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A SURVEY OF THE LITERATURE ON PREDICTION OF AIR FORCE PERSONNEL REQUIREMENTS

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FOREWORD

This report was prepared under the Applied Research Project No. 7190, "Weapon System Qualitative Personnel Requirements and Utilization," of the Training Psychology Branch, Behavioral Sciences Laboratory, Aerospace Medical Division, of the Wright Air Development Division, with Mr. Melvin T. Snyder as project scientist.

The report reviews and reports on the professional, unclassified literature covering methods of predicting personnel requirements for future Air Force weapon systems and is part of an overall review of the literature. A companion classified technical report which reviews the many classified QPRI Reports for specific aircraft, missiles and electronic weapon systems is being prepared in-service. That report will review the classified Air Force QPRI Reports from 1955 to 1960 for methodology, the evolution of methods in practice, and evaluate the state of the art as practiced. These two reports will serve as a partial basis for the discipline of the Air Force Qualitative Personnel Requirements Program (QPRI) and will depict QPRI techniques based on theory and practice, serve as training literature, prevent duplication of research efforts as well as enhance the utilization of techniques already developed, provide data for assessing current techniques and indicate areas needing research to develop and improve the reliability of methods as practiced.

ABSTRACT

A survey of methods for predicting personnel requirements for future Air Force weapon systems is presented with abstracts of 121 unclassified, professional documents. Emphasis is placed on identifying procedures for deriving personnel requirements information, and the supporting rationales. The current state of the art is evaluated and presented with implications for future research requirements. Conclusions from the study show that fairly thorough procedures exist for describing tasks and positions and for combining tasks into positions. However, no evidence was found of any systematic evaluation of this method. Estimating manpower requirements often has been done but only one report describes a procedure for doing this. Determining skill level requirements and criticality of tasks has received little methodological attention. Most attention has been directed toward the rating of skill levels rather than toward any objective determination of skill requirements. One exception provides a seven-point scale of operationally defined performance levels. Like the other techniques found in this survey, this one has never been evaluated.

PUBLICATION REVIEW

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INTRODUCTION

This study reviews and reports the professional, unclassified literature covering the methods of predicting personnel requirements for future Air Force weapon systems. Four specific areas were examined, as follows:

(1) Methods of describing the tasks and positions for which the associated equipment is not yet developed
(2) Methods of combining predicted weapon system work units and tasks into projected weapon system positions required to operate and maintain projected equipment in its operational environment
(3) Methods of predicting the number of personnel by projected positions required by the weapon system
(4) Methods of predicting the skill level of a person to meet the requirements of a position described for future equipment.

Altogether 121 unclassified professional documents were reviewed. Of these, 44 were directly applicable to the problem, and expanded summaries of these documents compose Appendix I. Appendix II contains abstracts of the 121 documents reviewed and deemed relevant to the problem surveyed. Emphasis was placed on identifying methods and procedures suggested for deriving personnel requirements information, and the supporting rationales. Data content and the results of research projects or systems applications were not generally included, except where necessary as examples. Data collection and presentation techniques and formats, and research suggestions were sometimes included. Most of the relevant documents described work done by or for the military services. Of these, studies sponsored by the Air Force and applications to military systems predominated.

Three principal sources of material were Wright Air Development Division, the Armed Services Technical Information Agency, Washington, D.C., and the Technical Library of the American Institute for Research. A review of the professional journals and popular literature was not included, since they were not expected to provide much new or valuable information. The WADD files, the major source of material, included the files of the former Air Force Personnel and Training Research Center (ARDC).

There are four groups of information in this report. The first covers the results of the survey and includes an interpretation of the current state of the art of methods for predicting personnel requirements of future weapon systems. The second contains the bibliography of the documents abstracted. The third grouping contains the expanded summaries of the 44 key documents, and the fourth, abstracts of all documents reviewed.

Describing Positions

Reports on methods for describing positions can be put into three categories:

1. Explicit attempts to synthesize a procedure for describing or analyzing positions or tasks.

2. Methods developed incidental to the solution of another problem.

3. Statistical or inductive analyses of a variety of jobs in an attempt to develop a collection of activities that could be used to describe positions by selecting those pertinent to the particular position in question.

Synthesized Procedures

There are seven reports devoted to presenting comprehensive procedures for describing positions or analyzing tasks in positions. All of these reports appear to be derived to a great extent from A Method for Man-Machine Task Analysis (R. B. Miller, 1953b). Although each of the seven reports may add some feature to the basic procedure, or change terminology to some extent, they all follow the same general approach. This technique begins with a determination of system functions--what is the system supposed to do? From these, one proceeds to those aspects of system performance that are to be carried out by the man or men in the system. These are called operator functions. Each operator function is then analyzed into tasks and then into subtasks. The subtasks are described in terms of the stimuli, the response alternatives to each stimulus or stimulus configurations, and the effector activity associated with each response alternative. Slightly different procedures (and related formats for analysis) are provided for procedural tasks and continuous tasks. One important part of the technique that cuts across the various aspects of the description, regardless of the kind of tasks being analyzed is "program analysis." Program analysis is the process of identifying conditions or events that can occur during performance of a task or group of tasks that are thought to change the performance requirements to some extent. The usual kind of change is to make the task more difficult to perform, or to make it necessary for the performer to have skill or information he would not require to perform the task under routine, or ideal, conditions. An example of a "program" condition is inclement weather in flying an airplane.

Later reports that are apparently derived from the original Miller report are as follows: Glaser, Hahn, and Phillips (1953a) add to the basic task analysis the consideration of team factors or the relationships among various personnel performing related tasks at approximately the same time. This report also identifies some sources of various kinds of task analysis information for Navy systems. The later Miller report (1955a) is essentially a reworking of the original report, in an attempt to put it into a manual or guide form rather than in the form of a research and development report. This manual emphasizes three kinds of behavior for analysis: Perceiving, Decision-Making, and Manipulating, and provides rules and procedures for identifying job skill and knowledge requirements for each kind. About a year later, a revised version of the manual was prepared (Miller 1956a). This last formal report probably represents the most complete presentation of a method for position description found in this study. It undoubtedly includes new thinking that Miller put into the problem since the earlier reports, as well as a few years of experience in trying to use the task analysis methods proposed earlier. This last report did not present new concepts, but pulls together all of the previous work into a fairly complete technique.

Ray, Passey, Adams, Smader, and Simon (1957b) have taken bits and pieces of work done by Miller and his colleagues and put them together into what they called "Task Equipment Analysis." This report does not appear to add any new concepts or procedures to those that had already been described. Erickson and Rabideau (1957), do essentially the same thing, with the exception that they make more explicit the purposes for various aspects of the analysis, and describe the kinds of information needed for each.

Miller (1954b) proposed some "short cuts" that could be used in task analysis if the purpose of the analysis was limited to design of training devices. The main difference between the "short cut" method and the more complete technique was in the comprehensiveness in description of the detailed behaviors required. In the full-scale method, all procedural steps are described in detail. In the "short cuts" method, only those behaviors judged by the analyst as requiring some kind of special training device facilities or characteristics are described. This technique, designed to save time and effort in preparing task analyses, puts considerably more reliance on the judgment of the analyst. Once the judgment is made to exclude some item of the analysis because it is thought that it will require no special training device features, no check can be made on this judgment until it is probably much too late to change it if incorrect.

A study done in support of the position description--task analysis work, identifies sources of information for doing these analyses before system equipment is built. The major report of this study (Miller, Meister, & Feroglia, 1955) transposes information required for task analysis into equipment or system information needed for derivation of task analysis information. The report then describes sources for these kinds of information. Most of the sources are described in Air Force terms, particularly when referring to the various documents that are prepared during system development.

An ARDC report (1958) reviews QPRI procedures and specifies the content of the required QPRI report. The procedures include suggested ratings for difficulty, criticalness, and newness of tasks. The definitions of the points on the rating scales are not entirely operational, however, and would probably not be particularly helpful in deciding upon training content or personnel requirements.

One group of reports deals with a particular aspect of task analysis--determining the knowledge requirements for a given position. This problem is given considerable emphasis in the Miller techniques mentioned earlier. Miller and Van Cott (1955) present a procedure for job knowledge analysis. This report includes a checklist of job situations that usually require the application of some kind of job knowledge, and a procedure for identifying the particular knowledges required for a particular job. The procedure is rather involved, but is the only one found in this survey. Van Cott, Berkun, and Purifoy (1955) present a number of examples of applications of the Miller and Van Cott techniques. Bamford (1954) presents an early attempt at determining the conceptual content of a job by applying methods then available to the job of changing a tire on an automobile.

The major characteristic of all of the task analysis methods described above is that they require, in varying degrees, the detailed description of all procedural steps to be performed in carrying out the job. The result is usually a voluminous compendium of such descriptions, to be used for a variety of purposes in developing the personnel subsystem during system development.

