VOLTAGE Meter Main Power On		Main Power		
STANDBY Lamp or BCC STANDBY Lamp		Main Power	LINE VOLTAGE Meter	
Standby Only		Standby Energize		
LV PWR SUPS Meter		Main Power	LINE VOLTAGE Meter	
Standby		Standby Energize	STANDBY or RADIATE Lamp	
LV PWR SUPS sw: #1-6.3, #2-6.3		Dc Filament Power		
RADIATE Lamp or BCC RADIATE Lamp		Main Power	LINE VOLTAGE Meter	
Radiate, Full Radiate		Standby Energize	STANDBY or RADIATE Lamp	
		Radiate Energize		
LV PWR SUPS Meter		Main Power	LINE VOLTAGE Meter	
Radiate or Full Radiate		Standby Energize	STANDBY or RADIATE Lamp	
LV PWR SUPS sw: +250, +100, -100		Radiate Energize	RADIATE Lamp	
		Dc Regulated Power		

Figure 17 (continued)

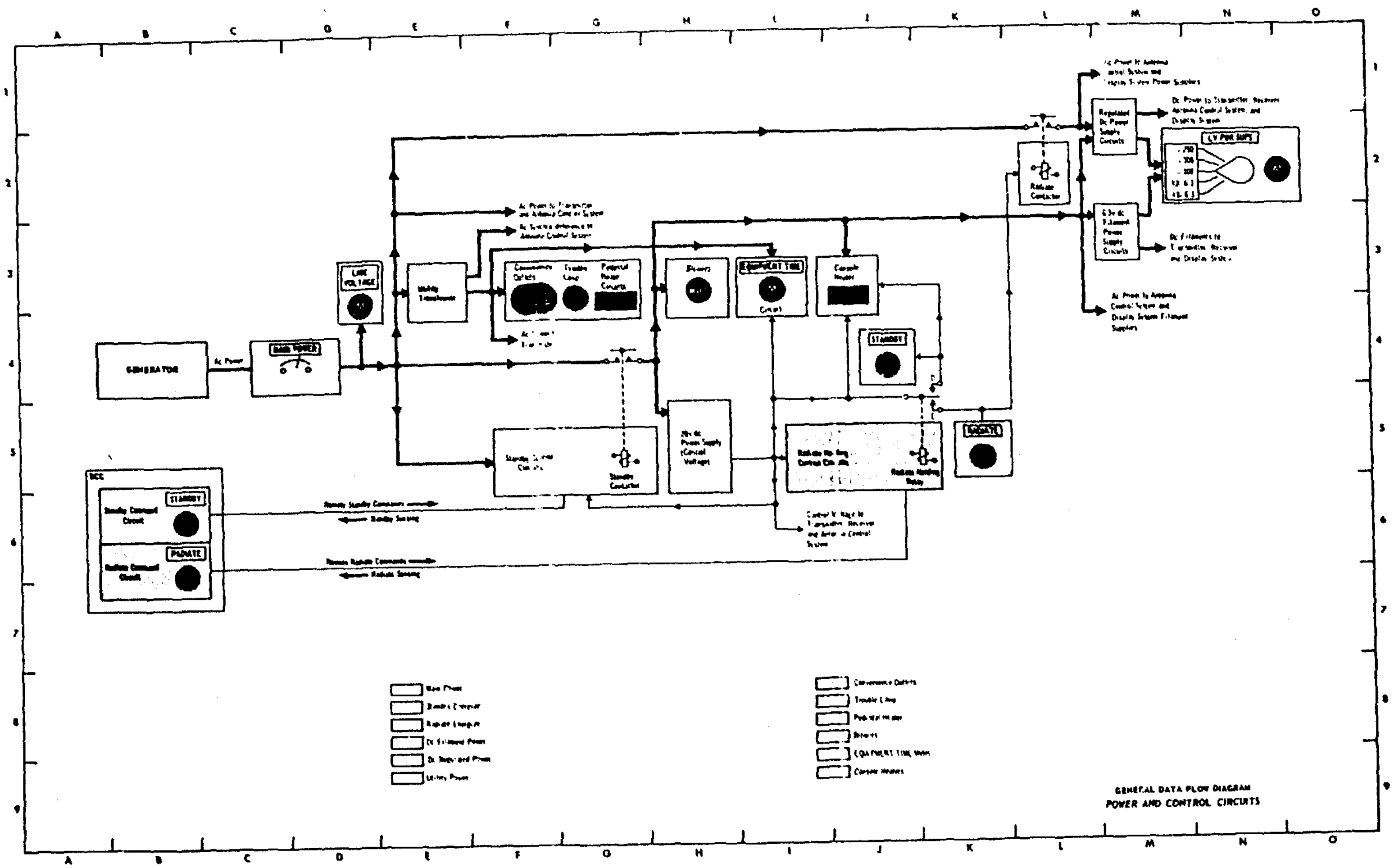

GENERATOR
Ac Power
LINE VOLTAGE
STANDBY
RADIATE
LV PWR SUPS
GENERAL DATA FLOW DIAGRAM
POWER AND CONTROL CIRCUITS

Figure 17

For example, assume that the student obtained an incorrect reading on the Low Voltage Power Supply Meter (see Figure 17, LV PWR SUPS Meter; lower left-hand corner of the written instructions): The Indicator and Conditions column states that the radar should be in either a local or full radiate condition to perform this check; the Circuits Used column indicates that the source of the malfunction could be in four circuit areas (Main Power, Standby Energize, Radiate Energize, or Dc Regulated Power); the Switches & Checks column specifies the indicator that would be used to check each of the four possibly malfunctioning circuits.

However, three of these four checks are identical with the checks specified for malfunction that could appear on four other indicators listed in the chart. While this approach to specifying the symptom-collection procedures permitted the student maximum flexibility in beginning the troubleshooting procedures, it also contained considerable redundancy in the information contained in the symptom-collection instructions.

In the revised CWAR symptom manual, the sequence of checks was organized in a different manner. The revised procedures for the Power Subsystem, shown in Figure 18, include the same five checks used originally. plus one additional check concerning remote circuits.

In contrast with the original CWAR manual, the revised CWAR (and the revised HPIR manual prepared for the second experiment) required the student to follow a series of checks, each of which progressively partitioned the equipment into smaller symptom areas. It was hoped that the increased structuring of the sequence of procedures in the revised manual would reduce the difficulty of initial learning and aid recall of the procedural sequence.

Other changes were made to the CWAR manual:

(1) The symptom-collection diagrams were reduced in complexity by eliminating detailed circuitry that was insignificant as far as the symptom procedures were concerned. This additional circuitry detail was reported to have confused students in the previous classes.

(2) The number of diagrams was increased to reduce the circuit complexity of each diagram. In the original manual one diagram may have been used to show the circuits that affected a large number of indicators (10-12); this approach was used to illustrate the relationships between many indicators and their circuits in a single diagram. However, the diagram proved to be difficult for students to use to follow the instructor's oral recitation of the sequence of check procedures, particularly during the initial portion of the course. Partitioning the circuits into smaller symptom areas simplified the tasks of both instructor and students, and it was hoped that comprehension and memorization of the procedures would be increased.

(3) The number of diagrams that used colored areas for coding was substantially reduced. In addition, the number of different colors used per page was approximately halved.

(4) The contents of the manual were re-organized to reflect changes in the POI. For example, instruction on the Antenna Positioning System of the CWAR was moved ahead of instruction on the transmitter because the circuits of the antenna system are less complex.

(5) The nomenclature used in referring to the CWAR circuits and subsystems was changed to correspond to the nomenclature used for describing the CWAR in the daily checks procedures.

(6) Whereas the symptom-collection procedures in the original manual were organized primarily with reference to the performance of the daily checks, the revised manual also included those malfunction symptoms that could appear on indicators that are monitored when doing the weekly checks.

Sample of Revised Format for CWAR Symptom-Collection Manual

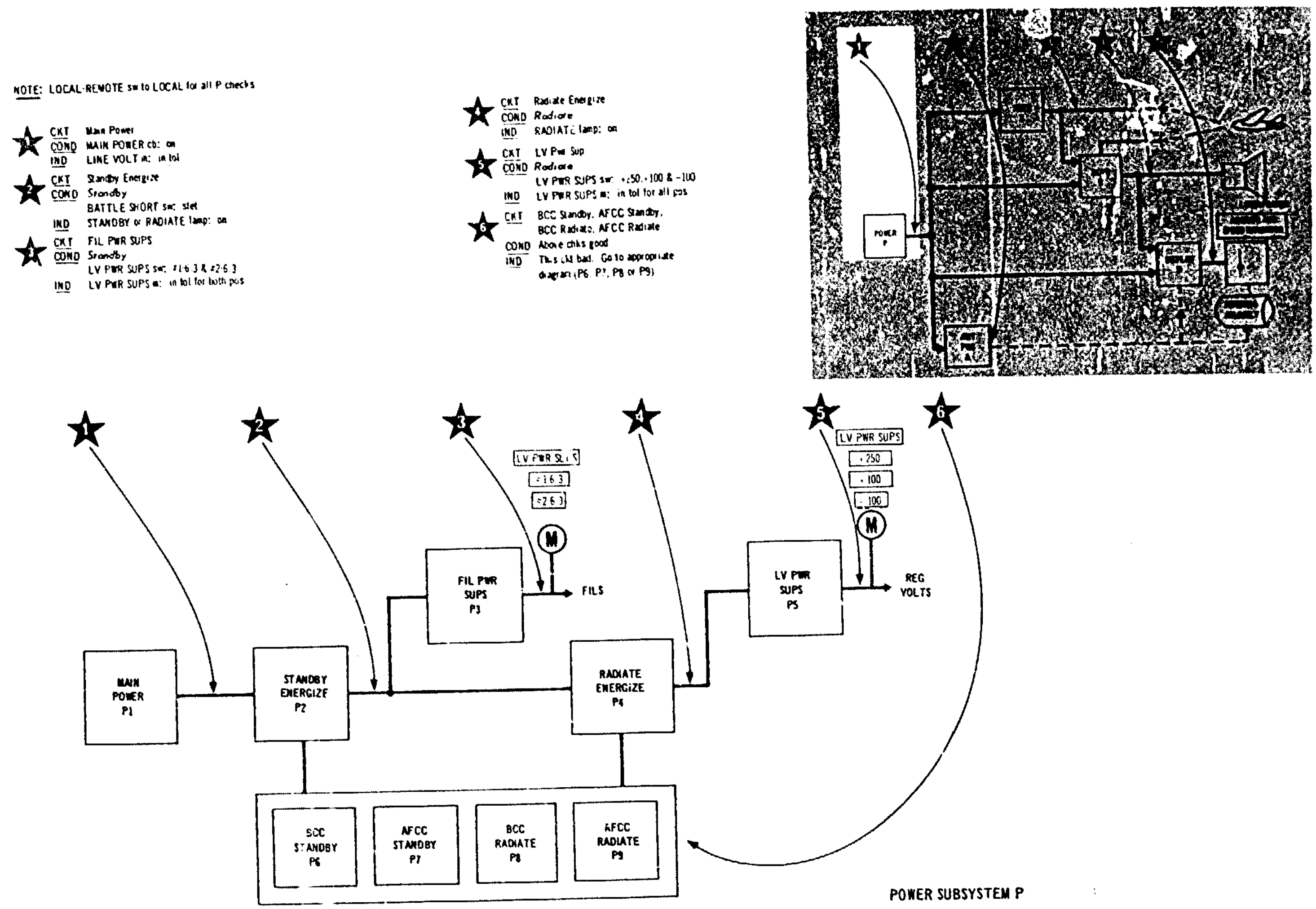


Figure 18

(7) In the original manual only the tie-in between the CWAR and the Battery Control Center (BCC) was included. The revised manual also included the tie-in between the CWAR and the AFCC.

(8) New diagrams and procedures were developed to depict the troubleshooting procedures for the ECCM circuits. These circuits had appeared in the original manual but had not been identified as such.

INSTRUCTORS

The experimental class was trained by instructors who had either taught or graduated from previous experimental classes. These instructors followed the POI that had been used for the second experimental class, with the addition of one week on the AFCC. The AFCC training was developed by one of the USAADS instructors.

Throughout the training of the third experimental class, the research staff provided no guidance or supervision to the instructors. Instruction was supervised and controlled by USAADS personnel following normal USAADS policies and procedures.

END-OF-COURSE TEST

At the end of training, students in both the experimental and the control classes were administered a 20-item troubleshooting proficiency test. This test, which was developed jointly by USAADS personnel and the research staff, consisted of six items on the CWAR, ten items on the HPIR, and four items on the AFCC. This distribution of items was based on availability of equipment, but provided a reasonable representation of the course elements. The CWAR and HPIR items were selected from Forms A and B of the test used in evaluating the first experimental and control classes. The procedures for administration and scoring of the test were the same as those used for the previous classes.

RESULTS

Attrition

Prior to the end of the course, five of the original 27 students in the control class and four of the 29 students in the experimental class had been dropped for non-academic reasons (e.g., illness, loss of security clearance), leaving a control group of 22 and an experimental group of 25.

The "no turn-back" procedure followed in the first two experimental classes, under which all experimental students were retained in training for end-of-course proficiency testing, was not used by the USAADS in its presentation of the course. Seven students in the control class and two in the experimental class were dropped by the School during the course for academic deficiency. Thus only 15 students in the control class and 23 in the experimental class were available for testing at the end of the course.

