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A STUDY OF TRAINING PROGRAM IMPROVEMENTS

Volume II: Recommendations for Improvement

February 1972

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16. Abstract

An analysis was made of the Federal Aviation Administration's Air Navigation Facilities Maintenance Training Program. The analysis included: (a) study of the overall training philosophy; (b) comparison of specific instructional activities with the kinds of instructional activities that should be carried on in order to meet the training outcomes required by maintenance concepts; (c) study of the criteria and standards governing the purchase and installation of equipment at the Academy for maintenance training purposes; (d) evaluation of the effectiveness of various teaching methods used to produce the training outcomes required in courses. Documents on the training system were collected and, where documentation was not appropriate for the collection of information, data collection instruments were constructed for the purpose of assessing the adequacy of the instructional system. Conclusions and detailed recommendations pertaining to the improvement of the training program are made.

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PREFACE

This is Volume II of a two-volume report describing the analysis of the Federal Aviation Administration's Air Navigation Facilities Maintenance Training Program. Volume I consists of specific objectives of the study, methods of procedure, and presents conclusions pertaining to areas where the training program can be improved. ~~The present~~ This volume presents the recommendations for improvement and describes basic implementation plans, costs, and schedules which are associated with the recommended improvements.

The work described in this volume of the report was performed by the Human Resources Research Organization (HumRRO), Division No. 1 (System Operations), Alexandria, Virginia, Dr. J. Daniel Lyons, Director, under the sponsorship of the Federal Aviation Administration (Contract No. DOT FA 71 WA-2687). Dr. Alan G. Hundt was Principal Investigator, Mr. Robert C. Trexler was Program Manager and Senior Staff Scientist assigned to the project, and Mr. P.J. Butler, Research Scientist, participated fully in the preparation of the recommendations and the implementation plans.

PROBLEM

A comprehensive examination of the Air Navigation Facilities (ANF) Maintenance Training Branch's program was undertaken by the Human Resources Research Organization (HumRRO) under an award by the Federal Aviation Administration (FAA) (Contract No. DOT FA71 WA-2687). As a consequence of the study, recommendations were to be developed as well as implementation plans, possible costs, and schedules.

SUMMARY

The purpose of the study of the ANF Maintenance Training Program was twofold. First, a comprehensive study was undertaken to determine areas where the program could be improved in its effectiveness and in its costs. Secondly, recommendations were constructed based on the study and a plan was devised to implement the recommendations for improvement in the training program.

SPECIFIC OBJECTIVES

The first requirement was the development of specific recommendations based on the findings presented in Volume I of this report. This was performed by extracting all findings that indicated areas for improvement.

Next, the recommendations were grouped according to the specificity of the area recommended for improvement. If the recommendation pointed to a problem which basically was indigenous to the ANF Training Branch, it was set aside for presentation and discussion in the section dealing with specific recommendations for the Branch itself. If it was determined that the improvement required a revision of the FAA's overall approach to ANF maintenance training, the recommendation and related material were set aside for presentation and discussion along with other programmatic recommendations.

The third task was the construction of plans for the implementation of recommended changes in the FAA program and the ANF Branch's specific activities. Where it was possible to do so, approximations of the amount of manpower or resources necessary to implement the recommendations were also given. Such manpower figures and costs should be taken with reservations because of the differences in costs that could arise, depending upon decisions related to the implementation of the recommendations, and the FAA's evaluation of the scope of improvements that should be undertaken.

METHODS OF PROCEDURE

The general procedure was to develop the recommendations from analysis of the comprehensive study performed by HumRRO. Secondly, practical principles of modern training technology and education were utilized to define solutions to many of the areas requiring improvement, and to generate the estimates of implementation costs. All efforts were directed toward the development of recommendations and plans which were specifically suited to the FAA's needs.

RECOMMENDATIONS

The recommendations, implementation plans, costs, and priorities are detailed in the following sections. In general, they fall into two major categories:

(1) Recommendations that are programmatic and require a reorientation of the maintenance training program toward the requirements of the maintenance task itself. These include the development of basic documentation which defines the maintenance tasks, the job requirements, job performance standards, and training course objectives. A quality control program is an essential ingredient of the training and operational system. Considerable improvements in the present quality control system were recognized as necessary and specific recommendations for developing and implementing a quality control system were presented.

It was recommended that model training courses be developed in several content areas, along with documentation and procedures designed to control the quality of instruction. It was emphasized that in-depth involvement of FAA Academy and other personnel would be essential in the development of model programs and the quality control system. Without such involvement, the utilization of the models and the development of other courses by FAA personnel would be seriously compromised.

(2) Recommendations that pertain to areas for improvement that were primarily restricted to activities performed within the ANF Maintenance Training Branch itself. While many of these recommendations for improvement are related to the programmatic changes that are recommended, it is still true in most cases that considerable improvement can be effected in some areas by measures that can be taken solely by ANF personnel. This is not intended to mean that all of the problem areas which have been defined exist because of failures in the ANF Branch itself. Rather, it is a presentation of steps that can be taken at the local level to improve the training program, which are consistent with any programmatic changes that may be instituted. For the most part, they can proceed to be implemented in advance of the programmatic changes. Consequently, *immediate improvement in the program* can be realized in many areas by adopting a number of important corrective measures.

Because the present contractor was required to present costs as part of the implementation plan, estimates were given where appropriate. This occurs where it was found that the FAA has options on how they may wish to allocate their resources. This happens primarily in areas where extensive programmatic changes were recommended. In such instances, manpower requirements were estimated for the performance of the work by non-FAA organizations as specified by the contract. The use of non-FAA personnel to perform such work would require collaboration with FAA personnel. Consequently, the implementation plan describes adjustments that should be made in the event the recommendations are not directly implemented by FAA.

The presentation of costs and adjustments in the implementation plans should not be construed as a recommendation that the work should be performed by non-FAA personnel. The information is presented to satisfy a specific contractual requirement. When use of a contractor is recommended as an alternative, it should not be construed that the present contractor is being recommended.

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A STUDY OF TRAINING PROGRAM IMPROVEMENTS

Volume II: Recommendations for Improvement

Chapter 1

PROGRAMMATIC RECOMMENDATIONS

The major programmatic effort the FAA should undertake to improve ANF technician training is to ensure that the training adequately reflects job requirements.

Two related activities should be given immediate priority to achieve this objective. First, job requirements need to be determined. Second, training programs should be constructed to take into account job requirements information. Other facets of curriculum engineering[1] should be developed within the structure of the ANF Branch.

Job requirements information would need to be gathered for any course selected for revision. However, because of the effort the collection of such data entails, it would not be advisable for the FAA to initiate a large-scale, wholesale project to collect it for all ANF courses at once. Consequently, the first project to undertake would be the determination of the relative priorities among the courses in terms of revision. Once this listing has been prepared, the collection of job requirements information can proceed in a rational and cost-effective manner.

The development of an in-house capability to apply modern curriculum engineering technology can be undertaken simultaneously with the determination of priorities for course revision. This can be done by revising one course in each of the five career fields within the ANF Branch to provide a model for the courses in each career field. Participation of ANF staff in the development process would result in their in-depth appreciation of the method and insure their ability to continue with the process.

Although, in the interest of making timely improvements, it may seem desirable to wait until course revision priorities have been established, it is imperative to make a start on development of the in-house capability immediately, even though the findings of the course revision priority study may indicate the courses under revision are of relatively low priority. It is recommended that the courses to be used as models to demonstrate the methods of curriculum engineering be selected from among those of the present study, in order to take advantage of the systematic analyses already performed on them.

PRIORITY RANKING OF COURSES FOR REVISION

Considering the number of courses ANF currently conducts, analytical methods must be employed to identify those courses which should undergo revision. First, it would be wasteful to direct the ANF Branch to simultaneously conduct job analyses and performance standards determinations for all courses. Some courses may be on their way to extinction, while others may deal with equipments that have a relatively low operational criticality. Consequently, the following recommendation is made.

[1] Curriculum engineering, as used here, indicates a systematic and orderly process for the determination, design, development, and evaluation of training curricula to prepare and enable personnel to perform their assigned jobs. In this context, curriculum engineering is considered to be a more inclusive term than curriculum development in that the engineering of a training curriculum involves the determination, design, and evaluation processes as well as the development process.

RECOMMENDED ACTION

Current ANF equipment-specific training programs should be surveyed to determine the relative priority of revising them.

Two products would result from the survey: (a) the list of courses in their recommended order for revision, and (b) job data upon which to base the selection of the means for performing Job Analyses.

To rank order courses for revision, specific criteria must be established. The courses' relative priority for revision should certainly take cognizance of the number of students involved and certain cost tradeoffs. The selection, definition, and weighting for the criteria should be determined by the FAA or can be a joint effort of a contractor and FAA officials. Consideration would be given to both the job and the individual training programs required to meet the job requirements.

Certain kinds of job information would be collected for use in establishing criteria, for example: individual training programs involved and their sequence; methods used in individual training programs; length and cost of individual training programs, and student loads.

The length of the training programs and the methods involved can be identified from the course catalog. Course control documents with their related Instructor Guides would be needed for a more detailed study of the programs and methods. The cost of individual training programs could be obtained from Training Plans.

IMPLEMENTATION

This study should commence at the earliest possible date, as it provides a rational basis for ordering the course revision process.

It is estimated that the survey would require approximately six man-months of effort. This figure could vary plus or minus 50% depending on a more precise definition of the scope of effort. It would result in a report describing the methods, findings, results (the ranking in time sequence), and the rationale for the rankings.

A MODEL FOR CURRICULUM DEVELOPMENT

One way for the FAA to acquire additional knowledge of effective methods of improving their instructural system would be for curriculum developers to obtain, study, and apply the guidance presently available in related published documentations. For example, the U.S. Army Continental Army Command (CONARC) Regulation 350-100-1[1] provides guidance for course design, and *The Engineering of Educational and Training Systems*[2] describes methods and techniques for design and implementation of effective systems.

As an alternative, an effective way to transfer the necessary skills and knowledges to curriculum developers is through the use of a model or demonstration project. Although it would be possible to revise an existing equipment course without involving course development personnel, it would not be wise to do so. First, since these personnel would not have participated in the application of the methods or the construction of materials, they would not have the experience in these activities or the appreciation for the benefits

[1] U.S. Continental Army Command (CONARC). *Systems Engineering of Training*, Regulation 350-100-1, February 1968.

[2] Robert G. Smith. *The Engineering of Educational and Training Systems*, Lexington, Mass., D.C. Heath, 1971.

of applying the model. Second, the construction of an effective training program entails not only the application of knowledge of curriculum engineering, but also substantial expertise in the technical content of the program to be constructed.

While the contractor must develop some level of expertise in the content, the overall expense would be far less if FAA personnel were to collaborate with a contractor. Thus, in the interests of timely implementation of program revision, it would be highly desirable to make use of the content expertise already available in the instructional staff. A joint effort among the contractor, the present instructional staff, and other FAA organizational elements is believed to be the most effective and time-saving method to employ in developing the capability specifically needed to revise existing equipment-specific training programs.

While the methods to be employed are quite general, applying them to the solution of specific training problems requires considerable judgment. For example, it is possible that differences between the class of equipments in the communications career field and the class of equipments in the data processing field will require somewhat different approaches to the application of the methods. In addition, since the ANF branch is organized for the conduct and administration of training along career field lines, it would appear desirable for each section to participate in a model course revision exercise. That is, one course from each of the five career fields would be selected for revision, and one or more content experts from each of the presently conducted courses would participate in the modeling process.

In summary, the rationale for selecting one course from each career field is that (a) as a sample they provide an adequate basis for demonstrating the basic process for implementing the recommendations; (b) limiting the implementation to five courses would afford the opportunity for a "faster fix" on the areas of training to be improved; (c) courses from each career field would be necessary to fully represent the total training system because of expected differences in personnel, equipment, technical language, job requirements, and so forth, in the various career fields.