Methods Developed in Solution of Other Problems

As might be expected, most of these methods are slanted toward the particular problem being considered when the method was developed, and may therefore have limited applicability. Altman and Purifoy (1959) provide a comprehensive checklist of items on ten different dimensions, to be used for early estimates of training requirements. The use of this checklist is not intended to replace the more detailed type of analysis characterized by the reports mentioned in the previous section, which is applicable at later stages of system development.

A series of reports dealing with analysis of maintenance job requirements for electronic systems also made use of the detailed procedural task descriptions, but in addition provided behavior categories for summarizing the tasks. Miller and Folley (1952) used such categories as "Discriminations and perceptions," "Knowledges," "Mental skills and abilities," and "Manual skills and abilities" to describe the job requirements for maintenance of the AN/APQ-24 bombing system. These same categories were used in later studies of electronic maintenance jobs (Miller, Folley, & Smith, 1953a; Miller, Folley & Smith, 1954; and Folley & Miller, 1955).

Categories of tasks were also used by Indiana University (1953) in a study of the K-system bombing system. In this study, tasks were put into four classes graded according to "complexity." The four classes of complexity were derived from the degree of abstractness of the tasks. The four classes were in one sense quite broad, as might be expected, but in another sense were quite specific to this particular study. The given classes are: "Reading dials and indications," "Knowledge of what happens when certain controls are manipulated," "Knowledge of the rudiments of data flow," and "Knowledge of the bombing problem." The technique was apparently applied only to procedural tasks.

North American Aviation (1958) also reports a task-equipment analysis for a particular system. The method used here reports mainly the overt physical information about the tasks. Little is said about how the skills and knowledges were determined, except that determination of skill and knowledge requirements for the tasks was done "by expert personnel."

R. S. French (1957) used a detailed description of each procedural step as his beginning point for determining required characteristics for a training device. Each step of the procedure was rated on each of ten dimensions designed to provide suggestions for training device characteristics. Many of the ratings lacked operational definitions, which reduced their value for this purpose. For example, one rating for one of the dimensions is "above average reasoning ability is desirable."

Analyses of Groups of Jobs

Relatively little work appears to have been done with this approach, possibly because the results have not been particularly good. May (1951) examined a sample from over two thousand Air Force jobs in an attempt to develop a list of activities of behaviors from which future job analysts could select items to describe other jobs. He found that most of the statements describing the jobs were either too specific to the particular job, so that they would not be applicable elsewhere, or else so general as to convey very little information. He concluded that a different approach was necessary. Thorndike, Hagen, Orr, and Rosner (1957) did a factor analysis on a large number of activities that had been rated on a five-point scale of frequency of performance by a sample of Air Force personnel. This analysis resulted in fourteen general dimensions on which Air Force jobs could be described. Examples of these dimensions are "Social-verbal" and "Reasoning."

In another statistical analysis of a group of aircrew jobs, Hahn (1954) developed eleven "ability" elements, exemplified by "Understanding verbal materials," and four personality or motivational elements, exemplified by "Accepting organizational responsibility." In a similar type of analysis, Besnard (1954) studied the job of aircraft mechanic to determine whether it could be reasonably "shredded out" into several jobs. He had tasks rated on "difficulty" by a group of technical experts ("Relatively difficult," "Average difficulty," "Simple"). Tasks were then clustered on the basis of their difficulty. He found that four jobs, all differing from one another on this dimension of "difficulty" could be shredded out from the formerly single job of aircraft mechanic.

The methods employed in this group of studies has the characteristic that some kind of performance data must be available on the jobs to be studied. This requirement virtually eliminates these techniques as possibilities for predicting personnel requirements for systems under development.

Methods of Presenting Descriptions

Preliminary position descriptions are relatively brief and fall into the traditional presentation format, which includes some identification of the work environment and the relationship of the position to other positions. Variations of this format are suggested by the Air Force Personnel and Training Research Center (1956), Stackfleth (1958) and Air Research and Development Command (1958). Weislogel and Jacobs (1956) suggest an overlay technique applicable to presenting sequential gross task data with the possibility of superimposing those additions or variations of tasks imposed by different "program variables" or contingencies. This technique is also suggested for presenting functional and time loading within a position. Jones and Miller (1956) recommend functional block diagrams for the presentation of temporal task sequences, and work flow "route maps" for the display of geographic location relationships, and the transportation requirements they generate.

More detailed presentation techniques and formats are called for by final position descriptions. Generally, a tabular form of data summary has been used to handle the large amounts of detailed data. Miller (1956a), Air Force Personnel and Training Research Center (1956), French (1957), Stackfleth (1958), and Air Research and Development Command (1958), suggest a variety of alternatives. As Miller (1956a) and Kershner (1955) point out, the analysis-presentation format and level of specificity should vary depending on the purpose and data requirements which initiated the analysis. Erickson and Rabideau (1957) reiterate some of the above formats.

Glaser, Hahn, and Phillips (1953a) suggest an overlap table for the presentation and identification of similarity among tasks of related positions. The comparison is at a fairly gross level, although it requires moderately detailed equipment data. Miller, Folley, and Smith (1954) use a set of behavior categories for comparing the behavioral activities of two similar positions. Jones and Miller (1956) suggest detailed block diagrams and flow charts to present functional sequences and relationships, including the effect of program variables and contingencies and the possible alternatives of action. Block and circuit diagrams are suggested for presenting troubleshooting and other task procedures and strategies. Flow charts are suggested for presenting work cycles and location interrelationships.

Knowles (1959) presents a code for summarizing the steps in task procedures, including procedures with specifiable alternative sequences. This code presents numbers, representing the number of simple control actions, and letters to indicate sensory inputs (S), skilled motor acts (M), recall (R), and decision points (C). A procedure might look like this: 5-M-S-2-R-S. It obviously depends upon categorization of procedural steps into one of these classes. The technique is not a method of task analysis, but a method for summarizing procedures. It permits a check of whether any procedures are incomplete in the sense of leaving any "loose ends" for which steps have not been specified. Snyder (1959) suggests describing tasks on flow charts using symbols to indicate various kinds of activity. Triangles indicate information, circles indicate decisions, and squares indicate action. The symbols always appear in this order to describe a task. Verbal description of the symbols is placed along the side of the flow chart.

Ghiselli and Brown (1955) and Erickson and Rabideau (1957) suggest one form of time-line presentation of temporal behavior interrelationships. Another type of time line is described by Miller (1953b), which has the added flexibility of presenting both behavioral elements which must be performed in a fixed sequence and time, and those elements which are required but are not fixed in the time of their occurrence. This type of technique is applied to several positions in Murphy, Fairman, Lindner, Smith, and Purifoy (1959).

Combining Work Units and Tasks into Positions

There are two major methodological reports pertinent to this part of the survey. A few others, dealing with identifying common elements among jobs, or with classifying tasks, complete the information available at this time.

Miller (1956b) suggests a procedure and several criteria for grouping tasks into positions, and presents three methods for testing the soundness of the groupings. He states that the structure of operator positions is largely predetermined by design of the equipment. He therefore gives relatively little attention to the problem of how operator positions can by synthesized. Rather, he presents the three methods for evaluating the positions that have evolved. He points out that unless equipment redesign is permitted, corrective action based upon unfavorable results of tests such as these will be limited to reallocation of tasks among already-existing positions. In discussing maintenance and support positions, however, he suggests a number of criteria to be used in assigning tasks to a given position. It would appear that these same criteria could be used for operator positions as well, if they were applied early enough in development to have significant effect on system design. Examples of these criteria are:

1. Tasks requiring similar knowledges and skills should be grouped together.

2. A sufficient number of tasks should be included in a position to keep the man busy for a typical work period.

3. Tasks should be grouped so that the resulting positions resemble comparable positions on other similar systems.

The three tests are the blackboard test, the simulator test, and use of the Operational Suitability Test situation. The blackboard test is conducted like a game with a proponent, opponent, and umpire. The umpire makes judgments about the effectiveness with which the proponent can carry out specified missions or work cycles posed by the opponent. Observations made by all parties are collated and the results evaluated. Presumably ideas are generated for modification of the position structure that would result in more effective meeting of the problems posed by the opponent.

The simulator test requires presentation of anticipated "programs" and problems in a simulated work situation. Observations are made and suggestions generated for modification of the position structure to increase effectiveness in meeting the problems. Use of the Operational Suitability Test situation consists merely of taking advantage of an opportunity to obtain information about system performance. The analyst usually is not able to control the problems on which he obtains his data in this situation, so data may not be as systematically obtained as in the other two types of tests.

The procedure for working out provisional position structure is spelled out in considerable detail. It builds from the established system requirements, such as the flow of events in a typical work cycle, allowable turn-around time, number of aircraft (or other units) per organization, and, in the case of maintenance activities, the location at which the various levels of maintenance will be performed. The procedure requires many judgments on the part of its user (for example: "Estimate the performance time for each task"), but does lead to a structuring of positions.