The lowest score in the control class was nine chassis and two piece-parts, thus setting the minimum standard for graduation in the experimental class at a total of 11 chassis and/or piece-parts. Two students in the experimental class failed to meet the minimum standard and were not graduated. Thus the total academic attrition in the experimental class was 14%, as compared with 26% in the control class. Although this difference was not statistically reliable, the attrition rate for the third experimental class was reliably less than the average attrition for all conventional classes (30.1%) in FY 1967 (chi square test, $p<.05$) (Table 4).

Table 4

Academic Attrition in Course 23R (221) for the Third Comparison

Class	Student Input	Academic Loss	Percent Attrition
67-1	30	10	33.3
67-2	28	8	28.6
502	31	13	41.9
503	28	6	21.4
504	22	7	31.8
505	22	5	22.7
506[a]	27	7	25.9
507[b]	29	4	13.8
509	37	14	37.8
8	31	8	29.6
515	35	14	33.6

[a]Control group
[b]Third experimental class

Performance

Among graduates of the experimental class, the average success to the chassis was 64% (SD = 13.7), as compared with 58% (SD = 9.2) for graduates of the control class. This difference is statistically reliable (Mann-Whitney, $p<.05$). Graduates of the experimental class were successful in finding the piece-part 27% of the time, as compared with 20% for graduates of the control class. This difference was not statistically reliable.

Of special interest is the performance on the four items on the AFCC, representing instruction appearing in the course for the first time. On these four items, the control class found the correct chassis an average of 84% of the time, while the experimental class was successful 72% of the time. The control class was successful in finding the piece-part 39% of the time, while the experimental class was 27% successful. These differences were not statistically reliable; however, the trend was consistent in that control class performance was higher than that of the experimental class on each of the four AFCC items.

Chapter 7

FIELD FOLLOW-UP[1]

BACKGROUND AND APPROACH

Approximately one year after the first experimental class had graduated, a follow-up questionnaire was sent to commanders of all personnel in both the first experimental and control classes who had been assigned to overseas commands. The overall purpose of the questionnaire was to evaluate the long-range effects of the training program. Primarily, the field follow-up was concerned with obtaining answers to the following general questions:

(1) Are the basic skills involved in performing daily and weekly checks retained as well after procedure-oriented training as when learned in a conventional course?

(2) Does troubleshooting performance in the field differ between personnel who completed the procedure-oriented training and personnel who completed conventional training?

(3) Are technicians trained by the procedure-oriented method at a disadvantage in the area of technical communication with peers and superiors, compared to men trained by conventional methods?

It was not expected that the experimentally and conventionally trained technicians would differ in their ability to perform daily and weekly checks. Both groups had performed checks extremely well on the end-of-course test, and practice and learning in the field presumably would have been similar.

However, it was thought somewhat more likely that the groups might differ in troubleshooting ability and communication skills. The performance level of an experimentally trained student on the end-of-course proficiency test depended on the extent to which he could accurately remember the symptom-collection procedures. Since the training materials on symptom collection could not be carried to the field as job aids, it was expected that some amount of forgetting of the specific procedures would occur. Therefore, it was possible that, over time, the experimentally trained men might not perform troubleshooting activities as well as the conventionally trained men.

Also, since the experimentally trained men did not receive a formal course in Basic Electronics (BE), it was conceivable that they might not have learned enough of the technical vocabulary and standard phraseology employed by others in the electronics field. Any lack of ability to communicate presumably would have an adverse effect on job performance levels and would be noticed by supervisors.

While a carefully controlled field performance test would provide the best information relating to the performance of daily and weekly checks and troubleshooting activities, administration of such a test was not feasible because of the scattering of personnel to be tested. A questionnaire seemed to be the only practical means of obtaining any information for a follow-up comparison of the two types of training.

[1]This phase of the study was conducted by Dr. A.L. Kubala, who was responsible for the questionnaire analyses and the interpretation of the results.

Administration of a questionnaire was scheduled[2] for locations where men on short duty tours would still be functioning in their original assignment, but should have had ample time on the job to permit supervisors to adequately assess their performance.

One aspect of the assignment, other than the training, of this experimental group might be expected to affect the group's ratings in the field. Six of the experimentally trained men from the first class had been selected as instructors for the second experimental class and hence had not received field assignments. Since this selection was based largely on performance during training and on the end-of-course proficiency test, it appeared that the men assigned to the regular duties of their MOS would not be fully representative of the proficiency level of the group.

CONDUCT OF THE SURVEY

In November 1966 the current assignments of all personnel in both the first experimental and the first control classes were requested from the Office of Personnel Operations (OPO). It was learned that a total of 12 men from the experimental class and 29 from the control classes had been assigned to units stationed in Europe and the Far East. For the purpose of comparing the job performance of the two groups, it was unfortunate that so few of the experimentally trained personnel had been assigned to tactical units.

A questionnaire constructed by personnel at HumRRO Division No. 5 was sent on 2 February 1967 to the battalion commander of each man with an overseas assignment, with the request that the man's battery commander and technical supervisor work together to complete it. The major sections of the questionnaire dealt with (a) the technician's level of performance on routine checks and adjustments; (b) on trouble-shooting the CWAR and HPIR,[3] and on isolating system malfunctions; and (c) with a more general evaluation of his technical knowledge.[4] A copy of the questionnaire is shown in Appendix F.

By the cut-off date of 1 May 1967, relatively complete questionnaire data had been received for 11 of the 12 field-assigned graduates of the experimental course and 23 of the 29 field-assigned conventionally trained technicians. Neither the current nor the previous assignment of one experimentally trained man could be determined. Of the conventionally trained technicians, there was no response for two men (despite a followup letter), two men had been reassigned and could not be located prior to the cut-off date, one had received an MOS change, and the data on the sixth were not complete enough to be included.

Also, for two experimentally trained and seven conventionally trained men, the raters did not supply data for the section dealing with routine checks and adjustment. In some cases the raters simply did not remember the man's problems, how long he had taken to learn these checks, or both.

[2] This questionnaire was scheduled to be administered in February 1967.

[3] Since the AFCC had been added to the equipment for which the holders of the MOS were responsible, questions on the AFCC were included with those on the CWAR and HPIR. However, it developed that only five of the technicians covered by the survey had ever worked on the AFCC, so no attempt was made to utilize data from these questions.

[4] The questionnaire also included the technician's job assignments, the rater's knowledge of the technician, and a few questions concerning motivational and morale factors. With reference to the latter, the experimentally and conventionally trained men were compared in terms of (a) how well the technician got along with his superiors and associates, (b) his job motivation, and (c) frequency of disciplinary actions. In each comparison there was not a reliable difference between the ratings of the two groups.

Data for the two samples of men were compared to determine whether they were representative of the original groups. There is no indication that the samples are biased in terms of aptitude scores although the experimental students involved in the field follow-up had not performed as well on the end-of-course test as the experimental class as a whole (see Table 5). However, since this difference was not statistically reliable it was felt that a valid comparison of the two samples could be made.

Table 5

Comparisons of End-of-Course Test Scores of Field Samples and the Original Experimental and Control Classes

Test	Experimental		Control		
	Sample ($N=11$)	Total	Test A ($N=12$)	Test B ($N=11$)	Total Classes
GT	116.1	114.7	114.2	110.0	112.4
EL	116.3	116.8	114.4	114.0	115.0
Form A	54	60	47	--	48
Form B	66	70	--	67	67

RESULTS

The questionnaire items were grouped to form sub-questionnaires concerning five job requirements: (a) Isolating malfunctions to the chassis; (b) isolating malfunctions to the piece-part; (c) using test equipment; (d) general system knowledge; and (e) performing checks and adjustments. The descriptive alternatives for each item were transformed to numerical ratings, and a total score on each sub-questionnaire was obtained for each technician. The mean and standard deviation of the supervisors' ratings obtained by the experimentally and conventionally trained technicians are presented in Table 6.

Inspection of the results indicates there were no differences of any consequence in the ratings obtained by the two groups of technicians. Assuming the validity of the supervisors' evaluations, it appears that the graduates receiving the procedure-oriented training performed comparably with conventionally trained men during their initial duty assignments.

Table 6

Mean and Standard Deviation of Questionnaire Ratings

Job Requirement	Scores	
	Experimental Graduates	Conventional Graduates
Isolating Malfunction to Chassis		
Mean	24.9	23.9
SD	6.7	7.2
Isolating Malfunction to Piece-Part		
Mean	31.9	31.3
SD	7.7	7.5
Using Test Equipment		
Mean	21.9	20.9
SD	5.5	5.2
General System Knowledge		
Mean	19.1	19.3
SD	4.8	5.3
Checks and Adjustments		
Mean	15.2	15.6
SD	4.1	3.7

As a final check for possible differences between the groups, the experimental and control subjects were also compared on each item in the questionnaire. Data for each item were reduced to two-by-two tables, and the chi squared statistical test was employed to compare the two groups. In no instance was there a significant difference between the groups. Therefore, there seems to be no indication from the questionnaire that the two groups differed in supervisors' evaluations of their job performance.

The only other criterion of performance available for all of the subjects was the troubleshooting data from the end-of-course test. Therefore, an attempt was made to evaluate the validity of the score on troubleshooting to the chassis from the questionnaire by relating it to the comparable score from the end-of-course proficiency test.

The technicians were divided into those who had taken Form A of the end-of-course test and those who had taken Form B (since the subjects from the experimental class had taken both forms, they were members of both groups). The correlation between the questionnaire ratings and the score for Form A was not significant, while that for Form B (+.46) was $p<.05$. This may be due in part to the fact that the men from the control class in the follow-up sample who took Form A of the test were more homogeneous in their troubleshooting ability than were those who took Form B.

The standard deviation for the sample control subjects on Form A of the end-of-course test was 8.7 in contrast to 13.2 for the total control class on Form A; for Form B, the control sample had a standard deviation of 20.3, compared with a total control class value of 17.2. The restriction in range for the Form A sample could well have produced the very low correlation.

The conclusion that the experimental and control subjects did not differ in their job performance is based on the assumption that the questionnaire is a valid measure of that performance.

The fact that the questionnaire score was related to one form of the end-of-course test indicates that the questionnaire does have some validity as a measure of job performance. Actually, the observed relationships are probably underestimates of true validity since the men in the samples had been in the field for approximately one year, and the amount of troubleshooting practice, the quality of their supervision, and the capabilities of the aid received from their peers are all unknown quantities.

In any event, the fact that no differences were found between the experimental and control groups in the field provides answers to the three questions in the survey concerning the effects of procedure-oriented training. Skills learned in dealing with routine checks seemed to be equally well retained regardless of the method of training. It also appears that troubleshooting performance in the field did not differ between men who completed the experimental course and men who completed conventional training. Finally, it seems that the type of training completed was not a factor in a man's ability to communicate in a technical sense with his peers and superiors.

Chapter 8

DISCUSSION

ATTRITION AND PERFORMANCE

The three applications of the experimental POI were distributed over three USAADS academic fiscal years. The academic attrition for each HAWK CW maintenance mechanic class graduating during FY 1965-1967, including the three classes trained under the experimental POI, is summarized in Table 7.

The attrition level for each experimental class was less than or equal to the lowest attrition levels that occurred for all the conventional classes trained during each of the three comparison years. For each comparison year, the attrition rate that occurred for the experimental class was compared statistically with the average attrition rates for all preceding conventional courses in that year. For both FY 1965 and 1967, the reduction in attrition rates for the experimental classes in comparison with the conventional classes was statistically reliable; the difference for FY 1966 was not statistically reliable. As was previously mentioned, however, FY 1966 was characterized by a very low-average attrition level for this course.

From the RADAR IX (9) study of a "no turn-back" policy, in which overall attrition was found to be reduced simply by that policy, it might be argued that lowered attrition in HAWKEYE reflected the consequences of "no turn-back" rather than differences in training. However, in addition to RADAR IX data which showed a substantial correlation ($r = .85$) between achievement in basic electronics and accomplishment in maintenance portions of the course, data in RADAR IV (16) showed a strong correlation ($r = .60$) between overall achievement in training (as measured by school grades) and performance in an end-of-course proficiency test.

Table 7

Academic Attrition in Course 23R (221), FY 1965-FY 1967

Class	Input	Academic Loss	Percent Attrition
65-1	24	3	12.5
2	26	13	50.0
3	27	9	33.3
4	32	10	31.2
5	31	5	16.1
6	26	6	23.0
7	20	8	40.0
8	28	5	17.8
9	24	3	12.5
66-1[a]	30	1	3.3
104	34	0	0.0
66-2	25	4	16.0
3	26	4	15.4
4	31	1	3.2
5	41	1	2.4
6	21	0	0.0
7	29	1	3.4
8[b]	30	0	0.0
9	46	2	4.3
67-1	30	10	33.3
67-2	28	8	28.6
502	31	13	41.9
503	28	6	21.4
504	22	7	31.8
505	22	5	22.7
506	27	7	25.9
507[c]	29	4	13.8
509	37	14	37.8
8	31	8	29.6
515	35	14	33.6

[a]First experimental class.
[b]Second experimental class.
[c]Third experimental class.