The net result of the process would be one new course in each of the career fields, and a core of experienced curriculum developers in each section who could then be employed to administer and participate in the revision of additional courses within their own sections. This cadre would then teach others how to employ the methods in the context of revising other courses. In this way, the technology could be transferred within ANF and its own in-house capability be developed. Once the five courses were operational, the contractor's role would convert into a consulting one as a means of ensuring that the curriculum engineering methods are effectively utilized by cadre. Spot checking course development on a consulting basis would be appropriate.

RECOMMENDED ACTION

Development of ANF Branch in-house capability to apply curriculum engineering technology should be undertaken immediately through application of the technology to a "model" course from each of the five career fields.

PLAN DETAILS, METHODS, AND PRODUCTS

The approach to be used would be to re-engineer a sub-set of the 10 courses evaluated in this study. The principal advantage of this approach is that a lesser effort would be required because of the familiarity with job content and training program methodology gained as the result of the work performed on the 10 courses and presented in Volume I of this report.

It is proposed that the recommended changes be implemented and the training systems engineering process be demonstrated in the following courses in the five career areas:

Course	Career Field
ATCBI - No. 40317	Radar
Diesel Engine Generator - No. 40103	Electromechanical
9020 CCC for Technician - No. 43413	Data Processing
Wilcox Mark I ILS - No. 40216	Navigational Aids
VHF/UHF Direction Finder - No. 40210	Communications

Assuming these courses have been selected, the following eight steps would then be applied to each.

Step 1: Select a Set of Jobs from Each Career Field for Analysis

Method: With the selection of a particular course within a career field (for example ATCBI-3 in the Radar field) the next step will be to select a set of jobs within that field for analysis. Each job selected would involve maintenance responsibilities for the equipment taught in the course selected. However, these jobs will likely involve responsibilities for maintenance of other equipments as well. The jobs selected for analysis will be representative of all such jobs involving maintenance of the equipment taught in the course selected.

Job analysis (Step 2) requires identification of the specific jobs to analyze. Job data in Step 1 must be collected in order to identify and select a sample of individual jobs for analysis which would adequately reflect the maintenance requirements of the equipment in the course selected. In addition, the job data will be used to select the means for performing the job analysis.

Step 2: Perform Job Analysis

Training must be responsive to the requirements of the job. A key element in constructing a training program that reflects job requirements is the analysis of the job itself.

The work that a technician performs in a particular job is determined by the specific job position. If a given number of equipments are purchased for installation at operational sites which have the same design and configuration, the maintenance tasks imposed by the equipment itself should be the same with respect to site location.

From a technical point of view, the quality of circuit and equipment operation should also be unchanged from site to site. The required signal levels and their tolerances for circuits within the equipment should be known and standard for all systems of like type. In addition, the time required for journeymen technicians to perform the necessary checks, adjustments, alignments, and so forth, with specification of accuracy of performance, can also be determined, standard, and a joint function of constraints imposed by the hardware, and average journeyman capabilities.

The performance quality exhibited by the journeyman technician, certified to maintain a given equipment, in general, exceeds that attained in formal training. That is, journeyman level performance is only fully attained after some period of performance on the job. As a consequence, journeyman standards of performance must be determined. From these, entry level performance standards must be derived which can then be used as standards to direct resident training.

Method. Based upon consideration of the job data collected in Step 1, a determination would be made of the most economical and effective means for collection and compilation of the job/task data required. Then, using basic job and task analytical methods, the job performances required and standards to be met would be identified and described. This effort would be limited to maintenance requirements imposed by the specific end items of equipment associated with the job.

Products

(1) An inventory of the maintenance tasks to be performed and the minimum acceptable standard of performance for each task. The inventories would be organized and identifiable separately for each equipment end item involved.

(2) Those tasks identified as requirements for the training program selected from each job would be described in detail. The description would provide identification of each step required for performance of the task in terms of the action to be taken, the object to be manipulated, and the means for determining the step was performed correctly. Also included would be identification of significant features of the work environment associated with task performance—that is, tools and test equipment, special clothing or protective apparel required, and significant environmental conditions and an estimate of task criticality.

The results of the job analysis would be used to implement Step 3.

Step 3: Select Means of Training

Method. The next step would be to determine, on the basis of the individual tasks, the most efficient means, or combination means, of training. Means of training considered would include resident, formal OJT, and directed study. The selection process would involve evaluation of the tasks against the following criteria:

(1) Task criticality
(2) Task similarity to other tasks in the inventory
(3) Resource requirements and availability for the means considered
(4) Relative time required to attain proficiency
(5) Time available to develop proficiency
(6) Number of personnel to be trained
(7) The extent to which field maintenance documentation supports and guides task performance
(8) Whether a prerequisite ability for task performance already exists in trainee population
(9) Training media requirements and their relative appropriateness to the means considered

Products

(1) For each task appearing on the inventory, the identification of the means of training to be used and the level of proficiency to be attained.

(2) Identification of the terminal behavioral objectives to be achieved by each means of training selected.

(3) The data and information derived from the above analysis would serve as the data base for Step 4.

Step 4: Perform Analysis of Training Requirements

Method. Execution of this step would involve four sub-steps: (a) identification of the skills, knowledges, and attitudes required for successful task performance; (b) conversion of terminal performance objectives to training course objectives and criteria; (c) development of the course structure; and (d) development of a concept for evaluating the course. The detailed task data and work environment information developed under

Step 2 would be analyzed to identify the knowledges, skills, and attitudes which support task performance. The identified supporting knowledges and skills for a task and the job performance standards and work conditions for that task would be analyzed and converted into training course objectives.

Each training objective would specify what the student must be able to do, the training conditions under which student action would be observed and the acceptable level of performance to be achieved. A criterion for each training objective would be developed. The criterion would be derived from the training objective and be of the same format and type of information contained in the training objective. The criterion would state the student performances required for the training objective to be successfully accomplished.

Under sub-step 3, the supporting knowledges and skills and the related training objectives would be analyzed to determine an effective sequence of course instruction. The derivation of the course structure, the resulting instruction, the sequencing of material would be developed to directly reflect the performance of job tasks. The final sub-step would involve determination of the most appropriate testing schedule for evaluation of student achievement of course objectives. The schedule would identify the specific test points within the general sequence of course instruction and specify the course content upon which student achievement would be evaluated.

Products

(1) The specification of the skills, knowledges, and attitudes to be developed during training.

(2) A list of the course training objectives and criterion for determining student achievement of the objectives.

(3) A basic structure of the training course.

(4) A schedule for assessing student achievement of the training objectives.

Step 5: Develop Training Materials

Method. The data derived from the training analysis (Step 4) would be analyzed to identify specific aspects of the supporting skills and knowledges which should be taught for the student to accomplish the training objective. This analysis and the final selection of course content would be based upon consideration of the characteristics and abilities of the trainees and personnel to serve as instructors.

The instructional aspects or points would then be examined to derive and establish an effective sequence of instruction. Pertinent information source and reference materials would be identified for each instructional point. These materials would be used in developing most of the total content for the instructional points.

The selection of the method of instruction to be used would be based upon consideration of what the student must do to satisfy the training objective and the relative cost and effectiveness of alternative methods for facilitating the instruction to be accomplished. The method or combination of methods selected would be identified for each instructional point. The methods of instruction selected and the instruction to be presented would be examined to identify the training media, aids, and equipment required for the course. The selection process would give consideration to their relative effectiveness in supporting thy method of instruction, their relative cost, and the demands they would place upon the existing training facilities.

After estimating the amount of time required for the instructional points, the training objectives would be grouped into lesson units and the time required to present each lesson would be estimated. The previously derived information on each lesson would be used to develop a lesson plan or guide of a standardized format and content. Other course control documents to be developed would include a program of instruction (POI) and training schedule.

Requirements for training manuals, student handouts, and other types of training literature would be identified. The design and content of these materials would be selected to provide maximum support to student learning and achievement of the course training objectives.

Products

(1) Course lesson plans, program of instruction and training schedule.
(2) Student handout materials.
(3) Training manuals and similar literature.
(4) Training media and aids requirements.
(5) Training equipment or simulator requirements.

Step 6: Develop Course Testing Materials

The tentative testing schedule developed in Step 4 would provide the basic framework for this development effort. Each training objective would be examined to identify the specific aspects to be tested. Alternate versions of the training objectives would be identified for testing purposes and a plan for sampling as many of these variations as possible would be developed. A training objective concerning troubleshooting, for example, could have numerous different versions for testing purposes.

The basic purpose of the tests to be developed would be the evaluation of student achievement of the specified training objectives. They would be performance oriented and directed toward assessment of the total task performance rather than individual task components.

The test construction effort would place heavy emphasis upon test realism in terms of job requirements in the field, objectivity in test administration and scoring, comprehensiveness in coverage of all training objectives and the utility of testing results for controlling the quality of training.

The job performance requirements from Step 2 and the training objectives would be analyzed to identify specific test program standards. These standards would establish the minimum standard of student performance on each training objective which would be acceptable when measured by the testing program. Sub-standard performance, as reflected by the testing program, would indicate the need for improvement in the quality of the training. Each standard would specify the task to be performed, the conditions under which the student should perform the task, and the number of correct responses required. In addition, written procedures would be prepared for the administration and scoring of the tests developed.

The final step in development of testing materials would be to check the validity of the tests and to identify difficulties associated with test administration from the viewpoint of both the instructor and student.

Throughout this development effort, consideration will be given to the time, effort, and resources required to accomplish the testing proposed and suitable compromises will be identified and examined.

Products

(1) A complete set of testing materials to include alternate versions of the same test or test item.
(2) Test standards.
(3) A testing schedule.
(4) Written procedures for administration and scoring of tests.
(5) Identification of the test or test items to be used in measuring achievement of each training objective.

Step 7: Develop Training Quality Control System

Method. In terms of scheduling the various steps in the system engineering process, this step can be initiated shortly after Step 5 is completed, and can be executed concurrently with Step 6. This would be possible because different groups of personnel will be involved in Steps 6 and 7.

The prime purpose of the quality control system will be to continually assure that the product of training (the trainee) can meet the entry level requirements of the job and that the means employed by the training system in producing this product are cost-effective. Organizationally, the quality control staff should be free from direct supervision from those organizational elements responsible for the development, conduct, and administration of the training to be controlled.

Inasmuch as a number of the elements in a quality control system are known to presently exist at the Academy, discussion of the execution of this step will be limited to those quality control features pertinent to the recommendations of this study and found to be absent.

The effectiveness of any training quality control system is dependent upon the extent to which training adjustments and changes are based upon empirical data rather than opinions or judgments. The proposed implementation plan calls for the development of tests and procedures for a more objective evaluation of the effectiveness and quality of training programs. The first type of test to be developed would be one for monitoring the effectiveness of training. The key characteristics of these tests will be that (a) they will measure the student's ability and proficiency on total tasks, (b) they will be based upon and reflect course training objectives, and (c) they will be scored on a pass-fail basis. The emphasis will be on measurement of what the student is able to do.

A second type of tests will be developed to identify and determine the cause of training ineffectiveness. They would be diagnostic in purpose and would be used to determine why students failed to meet the criterion for given training objectives. They would measure the student's ability on the skills and knowledge components of a task and provide data for identifying the instructional content contributing to the observed failure. An effort would be made to check the reliability and validity of the tests developed. Procedures will be prepared for the administration and scoring of these tests and the interpretation of results.

Products

(1) Testing materials and procedures for monitoring the quality of training.

(2) Testing materials and procedures for diagnosis of instructional difficulties and instances of training ineffectiveness.

(3) Procedures to provide a continual flow of job-oriented performance data upon which to base decisions for the improvement of training quality and effectiveness.

Step 8: Conduct, Evaluate, and Revise Re-engineered Training Courses

Method. The actual conduct of the training would be accomplished by the ANF instructional staff. However, all changes in training media, techniques, and methodology would be discussed by the contractor with course supervisory and instructor personnel. The purpose of the discussions would be to describe the rationale for the change and identify the requirements for successful implementation.