Ray, Passey, Adams, Smader, and Simon (1957a) also propose a procedure for structuring positions. They also start from system "givens," e.g., allowable turn-around time, for aircraft maintenance jobs. The initial step in structuring the position is to add a term such as "mechanic" or "repairman" to the name of a major subsystem, such as "hydraulic," resulting in the tentative position of "hydraulic repairman," for example. Each task, taken from the nonposition-structured task analysis, is assigned a required skill level. Clear definitions of these skill levels are not given. They are apparently considered synonymous with the standard 3, 5, and 7 level of AFSC. This technique also requires substantial judgments of the analyst, once again requiring that performance times for each task be estimated. Apparently the problem of workload is used only in determining the numbers of personnel required to perform the total maintenance job, and does not enter significantly into the assignment of tasks to positions.

Other studies pertinent to the problem of combining work units into positions are Peterson (1956), Peterson, Jones, and Ellis (1957), and Cotterman (1959). The first two of these reports deal with analysis of task procedures to determine job knowledge requirements. The work on which these reports are based was concerned with finding common content between two maintenance positions for the purpose of establishing a "core" training course. In both cases, the technique is one of examining the procedural steps, and attempting to identify the information required to perform the steps. Information common to both positions would presumably be appropriate for the core course. In the second report, four aspects of the position were studied: Objects used on the job, Instructions, Precautions to be observed, and "Tricks" that facilitated job performance. It would seem that a similar approach could be used in comparing tasks for a determination of which tasks should be put into a single position.

Cotterman's report is concerned with the establishment of generally applicable classes of tasks or behaviors. He in effect proposes generalized definitions of "commonly recognized" tasks in the hope that other tasks can be fitted into the porposed definitions. Presumably all tasks that are adequately described by a given definition would have the characteristics mentioned in that definition. Selection and training characteristics established for the defined class of tasks would then be applicable to the particular task. This original work is a funcamental step in establishing a task taxonomy that will be helpful in predicting personnel requirements for systems under development. It is clearly not intended to be directly applicable to that problem at its present stage of development.

Estimating Manpower Requirements

Although this activity is performed on every weapon system that is developed, only one report was found that deals specifically with a method for making these estimates. Ray, Passey, Adams, Smader, and Simon (1957a) integrate manpower estimation for some positions, at least, with their technique for structuring the positions. Total maintenance time workload for a given work period such as turn-around time is estimated by combining, according to formulas provided, time required for routine and nonroutine maintenance that must be performed during that time. Time requirements must be estimated for each task, or taken from a task analysis in which the times have been estimated. An estimate is then made of the skill level required for performance of each task. The number of persons required at each skill level in each position is determined by dividing the total number of man-hours of work required, by the period of time in which it must be accomplished. The result is the number of personnel at that level in that position that will be required to do the work.

A procedure is described for making adjustments to this basic figure, depending upon the number of persons required to perform a given task, the skill levels required for the various tasks, and other factors. Other steps are described for converting within-position estimates into organizational manpower requirements.

The technique places much emphasis on skill levels required for performance of various tasks. Since the problem of "skill level" is perhaps one of the most poorly solved in prediction of personnel requirements, the technique suggested by these authors may not be built on a particularly firm foundation.

Determining Skill Level Requirements

The literature pertinent to determination of skill level is as sparse as that for establishing manpower requirements. No reports could be found that explicitly describe a method for identifying the skill level required for a given position. Ghiselli and Brown (1955) provide a list of 45 worker traits that can be used in describing a given job, and a three-point rating scale for specifying "how much" of each trait is required for performance of the job. An example of the traits is "Keenness of vision." The points on the rating scale are defined in terms of its presence in the general employed population. For example, a rating of "A" indicates that the amount of the trait required would be that possessed by only two per cent of the employed population.

Air Force Manual 35-2 presents two other rating scales, intended for evaluating existing jobs rather than for new positions in a system under development. One of the scales is for the physical aspects of the job. It is a six-point scale which rates the degree of dexterity required for performing the job. Examples of ratings are "Requires <u>little</u> dexterity or precision of movement, only slight muscular coordination and slow response to sensory cues" and "Requires <u>limited</u> dexterity and precision and coordination of movement with moderate responses to sensory cues." The other rating scale, designed for rating knowledges is equally inadequate. Two adjacent points on the rating scale are: "Requires <u>moderate</u> ability to comprehend reading material and instructions and perform elementary mathematical computations with limited formal or on-the-job training or adjustment" and "Requires <u>intermediate</u> technical knowledge, with considerable training prior to and during adjustment to work."

The rating of skill requirements for positions receives some attention from Kershner (1955) who quotes Rupe and Westen as stating that the ability of the job analyst to make psychologically meaningful estimates of skill and knowledge requirements of existing jobs is doubtful. Wiley, Harber, and Giorgia (1959) report that a sample of ROTC flight trainees shows consistent tendencies within individuals to rate high, low, or middle when judging the requirements for various Air Force positions. They conclude that the use of a small number of raters to determine the skill level requirements for a given position may result in highly erroneous conclusions about the requirements for the position.

In a study concerned with defining training standards, Murphy, Jones, and Folley (1959) concluded that "skill level should be defined in terms of required performance. They suggest that performance can be described in terms of four dimensions, as follows:

1. Time required to perform the specified task.

2. Accuracy in performance; the number and kind of errors made.

3. Amount and kind of supervision or coaching required.

4. Amount of reference to job aids other than those normally available and used in the operational performance of the task.

They describe a seven-point scale of "training standards essentially in these terms.

Summary of Results

In summary, then, we can conclude the following about the state-of-the-art in predicting Air Force personnel requirements for weapon systems, as revealed by this survey of the literature.

1. Fairly thorough procedures exist for describing positions and tasks. These procedures, or some modifications of them, have been used extensively. No evidence was found of any systematic attempts to evaluate the procedures to identify their strong and weak points.

2. There exists a procedure for combining tasks into positions. Once again, no evidence was found of any systematic evaluation of this method.

3. Estimating manpower requirements has often been done. Only one report attempts to provide a procedure for doing this. This method has apparently never been formally evaluated.

4. Determining skill level requirements has received little methodological attention. Most attention seems to have been directed at the rating of skill levels rather than at any objective determination of requirements. One exception provides a seven-point scale of operationally-defined performance levels. Like the other techniques found in this survey, this one has never been evaluated.

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APPENDIX I

SUMMARIES OF KEY DOCUMENTS

Air Force Personnel and Training Research Center. The qualitative personnel requirements information program: A briefing. Lackland Air Force Base, Texas: Author, August 1956.

Purpose

This document is the publication of a briefing held at the Air Force Personnel and Training Research Center, Air Research and Development Command, Lackland Air Force Base, on August 25, 1956, to present to the System Management Directorate the Qualitative Personnel Requirements Information Program as it relates to Weapon System Project Office responsibilities. It reviews the developing need for QPRI, the assignment of the program to AFPTRC as the responsible agency, the operation of the program, and the status of qualitative personnel requirements information for current systems, under AFPTRC jurisdiction. The sections concerning then-existing development systems and Air Force organization are omitted from this abstract, which is limited to the method of program operation then in use.

Conclusions

The QPRI method of operation in use during 1956 was divided into two phases, pre-mockup and post-mockup. Within these phases, the use of four types of analyses is described; the task inventory, hypothetical manning list, position description, and training devices information formats, illustrating the presentation of the results of these analyses.

Pre-mockup studies and reports are time phased according to the system mockup schedule. Two types of pre-mockup reports are furnished; manpower and organization, and special training device information.

The manpower and organization report contains the following material:

1. General section.

    a. System design
    b. Alternative assumptions

2. Manning document information.

    a. Identification of positions. See Figure 3.
    b. Task lists and ratings for new skills. See Figure 1.
    c. Recommended AFSC's. See Figure 2.

LANDING GEAR	INSPECTS	ADJUSTS	TROUBLE-SHOOTS	REPAIRS	REPLACES	SERVICES	OPERATES
MAIN GEAR	B B 1 2						
LEG	B 1	B 1	B 1	B B 1 2	B 1		
STRUT	B C 1 2	B 2	C 2	C 2	B 2	B B 1 2	
DRAG STRUT	B C 1 2	B 2	C 2	C 2	B 2		
WHEEL	A 1	A 1	A 1	A 1	A 1		
TIRE & TUBE					A 1	A 1	
BRAKES	A A 1 2	A A 1 2	A A 1 2	A A 1 2	A A 1 2		
MASTER CYL.	A A 1 2	B 2	B 2	B 2	B 2	A A 1 2	

1. AIRCRAFT MECHANIC
2. HYDRAULIC REPAIRMAN

A. COMMON TASKS
B. REVISED TASKS
C. NEW TASKS

Figure 1. Example of a Task Inventory for Maintenance

CODE	POSITION TITLE	AFSC	DEFINITION
1	Aircraft Mechanic	43151C	. . . . . .
2	Aircraft Hydraulic Repairman	42152	. . . . . .
3	Aircraft Electrical Repairman	42350	. . . . . .
4	Mech. Accessories & Equip. Repairman	42351	. . . . . .
5	Jet Engine Mechanic	42350	. . . . . .
6	Airframe Mechanic	53450	. . . . . .
7	Fire Control Systems Mechanic	32250	Responsible for all radar maintenance. Responsible for the visual sight calibration but not repair. Responsible for the I.R. sight. May be on the line or in the docks.