Thus, if training effectiveness were equal between HAWKEYE and conventional training, at the end of training the conventional group, in which academic attrition was allowed to occur, would be expected to perform better than the experimental group, since those with the poorest performance prognosis had been screened out of the conventional group. In fact, however, the experimental students performed, over all, equal to or better than conventional students, *in addition* to having a lower attrition rate. Therefore, whatever portion of the reduction in attrition is attributed to "no turn-back" is compensated for by training effectiveness of HAWKEYE, which avoided degradation in performance at the end of the course.

The results for the third experimental class are particularly interesting in this context. This class was completely under the supervision and management of the Air Defense School, which did not follow the "no turn-back" policy of the first two experimental classes. Attrition occurred during training on the basis of instructor evaluations, in addition to the end-of-course attrition resulting from the performance testing. It is of significance that the total attrition level for this third class was reliably lower than that characteristic of conventional classes. On the basis of the results for this class, it may be concluded that the procedure-oriented approach to training was successfully implemented by the team of instructors who had previous experience with this approach to training.

END-OF-COURSE PROFICIENCY

In each of the three comparisons it was found that the average proficiency test performance of the experimentally trained students was either equal to or above that of the conventionally trained non-experienced graduates.

Direct comparison of the average proficiency levels among the three experimental classes is not possible since portions of the end-of-course troubleshooting tests were different for the three classes. However, a direct comparison of proficiency levels was possible for the first and third classes, since 16 of the test items used for the third class also had been used for the first class. For the CWAR, the third experimental class correctly located reliably more chassis than the first experimental class ($p<.05$; Mann-Whitney test). For the HPIR test items, the difference between the two classes was not statistically reliable, although the third class located fewer malfunctioning chassis than the first class.

TROUBLESHOOTING USING SYMPTOM-COLLECTION MANUALS AS JOB AIDS

As part of the second comparison of troubleshooting proficiency, limited testing was conducted using the symptom collection manuals as a job aid. The results showed that the experimentally trained mechanics found considerably more malfunctions when aided by the special manuals (and existing DA TMs) than was characteristic of conventionally trained students who used DA TMs.

These results support previous research results (8) which have demonstrated that substantial gains in troubleshooting proficiency can be achieved by using job aids that present symptom-collection procedures for the trainee or maintenance technician. One specification for HAWKEYE experimental work was that job aids, in the form of symptom-collection procedures, were to be available only during training; toward this end, special attention was given in the design of procedures to keeping the number of procedures and the number of steps in a procedure relatively small, in order to make them easier for students to remember.

Thus, it is noteworthy that, in the limited test, proficiency with the special manuals used as job aids in performance was superior to proficiency using only DA TMs; this was despite the fact that considerable time was devoted during training to classroom and laboratory drill in an effort to have the students memorize the procedures thoroughly.

IMPLEMENTING THE FCT APPROACH

Highly varied and specialized knowledge and skills were required for the development of this example of procedure-oriented instruction. The staff included two research psychologists with a considerable amount of experience in the analysis of electronic systems and the proceduralization of troubleshooting activities. In addition, the technical staff consisted of four experienced equipment specialists, who were considered by USAADS as highly knowledgeable of the HAWK circuits and their functions.

By far the most difficult and time-consuming task involved was the development and refinement of the troubleshooting symptom-collection procedures that constituted the core of the experimental training program. As described in previous chapters, several different approaches (or formats) were used to delineate and document the specific procedures for the two CW radars. Although troubleshooting procedures were developed and symptom-collection manuals were published, the staff did not succeed in translating their experience into a *generalizable* method for preparing symptom-collection procedures adapted to a special characteristic of HAWKEYE—the expectation that special job aids would not be available in the field.

The problems in reducing procedure design methods to simple, communicable form derived primarily from two sources: First, the characteristics of complex electronic equipment are sufficiently heterogeneous that—at least sometimes—they preclude simple, invariant rules on selecting or devising effective and efficient procedures. Second, and unique to HAWKEYE, the need to keep the number of different procedures small and the number of steps in each procedure relatively low in order to produce material *practicable for memorization* strongly affected the process of developing procedures. That is, a great deal of sophistication was necessary, not only in electronics in order to select candidate procedures, but also in training technology so that learnability and rememberability could be taken into account. This required a complicated combination of skills, and often successive trials toward something that seemed workable—altogether, a process not readily adapted toward clearly specifiable methods.

During part of the third comparison, one of the equipment specialists who had been "loaned" to the research staff by USAADS developed symptom-collection procedures and prepared a manual for the AFCC, a piece of complex equipment that previously had not been included in the scope of this MOS. These USAADS-developed procedures and manual for the AFCC were patterned after the revised CWAR and HPIR manuals and were used during a 33-hour block of instruction that was added to the end of the experimental course (a comparable block of instruction, using the DA TM for the AFCC had been added to the conventional training).

The AFCC portion of the instruction was separately evaluated, the experimentally and conventionally trained students being compared with respect to the number of AFCC malfunctions located during the end-of-course test. The differences between them were not statistically reliable. However, the conventionally trained students tended to correctly isolate more troubles than the experimental students—a reversal that was inconsistent with all the other testing results, which either favored or tended to favor the experimental students. Factors that might have accounted for the AFCC result include the following:

(1) The AFCC manual used in the instruction was the initial draft and may have included technical inaccuracies, which would eventually be revealed by student and instructor usage during training. Such inaccuracies in the earlier drafts of the various HAWKEYE manuals were found in this manner in subsequent work.

(2) The symptom-collection procedures for the AFCC may have been incomplete in their coverage of the relationships between indicators and the corresponding circuits.

(3) The amount of instruction devoted to drill with this manual in the experimental course (33 hours, including eight hours of practical exercises) may have been insufficient for the students to learn and remember the procedures.

As noted earlier, the experience gained in preparing and then revising the various elements in the HAWKEYE materials did not enable the research staff to take the additional step of preparing documentation to supply *generalizable* techniques for building procedure-oriented courses for technical subject matter.

If learnable and rememberable troubleshooting procedures have to be produced, the complexity of combining knowledge of training technology and knowledge of electronics is such that service schools would experience considerable difficulty in attempting to develop courses of this nature; certainly specialized personnel would need to be made available to them. Another possible source for development of appropriate procedures might be the electronics industry, since equipment manufacturers would have the resources to assemble the specialized staffs that are needed to implement this approach to training.

If the procedures did not have to be rememberable—that is, if they could be incorporated in job aids available in the field—the problems connected with devising procedure-oriented training would be greatly simplified. Inclusion of symptom-collection procedures in the DA technical manuals published in support of the electronics system would permit preparation of these materials as part of the normal support materials in connection with system development. That is, the normal technical documentation for electronics systems could be modified by requiring that the equipment manufacturer specify symptom-collection procedures in addition to what is now standard documentation.

Preparation of such materials by schools would also be a more feasible project than would preparation of "rememberable procedures." However, should the requirement for preparing system symptom-collection procedures be placed upon equipment designers and manufacturers, service schools could concentrate their attention on improving the learning environment and teaching techniques rather than conducting the difficult electronics systems analysis required for developing explicit troubleshooting procedures.[1]

[1] At the time the final draft of this report was prepared, the U.S. Army Materiel Command had concurred in a proposal by the U.S. Army Air Defense School that symptom-collection procedures be included in the organizational maintenance manuals for the complete Hawk system. In addition, the U.S. Army Air Defense School had received USCONARC approval to conduct abbreviated programs of instruction for entry-level (or first enlistment) students for all of the Hawk maintenance MOSs. These non-theory courses evolved from the HAWKEYE experimental program and make extensive use of the training aids, devices, and texts developed during this research and development.

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AND

APPENDICES

LITERATURE CITED

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Appendix A

DRAFT POI FOR HAWKEYE CLASS NO. 2 (44.R-221.1-8-66)

1. The attached POI covers the CWAR portion of the course—513 hours, out of a total course of 877 hours (not including end-of-course proficiency test). This is a reduction of 30 hours from the CWAR portion of HAWKEYE Class No. 1 (543 hours). This 30 hours is being shifted to the HPIR portion of the course.

2. Scheduling requirements.

   a. HAWKEYE 22 (McGregor Range Trip) may occur on Wednesday, after second or third week of instruction.

   b. HAWKEYE 12 (Generator Operation) may occur anywhere between HAWKEYE 6 and HAWKEYE 15.

   c. Other blocks should occur in the order given, if possible.

3. All classes in the 700 area are classified CMHA, regardless of content, since a security clearance is needed in this area. All classes using a classified TM are also classified CMHA.

4. Abbreviations for facilities column:

   C - Conference room in LAM 600 area
   B - Basic Electronics lab
   L - LAM radar lab with indoor stations
   L(1) - LAM radar lab with indoor stations and 1 or 2 outdoor stations
   S - Special facilities (generator lab, McGregor Range, OID integrated radar systems, etc.)
   O - Two LAM lab-conference rooms, one set up with 6 stations for scopes and generators, and one for conferences. No radars needed.
   L-O - LAM radar lab with indoor stations, *plus* one LAM lab-conference room set up with 6 stations for scopes and signal generators.

SUMMARY OF CWAR POI (513 Hrs.)

	Hours					
	S	C	L	O	B	Total
Daily & Weekly Checks						16
CWAR Daily Checks			8			
CWAR Weekly Checks			8			
Operation & Troubleshooting						384
Symptom Collection		52	24			
Signal Tracing		8				
Symptom Collection & Signal Tracing		88	52			
Intrastage Troubleshooting		64				
Circuit Board Troubleshooting					68	
Integrated Troubleshooting		16	12			
Tools & Test Equipment						52
Meters					28	
Scope				20		
Soldering					4	
Examinations		18	18	4	4	44
Miscellaneous						17
(Orientation, Generator, Maintenance Concepts, Supply Procedures, McGregor Range)	9	8				
Totals	9	254	122	24	104	513

HAWKEYE POI

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 1 (LA4.8104, EL1.80001, LA4.30001) Orientation and Introduction	U	2-C	Welcome to Department, orientation on course content. Advantages of maintenance program and educational opportunities. School policy, security lectures, assignment of lockers, MIDLAM and BE facilities.	None
HAWKEYE 2 (LA3.50503) Introduction of Hawk System	U	3-S	Organization of Hawk battery, characteristics of major items of equipment, scheme of operations, and equipment demonstration.	None
HAWKEYE 3 CWAR Daily Checks	CMHA	8-L(1)	Energizing and de-energizing, local and remote operation. Daily check procedures. Major assembly and subassembly location.	TM9-1430-503-12/1
HAWKEYE 4 Symptom Collection 1	U	4-C	Introduction to maintenance and troubleshooting. Description on the maintenance job. Duties of the MOS. Overview of the course. Troubleshooting to a subsystem. Introduction to operation and symptom collection of power and control circuits in CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Page 3, P&CC)
HAWKEYE 5 Radar Symptom Collection 1	CMHA	4-L	CWAR troubleshooting to a subsystem.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Page 3); TM9-1430-503-12/1
HAWKEYE 6 Symptom Collection 2	U	4-C	Symptom collection of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC)
HAWKEYE 7 Test Equipment-Meters 1	U	4-B	Introduction to the use of the TS-505A/U for measuring ac and dc volts. Procedures for setting controls, connecting to circuit, and reading scales. Safety precautions.	HAWKEYE: Test Equipment-Meters (Block 1)
HAWKEYE 8 Test Equipment-Meters 2	U	4-B	Introduction to the use of the TS-505A/U for measuring ac and dc volts. Procedures for setting controls, connecting to circuit, and reading scales. Safety precautions.	HAWKEYE: Test Equipment-Meters (Block 2)
HAWKEYE 9 Symptom Collection 3	U	4-C	Symptom collection of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC)

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 10 Radar Symptom Collection 2	CMHA	4-L	Symptom collection and weekly checks in CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/1
HAWKEYE 11 Test Equipment-Meters 3	U	2-B	Practice using the TS-505 A/U for measuring ac and dc volts, unknown voltages, and incorrect voltages.	HAWKEYE: Test Equipment-Meters (Block 3)
HAWKEYE 12 (LA1.80902) Generator Operation	U	2-S	Generator function, start and stop procedures, preventive maintenance, indicators, and operator adjustments.	TM5-6115-325-10; LA1.80902
HAWKEYE 13 Symptom Collection 4	U	4-C	Symptom collection of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC)
HAWKEYE 14 Test Equipment-Meters 4	U	4-B	Introduction to the use of the TS-352A/U for measuring dc current, dc and ac volts.	HAWKEYE: Test Equipment-Meters (Block 4)
HAWKEYE 15 Signal Tracing 1	CMHA	4-C	Use of functional diagrams for signal tracing in the power and control circuits (wiring only). Determining signal path, selecting check points, determining what signal should be present, making checks, and determining what circuits could cause an incorrect reading.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/2
HAWKEYE 16 Symptom Collection and Signal Tracing 1	CMHA	4-C	Symptom collection and signal tracing of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/2
HAWKEYE 17 Radar Symptom Collection and Signal Tracing 1	CMHA	4-L	Symptom collection and signal tracing of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/1; -12/2
HAWKEYE 18 Symptom Collection and Signal Tracing 2	CMHA	4-C	Symptom collection and signal tracing of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/2
HAWKEYE 19 Test Equipment-Meters 5	U	2-B	Practice using the TS-352 A/U for measuring ac voltages, dc voltages, unknown voltages, incorrect voltages, and dc current.	HAWKEYE: Test Equipment-Meters (Block 5)