The evaluation effort would be accomplished by Academy personnel and would collect data to reflect upon two aspects of the revised course; (a) the effectiveness of the course in meeting its stated objectives and in producing personnel who can satisfy requirements of the job; and (b) the nature and extent of improvements realized from the implementation of recommended changes. Collaborative effort would be required to effectively specify the means of evaluation and criteria.

The results of the evaluation would be examined jointly to seek the means and methods for correcting identified course deficiencies and gaining additional improvements.

IMPLEMENTATION OF CHANGES

Active participation of ANF personnel will be required to achieve the goal of transferring the technology of curriculum development through the model restructuring of existing training programs. Although it is desirable to revise five courses simultaneously, it would be more efficient from a program point of view to phase the initiation of the particular course revision programs in time. The reason for this recommendation is that working relationships between any chosen contractor and ANF personnel must be developed, and administrative arrangements must be made for the allocation and execution of the required work. It seems wise to establish these arrangements while performing the work required for a single course rather than simultaneously for all five courses. This would take advantage of the possibility that the solutions derived for the first application might work for other courses, resulting in considerable savings.

It is recommended that Course No 40210 - VHF/UHF DF be selected as the initial course for revision, not because it is in any greater need than any other, but because it is relatively short (two weeks) and deals with an equipment that has no known modifications. Thus, the model could be developed quickly.

The following comments are indicative of the degree of involvement expected of ANF personnel in support of the revision effort as it is currently presented.

Step 1: Select a Set of Jobs From Each Career Field for Analysis. The job would be that required for the maintenance of the VHF/UHF DF. The objective of the task would be to acquire job information in order to select the most feasible method of performing the job analysis. This task would be executed by the contractor in consultation with a variety of FAA organizational elements. Once the means have been selected to perform the job analysis, the ANF instructor assigned to the project would begin his participation.

Step 2: Perform Job Analysis. Depending on the means selected, the instructor might be requested to draft a job analysis survey questionnaire; review and critique a questionnaire prepared by the contractor; visit selected operational sites to interview job holders in the company of the contractor for the purpose of developing, or trying out the questionnaire, or to collect job requirements information.

The instructor would be expected to organize the maintenance tasks identified into an inventory in a format prescribed by the contractor according to instructions provided. He would also prepare descriptions of each task identified as a training program requirement, collaboratively and interactively with contractor personnel.

Step 3: Select Means of Training. The assigned instructor would then participate in the determination of the most efficient means or combination of means of training and the level of proficiency to be attained in the individual tasks, according to specific criteria.

Step 4: Perform Analysis of Training Requirements. In this step the instructor would learn how to identify the skills, knowledges, and attitudes required for successful task performance, to convert terminal performance objectives to training course objectives and criteria, and to develop the course structure and would participate in the development of a concept for evaluating the course. Using the data base obtained earlier, the contractor would work closely with the instructor to ensure that he knows how to perform the required work.

Step 5: Develop Training Materials. The instructor's familiarity with the technical content would be utilized to assist in the identification of pertinent information sources and reference materials for each instructional outcome. His experience would also be called upon to estimate the amount of time required for an instructional outcome. He would also participate in the identification of training media, aids, and equipment, and in the preparation and review of course materials.

Step 6: Develop Course Testing Materials. Based on the work previously accomplished, the instructor would participate with the contractor in the development of course testing materials, to include checking the validity of the tests and examining administrative difficulties for both instructors and students. Since this latter activity would require the presence of equipment, it would be conducted at the Academy.

Step 7: Develop Training Quality Control System. The instructor's involvement in this step would be limited to a review and critique of the diagnostic tests developed by the contractor for the purpose of pinpointing deficient instruction.

Step 8: Conduct, Evaluate, and Revise Re-engineered Training Courses. The instructor who participated in the development program should conduct the first revised training program because he would know the materials thoroughly, and understand the goals and objectives of the revision. His experience in conducting the course would then be useful to him in performing the necessary revisions.

In summary, from the foregoing it is apparent that the program proposed would be thoroughly cooperative. It is only through this close working relationship that the techniques of curriculum development could be effectively developed and implemented in the ANF maintenance training context.

COSTS AND SCHEDULE

An estimate of manpower requirements has been prepared as required by terms of the present contract, based on the assumption that Course No. 40210 would be selected as the first to be revised and would be the course that could be used as a model for transferring the curriculum engineering technology to the Academy in the context of revising an existing program.

One may take present course length as a rough indicator of the relative magnitude of cost. That is not to say that a 36-week course would cost 18 times as much to revise as a 2-week course. Analysis of the job requirements and the consequent derivation of training requirements may well show that the 36-week program is too long by 16 weeks. In addition, it may well develop that a substantial portion of training materials presently in existence could be utilized with minor changes. The degree to which this may be the case can only be assessed in the light of information derived through the development of job requirements and related performance standards.

Table 1 is an analysis of the estimated professional man-days required to perform the work indicated for Steps 1 through 8 for the No. 40210 Course.

The figures cited in the table are not to be taken as final estimates, but rather as rough estimates of the manpower required to perform the work indicated. The actual figure could vary by as much as plus-or-minus 20%, and the costs would undoubtedly vary depending upon the contractor selected to perform the work.

PROCUREMENT POLICY

The location of equipment at the Academy is supposed to ensure that technicians can receive training which is sufficiently adequate to enable them to perform

Table 1

Man Days Required to Perform Work Indicated for Steps 1 Through 8 for Course No. 40210

Step	Task	Estimated Man-Days Required
1	Select Job Analysis Means	20[a]
2	Perform Job Analysis	40
3	Select Means of Training	10
4	Perform Analysis of Training Requirements	20
5	Develop Training Materials	40
6	Develop Testing Materials	25
7	Develop Quality Control System	35
8	Conduct, Evaluate and Revise Program	35
		225 man-days[b]

[a]This figure also includes time for program definition and start up.
[b]Estimated man-days required exclusive of FAA personnel participation.

maintenance functions at specific levels of performance when they report for duty at a field site. It is normally expected that training programs which utilize prime equipment at the Academy will provide the trainee with the basic information, skills, and procedures that he needs to further develop his competence as an ANF technician. How does the procurement process actually work? Is the prime equipment always necessary to achieve these goals? What would be an effective procurement policy for the ANF Training Program?

Examination of the present method for processing equipment has shown that it is an informal process. Although the data that were collected showed that substantial errors in procurement of equipment for training purposes have not occurred, the equipment problem grows increasingly more complex. A more fully documented equipment procurement procedure should be established.

The solution to the procurement problem depends as much upon exercising basic principles of modern technology as it does upon utilizing an artful and reasonable approach to the problem.

The definition of an equipment procurement policy requires three principal components: (a) a basic logic or rationale for procurement; (b) the definition and availability of certain kinds of data which pertain to each specific procurement problem; (c) the availability of knowledgeable and responsible people to activate the decision-making machinery.

A system employed by the U.S. Air Force since the early 1960s, described in Air Force Systems Command (AFSC) Manual 80-3,[1] obtains data from manufacturers during the early conceptualization and development phases of new equipment acquisition. Such data are used to develop a Training Equipment Planning Information report describing training equipment requirements well in advance of production of the equipment.

[1] Air Force Systems Command. *Handbook of Instruction for Aerospace Personnel Sub-Systems Design,* AFSC Manual 80-3, January 1966.

While present training technology does allow the computation of equipment costs amortized over specified benefit periods, effectiveness measures, and precise calculation of the answers to some problems, the basic procurement question and its answer are most usefully described in extremely straightforward terms.

Step 1. Early in the development of a procurement of operational equipment, the manufacturer and the Federal Aviation Administration should ensure that a detailed specification of the maintenance requirements for the device are defined. Considerable care should be taken to ensure that the requirements are specific, that they define the specific maintenance responsibilities of the individual technician, the levels of skills, amounts of knowledge, and procedures that the technician must have at his disposal to maintain the equipment effectively.

Step 2. Basic information developed during Step 1 should then be reexamined to determine the minimum job entry level performance standards that the system maintenance service will accept from a technician reporting on site for duty to maintain the new operational equipment. This re-examination of maintenance requirements is necessary in light of the very strong possibility that the field site may seldom require that the technician reporting for duty be able to perform maintenance at the same level as a more experienced technician. Therefore, the standards applied to the new technician may vary from those that he would be expected to meet after a period of time on the job.

The job entry level performance standards should be specified in terms of: (a) specific skills which the technician must have and which, necessarily, require practice on operational equipment; (b) maintenance procedures which he is to follow which do not require practice, but which are guided by job aids and ancillary information; (c) classroom knowledge which provides sufficient background for the technician to implement troubleshooting procedures, utilize job aids, and understand the application of maintenance skills.

Step 3. Specific training objectives and standards should be established based on the inventory of acceptable job entry level of performance standards. Training objectives or the specific training outcomes to be required would be basically the skill, procedure, and knowledge capabilities expected of the technician when he reports for duty on the site. That is, the training outcomes required or the training objectives should be nearly identical with the job entry level skill, procedures, and knowledge standards.

Step 4. The skill, knowledge, and procedures training outcomes or requirements which have been defined must then be compared with skill, knowledge, and procedures training outcomes presently established as objectives in existing courses in the ANF maintenance training program. This would require, for each procurement, a detailed examination of the maintenance requirements of the new operational equipment and its associated training requirements with the training requirements of existing courses.

If the examination were to reveal that maintenance of the new operational equipment does not require that a new skill is required for the technician to meet the job entry level standards, then there is seldom any justification for the addition of the operational equipment to the Academy's inventory. Instead, the additional knowledge and procedures that the technician should know which are peculiar to the equipment can be imparted through standard classroom procedures utilizing inexpensive mock-ups, films, photographs, and other inexpensive audio-visual materials.

If at least one new skill must be imparted to the technician, the nature of that skill must be examined. If the development of the skill requires that the entire operational system be available for troubleshooting practice, then the equipment should be procured for use at the Academy on either a long or short term basis, depending upon the training pipeline requirement. If development of the skill does not require that the entire operational system be available for troubleshooting practice, then a feasibility study should be undertaken to determine whether a part task trainer[1] can be procured at a cost which is substantially lower than that of the operational equipment. Since operational equipment located at the Academy for training purposes frequently is sent to the field after its training mission has been fulfilled, it would be unlikely, generally, that the procurement of a part task trainer would be cost beneficial. However, each case should be examined on its own merits.

IMPLEMENTATION OF THE PROCUREMENT POLICY

Should this detailed analysis be performed each time operational equipment is being procured? Is it really practical to spend resources to examine each procurement and to what level of detail should each procurement be examined?

The cost of the analysis that has been described might appear to be prohibitive. However, it should be recognized that nearly all of the information that has been outlined as necessary to implement the decision-making process is the same information that has been recommended as being vital for the specification of maintenance training courses. It has been previously recommended that Maintenance Concepts, Job Analyses, and related documentation must be generated in order to increase the cost-effectiveness of developing maintenance training courses or programs. Other than the additional requirement to examine the functional capabilities of existing equipment to see if they satisfy new requirements, no additional information, or information burden, would be imposed upon the FAA to provide the basis for its procurement decision making.

The final, basic consideration is timeliness. That is, the development of the Maintenance Concepts, job analyses, job entry level performance standards, specific training objectives and standards, must all begin in the conceptual stage of the procurement of the equipment. The information must be developed and refined as the procurement process itself proceeds and is refined.

The cost of implementing the procurement decision process is therefore shared with the cost of basic course definition. Actually, this is where the real savings in training resources can occur. The comparison of job skills, knowledges, and so forth, required by the new maintenance requirement with the skills, knowledges, and procedures which are already the subject of instruction at the Academy is basic. The comparison must be performed to determine whether or not courses should be established, their curriculum content, and ultimately the types of training devices which must be available to implement the training requirements.

The possibly erroneous decision to expend $100,000 to $200,000 for operational equipment for training purposes is of lesser significance than an erroneous decision to develop and maintain courses which need not be developed or which may be unnecessarily long. The costs of conducting unnecessary training in the long run can far exceed the cost of an operational equipment for training.