Figure 2. Hypothetical Manning List (AFM 35-1)

Position Description Title (AFSC)

A. General Features

Supervisory & Maintenance Responsibilities
Working Enviroment
Tool & Test Equipment

B. Duties and Tasks

C. Resemblance to Existing Positions

D. Indicated Position Qualifications

For entry into initial training
For transition training

Figure 3. Position Description Organization

The special training device information report includes:

1. Identification of training requirements (AFR-50-19).

2. Gross training characteristics.

The post-mockup phase includes three reports, more specific than those of the first phase. They are change reports, recommendations for special training devices, and a quality control report.

The change reports are prepared when:

1. The operational concept is altered.

2. The maintenance concept is changed.

3. New equipment is developed.

4. Design revisions are made.

The detailed report on recommendations for special training devices includes:

1. Identification of the specific training task.

2. Statement of the general training content.

3. Specific training device characteristics. See Figure 4.

The quality control report evaluates the quality and usefulness of the qualitative personnel requirements information previously rendered.

In preparing the position descriptions (Figure 3) the following steps are followed:

1. Prepare the task inventory (Figure 1).

2. List the assumptions regarding the operation and maintenance concepts.

3. Prepare manning hypotheses for each assumption.

4. Integrate the manning hypotheses and the task inventory.

5. Assign a "difficulty code" to each task (Figure 1). See Miller (1956a) and ARDC (1958).

TRAINING AREAS	TRAINING GOALS	TRAINING DEVICE COMPONENTS	COMPONENT CHARACTERISTICS
B. Initial Scope Interpretation	B.	B.	B.
4. Decision Making	4a Be able to decide on a course of action when a radar return is detected based on: known tactical situation,...	4a(1) Inanimate visual aid	4a(1) The aid to show the attack geometry and the resultant display. The indeterminancies should be highlighted...
		(2) Animate visual aid	(2) The aid to include representative sample of dynamic attack geometries...
		(3) MA-X and connected target generators	(3) The MA-X should be mounted on a controllable platform simulating... MA-X controls should include,... Flight Platform should include throttle,...
	4b Understand the principle types of conversion maneuvers...	4b Inanimate visual aid	4b Each course of action should include the appropriate pattern...

Figure 4. An Example of Training Devices Information

6. Assemble the duties and tasks into the position definition. See Figure 3.

7. Define each task.

8. Prepare the section (Figure 3) on General Features.

9. Prepare the section (Figure 3) on Resemblance to Existing Positions.

10. Prepare the section (Figure 3) on Position Qualifications.

In preparing the special training devices information, these steps are followed:

1. Identification of critical tasks. See Gagne (1954) and ARDC (1958).

2. Analysis of the tasks for critical skills and knowledges.

3. Determine the background of personnel to be trained.

4. Estimation of the training context.

5. Inference of the training device characteristics. (Figure 4)

Air Research and Development Command Headquarters. Reference manual for QPRI. Wright Patterson Air Force Base, Ohio: Author, October 1958.

Purpose

QPRI defines the equipment-associated military positions required for a standard working shift for a weapon/support system. It includes information on duty positions for all operator and maintenance type people associated directly with the system. QPRI does not include position descriptions for logistics or base support type personnel positions, nor does it include statements of training requirements or training.

This document reviews the procedures for preparing qualitative personnel requirements information and the status of the QPRI program at the time of its publishing. Sections of the document, and in-house manual, on Responsibilities, Management Policies and Procedures, Project Status, and Regulations and Letters, are not abstracted here. The section on QPRI Report Content and Format is reviewed.

Conclusion

The format presented here is based on a Headquarters, USAF, 17 July 1958 letter to the Commander, ARDC, on "Production of QPRI," directing ARDC to assume responsibility for QPRI research and development. The following report format was established:

I. System Description.

1. Military purpose and operational characteristics.

2. Maintenance and operational concepts, plans, and assumptions.

3. Statement of development stage or phase.

II. Description of New Equipment.

III. Maintenance Operations Sequence Summary. Organizational and work flow diagrams.

IV. Manning Estimates.

V. Position Descriptions.

VI. Special Information or Problems.

Duties and Tasks	Equipment Involved	Special Tools, Test Equipment Used	Frequency	Time	Skill Identification
Supervises* Inspects Adjusts Checks Repairs Troubleshoots Operates Records	Identified to the component level.	Unusual tools and specialized equipment.	Daily, Weekly, Once a month.	Hours or minutes, as appropriate.	Coded 0-5, indicating the degree of skill, the complexity, or the knowledge required to perform the task.

*Other verbs may be used, as appropriate. These action verbs should include a statement of purpose for performing the duty or task.

Figure 1. Duty-Task Analysis Example

Three elements of information were suggested for the coding of each task.

1. How demanding it is in terms of physical, mental, or motor skills. This may be coded from 0 to 5 (none, slight, moderate, substantial, involved, critical). More complete definitions of these ratings may be found in AFM 35-2, page 18.

2. How critical correct performance is to weapon performance and mission success. Task criticality is rated a, b, or c.

    a. Non-critical. Improper performance would not jeopardize the over-all system performance or the mission success.

b. Critical for system operation and may result in system degradation, if performed. Affects equipment which is nice to have but without which mission can succeed using alternate modes.

c. Critical to system operation. If improperly performed, the system may not work or the operation would be degraded to an unacceptable level.

3. How new is the task, or are Air Force personnel presently doing it. Task newness is rated 1, 2, or 3. See Miller (1956a).

(1) The equipment is standard to the Air Force and requires no new skill or knowledge to perform. The task requires no formal training, only familiarization with the location and/or installation of the equipment.

(2) Standard equipment, reconfigured or repackaged. Special training required for new part, component, or subsystem. May require new skill.

(3) Requires new skills and knowledges. New principles or new application of existing principles may be involved. Special training and possibly fundamental training is required.

Altman, J. W., & Purifoy, G. R., Jr. AN/AMQ-15 weather reconnaissance system: Preliminary training report. Pittsburgh: American Institute for Research, January 1959. (Subcontract BSD P. O. A2736, Prime Contract No. AF 33(600)-37984)

Purpose

The purpose of this report was to outline an approach to the development of comprehensive and economical training recommendations for a complex weapon system, identify sources of information available for this analysis during the design development stage, and illustrate the application of this technique to the AN/AMQ-15 Weather Reconnaissance System. The Method of Analysis is abstracted here.

Rationale

Review of training research and development reports and rational analysis of the AMQ-15 training problem suggested that the dimensions below are of principal importance at present. Personnel functions were the basic data to which these skill and training dimensions were applied for analysis of training requirements.

Subsystem. Localizes the area of the system for which training content must be programmed.

Technical Field. Identifies the technological body of knowledge to be tapped for training content.

Skills and Knowledges. Suggests the underlying abilities required for effective performance of the observable job behaviors.

Background and Experience. Estimates how many of the required skills and knowledges will already be in the repertoire of the trainee, and to what degree of proficiency.

Performance Aids. Identifies the stimulus and response supports which will be available in the job environment, thereby affecting the required training.

Training Location. Suggests the situation(s) under which the subject training will be accomplished.

Stages of Training. Identifies the range of proficiency trained at each location.

Training Methods. Delimits the matrix of training within which aids and equipment will be used.

Training Aids. Suggests the symbolic supports to be used for vicarious practice.

Training Equipment. Defines the type and extent of simulation provided for more or less direct practice of job behaviors.

Scheduling or Phasing

This method was developed for application to a system in the early design development stage, before detailed equipment data are available for more specific, behavioral analyses.

Summary of Method

Each personnel function identified in a systems function analysis as part of a system-unique job was reviewed by an analyst and coded on each of the skill and training dimensions above. The code symbols for each function were recorded on a form identifying the position and function, and having columns headed by each of the training dimensions below. The coding dimensions below were determined by rational analysis and review of training research and development reports.

The coded training dimensions of each function were then sorted so that a cross section was obtained for each position. Training requirements summaries for each unique position were then prepared, based on the coded sheets. These summaries, of which the report contains samples, present:

1. A functional description of each position.
2. An outline of training requirements for each position, considering the background capabilities of each AFS and the stages and methods of training appropriate to the particular situation.
3. Recommendations for location of each training segment.
4. Recommendations for types of training and job aids for each training segment.
5. Recommendations for the types and characteristics of training equipment.