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 20 Symptom Collection and Signal Tracing 3	CMHA	4-C	Symptom collection and signal tracing of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/2
HAWKEYE 21 Radar Symptom Collection and Signal Tracing 2	CMHA	4-L	Symptom collection and signal tracing of CWAR power and control circuits.	HAWKEYE Operation and Symptom Collection Manual—CWAR (P&CC); TM9-1430-503-12/1; -12/2
HAWKEYE 22 (LA4.81504) McGregor Range Trip	U	4-S	Trip to McGregor Range to observe facilities and missile firing.	None
HAWKEYE 23 Symptom Collection 5	U	8-C	Operation and symptom collection of CWAR antenna control system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT)
HAWKEYE 24 Radar Symptom Collection 3	CMHA	4-L	Symptom collection and weekly checks of the CWAR antenna control system. Parts location.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT); TM9-1430-503-12/1
HAWKEYE 25 Signal Tracing 2	CMHA	4-C	Use of functional diagrams for signal tracing in electronic circuits. Determining signal path, selecting check points, determining what signal should be present, making checks, and determining what circuits could cause incorrect reading.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT); TM9-1430-503-12/2
HAWKEYE 26 Symptom Collection and Signal Tracing 4	CMHA	4-C	Symptom collection and signal tracing of CWAR antenna control system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT); TM9-1430-503-12/2
HAWKEYE 27 Test Equipment-Meters 6	U	4-B	Practice using the TS-505 A/U and TS-352A/U multimeters for voltage and current measurements.	HAWKEYE Test Equipment-Meters (Block 6)
HAWKEYE 28 Symptom Collection and Signal Tracing 5	CMHA	4-[illegible]	Symptom collection and signal tracing of CWAR antenna control system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT); TM9-1430-503-12/2
HAWKEYE 29 Radar Symptom Collection and Signal Tracing 3	CMHA	4-L	Symptom collection and signal tracing of CWAR antenna control system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (ANT); TM9-1430-503-12/1; -12/2
HAWKEYE 30 Examination	U	4-B	Practical examination and critique on use of TS-505 A/U and TS 352A/U.	HAWKEYE: Test Equipment-Meters

Subject & Block No.	Class-ifica-tion	Hours & Facil-ities	Scope	References
HAWKEYE 31 Symptom Collection and Signal Tracing 6	CMHA	4-C	Integrated symptom collection and signal tracing of CWAR power and control circuits and antenna control system.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2
HAWKEYE 32 Examination	CMHA	2-C	Written examination and critique on symptom collection and signal tracing of CWAR power and control circuits and antenna control system.	All previous references
HAWKEYE 33 Examination	CMHA	4-L	Practical examination and critique on symptom collection on the CWAR power and control circuits and the antenna control system.	All previous references
HAWKEYE 34 Test Equipment-Scope 1	CMHA	16-0	Introduction to procedures and practice in using the USM-50C for displaying, measuring amplitude, and estimating frequency of all signals. Displaying less than one cycle of a signal. Measuring time. Characteristics of USM-50C. When to use an oscilloscope.	HAWKEYE: Test Equipment-USM-50C Oscilloscope
HAWKEYE 35 Symptom Collection 6	U	8-C	Operation and symptom collection of CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR)
HAWKEYE 36 Radar Symptom Collection 4	CMHA	4-L-0	Symptom collection and weekly checks of the CWAR transmitter. Parts location. Practice using USM-50C with signal generator.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/1 HAWKEYE: Test Equipment-USM-50C Oscilloscope
HAWKEYE 37 Symptom Collection 7	CMHA	4-C	Symptom collection of CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR)
HAWKEYE 38 Symptom Collection and Signal Tracing 7	CMHA	4-C	Symptom collection and signal tracing of the CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR); TM9-1430-503-12/2
HAWKEYE 39 Radar Symptom Collection and Signal Tracing 4	CMHA	4-L	Symptom collection and signal tracing of the CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR); TM9-1430-503-12/1; -12/2
HAWKEYE 40 Symptom Collection and Signal Tracing 8	CMHA	8-C	Symptom collection and signal tracing of the CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR); TM9-1430-503-12/2

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 41 Radar Symptom Collection and Signal Tracing 5	CMHA	4-L	Symptom collection and signal tracing of the CWAR transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR (XMTR); TM9-1430-503-12/1; -12/2
HAWKEYE 42 Symptom Collection and Signal Tracing 9	CMHA	8-C	Integrated symptom collection of CWAR power and control circuits, antenna control system, and transmitter.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2
HAWKEYE 43 Examination	CMHA	2-C	Written examination and critique on symptom collection and signal tracing of CWAR power and control circuits, antenna control system, and transmitter.	All previous references
HAWKEYE 44 Symptom Collection 8	U	8-C	Operation and symptom collection of CWAR receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR)
HAWKEYE 45 Radar Symptom Collection 5	CMHA	4-L-O	Symptom collection and weekly checks of the CWAR receiver. Parts location. Practice using USM-50C with signal generator.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/1; HAWKEYE: Test Equipment—USM-50C Oscilloscope
HAWKEYE 46 Symptom Collection and Signal Tracing 10	CMHA	4-C	Symptom collection and signal tracing of CWAR receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/2
HAWKEYE 47 Radar Symptom Collection and Signal Tracing 6	CMHA	4-L-O	Symptom collection and signal tracing of the CWAR receiver. Practice using USM-50C with signal generator.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/1; -12/2; HAWKEYE: Test Equipment-USM-50C Oscilloscope
HAWKEYE 48 Symptom Collection and Signal Tracing 11	CMHA	4-C	Symptom collection and signal tracing of the CWAR receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/2
HAWKEYE 49 Examination	CMHA	4-O	Practical examination and critique on use of USM-50C oscilloscope, using signal generator.	HAWKEYE: Test Equipment—USM-50C Oscilloscope
HAWKEYE 50 Symptom Collection and Signal Tracing 12	CMHA	4-C	Symptom collection and signal tracing of the CWAR receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/2

Subject & Block No.	Classifica-tion	Hours & Facil-ities	Scope	References
HAWKEYE 51 Radar Symptom Collection and Signal Tracing 7	CMHA	4-L	Symptom collection and signal tracing of the CWAR receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR (RCVR); TM9-1430-503-12/1; -12/2
HAWKEYE 52 Symptom Collection and Signal Tracing 13	CMHA	4-L	Integrated symptom collection and signal tracing of CWAR power and control circuits, antenna control system, transmitter, and receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2
HAWKEYE 53 Radar Symptom Collection and Signal Tracing 8	CMHA	4-L	Integrated symptom collection and signal tracing of CWAR power and control circuits, antenna control system, transmitter, and receiver.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/1; -12/2
HAWKEYE 54 Examination	CMHA	2-C	Written examination and critique on symptom collection and signal tracing of CWAR power and control circuits, antenna control system, transmitter, and receiver.	All previous references
HAWKEYE 55 Examination	CMHA	4-L	Practical examination and critique on symptom collection and signal tracing of CWAR power and control circuits, antenna control system, transmitter, and receiver.	All previous references
HAWKEYE 56 Symptom Collection 9	U	8-C	Operation and symptom collection of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display)
HAWKEYE 57 Radar Symptom Collection 6	CMHA	4-L	Symptom collection and weekly checks of the CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/1
HAWKEYE 58 Symptom Collection and Signal Tracing 14	CMHA	4-C	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/2
HAWKEYE 59 Radar Symptom Collection and Signal Tracing 9	CMHA	4-L	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/1; -12/2
HAWKEYE 60 Symptom Collection and Signal Tracing 15	CMHA	4-C	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/2

Subject & Block No.	Class-ification	Hours & Facil-ities	Scope	References
HAWKEYE 61 Radar Symptom Collection and Signal Tracing 10	CMHA	4-L	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/1; -12/2
HAWKEYE 62 Symptom Collection and Signal Tracing 16	CMHA	4-C	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/2
HAWKEYE 63 Radar Symptom Collection and Signal Tracing 11	CMHA	4-L	Symptom collection and signal tracing of CWAR display system.	HAWKEYE Operation and Symptom Collection Manual—CWAR (Display); TM9-1430-503-12/1; -12/2
HAWKEYE 64 Symptom Collection and Signal Tracing 17	CMHA	8-C	Integrated symptom collection and signal tracing on all parts of CWAR with emphasis on symptom collection.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2
HAWKEYE 65 Radar Symptom Collection and Signal Tracing 12	CMHA	4-L	Integrated symptom collection and signal tracing on all parts of CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/1; -12/2
HAWKEYE 66 Symptom Collection and Signal Tracing 18	CMHA	8-C	Integrated symptom collection and signal tracing on all parts of CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2
HAWKEYE 67 Radar Symptom Collection and Signal Tracing 13	CMHA	4-L	Integrated symptom collection and signal tracing on all parts of CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/1; -12/2
HAWKEYE 68 Examination	CMHA	2-C	Written examination and critique of symptom collection and signal tracing on all parts of CWAR.	All previous references
HAWKEYE 69 Examination	CMHA	4-L	Practical examination and critique of symptom collection and signal tracing on all parts of CWAR.	All previous references
HAWKEYE 70 (LA4.40006) Maintenance and Supply Procedures	U	6-C	Maintenance concept and record system (TAERS). Supply procedures used at unit level. Use of TMs and CMMI procedures. Project TRIM and material readiness.	DA Pam 750-1; TM38-750; TM44-96; AS LA4.40006
HAWKEYE 71 Test Equipment-Meters 7	U	4-B	Introduction to the use of the TS-505A/U and TS-325A/U for measuring resistance and making continuity checks.	HAWKEYE: Test Equipment-Meters (Block 7)

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 72 Circuit Board Troubleshooting 1	U	4-B	Troubleshooting around a stage on circuit board No. 1.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 73 Intrastage Troubleshooting 1	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 74 Soldering 1	U	4-B	Introduction to soldering techniques.	
HAWKEYE 75 Intrastage Troubleshooting 2	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 76 Circuit Board Troubleshooting 2	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 77 Intrastage Troubleshooting 3	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 78 Circuit Board Troubleshooting 3	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 79 Intrastage Troubleshooting 4	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 80 Circuit Board Troubleshooting 4	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 81 Intrastage Troubleshooting 5	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 82 Circuit Board Troubleshooting 5	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 83 Intrastage Troubleshooting 6	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 84 Circuit Board Troubleshooting 6	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 85 Intrastage Troubleshooting 7	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 86 Circuit Board Troubleshooting 7	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 87 Intrastage Troubleshooting 8	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 88 Radar Troubleshooting 1	CMHA	4-L	Symptom collection, signal tracing, and troubleshooting around a stage on all parts of the CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/1; -12/2; -20
HAWKEYE 89 Examination	CMHA	2-C	Written examination and critique on CWAR symptom collection, signal tracing, and intrastage troubleshooting.	All previous references
HAWKEYE 90 Circuit Board Troubleshooting 8	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 91 Intrastage Troubleshooting 9	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 92 Test Equipment-Meters 8	U	4-B	Review of TS-352A/U and TS-505A/U meters.	HAWKEYE: Test Equipment-Meters
HAWKEYE 93 Intrastage Troubleshooting 10	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 94 Circuit Board Troubleshooting 9	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 95 Intrastage Troubleshooting 11	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 96 Circuit Board Troubleshooting 9	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage

Subject & Block No.	Class-ifica-tion	Hours & Facil-ities	Scope	References
HAWKEYE 97 Intrastage Troubleshooting 12	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual--CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 98 Circuit Board Troubleshooting 11	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 99 Examination	CMHA	2-C	Written examination and critique on CWAR symptom collection, signal tracing, and intrastage troubleshooting.	All previous references
HAWKEYE 100 Radar Troubleshooting 2	CMHA	4-L	Symptom collection, signal tracing, and troubleshooting around a stage on all parts of the CWAR.	HAWKEYE Operation and Symptom Collection Manual-CWAR; TM9-1430-503-12/1; -12/2; -20
HAWKEYE 101 Test Equipment-Scope 2	CMHA	4-0	Review of USM-50C Oscilloscope.	HAWKEYE: Test Equipment--USM-50C Oscilloscope
HAWKEYE 102 Circuit Board Troubleshooting 12	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 103 Intrastage Troubleshooting 13	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual--CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 104 Circuit Board Troubleshooting 13	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 105 Intrastage Troubleshooting 14	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual--CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 106 Circuit Board Troubleshooting 14	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 107 Intrastage Troubleshooting 15	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual--CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 108 Circuit Board Troubleshooting 15	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 109 Intrastage Troubleshooting 16	CMHA	4-C	Review of CWAR symptom collection and signal tracing. Troubleshooting around a stage.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 110 Circuit Board Troubleshooting 16	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 111 Examination	CMHA	2-C	Written examination and critique on CWAR symptom collection, signal tracing, and intrastage troubleshooting.	All previous references
HAWKEYE 112 Circuit Board Troubleshooting 17	U	4-B	Troubleshooting around a stage on circuit boards.	HAWKEYE: Troubleshooting Within a Stage
HAWKEYE 113 CWAR Troubleshooting 1	CMHA	8-C	Symptom collection, signal tracing, and troubleshooting around a stage on all parts of the CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 114 CWAR Weekly Checks	CMHA	8-L	CWAR Weekly Check procedures and adjustments.	TM9-1430-503-12/1
HAWKEYE 115 CWAR Troubleshooting 2	CMHA	8-C	Symptom collection, signal tracing, and troubleshooting around a stage on all parts of the CWAR.	HAWKEYE Operation and Symptom Collection Manual—CWAR; TM9-1430-503-12/2; TM9-1430-503-20
HAWKEYE 116 Radar Troubleshooting 3	CMHA	4-L	Symptom collection, signal tracing, and troubleshooting around a stage on all parts of the CWAR.	HAWKEYE Operation and Symptom Collection Manual-CWAR; TM9-1430-503-12/1; -12/2; -20
HAWKEYE 117 Examination	CMHA	4-C	Written examination and critique on CWAR troubleshooting.	All previous references
HAWKEYE 118 Examination	CMHA	6-L	Practical examination and critique on CWAR troubleshooting.	All previous references
HAWKEYE 201 HPIR Daily Checks	CMHA	8-L	HPIR daily check procedures.	TM9-1430-511-12/1
HAWKEYE 202 Symptom Collection 1	U	4-C	HPIR troubleshooting to a subsystem.	HAWKEYE Operation and Symptom Collection Manual—HPIR
HAWKEYE 203 Radar Symptom Collection 1	CMHA	4-L	HPIR troubleshooting to a subsystem.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1