Consequently, it is recommended that this assessment be made part of the integrated study of the need for any new course and for the specification of its curriculum.

[1] A part-task trainer is "a device which permits selected aspects of a task to be practiced independently of other elements of the task. Its purpose is to provide economical training on certain elements requiring special practice which are not dependent on the total equipment; for example, the Malfunction Circuitry Trainer (MAC)."—AFSCM 80-3 Handbook of Instruction for Aerospace Personnel Subsystems Design.

QUALITY CONTROL OF TRAINING

The requirement for an improved Quality Control System has already been discussed in the context of curriculum development and elsewhere in the report. The purpose of this section is to present the general rationale for the establishment of an improved system, and, secondly, to describe a system that is appropriate to ANF Maintenance Training.

Rationale

It has been repeatedly stated that training programs must be tied to specific performance requirements with measurable standards. However, even when such programs have been constructed and are in use, they require periodic monitoring and adjustment. The most carefully engineered curriculum carries with it no guarantee of perfection. It is to be expected that the initial conduct of a course or program will reveal inadequacies. Some of these may be related to the students' inabilities to demonstrate mastery of tasks at specified training levels. Attention must be directed to determining why this has occurred, and corrective action must be taken to prevent its recurrence. The solution might be quite simple: Students should be given more time to develop the skill being tested, or, on further study, it might be found that insufficient time was used in developing the skills required for the execution of a related subtask.

Because the quality of the product—a trained technician—needs to be maintained, the quality of the training process needs to be controlled. The means by which the quality of the process is measured is through measuring the quality of the product. If the trainee cannot perform the task, the Quality Control System must examine those parts of the program that have been designed to teach him that task, and recommend changes based on additional diagnostic measurements.

It is also true that task mastery may be achieved at needless expense. The Quality Control System must examine not only situations in which trainees fail to perform to criteria, but also those in which trainees *always* master the task. While task mastery is the goal, closer examination of the process may show that task mastery can be achieved in less time than presently devoted to it. Thus, another function the Quality Control System can serve is to ensure that training is accomplished economically. The use of the system can be very effective in evaluating any proposal to modify a training course or program. If the rationale behind the proposed modification is a cost/beneficial improvement in a training course, quality control data on the current effectiveness of the course should be a part of the evidence supporting the recommended modification.

It is a general principle that the quality control function should be performed by personnel who are not involved in the process of producing the item being examined. Objective measurements and conclusions are more easily obtained by independent "inspectors."

The Evaluation and Standards staff (AC980) presently has a quality control function at the Academy. However, it is currently understaffed to assume the quality control activities required to effectively monitor and evaluate training programs. Consequently, were the Evaluation and Standards staff to be assigned the function of conducting diagnostic testing to determine where improvements need to be made, and to examine the effectiveness of improvements, its size should be increased considerably.

It is recommended that the FAA develop an improved Quality Control System. Figure 1 illustrates the essential components of the system. It must be noted that the system crosses many organizational lines and spans many areas of responsibility.

Data Flow Diagram Quality Control System

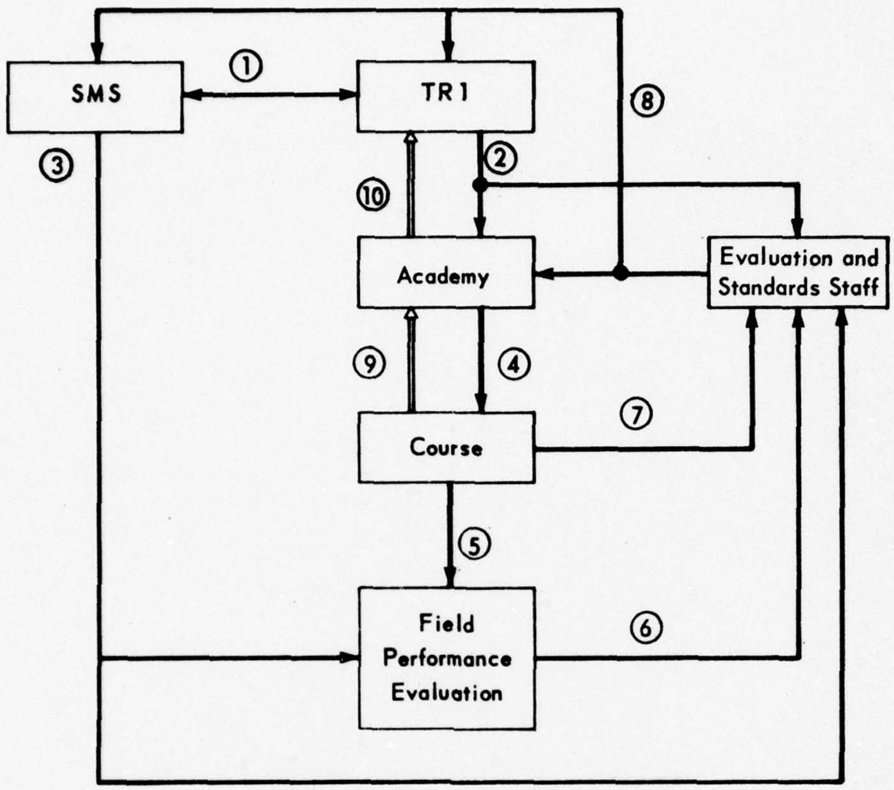

Figure 1

The system would be constructed and function in the following manner:

(1) SMS, in cooperation with TR1, determines both the job performance requirements and job entry level performance requirements.

(2) TR1 develops the training objectives and performance requirements and transmits them to the Academy and to the Evaluation and Standards staff for each course.

(3) SMS transmits job performance requirements and job entry level performance requirements to the field where trainees will ultimately be assigned, and to the Evaluation and Standards staff.

(4) The Academy transmits the training objectives and performance requirements information to the academic personnel responsible for course construction for their use.

(5) After the course has been conducted, trainees are returned to their field sites.

(6) Using the information supplied by SMS on job performance requirements, and job entry level performance requirements, field personnel evaluate the trainee after a short period on the job, and data are returned to the Evaluation and Standards staff for evaluation. Training Program Management Officers (TPMOs) should have a coordinating and consulting function.

(7) During the conduct of the training program, and at its conclusion, the Evaluation and Standards staff measures the trainee's ability to meet training objectives at required performance levels.

(8) The Evaluation and Standards staff reports results of evaluating training, and field performance to Academy, SMS, and TR1.

(9) Identified requirements for course revision are transmitted to Academy.

(10) Academy evaluates course revision request in terms of the Evaluation and Standards staff reports and transmits documented request for change to TR1.

Implementation

The improved structure can be established by cognizant authorities as soon as they decide that it meets the needs of the FAA. However, the information which is required to make the system meaningful must be developed in the context of redeveloping the curriculum as described elsewhere. Consequently, the major costs for establishing the system rest with the reorientation of the present course structure.

The establishment of the system concurrent with the revision of the curriculum is a high priority item. It will be a major tool to insure that the training product is cost/effective.

Chapter 2

ANF MAINTENANCE TRAINING BRANCH— SPECIFIC PROBLEMS, RECOMMENDATIONS, AND IMPLEMENTATION PLANS

There are fundamentally two kinds of recommendations that flow from the findings of this study. The first are programmatic, high priority, and of general system significance, and have already been discussed. The second recommendations are specific to the character and quality of the instructional system as it was observed and include items which can be remedied relatively quickly. Along with these, other recommendations that will take more time and effort, and some which should await the conduct of preparatory actions, are presented.

The form of the recommendation includes a brief statement introducing the recommendation in the context of the findings which led to it; a statement of the recommendation itself; and, finally, suggestions on how the recommendation can be implemented.

INSTRUCTIONAL SYSTEM

Visual Aids. From a study of Instructor Guides and other course materials, and from direct observation, it was found that increased utilization of audio-visual aids would *benefit the instructional process.*

Recommendations

(1) Inform instructors of availability of sources for additional visual aids. (See page 39)
(2) Provide instructors with additional training in the use of audio-visual aids.
(3) Increase utilization of motion pictures and filmstrips.

Implementation

(1) Inform instructors of sources identified now.
(2) Commence training instructors now in visual aids course at Academy.
(3) Upon identification of relevant motion pictures and filmstrips from sources cited, or others, acquire same and incorporate in training programs as instructors become qualified.

CONDUCT OF LABORATORY EXERCISES

It was found that laboratory instructors tended to be limited to laboratory exercise instructions to guide the students through their work. Increased learning could be expected to take place if the instructors were to provide greater individualized guidance to students. The problem of providing greater guidance was aggravated in some cases by the fact that students would be working on different experiments during the same laboratory period. Since the several experiments pertain to theoretical material taught in several previous lecture periods, immediacy of application of knowledge to the experiment could not be achieved in all cases.

Troubleshooting exercises on the prime equipment should be as realistic as possible. While ease of insertion and removal are important factors in selecting troubles, the troubles should realistically represent actual field-experienced difficulties.

Some laboratory exercises observed were actually demonstrations. As performed, they consumed far more equipment time than would be required were they to be treated as demonstrations. Moreover, the prime equipment should be utilized for the development of a maintenance skill.

Prime equipment is not always needed for teaching a procedure. Initial skill development and learning of the procedure can be taught on a low-cost mock-up. Employing such devices would have the effect of reducing the demand for the prime equipment for teaching maintenance skills which require it.

From a study of interviews with operating personnel and other data, it was found that preventive maintenance can be effectively taught on site.

Recommendations

(4) Require instructors to provide greater individualized guidance to students during laboratory exercises.
(5) Ensure that laboratories occur in time sequence as close as possible to the related theory presentation.
(6) Convert laboratory exercises to demonstrations whenever the exercise is not devoted to development of a maintenance skill.
(7) Select troubleshooting problems representative of field experience for insertion into prime equipment.
(8) Develop and use low-cost procedural trainers rather than the prime equipment for teaching procedural tasks. This should be done whenever prime equipment time is limited due to heavy scheduling.
(9) Use on-site equipment to teach preventive maintenance.

Implementation

(4) This could be done by administrative order, followed by supervisor spot-checks.
(5) This could be done by administrative order. To keep students who work rapidly and perform the experiments well in advance of the norm profitably employed, they can be utilized to help slower students in a peer-instructional method.
(6) Each laboratory exercise that uses prime equipment should be examined to identify and name the maintenance skill that is being developed. If no maintenance skill is being developed, convert the laboratory into a demonstration.
(7) Maintenance data should be collected from field sites to determine the cause, frequency, and criticality of equipment failures. A representative sample of these failures can then be selected as troubleshooting training problems. The effort to collect such data for each equipment for which training is being provided can begin immediately.
(8) Each laboratory exercise should be reviewed to determine whether it teaches procedural tasks, such as "turn on, operate." For those that do, prepare scale drawings to be used in place of the equipment for this training. Work on making these determinations can be started now.
(9) Instructor Guides should be examined to determine whether preventive maintenance is being taught in resident training. When detected, the content should be placed in OJT materials, and removed from resident training materials. Work on this can commence now.

COURSE MATERIALS

Although Instructor Guides are required to contain a statement of student outcomes, there is no requirement that Lesson Plans (which are prepared by the instructor for his own use and are not controlled by management) contain them, unless the lesson plans are to be included in the course control document marked as "instructor guides." If lesson plans are not required to contain student outcome statements, there is little likelihood that instructors will remember what they are and inform the students. There is a requirement that Instructor Guides contain "suggestions how student outcomes can be achieved." Yet there is little evidence to show that these suggestions are actually included.

An instructor experienced in teaching a course will probably know what visuals to select for a given lesson. However, a new instructor would not. Neither would training management officials who desired to review the appropriateness or quality of the visual, since their identification is not usually specified by number in Instructor Guides.

Tests using multiple-choice questions are very popular because of their ease of administration and scoring. However, such tests, except in rare instances, measure a student's ability to recognize the right answer, rather than his ability to perform.