Skill and Training Dimensions

Subsystem

a. Aircraft
b. Horizontal
c. Vertical
d. Radar
e. Air Sampling
f. Computer
g. Data Link
h. Airborne Data Storage
i. Console
j. Ground Data Processing
k. Ground Support Equipment
l. Test Equipment

Technical Field

a. Electronics
b. Electricity
c. Pneumatics
d. Hydraulics
e. Mechanics
f. Chemistry
g. Optics
h. Meteorology
i. Aerodynamics

Skills and Knowledges

a. Discrimination (perception)

	a) Visual	b) Auditory	c) Tactual
1) Go, no-go			
2) Comparative	.	.	.
3) Categorical	.	.	.
4) Quantitative	.	.	.
5) Language	.	.	.
6) Code	.	.	.

b. Manipulation

1) Discrete control
2) Continuous control
   a) Discrete feedback
   b) Continuous feedback
3) Gross tool
4) Fine tool
5) Lifting
6) Positioning
7) Connecting

c. Decision-making

1) Computation

2) Selection of well-defined alternatives
   a) With objective probabilities of outcome
   b) On the basis of subjective probabilities
3) Definition and selection of alternatives
4) Educated trial and error
5) Following routine procedure, but determining when routine is not applicable
6) Circuit analysis
7) Systems analysis

d. Recall

1) Short term — a) Specifics — b) Principles
2) Long term

Background and Experience

1. Fully adequate for satisfactory performance
2. Requires only orientation and refresher training
3. Contains primary skills and knowledges but requires specifics
4. Contains only fundamentals

Performance Aids (also Training Aids)

1. Job-oriented manual
2. Equipment-oriented manual
3. Procedures checklist
4. Wall chart
5. Panel-mounted diagram of equipment (training aid only)
6. Panel-mounted photograph of equipment (training aid only)
7. Movie (sound)
8. Movie (silent)
9. Film strip (sound)
10. Film strip (silent)
11. Slides
12. Closed circuit TV
13. Recording or tape
14. Fractional scale model
15. Data flow diagram
16. Schematic diagram
17. Notebook sized diagram of equipment
18. Notebook sized photograph of equipment
19. Proceduralized troubleshooting guide
20. Troubleshooting form boards or paper-and-pencil equivalents (training aid only)
21. Overlays

Training Location

1. School
2. Detachment
3. OJT

Stages of Training

1. Orientation or indoctrination
2. Nomenclature
3. Locations
4. Simplified practice
5. Full-difficulty practice

Training Methods

1. Lecture
2. Demonstration
3. Discussion
4. Coached practice
5. Self-practice

Training Equipment

1. Unmodified operational equipment
2. Modified operational equipment
3. Full task simulator
4. Troubleshooting trainer
5. Procedures trainer or mock-up (functional)
6. Procedures trainer or mock-up (semi-functional)
7. Procedures trainer or mock-up (nonfunctional)
8. Tracking trainer
9. Teaching machine (written response)
10. Teaching machine (multiple-choice response)
11. Cutaway (animated)
12. Cutaway (nonfunctional)

Comments

This approach was developed to provide an initial overview of system personnel and training requirements prior to the point in the development phase when equipment information, as needed for even a preliminary task-equipment analysis and subsequent personnel and training analyses, becomes available. It was not designed to replace the more detailed and psychologically oriented methods which may be used just a few months further along in the development cycle.

American Institute for Research. A study of methods of anticipating requirements for maintenance of complex electronic equipment. Final Report. Pittsburgh: Author, February 1955. (Air Force Personnel and Training Research Center Project No. 7709, Task No. 77151, Contract No. AF 18(600)-600)

Purpose

This report summarizes the whole study briefly. It was an attempt to demonstrate that a detailed training program based on a task analysis of a line maintenance job (for the A-3A in this study) could be developed prior to production of an electronic equipment. The study also considered what maintenance activities were common to three electronic systems (Folley & Miller, 1955) as a preliminary view of what might be included in fundamental training. The characteristics of a training program and the format and content of a line maintenance handbook were also to result.

This document also contains administrative type material which is not reviewed.

Procedure

The task analysis of A-3A line maintenance was begun first, along with the development of hypotheses regarding training, the handbook, and the comparison of job requirements. The tasks, derived from interviews and examination of the prototype and written procedures, remained stable although changes were made within some of the tasks. Enumeration of the tasks permitted a review of the adequacy of suggested maintenance procedures and brought to light inadequacies in the procedures (no provision had been made for a line quantitative check of system accuracy) which were later rectified.

The maintenance tasks were recorded on Job Behavior Forms developed earlier (Miller & Folley, 1951a; Miller, Folley & Smith, 1953a). Separation of the procedures into discrete steps permitted comparison of behaviors between equipments, and use as simple job instructions.

An Activity Analysis (Miller & Folley, 1951a) was also attempted of maintenance activities as practiced on the prototypes. However, it was difficult to distinguish between regular maintenance and special test and development procedures. While records were kept of components which failed, useful as malfunction examples for training, it was felt that this same end might better be achieved by the preparation of hypothetical problems illustrating the application of the principles of troubleshooting which seemed important.

When the contractor maintenance instruction handbook was published, the task analysis was revised and updated. In preparing the final job-task description, both the contractor troubleshooting procedure, based on the preflight check, and another troubleshooting procedure developed by this study, were included. The latter procedure, also based on the preflight check, emphasized the operation of the A-3A by modes, and did not require empirical malfunction data. This method was considered an improvement and the study hoped to show that the teaching of job relevant principles of troubleshooting could be incorporated into the statement of training content.

The characteristics for training course content were based on the job-task description, which provided the details of what was to be demonstrated and practiced. Both troubleshooting methods were included. Since troubleshooting was the most difficult thing to be learned, the tasks and information needed for it preceded it in the training program. Grouping of subtask activities into optimal training units was done on the basis of common skill or knowledge requirements, or on the basis of amount of demonstration required prior to practice.

Training devices were viewed as supports for demonstration and practice of the required job behaviors. Recommendations for training devices, for demonstrations, and for actual practice, were influenced by the operational equipment which could reasonably be expected to be available for training.

The line maintenance handbook, as training and job support, included statements of behaviors and supplementary knowledge required on the job, derived from the job-task descriptions. Emphasis was placed on the optimal form and information content of the diagrams and troubleshooting schematics (Jones & Miller, 1956). The format was derived from the way in which the handbook was to be used on the job.

An earlier comparison of common job requirements for the Q-24 and K-1 (Miller, Folley & Smith, 1954) was extended to include the A-3A (Folley & Miller, 1955). Individual behaviors such as dial reading were common to all three jobs, but the organizations of these behaviors were different. Only if logical, systematic troubleshooting procedures were used was there a common basis of problem-solving strategy. While there was a fair amount of common behavioral content, there was not much basis for abstracting a separate "basic" course.

Recommendations

The development of a quite detailed outline and format for the presentation of training recommendations would probably aid in maintaining a consistent level of discourse, especially if this document is to be prepared by the equipment contractor. The structure should indicate exactly what kind of information is required for each item in the structure.

Bamford, H. E. Task and conceptual analysis of the changing of a tire. Pittsburgh: American Institute for Research, October 1954.
(Appendix to: Miller, R. B. Preliminary statement of some working definitions and hypotheses on the conceptual process as it relates to training and job operations: Memorandum Report No. 1. Pittsburgh: American Institute for Research, October 1954). (Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205)

Purpose

This document presents the sample formats for a task analysis and resulting conceptual analysis, to illustrate the abstraction of conceptual content from a description of job behaviors. No judgment is implied as to the relative influence on job performance of these examples of conceptual content. Neither are the examples indicative of the form in which the conceptual content of a job would appear in training. It is merely an indication of an approach to the problem of conceptual analysis of job behaviors.

Rationale

The task analysis consists of a detailed description of the discriminations and other responses which are required by the job. See Figure 1. The conceptual analysis sets forth the conceptualizations which might or should mediate those discriminations, decisions, and motor responses. See Figure 2. Conceptual content is thought of throughout as stored information (mediating particular job behaviors), in any one of the following modes:[1]

1. Object-imagery on map-like conceptualization.
2. Abstraction and classification of objective stimuli.
3. Process sequence and cause-effect conceptualization.
4. Symbol or image transformation.
5. Conceptualization of procedures.

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[1]For a discussion of these terms, refer to the Memorandum Report No. 1 to which this document was appended.

Summary of Method

It will be noted that conceptual content mediating each job behavior for which conceptual content was abstracted is referred to by number in the MEDIATION column of the task analysis. Also, each example of conceptual content is referenced by task number to the task steps which it mediates.