Subject & Block No.	Class-ification	Hours & Facil-ities	Scope	References
HAWKEYE 204 Symptom Collection 2	U	4-C	HPIR troubleshooting to a subsystem.	HAWKEYE Operation and Symptom Collection Manual—HPIR
HAWKEYE 205 Radar Symptom Collection 2	CMHA	4-L	HPIR troubleshooting to a subsystem.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1
HAWKEYE 206 Operation and Troubleshooting—HPIR Power Circuits 1	CMHA	4-C	Operation and troubleshooting HPIR Power circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 207 Operation and Troubleshooting—HPIR Power Circuits 2	CMHA	4-C	Operation and troubleshooting HPIR Power circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 208 Radar Troubleshooting—HPIR Power Circuits 1	CMHA	4-L	Troubleshooting HPIR Power circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 209 Operation and Troubleshooting—HPIR Power Circuits 3	CMHA	4-C	Operation and troubleshooting HPIR Power circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 210 Radar Troubleshooting—HPIR Power Circuits 2	CMHA	4-L	Troubleshooting HPIR Power circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 211 Operation and Troubleshooting—HPIR Antenna 1	CMHA	4-C	Operation and troubleshooting HPIR Antenna.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 212 Radar Troubleshooting—HPIR Antenna 1	CMHA	4-L	Troubleshooting HPIR Antenna	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 213 Operation and Troubleshooting—HPIR Antenna 2	CMHA	4-C	Operation and troubleshooting HPIR Antenna.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 214 Radar Troubleshooting—HPIR Antenna 2	CMHA	4-[illegible]	Troubleshooting HPIR Antenna.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 215 Operation and Troubleshooting—HPIR Antenna 3	CMIA	4-C	Operation and troubleshooting HPIR Antenna.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 216 Radar Troubleshooting—HPIR Antenna 3	CMIA	4-L	Troubleshooting HPIR Antenna.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 217 Integrated Operation and Troubleshooting 1	CMIA	4-C	Integrated operation and troubleshooting of HPIR Power circuits, and Antenna, and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 218 Radar Integrated Troubleshooting 1	CMIA	4-L	Integrated troubleshooting of HPIR Power circuits and Antenna.	All previous references for HPIR
HAWKEYE 219 Examination	CMIA	3-C	Written examination and critique.	All previous references for HPIR and CWAR
HAWKEYE 220 Examination	CMIA	4-L	Practical examination and individual critique.	All previous references for HPIR
HAWKEYE 221 Operation and Troubleshooting—HPIR Computers 1	CMIA	4-C	Operation and troubleshooting HPIR Computers.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 222 Radar Troubleshooting—HPIR Computers 1	CMIA	4-L	Troubleshooting HPIR Computers.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 223 Operation and Troubleshooting—HPIR Computers 2	CMIA	4-C	Operation and troubleshooting HPIR Computers.	HAWKEYE Operation Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 224 Radar Troubleshooting—HPIR Computers 2	CMIA	4-L	Troubleshooting HPIR Computers.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 225 Operation and Troubleshooting—HPIR Computers 3	CMIA	4-C	Operation and troubleshooting HPIR Computers.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 226 Radar Troubleshooting—HPIR Computers 3	CMIA	4-L	Troubleshooting HPIR Computers.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1, -12/2; -20

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 227 Integrated Operation and Troubleshooting 2	CMHA	4-C	Integrated operation and troubleshooting HPIR Power circuits, Antenna and Computers, and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 228 Radar Integrated Troubleshooting 2	CMHA	4-L	Integrated troubleshooting HPIR Power circuits, Antenna, and Computers	All previous references for HPIR
HAWKEYE 229 Operation and Troubleshooting—HPIR Transmitter 1	CMHA	4-C	Operation and troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 230 Radar Troubleshooting—HPIR Transmitter 1	CMHA	4-L	Troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2 -20
HAWKEYE 231 Operation and Troubleshooting—HPIR Transmitter 2	CMHA	4-C	Operation and troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 232 Radar Troubleshooting—HPIR Transmitter 2	CMHA	4-L	Troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 233 Operation and Troubleshooting—HPIR Transmitter 3	CMHA	4-C	Operation and troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 234 Radar Troubleshooting—HPIR Transmitter 3	CMHA	4-L	Troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 235 Operation and Troubleshooting—HPIR Transmitter 4	CMHA	4-C	Operation and troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 236 Radar Troubleshooting—HPIR Transmitter 4	CMHA	4-L	Troubleshooting HPIR Transmitter.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 237 Integrated Operation and Troubleshooting 3	CMHA	4-C	Integrated operation and troubleshooting HPIR Power circuits, Antenna, Computers, and Transmitter, and CWAR circuits.	All previous references for HPIR and CWAR

Subject & Block No.	Classifica-tion	Hours & Facil-ities	Scope	References
HAWKEYE 238 Radar Integrated Troubleshooting 3	CMHA	4-L	Integrated troubleshooting HPIR Power circuits, Antenna, Computers and Transmitter.	All previous references for HPIR
HAWKEYE 239 Examination	CMHA	3-C	Written examination and critique.	All previous references for HPIR and CWAR
HAWKEYE 240 Examination	CMHA	4-L	Practical examination and critique.	All previous references for HPIR
HAWKEYE 241 Operation and Troubleshooting—HPIR Receiver 1	CMHA	4-C	Operation and troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 242 Radar Troubleshooting—HPIR Receiver 1	CMHA	4-L	Troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 243 Operation and Troubleshooting—HPIR Receiver 2	CMHA	4-C	Operation and troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 244 Radar Troubleshooting—HPIR Receiver 2	CMHA	4-L	Troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 245 Operation and Troubleshooting—HPIR Receiver 3	CMHA	4-C	Operation and troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 246 Radar Troubleshooting—HPIR Receiver 3	CMHA	4-L	Troubleshooting HPIR Receiver.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 247 Integrated Operation and Troubleshooting 4	CMHA	4-C	Integrated operation and troubleshooting HPIR Power circuits, Antenna, Computers, Transmitter, and Receiver, and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 248 Radar Integrated Troubleshooting 4	CMHA	4-L	Integrated troubleshooting HPIR Power circuits, Antenna, Computers, Transmitter, and Receiver.	All previous references for HPIR
HAWKEYE 249 Integrated Operation and Troubleshooting 5	CMHA	4-C	Integrated operation and troubleshooting HPIR Power circuits, Antenna, Computers, Transmitter and Receiver, and CWAR circuits.	All previous references for HPIR and CWAR

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 250 Radar Integrated Troubleshooting 5	CMHA	4-L	Integrated troubleshooting HPIR Power circuits, Antenna, Computers, Transmitter and Receiver.	All previous references for HPIR
HAWKEYE 251 Operation and Troubleshooting—HPIR Doppler Circuits 1	CMHA	4-C	Operation and troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 252 Radar Troubleshooting—HPIR Doppler Circuits 1	CMHA	4-L	Troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 253 Operation and Troubleshooting—HPIR Doppler Circuits 2	CMHA	4-C	Operation and troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 254 Radar Troubleshooting—HPIR Doppler Circuits 2	CMHA	4-L	Troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 255 Operation and Troubleshooting—HPIR Doppler Circuits 3	CMHA	4-C	Operation and troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 256 Radar Troubleshooting—HPIR Doppler Circuits 3	CMHA	4-L	Troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 257 Operation and Troubleshooting—HPIR Doppler Circuits 4	CMHA	4-C	Operation and troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 258 Radar Troubleshooting—HPIR Doppler Circuits 4	CMHA	4-L	Troubleshooting HPIR Doppler circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 259 Integrated Operation and Troubleshooting 6	CMHA	4-C	Integrated operation and troubleshooting HPIR and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 260 Radar Integrated Troubleshooting 6	CMHA	4-L	Integrated troubleshooting HPIR circuits.	All previous references for HPIR
HAWKEYE 261 Integrated Operation and Troubleshooting 7	CMHA	4-C	Integrated operation and troubleshooting HPIR and CWAR circuits.	All previous references for HPIR and CWAR

Subject & Block No.	Class-ification	Hours & Facil-ities	Scope	References
HAWKEYE 262 Radar Integrated Troubleshooting 7	CMHA	4-L	Integrated troubleshooting HPIR circuits.	All previous references for HPIR
HAWKEYE 263 Examination	CMHA	3-C	Written examination and critique.	All previous references for HPIR and CWAR
HAWKEYE 264 Examination	CMHA	4-L	Practical examination and critique.	All previous references for HPIR
(LA4.65401) HAWKEYE 265 Field Experience	CMHA	1-C	Maintenance and siting experience of Hawk units employed in the field.	Instructor's notes
(LA4.43801) HAWKEYE 266 Lightning Protection for Trailers and Shelters	U	1-C	Procedures and need for lightning protection. System grounding and ground check protection.	AS LA5.60306 ANNEX A
LA4.65502) HAWKEYE 267 Operational Readiness Evaluation	CMHA	2-C	Conduct of an operational readiness evaluation.	ORE checklist
(EL5.20102) (EL5.07101) HAWKEYE 268 ECM, ECCM	C	3-C	Techniques of ECM, to include active and passive measures and types of equipment used to provide ECM and the effects on radars. ECCM devices employed on air defense radars, and the operator techniques used to defeat ECM.	TM11-750; -751; Instructor's notes
HAWKEYE 269 HPIR Weekly Checks	CMHA	8-L	HPIR weekly check procedures. Rigging Hawk equipment for helicopter airlift.	TM9-1430-511-12/1; TM9-1430-500-12/1
HAWKEYE 270 Operation and Troubleshooting—HPIR Special Circuits 1	CMHA	4-C	Operation and troubleshooting HPIR Special circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 271 Radar Troubleshooting—HPIR Special Circuits 1	CMHA	4-L	Troubleshooting HPIR Special circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20
HAWKEYE 272 Operation and Troubleshooting—HPIR Special Circuits 2	CMHA	4-C	Operation and troubleshooting HPIR Special circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/2; -20
HAWKEYE 273 Radar Troubleshooting—HPIR Special Circuits 2	CMHA	4-L	Troubleshooting HPIR Special circuits.	HAWKEYE Operation and Symptom Collection Manual—HPIR; TM9-1430-511-12/1; -12/2; -20

Subject & Block No.	Classification	Hours & Facilities	Scope	References
HAWKEYE 274 Integrated Operation and Troubleshooting 8	CMHA	4-C	Integrated operation and troubleshooting HPIR and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 275 Radar Integrated Operation and Troubleshooting 8	CMHA	4-L	Integrated troubleshooting HPIR circuits.	All previous references for HPIR
HAWKEYE 276 Integrated Operation and Troubleshooting 9	CMHA	4-C	Integrated operation and troubleshooting HPIR and CWAR circuits.	All previous references for HPIR and CWAR
HAWKEYE 277 Integrated System Maintenance	CMHA	50-L	Interrelationships of the CW radars, Battery Control Central, Assault Fire Command Console, ROR and Launcher. Alinement and operation of a Hawk battery. Isolation of troubles in a complete Hawk battery. Daily and Weekly checks and adjustments, and troubleshooting the CWAR and HPIR tied in with a BCC, AFCC, Launcher, and ROR. Use of all applicable TMs and maintenance forms.	All previous references
(CS4.66102) HAWKEYE 278 Counterinsurgency and Unconventional Warfare	U	2-C	Characteristics, capabilities, and limitations of partisan warfare. Organization, mission, and training objectives of U.S. Army Special Forces groups.	Instructor's notes
HAWKEYE 279 Examination	CMHA	4-C	Written examination and critique.	All previous references for HPIR and CWAR
HAWKEYE 280 Examination	CMHA	8-L	Final practical examination.	All previous references

Appendix B

TROUBLESHOOTING WITHIN A STAGE

1. Check applied voltages, including filament voltages:

   Call it "good" if it is within 10% of the stated value. Be sure to check where it is applied to the circuit, not where it enters the chassis. Check B+, not plate voltage.