Training materials, such as student guides, Vugraphs, and laboratory exercise instructions, contain errors. Some of these errors were known to the instructor who pointed them out, and asked students to make the necessary corrections when they could (as in student guides). Other errors were detected in the course of the presentation. In consideration of the mass of training materials that exists, it is believed that the problem is not severe; but because it appeared during the observational period often enough to be noticeable, it is considered to be worthy of attention.

The analysis of conent within a succession of courses within career fields detected evidence of content duplication. That is, topics that appeared in a first course also appeared in subsequent courses required to be taken for certification on a given equipment. Duplicated content is clearly wasteful of training time and should be removed if no adequate justification can be made for its retention. (See later section for expanded discussion of content duplication.) However, a determination of duplicated content for all courses should be made after career progression plans have been established, since what now might appear to be duplicated content in the context of present training paths may not be after the training paths have been redefined.

The addition of a new course prior to redefining the present training paths could also result in the duplication of course material. The course might not duplicate material given in the present training paths, but could contain duplication after the new training paths were developed.

Recommendations

(10) Supervisors should see that lesson plans include statements of student outcomes.

(11) Require visuals to be explicitly identified by number or other identifier.

(12) Require instructors to state purpose of lesson, what students will be expected to do as a consequence of the instruction, and the level of performance they should achieve (when the later information becomes available). This should be done at the beginning of the lesson, and repeated every four hours if the lesson is that long.

(13) Enforce the requirement that "suggestions on how student outcomes can be achieved" be included in Instructor Guides.

(14) Reduce reliance on multiple-choice questions.

(15) Require training materials to be free from known errors.

(16) Remove duplicated topics in those instances where they were detected (as reported in Volume I), retaining them in the first course where they appeared if analysis of job requirements justifies their presence.

Implementation

(10) This can be done administratively, and implemented now.

(11) This can be done by clerical personnel with assistance from instructors. Instructor Guide masters should be updated so that future reproductions will have the necessary data. This work can be commenced immediately.

(12) This can be done administratively, implemented now, and spot checked by supervisors.

(13) This will require effort from instructors, supervisors and/or curriculum developers to write the necessary additional material for inclusion in the Instructor Guides. It is judged to be a low priority item for a course in being, but a high priority item for new courses (those being developed, or to be developed).

(14) This will require a re-examination of the content currently being tested through the multiple-choice question method to construct test items that will require the student to demonstrate his ability to apply the knowledge. Reasonable progress in the conversion of multiple-choice questions should be visible within a stated time frame, for example, 20% within three months.

(15) Vugraphs and slides containing known errors should be corrected immediately. Clerical help should make changes on student guides and handouts prior to issuing them to students until current supply is exhausted.

(16) Topics indicated in Volume I as duplicated in the various courses should not be removed until instructors teaching the topics in question have conferred with their counterparts in all courses in the related training path containing the topic to determine that duplication actually exists, the degree, and whether the requirements of the job relative to the first training program where it appears justifies its presence there. If conferees determine that duplicated topics should be retained in courses other than the first where it appears, they should set forth in a report the reasons for their determination. Conferences should be scheduled immediately for this purpose.

TRAINING EMPHASIS

It was found that a sizable portion of the lecture material presented in resident instruction in equipment-specific courses was devoted to descriptions of the theory of operation and circuits in their normal mode of operation. Related student guides for such courses often contain circuit descriptions at a level of detail comparable to that provided by the instructor in class. Since students are permitted to retain their student guides for future reference, the time spent by instructors in describing orally the content of the student guides appears to be excessive.

In addition, the primary emphasis in describing circuit theory is to present the normal circuit conditions. Other than in his capacity to perform preventive maintenance, the technician's real usefulness on the job is in terms of how well and how fast he can restore abnormal circuit conditions to normal. Therefore, in order to enhance this capability it is reasonable to reduce the amount of time spent describing normal operations, since it is covered in student guides, and require consideration of abnormal operation in the context of teaching normal operation.

Recommendations

(17) Reduce time devoted to description of theory and operation of circuits in courses that have adequate coverage in student guides.

(18) Increase emphasis on maintenance in resident instruction by requiring students to practice theoretical troubleshooting in the context of learning circuit theory.

Implementation

(17) Instructors and supervisors should examine student guides to determine which have adequate circuit descriptions. For those courses which do, lecture time devoted to circuit descriptions should be reduced. A target to strive for would be a reduction of as much as 50%, depending on the characteristics of a particular course. Instructor Guides and lesson plans should then be modified to reflect the change in depth of coverage in the lectures, and time reduction.

(18) Requiring students to practice theoretical troubleshooting in the context of learning circuit theory will require rewriting Instructor Guides and lesson plans to include problems for solution, with statements of symptoms observed, and condition of signals resulting from the hypothetical out-of-tolerance condition. Implementation of this recommendation should be deferred for those courses likely to be reorganized, in order to avoid reworking course materials more than once. The maintenance orientation can also be facilitated through drawing from field experience.

ADMINISTRATIVE AND COURSE CONTROL

It was observed that training outcomes are not uniformly specific. To have utility, these outcomes must be phrased in terms that are as specific as practical.

In addition to the purely technical data required for course generation, curriculum developers need a knowledge of the specific character of the job requirements and the performance standards which are required of the student as he reports for duty after training.

Although there is no assurance that instructors will follow their lesson plan even if they have one, it is nonetheless mandatory that the lesson plan cover the topics identified in the Instructor Guide. Unless they do, there is even less likelihood that instructors will be teaching the planned topics.

Since lesson plans are developed independently by instructors, there is no method short of physical inspection and comparison with the Instructor Guide to determine that lesson plans contain the required ingredients.

Recommendations

(19) Remove the training outcome "assume full maintenance responsibility," and similarly worded statements.

(20) Require that job requirements and performance standards be utilized by curriculum developers in constructing courses. Require Instructor Guides to contain specific measurable training performance standards. Key the Instructor Guides to the job requirements and performance standards so that instructional content may be objectively justified.

(21) Require supervisors, in their semi-annual instructor evaluations, to compare lesson plans with Instructor Guides to determine completeness: for example, student outcomes, time allocation to sub-topics, visual aid identification, and

performance standards when they become available. The Evaluation and Standards staff should also include this as part of its evaluation actions.

Implementation

(19) This can be done now. These statements should be replaced with specific training outcomes which define the maintenance responsibility to be assumed.

(20) This will have to be deferred until job requirements and performance standards have been specified.

(21) This will require instructors to add the material presently in Instructor Guides that is missing from lesson plans, and to determine what time allocation to place on sub-topics. This should be done immediately. Supervisors should plan to make the comparisons at their next normally scheduled evaluation. The Evaluation and Standards staff should make certain this factor is considered in their evaluations.

ON-THE-JOB TRAINING

It was found that sector management could benefit from additional appreciation of the manpower costs associated with conducting OJT of either the formal or informal types. Moreover, because they were not connected into the communication link between the Academy and the trainee, they had little knowledge of the state of training, except when a trainee ran into difficulty. The quality of OJT instructors was likely to be highly variable and could be improved through training. The quality of the training itself could be improved through including in the OJT lesson outlines specific points or facts trainees are supposed to be able to do or state, and providing the trainee the opportunity to practice knowledge immediately after learning it. (See pp. 32-34)

Recommendations

(22) Require sector managers to collect man-hour expenditures from all sector personnel for their participation in OJT.

(23) Include sector management in the communications link so that they may keep abreast of the state of training of OJT trainees.

(24) Add specific points or facts trainees are supposed to be able to do or to state in the OJT lesson outlines.

(25) Provide the OJT trainee the opportunity to practice knowledges immediately after having learned them.

(26) Require all OJT trainers to take the directed study program, "On-the-Job Training Techniques."

Implementation

(22) This can be accomplished immediately by administrative order.

(23) This can be accomplished immediately by administrative order, to include the routing of communications through sector management office where training status information should be abstracted and recorded for review and analysis by sector management personnel.

(24) This will require a review of the outlines and training materials to determine what the points are; revision to incorporate them should begin now.

(25) This is a problem most appropriately solved at the OJT trainer and sector management level, although guidance can be provided them on specific topics

where it can be applied. Operating elements should be directed to attend to it immediately.

(26) This can be accomplished immediately.

LONG TERM RECOMMENDATIONS

The following recommendations are interrelated and should be implemented in the context of re-engineering training programs.

It was found that the maintenance concepts studied did not contain sufficient detail or level of specificity to establish measurable training objectives. In addition, they were not written so as to reveal the aspects of equipment design and utilization that impact upon maintenance requirements. Maintenance technician performance criteria need to be defined in terms of what is needed by the job and to be obtained in training.

Since performance measures are unspecified, the quality control system as it exists cannot measure the training program's effectiveness, training outcomes are deficient, instructors have no standards against which to measure student achievement, laboratories are not used to develop measurable performance capabilities, and performance levels to be achieved in OJT are not known. Re-engineering of the training programs would include the specification of performance standards which could then be integrated into the course materials and provide the substance which the quality control program could work with.

Recommendations

(27) Write maintenance concepts so as to delineate what aspects of equipment design and utilization impact upon what maintenance will be required.

(28) Increase detail and level of specificity in Maintenance Concepts so as to establish measurable training objectives.

(29) Define and specify training outcomes in equipment-specific terms on the basis of equipment analysis, utilization analysis, and trainee capability to include definition of performance criteria required by the job and that to be obtained in training.

(30) Require the training plan Job Function Summaries to be equipment-specific when they are for equipment-specific training programs.

(31) Establish and maintain a specific level of detail and time allocation within and across course outlines. The course outline for communication equipment may be taken as a model.

(32) Develop a quality control system based on detailed statement of training objectives based on job requirements, proficiency measures, tests which require performance rather than recognition and analyses to pinpoint ineffective instruction. Permit flexibility to re-allocate time within course to effect quality control determined required changes.

(33) Develop diagnostic tests to determine what part of the training program needs improvement.

(34) Require instructor guides to contain student outcomes stated in terms measurable by instructor with performance standards to be achieved by the students.

(35) Define time to spend on each major topic within the lesson so as to achieve greater control over emphasis of presentation.

(36) Require instructors to determine that outcomes have been achieved to standard by assessment within lesson. Sample student achievement.

(37) Design laboratory exercises to make it possible for students to achieve mastery of tasks at a level required of them upon assumption of duties on site.
(38) Incorporate performance measures and standards into OJT packages.
(39) Improve integration of Directed Study and OJT I.

Implementation

(27) & (28) Work should begin immediately on preparing a guidebook for writing maintenance concepts.
(29 through 39) Most of these recommendations depend upon the identification of training objectives based on job requirements and performance standards. The most effective implementation of these recommendations, therefore, should await both the results of the study to rank order the course in their relative priority for revision, and the transfer of curriculum engineering technology to ANF personnel which is recommended to be performed in the context of re-engineering five selected training programs, described within the programmatic recommendations in this volume.

There is, however, no particular reason to defer defining time allocations to major topics within lesson plans so as to achieve greater control over emphasis of presentation in the present programs.

CAREER DEVELOPMENT

There is no centrally managed program for guiding and controlling career progression for individual technicians from point of entry as new hirees through retirement. As a consequence, it is difficult to project personnel and training requirements, and because there is no career progression, training is costly and complex. The relative freedom technicians have to move from one career field to another can run at cross purposes with the goal of maximizing the return on training investment. The matter of establishing a "core" curriculum is related both to career progression and to the content of present training programs. Until career progression patterns have been established which are supportive of the FAA's long-term maintenance work force goals, and until the present courses have been redesigned in terms of job requirements and performance standards, the development of a core curriculum would be premature. (See later section for additional discussion of career development and progression.)

Recommendations

(40) Develop plans and procedures to measure personnel career progression and to project personnel and training requirements.
(41) Restrict entry prerequisites for those courses which presently permit entry of a wide mix of students in terms of their training, background, and experience.
(42) In choosing between equally qualified technicians to cross from one career field to another, select the one which minimizes the loss in trained investment.
(43) Defer establishing a core curriculum until present courses have been refined in the light of training requirements and performance standards, and definition of career progression patterns.