TASK STEP	DISPLAY		MEDIATION	CONTROL DESCRIPTION	CONTROL ACTION	INDICATION OF RESPONSE ADEQUACY
	DESCRIPTION	CRITICAL VALUE				
Job	Segment 1 Replace tire and wheel with spare					
Task	1.1: Secure wheels of car					
9	Car	On incline	Decision to select block for wheel. (Concepts 6,12,19)	Blocks	Approach	Blocks within easy reach
10	Blocks	Different sizes & shapes	Selection of one block. (Concepts 12, 19)	Block	Pick-up	Block in hand
12	Block	In hand	Decision to place under wheel. (Concepts 12, 19)	Block	Place under wheel	Block properly placed
12.5	Block	Under wheel	Decision to test adequacy of block. (Concepts 12, 19)	Emergency brake	Release	Car does not roll down hill

Figure 1. Task Analysis of Procedures

No. 19 | Rolling of Wheel | Mode: Process sequence and cause-effect conceptualization.

Content: A. Statment of principle. It is much more difficult to move a wheel from one place to another by dragging it or by carrying it than by rolling it. On an incline a wheel will tend to roll unless restrained or laid flat.

B. Essential variables of principle in operation. Slope of incline, weight of wheel.

C. Limiting conditions for application. If a wheel is permitted to roll without restraint it may acquire a dangerous momentum.

Job Behaviors Mediated: 9, 10, 12, 24, 25, 32

Errors Prevented: Releasing wheel while standing on incline, jacking up car without blocking wheel, dragging or carrying wheels about.

Suggested Training: Demonstration plus verbalization.

Figure 2. Sample Conceptual Analysis

Besnard, G. G. Shredouts of tasks performed by senior B-29 mechanics (AFSC 43151-B). Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, April 20, 1954. (Technical Report 54-4) (Project No. 507-015-0001)

Purpose

To determine whether a job is divisible into "shredouts" according to the number and average difficulty of the tasks in the total job that each shredout performs.

Procedure

The job, AFSC 43151-B, Senior Aircraft Mechanic on the B-29, was chosen as one in which the tasks were well defined and consistent from base to base.

To break the job into component parts, a task checklist was given to job incumbents. The tasks were derived from job analyses, technical orders, and supervisory personnel long acquainted with the equipment. Sample incumbents indicated which tasks were ones they performed.

The technical difficulty of each task was established by averaged evaluations by equipment experts, assigning ratings of "relatively difficult," "average difficulty," or "relatively simple."

To identify clusters of related tasks, an inverse factor analysis was made of a subsample of incumbents; the factors resulting were then clusters of men. Six factors of men performing similar tasks resulted, and each factor was defined by the tasks within that factor performed by 90 percent of the factor as well as by the tasks which no one in the factor performed. The remaining incumbent-subjects were classified into the one factor on which their total "score" was 85 percent of maximum correspondence with the factor definition, and 70 percent of the tasks performed. Because some incumbents scored high on several factors, differentiating tasks were isolated which were performed regularly by numbers of one factor and seldom by members of other factors.

To determine whether the shredout factors differed on the basis of technical difficulty, each factor was scored by summing 3-2-1 weights attached to the difficulty ratings above. The factor sums were checked to be sure that the differences between them were statistically significant, and the two pairs of factors whose divergence was not sufficiently significant were combined, leaving four job factor shredouts which are differentiated on the basis of total average difficulty of the jobs each group performed.

By graphing the number of tasks for each factor as they were rated at each level of difficulty, it was also seen that the most difficult job included more tasks at each level of difficulty, that the least difficult job included the least number of tasks at each level, and that the other jobs fell in order in between.

The average experience on the job, and the average rank of the incumbents did not seem to be related to the technical difficulty of the shredouts.

Results

The job of Senior Aircraft Mechanic, AFSC 43151-B, was seen to be shredded-out operationally into six different part-jobs. These six could be combined into four "jobs" on the basis of technical difficulty, each of the four being significantly different from the others on the dimension of difficulty.

Conclusions

The implications of these results in the field of training is that broad formal training for all incumbents of an AFS is often not utilized on the job, and that a basic course of practical information would be more economical.

Comments

This report presents an interesting statistical analysis of the hypotheses under consideration, i.e., that a standard AF job is divisible into shredouts according to the number and average difficulty of the tasks of the total job which each shredout performs. The technique is more directly related to incumbents of well-established jobs, however, and does not appear to be directly applicable to the anticipation of task structures. The analysis indicates that at least within some AFS's there are several shredout jobs. It does not indicate the extent of task variation permissible within a single anticipated job, or indicate satisfactory techniques or rules for combining tasks into jobs.

Christensen, J. M. Arctic aerial navigation: A method of analysis of complex activities and its application to the job of the arctic aerial navigator. Mechanical Engineering, 1949, 71, 11-16, 22.

Purpose

This study was conducted to gather data which would answer three questions for the arctic aerial navigation work situation:

1. What new equipment or changes in present equipment will result in the greatest improvement in the arctic navigator's efficiency?

2. What is the optimal equipment layout in the arctic navigator's work place with regard to convenience, importance, frequency of use and reduction of fatigue?

3. What minimum crew requirements will insure satisfactory navigation of present aircraft in the arctic, and how can the number safely be reduced in the future?

Rationale

The basic problem is that of reducing the number of required crew members, because as new aircraft are developed, the problem of weight and room becomes more critical, as suggested by question 3, above. Any saving made possible by redesigning equipment and/or a better allocation of tasks is not only a saving in the total work load time but possibly also a saving in the number of required personnel, and thereby, in the total crew weight and operating space required.

The time saving may seem more realistic if the total weight liability of one crew member (about 1500 lbs.) is divided by 60 minutes. The resulting assumption that one minute of time saved is equivalent to 25 lbs. eliminated provides a rough guide for equipment design in terms of weight liability. The point of view admittedly does not consider such factors as training air crew members in a multiplicity of duties, maintaining satisfactory proficiency in all duties once they are trained, ground and aerial maintenance of any equipment used in lieu of personnel, nor the relative effectiveness of equipment and personnel for a specific job.

Scheduling

The method described here was an observation technique applied to an operational situation with existing systems. However, as suggested in the article, study of some of the factors involved have been made on the ground, and it is considered a possibility that careful programming of an anticipated operational situation on mock-up or prototype console equipment might provide a satisfactory basis for a simulation study, using this technique, during the development stage. See Miller, (1956b).

Summary of Method

The method, a sampling technique, was called "Activity Analysis." This new technique was developed because the operational situation was not suited to the space and light requirements of photographic recording (although infrared might be used), and each change in activity would not be recorded fast enough using the standard stop-watch procedure. It uses sampling theory to obtain the times devoted to different elements of a complex activity, and the general sequence in which those elements are performed.

The length of the sampling interval is arbitrary. In this case, a buzzer was set to ring every five seconds, since the shortest activity in which the observer was interested took more than five seconds, the observer could record the activities of the navigator under all flight conditions in that time, and the buzzer sounded often enough to keep the observer awake for the 12 - 15 hours of the mission. Later analysis showed that 30 second intervals would have been just as effective, permitting the observation of three men alternately, one every 10 seconds.

Within limits, the point of view of activity analysis is centered in the person being observed. The analyst looks for total job elements which should be replaced by equipment, changes which should be made in the design of present or suggested equipment, and changes in the design of work places which would maximize the operator's efforts.

The chief merits of the method are simplicity and flexibility. They include the factors that the observer can keep pace with the subject for long periods of time, that the equipment involved is negligible and requires no special installation in the aircraft (a special head set connected to the battery operated buzzer signal at one ear and the intercom at the other), and that the large number of samplings assures that the less time-consuming activities are adequately sampled. It also tells exactly what the operator is doing, what equipment he is using, how long he uses it, and how frequently he uses it. The one desirable prerequisite is that the analyst be as familiar with the position or type of position being studied as possible.

The data obtained were then plotted in bar graphs for each of the three men, showing the per cent of total time spent in each type of activity.

Results

By employing activity analysis, it was possible to determine how often the operator used each control and the sequence in which he used them. The two controls used most frequently and in rapid sequence were located about as far apart as possible.

Analysis of the data and bar graphs permits estimation of the minimum time requirements for arctic navigation. In this study, two alternatives were evident. Either two men would have to remain assigned to do the navigation, or more automatic and better equipment, and a more efficient work place would have to be provided for one operator. In this case, however, even a "perfect" work place alone (i.e., no transition time) would not permit one to do all the work--there would still be 83 minutes of activity per hour. Equipment and procedural changes would be necessary, in addition, to permit one navigator to replace the two. The possibility of two men doing the work of three (first navigator, second navigator, and radar operator) appeared much more feasible.

Comments

The specific recommendations for changes in the equipment, work space layout, and task allocation outlined in the article are not abstracted.

This technique of activity analysis has special applicability to operator positions, where the time of task performance is a factor. For maintenance activities where time is less critical, a technique such as the Standard Maintenance Form (Miller & Folley, 1951a) may be equally or more satisfactory for obtaining activity analysis information. As suggested under Scheduling, this technique might be used with modification in simulator and/or early prototype testing, in determining loading and job design.