2. Quick resistance checks

CAUTION: TURN POWER OFF

   (A) Resistors: Check directly across each resistor, allowing time for capacitors to charge. Each one should be within ± 50% of the value stated on the schematic. Resistors more than 50% above value shown on schematic should be replaced immediately, and resistors more than 50% below value shown on schematic require short circuit checks.

   (B) Crystal diodes: Check directly across each diode. Front to back ratio should be at least 100 to 1.

   (C) Inductors (including each coil of transformers): If above 100K, the coil is open.

   (D) Short circuits:

   If any resistance check gave a low reading, look for an alternate dc path. Alternate paths may exist through power supplies. If an alternate path exists, open the circuit and repeat the resistance check before making short circuit checks. Before starting short circuit checks, disconnect one end of the part that was being checked when the low resistance reading was obtained.

   (1) Check resistor which gave low reading. Continue 50% tolerance of stated value. If reading is under or over by 50% at this time, replace immediately.
   (2) Check each resistor and crystal diode that is connected to the part being checked when the low reading was found.
   (3) Check each tube element that is connected to part giving low reading to be sure there is no short within tube.
   (4) Check each capacitor that is connected to part giving low reading to be sure it is not leaking. A resistance of less than 100K indicates the capacitor is shorting.

3. Replace soldered-in tubes, then repeat signal tracing check to see whether it has corrected the trouble. Plug-in tubes should have been replaced as soon as signal tracing was completed.

4. Voltage checks on parts: (Check both sides to ground or reference)

   (A) Dc capacitor checks (there should be some dc difference across the capacitor). Check in order: grid circuits, plate circuits, cathode circuits. Make these checks with power applied to the circuits.

(B) Ac capacitor checks (the ac drop across the capacitor should not be less than 10% of the signal). In resonant circuits this is not strictly correct. The instructor should point out these special cases *when they come up*. If the students forget the exceptions, they will still follow the safe action; that is, replace the part when in doubt.

(C) Ac inductor checks (there should be some ac difference across each inductor.)

5. Final checks on parts:

(A) Disconnect output load and repeat signal tracing checks. If the signal is good with the load disconnected, there is a short beyond the point at which the output was disconnected.

(B) Isolate and check each resistor to be sure it is within TM tolerance.

(C) Check each capacitor for leakage by placing ammeter in series with the capacitor. *Any* measurable current is cause for replacing the capacitor. (*Filter* capacitors in power supplies may leak as much as 1 μa, even when good. Instructor should point this out when this special case comes up.)

(D) Inductors cannot be fully checked with equipment available at second echelon. Try replacing them at this point.

NOTE: After replacing a component or on completion of troubleshooting within a stage, repeat signal tracing check of stage to insure proper operation.

Appendix C

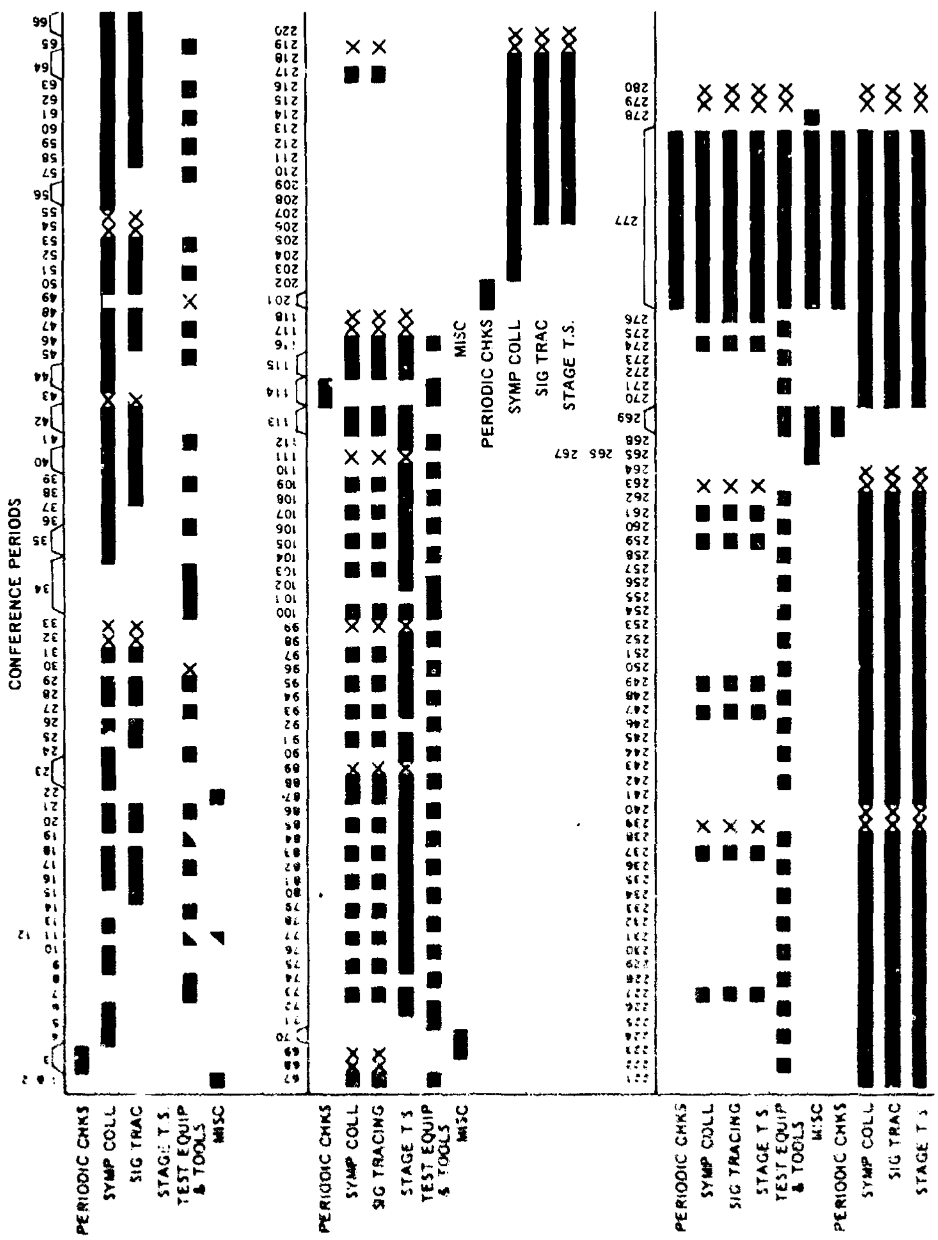
PROFICIENCY TEST FOR EXPERIMENTAL CLASS NO. 1

Trouble No.	Radar	Location	Bad Part
		"A" Form	
A1A	CWAR	Power	Tube
A2A	CWAR	Receiver	Adjustment misadjusted
A3A	CWAR	Display System	Capacitor shorted
A4A	CWAR	Display System	Crystal shorted
A5A	CWAR	Transmitter	Resistor open
A6A	CWAR	Antenna	N/A (Unauthorized at 2d echelon)
I1A	HPIR	Computer	Resistor open
I2A	HPIR	Doppler	Tube
I3A	HPIR	Transmitter	Tube
I4A	HPIR	Energizing	Wire open
I5A	HPIR	Receiver	Wire open (transistor stage)
I6A	HPIR	Antenna	Capacitor shorted
		"B" Form	
A1B	CWAR	Energizing Circuit	Wire open
A2B	CWAR	Antenna	Tube
A3B	CWAR	Receiver	Tube
A4B	CWAR	Transmitter	Wire open
A5B	CWAR	Display System	Capacitor shorted
A6B	CWAR	Display System	Resistor open
I1B	HPIR	Antenna	Adjustment fully CCW
I2B	HPIR	Transmitter	N/A (Unauthorized at 2d echelon)
I3B	HPIR	Doppler	Capacitor shorted
I4B	HPIR	Auto	Tube
I5B	HPIR	Doppler	Resistor open
I6B	HPIR	Receiver	N/A (Unauthorized at 2d echelon)