Implementation

(40) A study should be initiated at the earliest practical moment to define the long-term maintenance work force goals in the light of equipment distributions,

site configurations, and known anticipated equipment procurements, and to establish training paths to satisfy the goals while minimizing loss of training investment.

(41) This can be implemented immediately assuming that sufficient numbers of trainees can be found with the more restricted prerequisites to satisfy the needs.

(42) This can be implemented immediately.

(43) Defer implementation of "core" curriculum.

EQUIPMENT UTILIZATION

Even though pre-production model equipment differs, in general, from production line equipment, there are definite advantages in utilizing it for certain purposes. In the interests of acquiring knowledge of an equipment in the pre-production stage, instructors can be sent to the manufacturer's plant for training on the prototype. The primary advantage is in terms of the time required to prepare instructional materials. Instructors so trained will be in a better position to construct a training program for the production model, although it may differ from the prototype, in a shorter period of time than if they were required to wait until the production model appeared.

Recommendations

(44) Use pre-production model equipment for training course development personnel at contractor's site.

Implementation

(44) Implement as required and appropriate.

EQUIPMENT RETIREMENT

No explicit procedures were found which prescribe a method to use in deciding when equipment should be retired. Although Paragraph 15, Appendix 4 to 3006.6A, Chg2 *TRAINING* addresses Training Course Termination, the three program standards state that "procedures are established" to help determine whether a course should be terminated, not if and when to retire equipment. It is quite possible to find a justification for *not* retiring equipment even when the course has been terminated. Hence, training course termination is not equivalent to equipment retirement.

Recommendation

Develop and employ equipment retirement policies and procedures.

Implementation

The development of such procedures and policies would not have a direct impact on the improvement of ANF training. It would have an indirect effect in the sense that resources currently applied to the maintenance of equipment no longer required could be re-directed to more pressing requirements. Consequently, the benefits to be derived must be viewed from the long-term perspective.

The purpose of the following discussion is to highlight some of the factors which should be considered in the development of such policies and procedures.

Why should equipment once installed at the Academy ever be retired? There are at least two reasons: (a) the costs to maintain the particular equipment may have become excessive, and (b) the need for maintenance training on the equipment may have vanished.

It will be assumed that the equipment will be utilized in satisfying attrition training requirements. After some period of utilization has elapsed, the costs of maintaining an equipment will begin to rise exponentially because the failure rate will rise exponentially. If a replacement unit were to be purchased, its maintenance costs would be essentially flat during the period when the costs of the first equipment were rising. If the difference between the maintenance costs for the two equipment were computed, it would be possible to determine when to buy the second equipment so that the savings obtained by not maintaining the first equipment equalled the costs of procuring the second. This, then, would be the economic buy time for the second equipment. Naturally, if it turned out that the costs to procure exceeded the savings because the buy point exceeded the anticipated training requirement duration, it would be unwise to buy.

The second factor to be considered is the requirement for the equipment in training disregarding its state of repair. Here, for those instances where the demand for training is diminishing, the cost of maintaining a training program—that is, course materials and instructors ready to perform—must be considered. One way of approaching the problem is to estimate the costs of converting the resident training program to directed study and OJT. These costs could then be divided by the anticipated student load over the life expectancy of the equipment to obtain a cost per student. If these costs were less than those to be expended in maintaining a resident program in readiness for the same student load over the same time period, then it would be wise to discontinue the resident program.

CAREER PROGRESSION

In Volume I of this report, the absence of clearly defined career progression patterns was noted. The matter of content duplicated within several courses and that which is superfluous to the needs in a given training course is related to the career progression problem.

It is recommended that Career Progression Plans be developed and documented.

Career progression practices are a very important determinant of the overall composition of the FAA Maintenance Force. They have a broad interface with and strong impact upon personnel policies and the ANF training mission. Notwithstanding the complexity of this manpower development system, there remains an urgent requirement for management to place some structure and control on career progression of its airway facilities maintenance personnel.

Full benefits from the training investments will not be realized until definitive policies have been established to describe and delineate how personnel will move into and through certain job responsibilities to create the overall maintenance capability imposed by airway facilities equipment. Firm action in this direction would also create the possibility for major improvements in the effectiveness and efficiency of ANF training. Training administrators would be able to tailor the content of their courses more specifically to a predictable training input. The technicians and engineers, working with personnel and administration representatives, should be able to arrive at more reliable and valid conclusions concerning their future careers.

It would not be an overwhelming task to begin by defining the overall maintenance capability required of the various types of facilities and further reducing these to sets of maintenance capabilities for individual personnel. For example, what equipment system(s) would a Radar Technician at an ARTCC be expected to maintain? Given a job vacancy among the ARTCC Radar work force, what is the most efficient sequence of training-work experiences to satisfy the missing maintenance capability?

With the NAS program picking up momentum, a solid effort in this direction should make it possible for all parties involved to develop realistic plans to meet the manpower requirements of this program, especially for those instances requiring personnel to move across career fields. Hopefully, the ability to make longer-range plans concerning personnel training needs would drastically reduce the practice of waivering prerequisite requirements, and thereby reduce the heterogeneity of the training input at ANF.

The certification program appears to be the single most important element in controlling career progression. Due to its criticality, it appears that efforts should be made to determine if the two different parts of this program (theory and performance) are assessing the maintenance capability required and if they are measuring the same factors. Since the written examination also serves as a screening or selection device for certain ANF courses, an investigation of its effectiveness in this role should be explored. It is possible that this instrument, used to serve two masters, is not serving either one satisfactorily. For example, one would suspect a screening instrument based upon the content in the Radar Principles courses would be more effective than the system concept oriented R1 examination as a prerequisite for ASR-4, 5, and 6 course. There is a possibility that ANF training administrators require different types or sets of data for screening the training input where the individual is a new hire as opposed to someone already certified. This, too, should be explored.

TOPIC DUPLICATION

It is recommended that course topic duplication be re-evaluated following establishment of career progression plans.

Not all instances of duplicate topic between courses should automatically be labeled as inefficient or unnecessary. Such evaluations should be reserved for situations where it can be clearly demonstrated that a majority of students in one course received instruction which was nearly identical to instruction that they had received in a previous course. If this instruction is found to be repeated for a small portion of the students and can be definitively justified in terms of the skills and knowledges to be developed, it then is an instance of required inefficiency. The key word here is required.

The essential element to the determination of what is required is a specific statement describing behaviorally what the student will be able to do, the manner in which he will show this behavior, and a standard of accuracy, speed, or precision to be attained as a result of the instruction. Furthermore, these instructional objectives should be directly related to specific maintenance tasks found on the job. The final selection of topics for a given course involves consideration of knowledges and skills expected to be present in the training input. Any constructive effort by course developers to correct or prevent topic duplication is not likely to reap full benefits unless their assessments of the planned training input are accurate. This is not likely to be the case until some definitive policies concerning career progression are established.

The ANF resident curricula might be grouped into three categories. The first group would contain those courses aimed at developing basic theories, principles, and knowledges of basic components, their operation, and applications. This group would include the following courses: Solid State Devices, Digital Logic Principles, Electrical Principles, Solid State Fundamentals, and parts of the ILS/VOR Principles and Communications Equipment and Rho-Theta Principles. The second group would contain those courses concerned with components and circuits found in a family of equipment such as Radar

Principles A and B, Rho-Theta Principles, Data Processing Principles Phase II, and Air Conditioning. The third group would include all of the equipment-specific courses designed to prepare someone to maintain a specific end item system, such as BRITE-1, RTC-3, and APULS.

Addressing the topic duplication question in terms of these groups, personnel are likely to attend more equipment-specific courses than those of other groups. For detecting duplicate topic within a given career field, the greatest return would be obtained by examining the equipment-specific courses, especially for the Radar and Data Processing career fields. Relating this to the charts, the assumption is that once someone is certified on a given Radar equipment system, the training progression becomes vertical in most instances. This would not appear to be the case in the Navaids career field where the thrust of training progression could be horizontal until certification on three different equipments is achieved. In attempting to identify topic duplication between the equipment-specific group of courses, one should examine closely instruction devoted to the development of maintenance skills involving the operation and use of test equipment, maintenance techniques or procedures, and detailed analysis of circuits found in both equipment systems.

Any attempt to identify topic duplication resulting from career progression across career fields can only be speculative in the absence of any information of typical patterns. In the majority of cases of crossing to a new career field, personnel would have to attend some course in the second group—instruction related to a family of equipment. For a Radar Technician to become a Navaids Technician he would have to take (in most instances) ILS/VOR Principles and Rho-Theta Principles. Career progression in the opposite direction would mean attending the Radar Principles course(s). This group of courses should receive a high priority in detecting content duplication.

Looking at the Radar and Data Processing career fields on the chart, it is apparent that the Solid State Devices and Digital Logic Principles courses are present in most of the training paths. In the Radar career field these courses are followed by Radar Principles A, and in the Data Processing area they precede the Data Processing Principles course. A natural assumption would be that the Radar Principles and Data Processing Principles courses have something in common or, if not, their prerequisite courses contain instruction which can be justified by one but not the other.

With the new jobs being created in the environmental controls system area, the requirement for training experience in solid state and digital circuits suggests a closer look at the Solid State Devices and Solid State Fundamental courses. This is based upon the assumption that sometime in the future large numbers of electro-mechanics will begin to cross into other career fields.

POSSIBLE MEANS FOR IMPROVING COST AND EFFECTIVENESS OF VARIOUS TRAINING METHODS

The objective of performing this task was, specifically, to arrive at recommendations. Consequently, the results of the effort are reported in Volume II rather than in Volume I. Four methods are discussed: Resident Training, On-the-Job Training, Directed Study, and Programed Instruction. In addition, an analysis of cost factors to be considered in preparing programed instructional materials is presented.

For the most part, these recommendations can be instituted independently of any general changes in the ANF Branch's approach to training. They can become part of the daily measures taken by personnel to develop, update, and improve courses.

During the course of this effort, numerous possibilities for the improvement of FAA electronic maintenance training have been identified and considered. These possibilities were examined in the context of the individual training method for which they were found applicable. The training methods included Resident Training, OJT, Directed Study and Programed Instruction. The changes recommended are discussed below.

A. Resident Training

(1) Increase the level of detail and specificity of the Instructor's Guides.

An improvement in the effectiveness of classroom lectures can be expected because lecture content would be more standardized and key knowledges more uniformly emphasized across classes and instructors.

(2) Develop and include specific statements of student outcomes in all Instructor Guides for all units of instruction.

FAA Handbook No. 3000.6A,[1] paragraph 404d(1), provides an excellent definition of a properly written outcome. The availability and utilization of more specific student outcomes by instructors would increase the effectiveness of training. The basic psychological concepts which would be involved and require the presence of student outcomes are defined in *A Program of Instruction for Instructor Training* prepared by the Training Development Division of the FAA Academy. The definitions are as follows: "These concepts emphasize that instruction is more meaningful and effective when the subject matter is furnished to fulfill an identified need to improve performance. Effectiveness is increased when the subject matter is presented in relation to the situation in which it will be used rather than as isolated information."

FAA Handbook No. 3000.6A states the outcomes "must be written in measurable terms and be job function oriented." The utilization of more specifically defined student outcomes by instructors to (a) identify and emphasize how knowledges to be developed in training relate and are applied to specific maintenance activities, and (b) identify for the student the performance standards he is to achieve during a unit of training, would make substantial improvements in the effectiveness of the training conducted.

(3) Develop and incorporate diagnostic tests as part of existing training quality control system.

When instances occur where significant numbers of students fail to achieve the outcome standards established for some unit of instruction, effective corrective action is dependent upon accurate identification of the cause for the occurrence. Diagnostic tests can provide the means for determining whether the knowledges being developed in class are appropriate to and required by the behavior defined in the student outcome. On the other hand, they can also determine whether the failure is attributable to the use of ineffective training media or methodology. The implementation of diagnostic testing as part of the quality control system would result in more accurate identification of the causes of training ineffectiveness and the corrective actions required.