The technique described in this article might well be considered in conjunction with an analytical approach to manning problems such as suggested by Ray, Passey, Adams, Smader, & Simon, (1957b). Warren, Wolbers, Atkins, Darrow, Goedinghaus, Mahoney, & Piatt (1953) discuss a technique of observation and analysis similar to Christensen's approach.

Cotterman, T. E. Task classification: An approach to partially ordering information on human learning. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center. January 1959. (WADC Technical Note 58-374)

Purpose

Exchange of ideas related to establishing a unified knowledge of human learing as it applies to training issues.

Proposes (a) needed research and an approach to each area, and (b) an illustrative set of generalized definitions of familiar learning situations and associated traditional labels.

Summary

For convenience, the mass of information on human learning ought to be reduced to a set of principles or rules. Most of the learning research has been related to a given type of task and conclusions are not generalizable to other types of tasks. The first step is to classify the tasks somehow. The metapsychological language in which tasks have traditionally been described--"verbal learning," "perceptual-motor learning" etc.--is not the most useful for training issues. Tasks should be defined in general language and in categories of learning situations which have specified physical characteristics in common and especially require the same types of transformation.

A set of abstract task definitions in terms of generalized descriptions of stimuli, responses, and their relationships useful as a basis for establishing task categories, is presented below:

	Traditional Task Label	Generalized Definition
1.	Classical conditioning S-R association Simple association	For each succeeding occurrence of essentially the same discrete input, essentially the same specified discrete output occurs.

	Traditional Task Label	Generalized Definition
2.	Paired associates S-R association Simple association	For each succeeding discrete input drawn from a finite set of n different discrete inputs, a corresponding discrete output drawn from a finite set of n different outputs occurs, such that the inputs and outputs and their core correspondence remain invariant.
3.	Serial learning Procedural task procedures	For any one of a specified finite set of discrete inputs, a specified finite series of discrete outputs occurs, the order of occurrence remaining invariant.
4.	Absolute discrimination Absolute judgment Stimulus rating	For each succeeding discrete input drawn from a set of discrete inputs orderable according to a specified quality, a corresponding discrete output drawn from a finite set of outputs orderable with reference to the same quality occurs, such that the output bears the same ordinal relation to members of the output set as does the input to members of its set.
5.	Ranking	For each succeeding set comprised of n simultaneously occurring discrete inputs drawn from a set of discrete inputs orderable according to a specified quality occurs, such that each output corresponds with one input only and bears the same ordinal relation to members of the output set as does the input to members of its set.

Traditional Task Label	Generalized Definition
6. Simultaneous discrimination Relative discrimination Choice discrimination Paired comparison	For each succeeding pair of simultaneously occurring discrete inputs drawn from a set of discrete inputs orderable according to a specified quality, one of a set of two (or three) discrete outputs denoting the relative spatial orientation of the respective input events occurs, such that the input event so corresponding with that output bears a specified invariant ordinal relation to the other input (e.g., "greater than" or "less than").
7. Successive discrimination Relative discrimination Choice discrimination Paired comparison	For each succeeding pair of successively occurring discrete inputs drawn from a set of discrete inputs orderable according to a specified quality, one of a set of two (or three) discrete outputs denoting the relative temporal position of the respective input events occurs, such that the input event so corresponding with that output bears a specified invariant ordinal relation to the other input (e.g., "first" or "last").
8. Tracking Continuous adjustment	Concurrently with continual quantitative variation in one or a set of specified input qualities, continual quantitative variation through infinite degrees in one or a set of specified output qualities occurs, such as to continually minimize the input variation.
9. Skilled act (single criterion response)	For each succeeding occurrence of essentially the same discrete input, a discrete output drawn from an infinite set occurs, such as to result in a secondary input event which deviates minimally from a specified limit expressed in terms of an input quality.

	Traditional Task Label	Generalized Definition
10.	Simple skill (multiple criterion response)	For any one of a set of discrete inputs orderable according to a specified quality, one or several discrete outputs drawn from an infinite set occur(s), the order of occurrence remaining invariant such as to result in a secondary input event which deviates minimally from a specified limit expressed in terms of an input quality.
11.	Concept formation	For each succeeding discrete input drawn from a finite set of discrete inputs orderable according to multiple qualities, a corresponding discrete output drawn from a finite set of discrete output occurs; such that a given output always occurs when an input, member of that subset of inputs, bearing a specified ordinal relation to the other inputs as ordered according to a specified quality, occurs.
12	Problem solving Decision making Troubleshooting Medical diagnosis Thinking	Upon the successive and/or simultaneous occurrence of a number of discrete and/or continuous inputs, a corresponding discrete and/or continuous output (s) drawn from that set of outputs capable of bringing about secondary input events or a specified quality occurs, such as to produce that or those secondary inputs satisfying a limit expressed in terms of the specified quality.

The criterion for a category of tasks is that for all tasks subsumed under it, the effects of certain basic variables or principles remain reasonably invariant. To be useful the number of categories should be less than a dozen.

Conclusions

A valid and reliable task classification, applied to the problem of determining the different tasks and their training requirements in new man-machine systems, would bridge the gap between the laboratory and "real life."

Such a classification would also serve the general purpose of making it easier to interpret, predict, and control learned behavior through the convenient and coherent ordering of information making explicit the application of learning principles to various tasks and providing guidance to future research on basic and task variables and their interactions.

Comments

Research suggestions contained in the report:

1. The development of mathematical and logical symbolic representation of categories of tasks.

2. Three methods of developing categories of tasks are described in general terms: (a) factor analysis, (b) long term inductive approach, and (c) the short term inductive approach. The first two of these are judged to be impracticable.

3. When categories are tentatively established, validity may be assessed by recourse to the literature and by special experiments designed to determine if categories hold up. Reliability may be indicated by consistency with which psychologists can place actual tasks in the various categories. Efficiency and value probably would have to rest upon the degree of acceptance by psychologists.

Erickson, C. J. & Rabideau, G. F. Function and task analysis as a weapon system development tool. Hawthorne, Calif.: Northrup Aircraft, Inc., October 1957. (NAI Report No. 57-1148)

Purpose

This study of function and task analysis methodology has as its purpose the establishment of initial basic parameters for an economical and effective task analysis methodology compatible with design and weapon system schedule requirements. By incorporating human engineering recommendations concerning the allocation of system functions to the man and to the machine, the system will be maximally safe and effective, while demanding minimal manpower skills and quantities.

The study considers function and task analysis procedures in the light of the following variables; required levels of analytical detail, function and task analysis data sources and their use in terms of level of analysis, and function and task analysis methodology.

The value of this form of activity analysis, as it assists in the determination of the following items, is discussed:

1. Crew Size - The determination of sequential and simultaneous tasks, their relative difficulties, and time limitations, will help determine this manning factor.

2. Crew Duties - Function and task analysis data will assist in man-machine inter-crew and intra-crew function allocations.

3. Equipment Design - Recommendations for controls and displays depend in part on these analyses.

4. Personnel Skills and Training Requirements - Task analyses identify task complexity, probable skill-level requirements, and effective types of training.

Rationale

According to Van Cott and Altman (1956), the end products of function and task analysis include:

1. Allocation of functions to men and machines.

2. Determination of input-output requirements pertinent to equipment and workspace design.

3. Specification of procedural requirements.

4. Checking of operator performance descriptions.

5. Information basic to recommendations for training device design requirements and training curricula, or procedures.

6. Evaluation of developmental prototype equipment.

Miller (1953b), who has done much to originate task analysis concepts and methodology, suggests that task analyses may be used in the designing of job supports, operating and training procedures, and workplace layouts.

This report suggests that a function and task analysis considers all of the following analytical variables, whereas by comparison, motion, process, and job analysis together are able to consider only about half of them:

1. Description of the System: System criterion outputs, system or process functions, operational programs or missions, and mission segments.

2. Description of Environment: Physical conditions, physiological conditions, feedback channels, and environmental "noise."

3. Description of Man Activities: Work cycles or tasks, stored information requirements, sensory inputs, perceptual discriminations, decisions, responses.

"Task-equipment analysis," for instance, is typically done in conjunction with the development of training requirements, training programs, and training equipment design. This form of analysis, as done at Northrup, closely resembles job analysis, and is inadequate in supplying training data, since it does not analyze feedback channels, environmental "noise," sensory inputs, and perceptual discriminations. Miller (in WADC-TR-54-563) points out the importance of task analysis for the design of training equipment.

Scheduling and Planning

The concept of differentiating levels of analysis was developed by the authors, who found that the following factors interact to determine the level at which a given analysis will be initiated or terminated.

1. The state of system development.

2. Availability of data on system functions, preliminary performance, and design concepts.

3. Availability of operational mission and environmental program data.

4. The applications desired of task analysis data.

5. Time and manpower available to perform the analysis.

6. The over-all complexity of the system being analyzed.

The level of a function and task analysis depends on three orthogonal variables: the extent of system data used, the number of analytical steps completed, and the varieties of human activities analyzed.