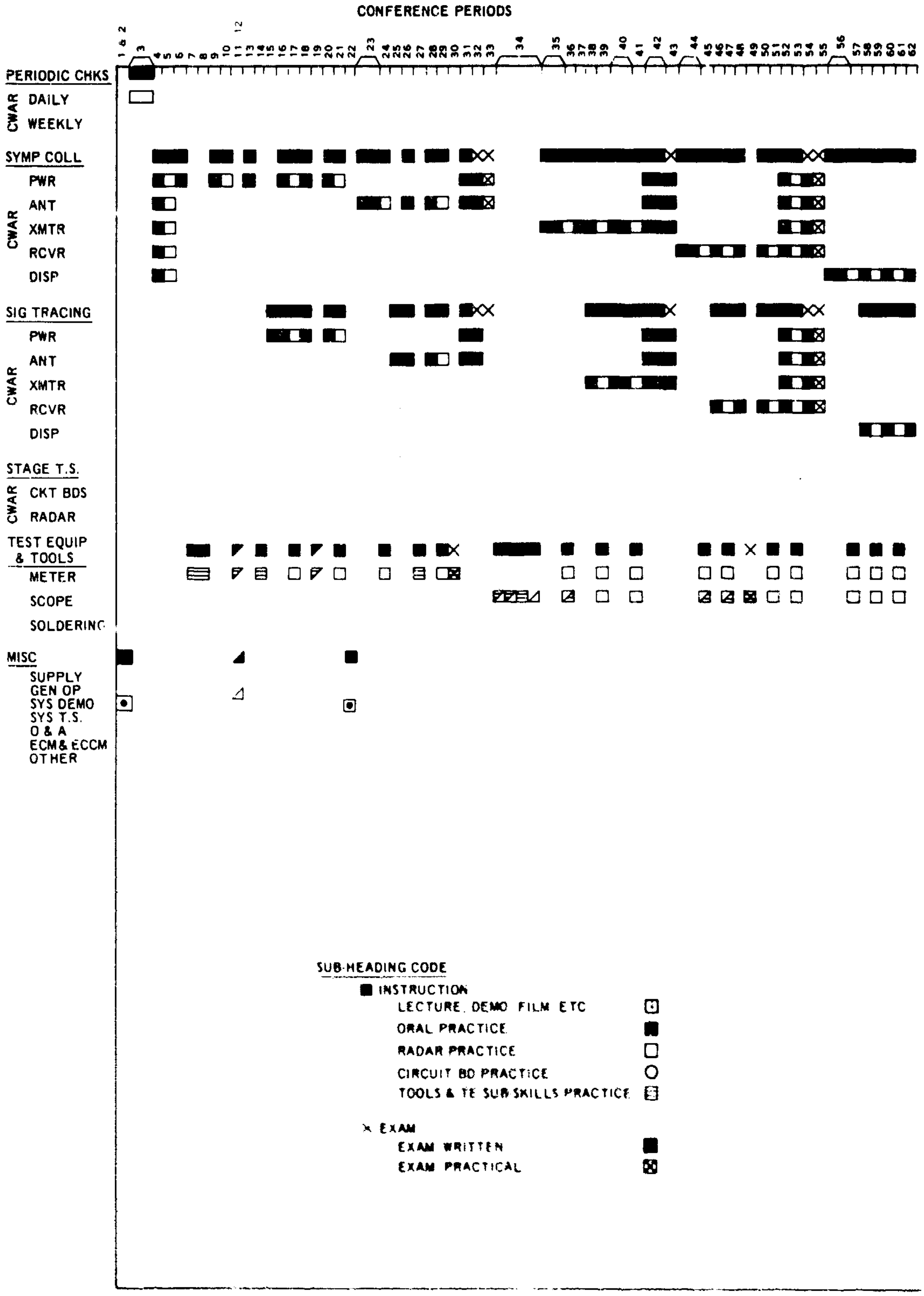
Appendix D

DETAILED TRAINING SCHEDULE

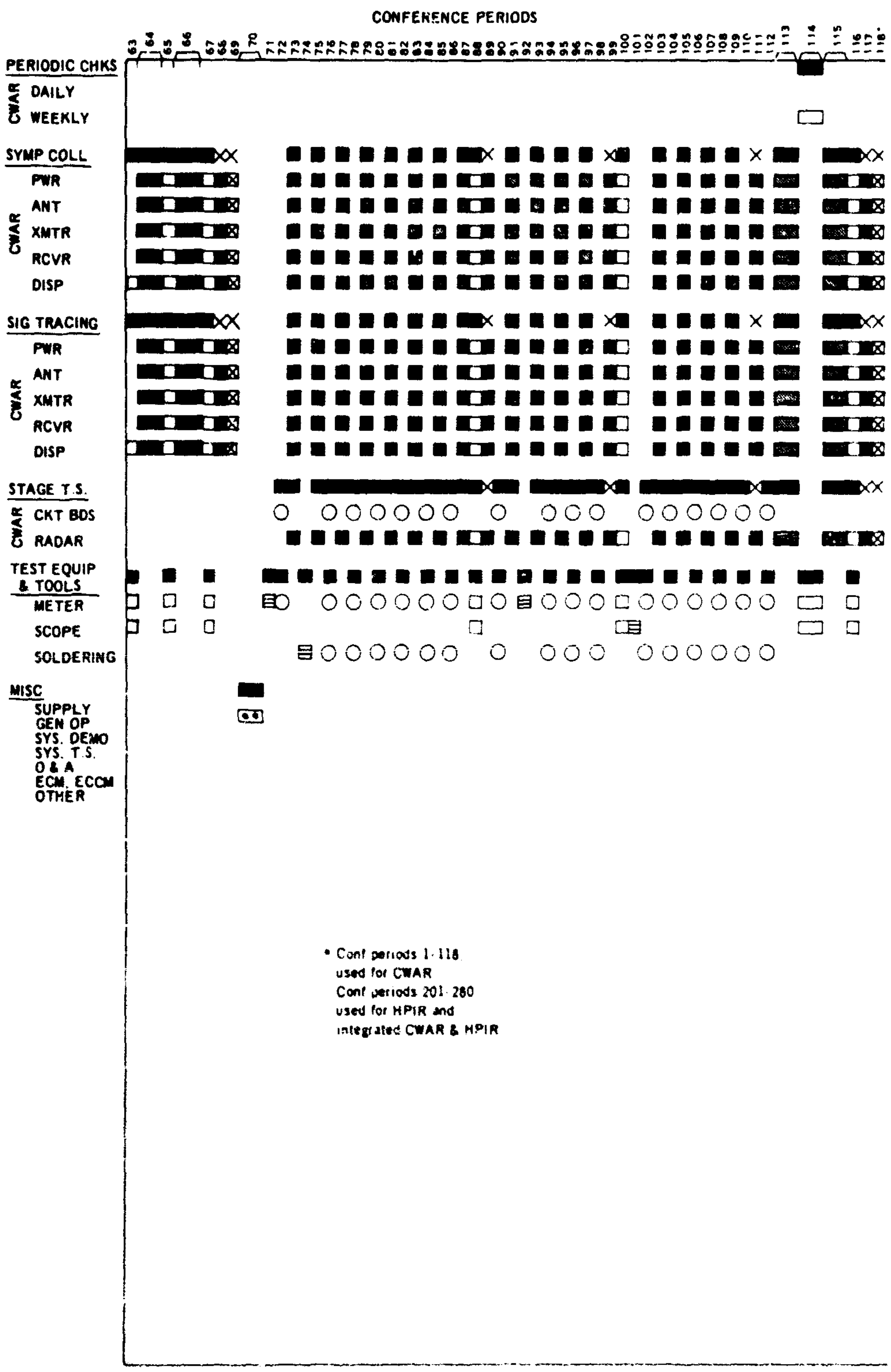
SCHEDULE OF COMPLETE POI



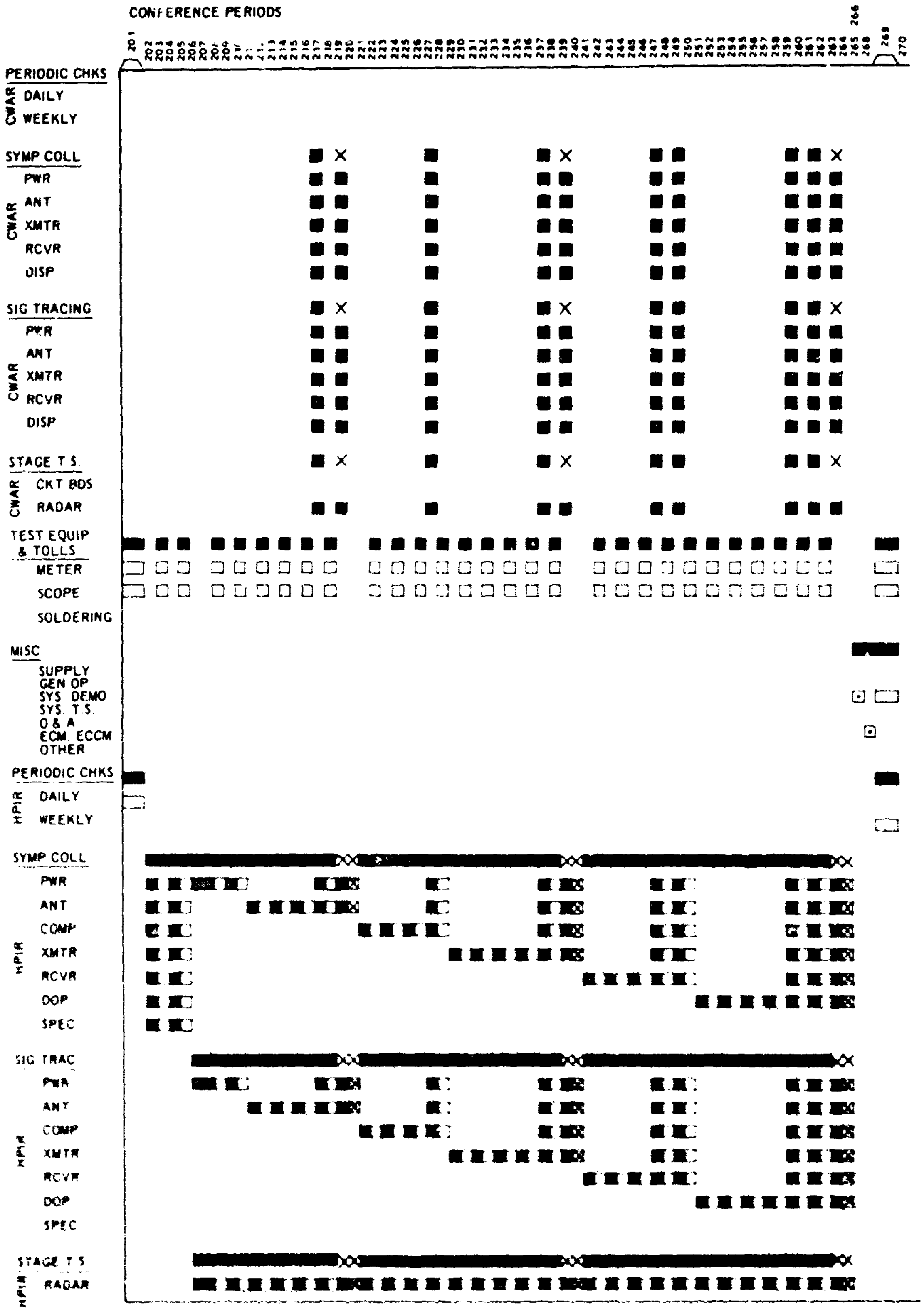
DETAILED SCHEDULE OF CWAR TRAINING



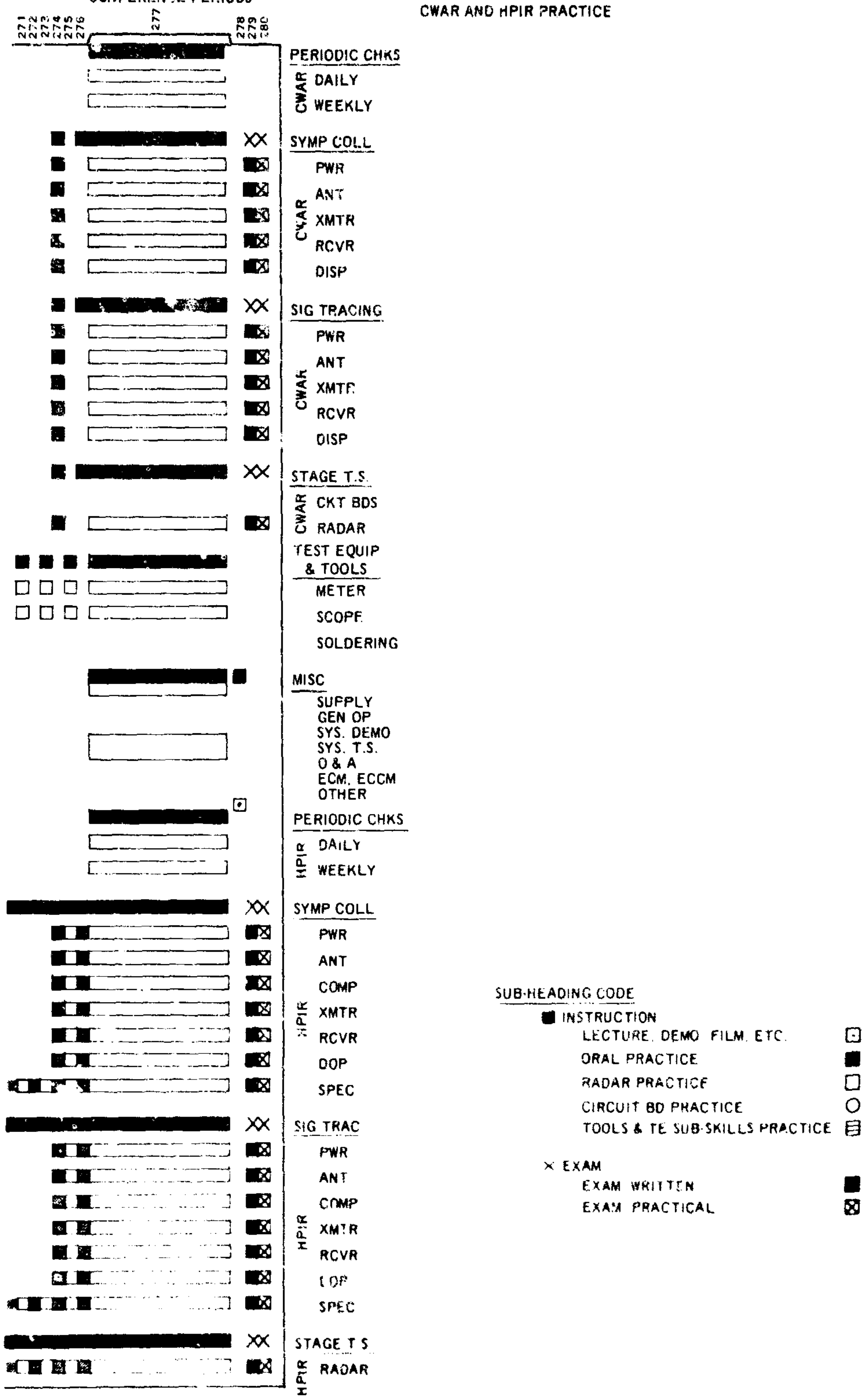
DETAILED SCHEDULE OF CWAR TRAINING



DE... ED SCHEDULE OF HPIR TRAINING AND INTEGRATED
CWAR AND HPIR PRACTICE



DETAILED SCHEDULE OF HPIR TRAINING AND INTEGRATED CWAR AND HPIR PRACTICE



Appendix E

PROFICIENCY TEST FOR EXPERIMENTAL CLASS NO. 2

Trouble No.	Radar	Location	Bad Part
		"C" Form	
A1A	CWAR	Display System	Capacitor shorted
A2A	CWAR	Power	Wire open (Low Voltage Power Supply)
A3A	CWAR	Display System	Open resistor
A4A	CWAR	Antenna	Tube
I1A	HPIR	Computer	Shorted chopper
I2A	HPIR	Transmitter	Tube
I3A	HPIR	Electronic Counter-Countermeasure	Tube
I4A	HPIR	Energizing Circuit	Wire Open
		"D" Form	
A1B	CWAR	Display System	Resistor open
A2B	CWAR	Receiver	Unauthorized at 2d echelon
A3B	CWAR	Energizing Circuit	Wire open
A4B	CWAR	Antenna	Adjustment fully CCW
I1B	HPIR	Antenna	Open resistor
I2B	HPIR	Computer	Tube
I3B	HPIR	Receiver	Open resistor (transistor stage)
I4B	HPIR	Transmitter	Shorted crystal
		Special Items	
A5A	CWAR	Transmitter	Wire open
A6A	CWAR	Transmitter	Tube
I6A	HPIR	Antenna	Adjustment fully CCW
A5B	CWAR	Display System	Tube
A6B	CWAR	Receiver	Wire open (Power Supply)
I5B	HPIR	Doppler	Shorted capacitor

Appendix F

FIELD FOLLOW-UP QUESTIONNAIRE

JOB PERFORMANCE QUESTIONNAIRE

Instructions to Raters

The man whose name appears at the top of the next page participated in an experiment to evaluate the attitudinal or motivational effects of some changes in training techniques while at the Air Defense School. This questionnaire is part of the follow-up designed to study the effects of the experiment on posttraining performance.

Separate instructions will precede each block of questions when required for clarification. Do not spend too much time on any one question. Usually, your first well-considered opinion is best.

If you feel that a particular question cannot be answered from your combined personal knowledge, place a check mark (✓) in the space which follows that question and go on to the next question. However, you should answer every question that you can even though your combined knowledge of the man in that area may not be as great as you would like.

The answers are being requested so that the relative effectiveness of different training programs can be evaluated. The evaluation will *not* be included in the EM's personnel records; but the evaluation is needed to determine whether the different motivation techniques should be recommended for general adoption for technical training. All questionnaires will be treated as personal in nature and all references to individuals will be destroyed after the information for all technicians has been extracted and summarized.

PERSONAL DATA ON RATERS

1. Battery Commander
   a. Name ______________________ b. Rank ______
   c. Sr. No. ______________ d. Current MOS ______________
   e. Previously Held MOS (if any) ______________
   f. Months in present duty position ______
2. Technical Supervisor
   a. Name ______________________ b. Rank ______
   c. Sr. No. ______________ d. Current MOS ______________
   e. Previously Held MOS (if any) ______________
   f. Months in present duty position ______

Technician to be Evaluated:

Name ____________________

Present Duty Position ____________________ Duty MOS __________

Time in Present Duty Position (months) __________ __________

Time Battery Commander has known technician (months) __________

Time Technical Supervisor has known technician (months) __________

I. JOB RESPONSIBILITIES

The above named technician received training for MOS 23R, Hawk CW Radar Mechanic:

A. If he is currently assigned a duty MOS of 23R, omit Items 1 and 2 below and go directly to Section II, RATER'S KNOWLEDGE OF TECHNICIAN.