(4) Change emphasis and methodology of within-course testing.

An improvement in the effectiveness of training should be expected if relative achievement testing was de-emphasized and replaced with testing to assess the extent to which each individual student attained the prescribed outcome. Since the maintenance requirements of an equipment

[1] Federal Aviation Administration. *Training*, FAA Handbook No. 3000.6A, 11 September 1969.

are not relative to, and do not change as a function of individual differences of student members of a class, or differences between successive classes, the required level of achievement for a given outcome must be absolute for each student and independent of a classmate's performance and that of previous classes.

The reliance on multiple-choice test questions should be decreased. In those instances where the outcome states the student must possess a given knowledge, a measurement methodology, which requires the student to recall and formulate the objective response, is a more valid means of testing for the achievement of that objective than one which requires the student to recognize the knowledge among several alternative choices.

This change would cause some increase in test administration and evaluation time. However, the additional costs may be more than justified by the improvement in the effectiveness of the measurement of student outcome achievement.

(5) Selection of more appropriate media for training.

Observations of ANF-conducted training suggest there is some opportunity to reduce the cost of training for certain courses by selection of less expensive media. There were instances of laboratory demonstrations conducted on the prime equipment which could have been conducted on a mock-up with little expected loss in effectiveness. Re-examination of laboratory demonstrations presently requiring the prime equipment to determine the possibility of using other media could provide a basis for reducing training costs.

(6) Increase the level of supervision and monitoring of student performance during laboratory exercises.

One instructor cannot provide an effective level of student supervision and monitoring during laboratory exercises involving student practice on different activities. The student's performance needs to be more closely monitored to (a) determine that he is practicing the task assigned, (b) detect incorrect responses and provide corrective guidance, and (c) assess the progress being made toward achieving the outcome. The effectiveness of such laboratory exercises would be greatly improved with the addition of another instructor.

(7) Increase the level of student participation during lectures.

The effectiveness of the instructor in presenting information to the students would be improved by increasing the level of his interaction with the students.

Learning is more effective when the student is active than when he is passive. A more concerted effort during lectures should be made to determine whether the student comprehends the instruction and to create situations requiring the student to apply that which he has learned. To be most effective, this higher level of student participation should not be restricted to either the beginning or the end of the lecture but should be uniformly present throughout the duration of the lecture.

B. On-the-Job Training

The following possibilities for improvement of the cost and effectiveness of this method of training are restricted to that form of OJT found in integrated programs; that is, OJT-I and OJT-II.

(1) Increase the standardization of knowledges to be learned.

The supervisor in his role as the trainer is a critical factor in determining the level of skills and knowledges trainees acquire during an OJT program. It is logical to expect these personnel in this role to vary considerably in terms of technical competence and as a medium of instruction. Such variability can be expected to be reflected in the quality of the training product—the OJT trainee. The OJT manuals are excellent examples of efforts to compensate for trainer individual differences and to assure a more uniform product of known quality.

However, there is some possibility for greater improvements in this direction. In those instances where an OJT lesson outline contains, for example, an objective, such as "demonstrate a basic knowledge of . . .," the training would be more effective if the trainer were provided a list of the specific points or facts the trainee should be able to provide. The trainer needs more specific guidance as to what specific pieces of information constitute an adequate "basic knowledge" and satisfy the lesson objective. A very conscientious trainer, being uncertain as to the specific aspects of the knowledge involved, would probably attempt to examine the objective and establish his own criteria for determining if the objective was attained. This also suggests the possibility of an additional benefit; that is, the trainer, having been provided the means for evaluation, would have to spend less time in determining whether the trainee satisfied the lesson objectives.

(2) Increase the utilization of the "learning by doing" principle in OJT-I.

Based on study of the OJT-I manual for the ATCBI-3 and using it as an example, the effectiveness of this type of training course would be improved if the student were required to practice tasks requiring application of knowledges being developed. For example, shortly after completion of Lesson 8, the student should perform, or be involved in, the performance of some task requiring knowledge of safety factors, maintenance procedures, name and location of major equipment units and their switches and controls, and other knowledges involved in this set of lessons.

This restructuring of the OJT program would also result in making the content more meaningful to the student by requiring performance of task(s) which clearly demonstrate a "need to know" to the student, and provide him with the opportunity to translate knowledges acquired into performance. Without the opportunity to practice the knowledges to be developed by this program, one should not expect the student to retain much of that to which he was exposed.

In discussions with field personnel concerning types of content most suitable to OJT, preventive maintenance was recommended. It would appear that preventive maintenance tasks would offer an opportunity for practice of many of the knowledges forming the content of Lessons 1 through 8.

(3) Provide more support and guidance to the supervisor in his role as a trainer.

Field personnel reported that one of the principal problems with OJT was the availability of personnel who were competent and effective as instructors. Woolman[1] reported some success in providing relief to this

[1] M. Woolman. *On-Site Training of Guided Missile Operators*, HumRRO Technical Report 64, August 1960.

general problem. He reports development of an on-site training method which "gives the instructor—a skilled operator but usually a novice at teaching—an easily applied technique for teaching a procedure to his two trainees."

The method included standardized training procedures and supporting administrative and evaluation materials. Woolman's effort in this area supports the possibility of a manual for the OJT trainer which would guide and direct him towards a more effective role as an instructor. The effectiveness of this manual in improving the quality of OJT would depend upon the extent to which it provided the trainer guidance and support in the following three areas: (a) specification of student behaviors to be observable as the result of training; (b) instructional media, methodology, or techniques to be employed; (c) definition of the means and standards to be used for determining whether the training outcomes were met.

Another possible approach for improving the effectiveness of OJT where the basic area of interest is the trainer's role as an instructor, is to provide all personnel who serve as OJT trainers with OJT Instructor Training. It would appear that the proposed directed study program on "On-the-Job Training Techniques" could serve this purpose. However, not all of the content proposed for this program would be required to provide relief to the problems discussed here. A shortened version of this program which excludes, for example, content on determining training needs and developing training objectives would be more appropriate here. The present OJT-I and II programs prescribe the training to be accomplished.

Either of these two approaches is likely to produce greater improvements in the effectiveness of OJT-I than OJT-II. The reason stems from the observation that OJT-I is concerned with the more cognitive aspects of the job. OJT-II, on the other hand, is aimed more at the development of proficiency in tasks for which a basic performance capability was previously acquired in resident training. The reason also rests on the belief that training aimed at the development of the cognitive components of complex tasks places greater demands on the pedagogical skills of a trainer than training to develop speed and accuracy in performance, as found in OJT-II.

C. Directed Study

(1) Increase the use of programed instruction.

Excellent models of the application of programed learning principles in the printed text medium can be found in both resident training (No. 40115 and No. 40504) and directed study courses (I/O Equipment for Technicians). The conversion of a study manual from a narrative format (e.g., ATCBI-3) to "programed" text (e.g., I/O Equipment) would be expected to increase student learning.

However, even without conversion to a programed text, other possible means of improvement exist. Comparison of the directed study manuals for the Diesel Engine Generator and ATCBI-3 resulted in the opinion that the Diesel Engine Generator (DEG) would produce greater student learning, since the DEG manual makes more effective use and application of certain established principles of learning. These principles center on three aspects of the learning process—practice of the knowledges, knowledge of results, and reinforcement of correct responses. On a comparative basis, the DEG manual (a) has more provisions for the student to apply or practice what he has learned, (b) provides practice more frequently and after shorter bodies of content, and (c) has provisions for telling the student whether he has made the correct response—that is, whether he has learned the material.

Modification of the more purely narrative type manuals, such as for the ATCBI-3, to include those features identified earlier should result in more effective training. The addition of learning objectives should further improve the effectiveness of the DEG manual.

(2) Improve the integration of Directed Study with OJT-I.

Examination of student study materials from both types of courses suggests the possibility for improvement in both courses by providing more specific information to the trainee and trainer on how the courses are to be conducted concurrently. A possible analogy of the relationship between directed study and OJT-I is the classroom lecture and laboratory exercise in resident training. This relationship appears to require better definition, coordination, and scheduling. Consider the relationship between ATCBI-3 directed study content on the transmitter site and Lesson No. 5 in OJT-I which involves a familiarization tour of the transmitter site. If a student completed the directed study lesson two or three days before the tour, it is very likely he would have forgotten much of what he studied. Furthermore, if it were clearly stated to him what specific information in the directed study lesson he would be required to provide during the OJT-I tour, he could study more effectively.

These comments can be applied to other similar situations where knowledges developed in directed study are required to be demonstrated in an OJT-I lesson.

There is some evidence to support an observation that the same directed study and OJT-I course content would not be equally effective in preparing a new employee, an employee changing career fields, or an employee who is seeking certification on a second or third equipment within the same career field for a "smooth transition" into resident training. There are likely to be pronounced differences in the skills and knowledges which have to be developed during directed study and OJT-I in order to assure smooth transition into resident training by a new hire, compared to someone already certified on equipment similar to that to be taught in the resident course. This would suggest courses with different content and possibly employing different training methods and/or media.

D. Programed Instruction

Programed instruction was examined as an alternative technology that might be used in one or more of the 10 courses studied. Purely from the standpoint of effectiveness, it can be considered as a method that could be employed in greater amounts in ANF training. However, its costs can be too large in relationship to the improvements that may be affected.

The SCT format used in Course No. 40115 can be improved as a programed instruction (PI) course. However, apart from the question of programed instruction (PI) being a wise choice for implementation in this course, one feature of it does make the course superior to most that were examined: namely, the effort to place the material in a programed instruction (PI) format resulted in a greater specification of what the student is to learn, and a strong basic organization of the materials. Therefore, the strength of this course is in the direction, specification, and organization of course content that exceed most courses that were examined.

In addition, however, the use of programed instruction in this course is a good choice because the content of the course is stable, that is, it is unlikely to be changed considerably because it considers principles rather than material on a specific piece of equipment.

Generally, courses that are likely to have stable content are more suitable for the use of programed instruction than those that are subject to frequent or extensive revision, because they will not require costly revision.

Because it is more difficult and expensive to revise programed materials than those presented by a live instructor, programed instruction is more suitable for relatively stable content areas than for those areas likely to experience rapid change. Depending upon its form, programed instruction can provide individualization of instruction to a degree that would be excessively time-consuming in a resident instructional situation. And, programed instruction, regardless of its form, permits the individual to proceed at a pace he finds most comfortable—obviously impossible to do in a resident training situation.

The initial cost to prepare a program is generally higher than that to prepare a course taught by a live instructor. This is because the program is constructed with an initially high capability to teach the subject matter. In a resident training program, the course can be revised and tailored by the instructors almost as it is being taught. In a resident program the costs continue to occur, due to the presence of the instructor, while in programed instruction the costs over the long run tend to be those of maintenance of the program, which for very stable subject matter would be minimal, instructor costs having been eliminated.

Because of the careful analysis which precedes the construction of a programed course, such courses tend to be more effective than those taught by an instructor. There is no reason why the same careful analysis should not precede the constructing of a resident course. If this were done, the courses might be almost equally as effective and certainly much less expensive. The choice as to which method to use, then, would depend upon the relative costs, and the consideration of factors which assign values to either method in terms of advantages and disadvantages.

The following is a cost analysis of a hypothetical course which might be put into a programed format.

<u>Example</u>

Assumptions:

(1) The course has a stable content, not likely to change in a five-year period.
(2) The course presently exists as a resident course with 50% laboratories, 50% lectures.
(3) Lectures are presently taught by one instructor.
(4) Because it is not feasible to send lab kits to the field, students will attend resident instruction for the laboratory portion of the programed course.
(5) The program will be constructed by Academy instructors.
(6) The rate of program production will be 100 hours of instructor effort to prepare one hour of fully tested programed material.