B. If he *has* held, but does *not currently* hold a duty MOS of 23R, complete Items 1 and 2 below before going to Section II, RATER'S KNOWLEDGE OF TECHNICIAN.

C. If he has *never* held a duty MOS of 23R, complete Items 1 and 2 below, and then complete *only* Sections II, III, and IV of this questionnaire.

- -

1. Why is this man *not* currently assigned a duty MOS of 23R?

   ___ a. Unit has a surplus of MOS 23R.

   ___ b. Man is assigned other duties for reasons of technical inability. (Check specific reasons)

      ___ 1. Failed to observe safety precautions.

      ___ 2. Damaged equipment.

      ___ 3. Could not perform routine maintenance.

      ___ 4. Could not troubleshoot equipment.

   ___ c. Other reasons (explain) ____________________

   ____

   ____

2. How long did this technician hold a duty MOS of 23R in this unit?

   ___ a. Never.

   ___ b. One month or less.

   ___ c. Between 1 and 3 months.

   ___ d. Between 3 and 6 months

   ___ e. Six months or more.

II. RATER'S KNOWLEDGE OF TECHNICIAN

1. In the blanks in front of the statements below, indicate which of the ways you have knowledge of this man. Check as many as are appropriate.

Battery Commander	Technical Supervisor		
____	____	a.	I have virtually no knowledge of this man.
____	____	b.	I have known this man during a previous assignment.
____	____	c.	I have supervised this man on his present job.
____	____	d.	I have not directly supervised, but I have had opportunity to observe this man on his present job.
____	____	e.	I know this man because of disciplinary action taken against him.
____	____	f.	I knew this man as a student at the Air Defense School.
____	____	g.	I know this man largely through what I have heard about him from others.
____	____	h.	Other, explain ______________________________

NOTE: If either of you checked Item (a) in the preceding question, obtain the Name, Rank, and Serial Number of your predecessor in your present duty position from the Battalion Personnel Officer. Complete the item below with this information, and complete as much of the questionnaire as possible.

Name ______________________________

Rank ______________________________

Sr. No. ______________________________

III. PERSONAL CHARACTERISTICS OF TECHNICIAN

The following questions pertain to the individual's characteristics other than technical competencies. To describe this man, place a check mark before the lettered item which in your combined judgment best completes the lead statement.

1. Relations with other enlisted men

   ____ Cannot evaluate this characteristic.

   This man gets along with other EM:

   ____ a. very poorly; he is not generally liked.

   ____ b. more poorly than the average soldier.

   ____ c. about as well as the average soldier.

   ____ d. better than the average soldier does.

   ____ e. extremely well; he is very well liked.

2. Relations with superiors

   ____ Cannot evaluate this characteristic.

   This man's relationships with his superiors:

   ____ a. leave much to be desired; he is a constant source of problems.

   ____ b. leave something to be desired; he occasionally causes problems.

   ____ c. are typical of superior-subordinate relationships in the Army.

   ____ d. are good; he is considered a good soldier by his superiors.

   ____ e. are excellent; he is the kind of man his superiors are proud to have serving.

3. Job motivation

   ____ Cannot evaluate this characteristic.

   When faced with difficulties in any task, this man:

   ____ a. gives up much too easily.

   ____ b. frequently gives up before he should.

   ____ c. has about average persistence.

   ____ d. sticks to the job longer than most.

   ____ e. persistently tries to complete the job by himself even though he reaches a point at which he should call for help.

IV. DISCIPLINARY RECORD

1. Has this man been disciplined for any of the following reasons during the past six months? (Check as many as are appropriate.)

____Have no relevant knowledge.

____ a. AWOL.

____ b. Drunkenness.

____ c. Fighting.

____ d. Negligent destruction of government property.

____ e. Illegal use or sale of government property.

____ f. Theft.

____ g. Other, explain ____

____

V. ROUTINE CHECKS AND ADJUSTMENTS

In the following, place a check mark in the blank following the lettered statement which provides the best answer to the preceding question concerning *each* of the major items of equipment.

1. After being assigned to any item of equipment, how long was it before this technician was able to perform *DAILY* checks satisfactorily?

	CWAR	HPIR	AFCC
Technician was never assigned to this item			
Neither rater had opportunity to observe			
a. Less than 2 weeks			
b. Between 2 weeks and one month			
c. Between 1 and 3 months			
d. Between 3 and 6 months			
e. 6 months or more			

2. Before this technician was able to do *DAILY* checks satisfactorily, what problems did he have? (Check as many as are applicable)

	CWAR	HPIR	AFCC
Technician was never assigned to this item			
Neither rater had opportunity to observe			
a. Technician was too slow			
b. Technician was too inaccurate			
c. Technician did not observe safety precautions			
d. Other, explain below			

(Explanations) ____________________

____

____

____

3. After being assigned to any item of equipment, how long was it before this technician was able to perform *WEEKLY* checks satisfactorily?

	CWAR	HPIR	AFCC
Technician was never assigned to this item			
Neither rater had opportunity to observe			
a. Less than 2 weeks			
b. Between 2 weeks and one month			
c. Between 1 and 3 months			
d. Between 3 and 6 months			
e. 6 months or more			

4. Before this technician was able to do *WEEKLY* checks satisfactorily, what problems did he have? (Check as many as are applicable)

	CWAR	HPIR	AFCC
Technician was never assigned to this item			
Neither rater had opportunity to observe			
a. Technician was too slow			
b. Technician was too inaccurate			
c. Technician did not observe safety precautions			
d. Other, explain below			

(Explanations) ____

____

____

____

VI. TROUBLESHOOTING

Complete the following:

A. CWAR

1. How frequently does this technician perform troubleshooting on the CWAR?

   ___ a. Almost never.

   ___ b. Occasionally.

   ___ c. Routinely.

NOTE: If choice (a) was checked in the preceding question, omit questions 2, 3, and 4, and go directly to Part B. HPIR. If choices (b) or (c) were checked, answer questions 2, 3, and 4.

2. Rate the technician's knowledge or proficiency in troubleshooting the CWAR in the following areas. (Take experience into account, and check as many as are appropriate)

	Superior	Above Average	Average	Below Average	Inferior
a. Ability to locate piece-parts	___	___	___	___	___
b. Use of Oscilloscope	___	___	___	___	___
c. Use of Multimeter	___	___	___	___	___
d. Use of special test equipment	___	___	___	___	___
e. Use of schmatics and functional diagrams	___	___	___	___	___

3. Which of the following best describes this technician while troubleshooting the CWAR? (Take experience into account)

   ____ a. Is both slow and inaccurate in diagnosing malfunctions.

   ____ b. Works at acceptable rate, but is too inaccurate.

   ____ c. Is reasonably accurate, but is too slow.

   ____ d. Is satisfactory in both speed and accuracy.

   ____ e. Is superior in both speed and accuracy.

4. In the blanks below, indicate the technician's level of proficiency in troubleshooting the CWAR.

	To the Chassis	To the Piece-Part	Wiring and Cable Malfunctions
No opportunity to observe	____	____	____
a. Very poor	____	____	____
b. Below Average	____	____	____
c. Average	____	____	____
d. Above Average	____	____	____
e. Excellent	____	____	____

B. HPIR

1. How frequently does this technician perform troubleshooting on the HPIR?

   ____ a. Almost never.

   ____ b. Occasionally.

   ____ c. Routinely.

NOTE: If choice (a) was checked in the preceding question, omit questions 2, 3, and 4, and go directly to Part C. AFCC. If choices (b) or (c) were checked, answer questions 2, 3, and 4.

2. Rate the technician's knowledge or proficiency in troubleshooting the HPIR in the following areas. (Take experience into account, and check as many as are appropriate)

	Superior	Above Average	Average	Below Average	Inferior
a. Ability to locate piece-parts	____	____	____	____	____
b. Use of Oscilloscope	____	____	____	____	____
c. Use of Multimeter	____	____	____	____	____
d. Use of special test equipment	____	____	____	____	____
e. Use of schematics and functional diagrams	____	____	____	____	____

3. Which of the following best describes this technician while troubleshooting the HPIR? (Take experience into account)

____ a. Is both slow and inaccurate in diagnosing malfunctions.

____ b. Works at acceptable rate, but is too inaccurate.

____ c. Is reasonably accurate, but is too slow.

____ d. Is satisfactory in both speed and accuracy.

____ e. Is superior in both speed and accuracy.

4. In the blanks below, indicate the technician's level of proficiency in troubleshooting the HPIR.

	To the Chassis	To the Piece-Part	Wiring and Cable Malfunctions
No opportunity to observe	____	____	____
a. Very poor	____	____	____
b. Below Average	____	____	____
c. Average	____	____	____
d. Above Average	____	____	____
e. Excellent	____	____	____

C. AFCC

1. How frequently does this technician perform troubleshooting on the AFCC?

   ___ a. Almost never.

   ___ b. Occasionally.

   ___ c. Routinely.

NOTE: If choice (a) was checked in the preceding question, omit questions 2, 3, and 4, and go directly to Part D. If choices (b) or (c) were checked, answer questions 2, 3, and 4.

2. Rate the technician's knowledge or proficiency in troubleshooting the AFCC in the following areas. (Take experience into account, and check as many as are appropriate)

	Superior	Above Average	Average	Below Average	Inferior
a. Ability to locate piece-parts	___	___	___	___	___
b. Use of Oscilloscope	___	___	___	___	___
c. Use of Multimeter	___	___	___	___	___
d. Use of special test equipment	___	___	___	___	___
e. Use of schematics and functional diagrams	___	___	___	___	___

3. Which of the following best describes this technician while troubleshooting the AFCC? (Take experience into account)

   ___ a. Is both slow and inaccurate in diagnosing malfunctions.

   ___ b. Works at acceptable rate, but is too inaccurate.

   ___ c. Is reasonably accurate, but is too slow.

   ___ d. Is satisfactory in both speed and accuracy.

   ___ e. Is superior in both speed and accuracy.

4. In the blanks below, indicate the technician's level of proficiency in troubleshooting the AFCC.

	To the Chassis	To the Piece-Part	Wiring and Cable Malfunctions
No opportunity to observe	___	___	___
a. Very poor	___	___	___
b. Below Average	___	___	___
c. Average	___	___	___
d. Above Average	___	___	___
e. Excellent	___	___	___

D. System Malfunction

1. When equipment malfunction occurs somewhere in the Battery, how proficient is this technician in isolating the malfunction to a major piece of equipment, such as the CWAR, BCC, or interconnecting cables?

   ____ Question not applicable to this technician

   ____ No opportunity to observe

   ____ a. Very poor proficiency

   ____ b. Below average proficiency

   ____ c. Average proficiency

   ____ d. Above average proficiency

   ____ e. Excellent proficiency

2. Does this man maintain or help maintain any equipment other than the CWAR, HPIR, and AFCC?

   ____ a. Yes, the ______________________________

   ____ b. No (omit next question)

3. What does this technician do on equipment other than the CWAR, HPIR, and AFCC? (Check as many as are appropriate)

   ____ a. Daily and/or weekly checks.

   ____ b. Troubleshooting.

   ____ c. Serves as an aid to another technician.

VII. TECHNICAL KNOWLEDGE

For each of the areas outlined below, indicate the technician's general level of capability or knowledge by checking the appropriate blank. Take experience into account.

_______ Cannot rate these characteristics

1. General or theoretical knowledge of equipment function

	System	CWAR	HPIR	AFCC
a. Not applicable or don't know	____	____	____	____
b. Very poor	____	____	____	____
c. Below Average	____	____	____	____
d. Average	____	____	____	____
e. Above Average	____	____	____	____
f. Excellent	____	____	____	____

2. Understanding function of electronic circuits

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

3. Understanding function of piece-parts

_____ No opportunity to observe.

___ a. Very poor understanding

___ b. Average understanding

___ c. Very good understanding

4. Use of schematic and functional diagrams

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

5. General understanding of electronics

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

6. Technical vocabulary (knowledge of fundamental electrical and electronic terms)

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

7. Communication skills (ability to discuss equipment function and malfunction with other men and superiors)

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

8. Knowledge of maintenance and supply procedures

_____ No opportunity to observe.

___ a. Very poor

___ b. Below average

___ c. Average

___ d. Above average

___ e. Excellent

If you have any additional comments to make concerning this technician, please write them in the section below.

____

____

____

____

When you have completed this questionnaire, return it to your Battalion Commander.

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13. ABSTRACT

In recent years the Army has experienced unacceptably high student failure rates in its electronics training programs. An experimental program was developed for training HAWK Continuous Wave Radar Mechanics, emphasizing the learning of specific sets of procedures for troubleshooting the radar. Three classes were given the experimental training over a two-year period, and were compared with contemporary conventionally trained classes. In each comparison, the experimental program's attrition levels were as low as or lower than conventional classes, and end-of-course performance was equal to or slightly superior to that of conventionally trained graduates.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Functional Context Training						
Functional Training						
Hawk Radar Maintenance						
Radar Technicians						
Troubleshooting Manuals						

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