General formulation:

Let R = Instructor salary, \$/hour

h = Number of course hours to be converted into programed instruction (PI)

r = Instructors programming rate (hours required to write fully tested hour of PI)

N = Number of times course presented in a year

s = Number of students in class

C_p = Cost of programming (instructor's effort)

p = Per diem rate \$/day

L = Life expectancy of program, years

S_i = Savings on Instructor salary over L

S_s = Savings on students per diem over L

S_t = S_i & S_s (total savings)

Instructor cost of programming:

$$C_p = R \times r \times h$$

Savings:

Instructor salary: $S_i = h \times N \times R \times L$

Per Diem: $S_s = \frac{h}{8} \times p \times s \times N \times L$

Total: $S_t = hNL\ (R + \frac{ps}{8})$

To make the example as explicit as possible, some further assumptions will be made:

(1) Present course length: 80 hours

(2) Amount to be programmed: 40 hours

Since it has been assumed that it will require 100 hours to present one hour of instruction, to program 40 hours will require 4000 hours of programming time. The present hourly rate of a GS-12 is approximately \$7.50. Multiplying the hourly rate by the number of hours required gives the cost of preparing the programed material in terms of instructors' salaries.

$R \times H = C_p$ or $C_p = R \times r \times h$

$\$7.50 \times 4000 = \$30{,}000$

$C_p = \$30{,}000$ $C_p = \$7.50 \times 100 \times 40$

$C_p = \$30{,}000$

It is assumed that students will still come to the Academy to perform the laboratory exercises. Therefore, travel costs will be the same in both the resident mode and the PI mode. However, they will be present for only 40 hours instead of 80 hours of instruction, and no instructor will be required for the programed portion of the course. Thus, there are savings in both per diem for students, and in the cost of instructor salary. How much these savings amount to depends upon the size of the class and the number of repetitions during a year.

Assume 16 classes per year, 12 students per class

Instructor salary savings:

$S_i = h \times N \times R \times L$

S_i = 40 hours x 16 classes = \$7.50 per hour x 5 years = \$24,000

Student per diem savings:

$$S_s = \frac{h}{8} \times p \times S \times N \times L$$

$$\frac{40}{8} \text{ days} \times \$16/\text{day} \times 12 \text{ students} \times 16 \text{ classes} \times 5 \text{ years} = \$76,875$$

Total Savings:

Instructor salary	\$24,000
	76,875
	\$100,875 over 5 years or \$20,175 per year.

Time to amortize instructor cost to prepare program:

$$\frac{30,000}{20,175} = 1.48 \text{ years.}$$

As indicated, over the five-year assumed useful life of the program, the savings in instructor and per diem costs would amount to: \$100,875.

This figure is probably low for it does not account for pay increases over the five-year period, or increases in per diem rates.

Taking it as a conservative estimate of the savings due to instructor salaries and per diem expense, the figure may be considered to be the break-even point for a program which has a five-year life expectancy. On that basis, one may permit the cost to prepare such a program to approach the \$100,000 mark, rather than the \$30,000 initially assumed.

There are, of course, additional costs in preparing the materials than the cost of programmers—cost of art work, reproduction costs, mailing costs, and so forth—but these costs would have to be almost double the programmer costs before the break-even point was reached in the example.

As a specific example, consider Course No. 40115, Solid State Fundamentals for Electromechanics. The ANF Training Quota Assignments for FY 72 indicates that there are 14 classes programmed, with an average of 16 students per class. It is a two-week program with 40 hours devoted to laboratory exercises. Although the text used in the course is a combination of narrative and "programed" types, the self-instructional capability of the program could be improved either by reducing the size of "jumps" between successive frames, or by inclusion of remedial sub-routines. In either event, the programed text would require revision and expansion. Were this to be done, students could then be brought to the Academy to accomplish the laboratory phase of the program, thus reducing the total resident time to 40 hours.

Applying the formulas previously developed, the following results are obtained:

$$C_p = R \times r \times h$$
$$= \$7.50 \times 100 \times 40 = \$30,000$$

This figure is undoubtedly high since the basic structure of the program already exists. For this reason, 25 hours per hour of instruction is probably a better estimate. Thus:

$$C_p = \$7.50 \times 25 \times 40 = \$7,500$$

With 14 classes per year, and 16 students per class, the savings would be calculated as follows:

$$S_i = h \times N \times R \times L$$

$$S_i = 40 \times 14 \times \$7.50 \times 5 = \$21{,}000$$

$$S_s = \frac{h}{8} \times p \times s \times N \times L$$

$$5 \times 16 \times 16 \times 14 \times 5 = \$89{,}600$$

$$S_t = S_i + S_s = \$110{,}600$$

or $22,120 per year.

As a consequence, the cost of revising the program could be amortized over the first year of its operation through the saving realized from reducing the requirement of the live instructor, and cutting the resident portion to 40 hours of laboratory exercises.

In conclusion, it can be seen that for the assumption made, the costs of preparing the program can approach the savings to be realized over the life expectancy of the program. These same formulae can be applied to any course material that becomes a candidate for reconstruction in the PI format.

AUDIO-VISUAL SOURCES

It is recommended that audio-visual materials be employed more frequently.

Motion picture films are particularly useful in teaching topics that require visualization of the interaction of nearly simultaneously occurring events, movement, and flow. Verbal presentations and the use of chalkboard and Vugraphs are not nearly so effective.

Increased usage of visuals will reduce training time in those situations where they may be substituted for instructor-created chalkboard drawings. So little use is made of motion picture films in the 10 courses that it is possible course personnel are unaware of certain sources they may turn to.

The central sales point for most completed U.S. Government AV items is:

National Audio-Visual Center
General Services Administration
Washington, D.C. 20409

It publishes a catalog of *U.S. Government Films.*

U.S. Army organizations which are authorized to stock and to lend official Army films, and so forth, are Audio-Visual Support Centers. Probably the closest one to Oklahoma City is:

Audio-Visual Support Center
Office of the Division Engineer
Department of the Army
1114 Commerce Street
Dallas, Texas 75202

The basic listing of Army films and other AV materials is DA Pamphlet 108-1 (dated September 1966) together with Change 1. In addition, AVSCs publish a regular newsletter announcing new films and other services.

Perusal of the catalogs from these sources should reveal titles of potential interest, especially in the fundamentals training areas. Copies of films could be obtained and reviewed for pertinency and timeliness and purchased, if desired.

INSTRUCTOR PRODUCTIVITY MEASURES

It is recommended that effective measures of instructor productivity be developed.

It is not logical to expect that in the development of materials for a new training program the ratio of hours of development to lesson hours to be developed is necessarily a fixed ratio. Allocation of time for such activities would have to take into account training objectives and standards of performance to be achieved by trainees, the complexity of the equipment system, the similarity of that system to one for which a training program had already been prepared, the prior experience of course developers in general, and in particular, with respect to developing materials for like systems, and historical data relevant to the man-hour expenditure for like purposes under similar conditions in the past. Development activities required for equipment which was essentially new and like no former equipment, and which had to be prepared by course developers who had had no prior experience in preparing course materials would necessarily consume a greater period of developmental time. In any event, the most profitable activity to undertake in this current instance is for ANF to begin collecting the data base from which projections can rationally be made.

Table 2 shows how to assign relative time weights to the preparation of instructional materials. It takes into account characteristics of both the equipment for which training materials are to be prepared and personnel characteristics of the instructors. The system that can be employed to gauge productivity is then explained in detail.

Along the left margin of the table is a listing of a number of possible products instructors may be required to produce. The headings classify the activities in terms of equipment and personnel characteristics.

The first major split occurs on the basis of whether the products to be prepared are for a revision of an existing course, or whether they are to be prepared for a new course. Course materials class: original or revision.

The second split occurs on the basis of whether the equipment is complex or simple. One way of making this decision is to consider the relative number of electronic components or stages that comprise the equipment, and the presence or absence of multiple modes of configuration.

The next split is on the similarity of the equipment to existing equipments. This classification is particularly important with respect to the construction of original materials, since if the new equipment is similar to an existing equipment, it is possible to take advantage of some materials already in existence to guide the development of new materials, and instructors may already have much of the knowledge required to construct the new materials because of their familiarity with the old.

The next split is on the basis of the writer's familiarity with the equipment. The writer may be familiar with the equipment because he attended a key personnel training program conducted by the manufacturer, or he may have maintained the equipment in another job. Since it is possible to assign writers who have varying levels of familiarity with the equipment, some weighting should be given for this factor.

The products listed in the left margin are representative of the materials to be produced and are by no means comprehensive. The numbers in the body of the table represent the relative weighting to apply to the production of the materials as a function of equipment and personnel factors.

For example: Under Instructor Guides, lecture, the number "1" appears in the situation where a course is to be revised, it is a simple equipment, like others being taught, and the writer is known to be familiar with the equipment. A "1" also appears when the equipment is unlike other equipments. This merely means that since the materials are to be revised for a simple equipment and the writer is familiar with the equipment, similarity of the equipment to others has no effect on the relative time

Table 2

Instructor Productivity Measures

(Relative Time Weights To Create Course Products as a Function of Instructor and Equipment Characteristics)

Course Materials Class	Original								Revision							
Equipment Class	Complex				Simple				Complex				Simple			
Similarity To Existing Equipment	Like		Unlike		Like		Unlike		Like		Unlike		Like		Unlike	
Writer's Familiarity With Equipment	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Products:																
Instructor Guides																
Lecture	9	12	12	15	3	5	4	6	3	4	4	5	1	2	1	3
Laboratory	11	14	14	18	4	6	5	7	4	5	5	6	1	2	1	4
Lesson Plans																
Lecture	9	12	12	15	3	5	4	6	3	4	4	5	1	2	1	3
Laboratory	11	14	14	18	4	6	5	7	4	5	5	6	1	2	1	4
Student Guides																
Lecture	45	60	60	75	15	25	20	30	15	20	20	25	5	10	5	15
Laboratory	55	70	70	90	20	30	25	35	20	25	25	30	5	10	5	20
Visual Aids	.9	1.2	1.2	1.5	.3	.5	.4	.6	.3	.4	.4	.5	.1	.2	.1	.3
Handout Materials	1.8	2.4	2.4	3	.6	1.	.8	1.2	.6	.8	.8	1.0	.2	.4	.2	.6

required to write lecture Instructor Guides. The number "1" is the multiplying factor to apply to the time it takes to write an Instructor Guide. If it takes one hour to revise an Instructor Guide for a simple equipment which is like other equipments by an instructor who is familiar with the equipment, it will take two hours to do if he is unfamiliar with the equipment. It would take three hours to do if he was unfamiliar with the equipment and there were no similar equipments.

The highest weighting is assigned to the writing of Instructor Guides in the situations where the equipment is complex and unlike no other, and the instructor is unfamiliar with the equipment.

The weightings for laboratory Instructor Guides are somewhat higher (about 20%) because of the assumed effort required to try out the materials on the equipment.

Lesson Plans were given the same weighting as Instructor Guides since although the structure and sequence of materials is prescribed in the Instructor Guides, the details of what to present must be developed for the Lesson Plans.

Student Guides were arbitrarily assigned a weight five times that of Instructor Guides. The reason for this is that Student Guides are texts containing pictorials as well as verbal matter.

Visual Aids were assigned one-tenth the weight of Instructor Guides, and Handout Materials assigned two-tenths the weight of Instructor Guides because they will probably contain more text than visuals.

As can be seen, the numbers in the body of the table have a logical relationship. No claim can be made for either the precision of the absolute number or the relative ratios. The object of the presentation is to demonstrate that certain factors have an influence on the productivity of instructional personnel in creating certain course materials and that a logical framework can be created for weighting the efforts.

The numbers, however, could be used as a first approximation and modified appropriately as data were developed in the process of revising existing course materials and in developing new course materials.

In order to implement this scheme, ANF should classify the equipment-specific training programs in the manner indicated, determine the relative familiarity of the instructor assigned to rewrite materials and collect the number of hours required for the instructor to perform the work. As the data are collected and summarized, the relative weightings which actually exist should emerge. When sufficient data have been collected it should then be possible both to evaluate an individual's productivity against the norm for that kind of work, and to project manpower requirements based on known average expenditures.