Tables I and II indicate the data needed to perform each level of analysis and the possible applications of the data resulting from each level. It may be seen from an examination of these tables that the function and task analysis sequence, to be really thorough and effective, should be started at the very beginning of system development, when the GOR's and system performance requirements become available, and continue through the analytical steps outlined by continued up-dating of the resulting data through the evaluation of production equipment. As pointed out, however, this planning may vary depending on the stage at which analysis is requested or the goals to be attained.

Summary of Method

Function and task analysis is that portion of a total systems analysis, concerned with the man component, his performance characteristics, his working environment, the demands of the man on the system machine elements, and the demands of the machine on the man. The fundamental procedures of function and task analysis are summarized below.

Table I

DATA REQUIREMENTS FOR EACH LEVEL OF ANALYSIS

Analytical Level	Data Required
System Mission Definition	1. GOR's 2. System performance requirements
Program Analysis	1. Systems operations data developed from GOR's 2. Preliminary system design concepts
Functional Analysis	1. Systems analysis data on functional requirements
Mission Segment Analysis	1. Above data and preliminary functional information about hardware components
Job Segment Analysis	1. Preliminary system design data 2. Performance specifications 3. Preliminary system drawings and specifications
Task Definition	1. Above data
Procedural Task Analysis	1. Detailed component drawings 2. Operation and maintenance descriptions for prior systems 3. Preliminary descriptions of operations and maintenance procedures 4. Probable personnel skill levels
Tracking Task Analysis	1. Above data 2. Input-output requirements for operators 3. Field operation and training experiences pertinent to present system 4. Human engineering evaluations of breadboard, mockups, and test models 5. Motion and time study data

Table II

LEVELS OF TASK ANALYSIS DETAIL REQUIRED FOR SPECIFIC APPLICATIONS

Application	Level of Analysis
1. Crew size Crew duty allocation System functions Decisions to automate	Function analysis Mission segment analysis Program analysis
2. Selection of: Sensing devices Integrating and decision-making devices Controls and displays Personnel work area Workspace design	Job segment analysis Beginning tracking task analysis and time-line analysis
3. Work loads Task difficulty Methods of rectifying out-of-tolerance conditions Safety procedures	Procedural and tracking task analysis
4. Checking of operator performance descriptions	Complete tracking and procedural task description as well as time-line analysis
5. Training: Simulators Curricula	
6. Prototype evaluation	Up-dated task descriptions consistent with prototype specifications for all pertinent subsystem components
7. Production model evaluation	Up-date all levels of analysis consistent with changes and re-design of equipment and UR's.

Function Analysis Steps

System Mission Requirements. Determination of the system mission is the first step in the analysis. This may be determined by such questions as "What is the role of the system within the total weapon system inventory; will it be both ground and airborne or only ground?" After distinguishing the general role of the system, the basic system mission, as well as any alternate missions anticipated, should be identified as specifically as possible, including statements of such requirements as speed, range, accuracy, ground handling, refueling, etc.

Specification of System Criterion Outputs. Criterion outputs are the man-machine outputs necessary for the system to successfully complete its mission requirements under all tactical and environmental conditions in which it must operate (Miller, 1953b). These should be as specific as possible, i.e., the required kill probability of an interceptor, the required accuracy of a range finder, etc. Identification of first criteria will suggest second-order criteria which must also be identified.

Identification of Operational and Environmental Programs. Programs are environmental and operational conditions under which the system must operate which directly affect the functioning of a man-machine system. As detailed a listing of alternate programs as possible is necessary. Such things as temperature, gravity, acceleration, light, precipitation, terrain, enemy attack, etc., should be considered, and new system functions which may result should be identified.

Allocation of System Functions. The system functions which have been identified are essentially the required system capabilities, not the actual performance or realization of these capabilities, which would be tasks. These system functions must be allocated to either a man or machine component, depending on which choice provides the over-all system with the greatest capability, considering such factors as equipment weight, complexity, task loads of individual men, and the effects of alternatives on the probability of successful completion of a mission. Sometimes a function will be allocated to a man-machine combination "component."

The authors suggest a function analysis format for the presentation of the resulting data. Each horizontal row of the format represents a system function. The vertical columns provide for the recording of the required machine functions, machine components (when known), required man functions, and the continuity of the function, either continuous, discontinuous, or intermittent.

On completing the function analysis, it is helpful to list the function tolerances under critical or "work case" programs or conditions as identified in the program analysis. These tolerances may be stated as time limits, precision of movement, and accuracy required.

In considering system functions, the author's suggest a simple system function time-line, to determine the moment-to-moment changes in system functional loads.

Task Analysis Steps

Establishment of Mission Segments. The division of the mission into mission segments is somewhat arbitrary, but the following criteria are generally used:

1. A change in short-range goals. Sample segments on this basis might be preflight, take-off, climb, cruise, attack, recover, cruise, let-down, and landing.

2. A change in personnel working toward short-range goals within the system goals. An example is a preflight ground crew being replaced by the aircrew.

Identification of Tasks. The mission segments are then reduced by analysis to those discrete tasks which are consecutive and those which are time-shared. Miller (1953b),defines a task as a "group of discriminations, decisions, and effector activities related to each other by temporal proximity, immediate purpose, and a common man-machine output."

Differentiation of Procedural and Tracking Tasks. Procedural tasks (Miller, 1953b) involve step-wise, all-or-none responses to discrete, perceptual cues. Tracking tasks require a continuously changing response where error indications are continually fed back to the operator; steering is an example. The distinction between the two types of tasks is made because they require different types of training. Because of the more critical nature of training and action feedback for the learning of tracking tasks as described by Miller (in WADC-TR-53-136), training equipment for such tasks must closely resemble the functional characteristics of the actual man-machine system. Procedural trainers, on the other hand, have much cruder simulation requirements.

Analyses of Individual Procedural Tasks. First, the procedural tasks should be arranged chronologically. Because of the discrete nature of procedural tasks, it is possible to estimate the time required to complete each task, either by time study on mock-up simulator runs, or as synthetic, estimated time standards. The format used by the authors for the presentation of procedural task analysis data is a modification of one developed by Miller (1953b). The following entries are made:

1. Task. A descriptive title of the activities under consideration should be placed in this column. The authors have used Miller's definition of subtask for their task titles, relegating the classical title of "procedural task" to the position of job segment.

2. Control. The control activated should be identified. Its name, location, identifying characteristics, and reference notes may be noted if deemed significant.

3. Action. The behaviors and/or decisions required of the man should be listed in this column.

4. Indication. Indications to the man of a requirement for the task and the frequency of performance of the task, as well as indications of operator response adequacy, should be noted here.

5. Remarks: Alternatives and/or Precautions. Possible alternative actions or special precautions are listed in this column.

Analysis of Individual Tracking Tasks. The analysis of tracking tasks is somewhat difficult because the critical aspects of tracking tasks often cannot be completely described or predicted. The variables involved in a continuous task analysis are described below briefly, as the continuous task analysis format developed at Northrup for the analysis and presentation of data is reviewed. A more detailed discussion may be found in Miller (1953b).

1. Task. The first column lists the tasks, as before.

2. Stimulus variables. The stimulus variables of the task include the informational inputs to the man which he requires to perform the task, the initial time aspects in the performance of the task (behaviors having close time tolerances), and perceptual noise, or those disruptive stimuli which interfere with the man's acquisition of information.

3. Decisions. The decisions which the man must make depend on the information inputs.

4. Control actions and feedback. The controls which the man manipulates and the manner of activation is stated in this column. Feedback deals with the information the man receives concerning the adequacy of his performance.

5. Characteristic errors, malfunctions, and contingencies. The typical or possible man errors, machine malfunctions, and contingencies are listed in this column, and are considered with reference to the ability of the system to complete the mission criterion outputs.

Time Plot

The authors have also developed a method for the display of tracking and procedural task information against time, in order that a graphic presentation of man activities may be plotted and compared against the time requirements of the system's mission. The presentation is essentially a man and machine time chart as described by Mundel.[1] See also Ghiselli and Brown (1955). Mundel's activity symbols were supplemented to meet the requirements of task analysis. The symbols used at Northrup represent: operation, movement, subtask--holding an object in position by a body member, computing, deciding, quantitative checking, qualitative checking, display scanning, communicating, and delay. Each symbol is defined both as it applies to the man and to the machine.

Time-line analysis consists of determining the time requirements for the performance of procedural subtasks and tracking tasks defined by task analysis. When prototype equipment is not availabe, time measurements may be obtained from previously developed items of equipment by extrapolation, or synthetic time standards evolved from mock-up experiments. It is understood that either of these approaches will provide only a preliminary estimate under a given set of program assumptions. Figure 1 presents a sample man-machine time chart. Although it does not include a time-shared tracking task, such a task could be handled in the same manner as the time-shared procedures shown.

[1] Mundel, M. E. Motion and time study: Principles and practice. New York: Prentice-Hall, Inc., 1950.

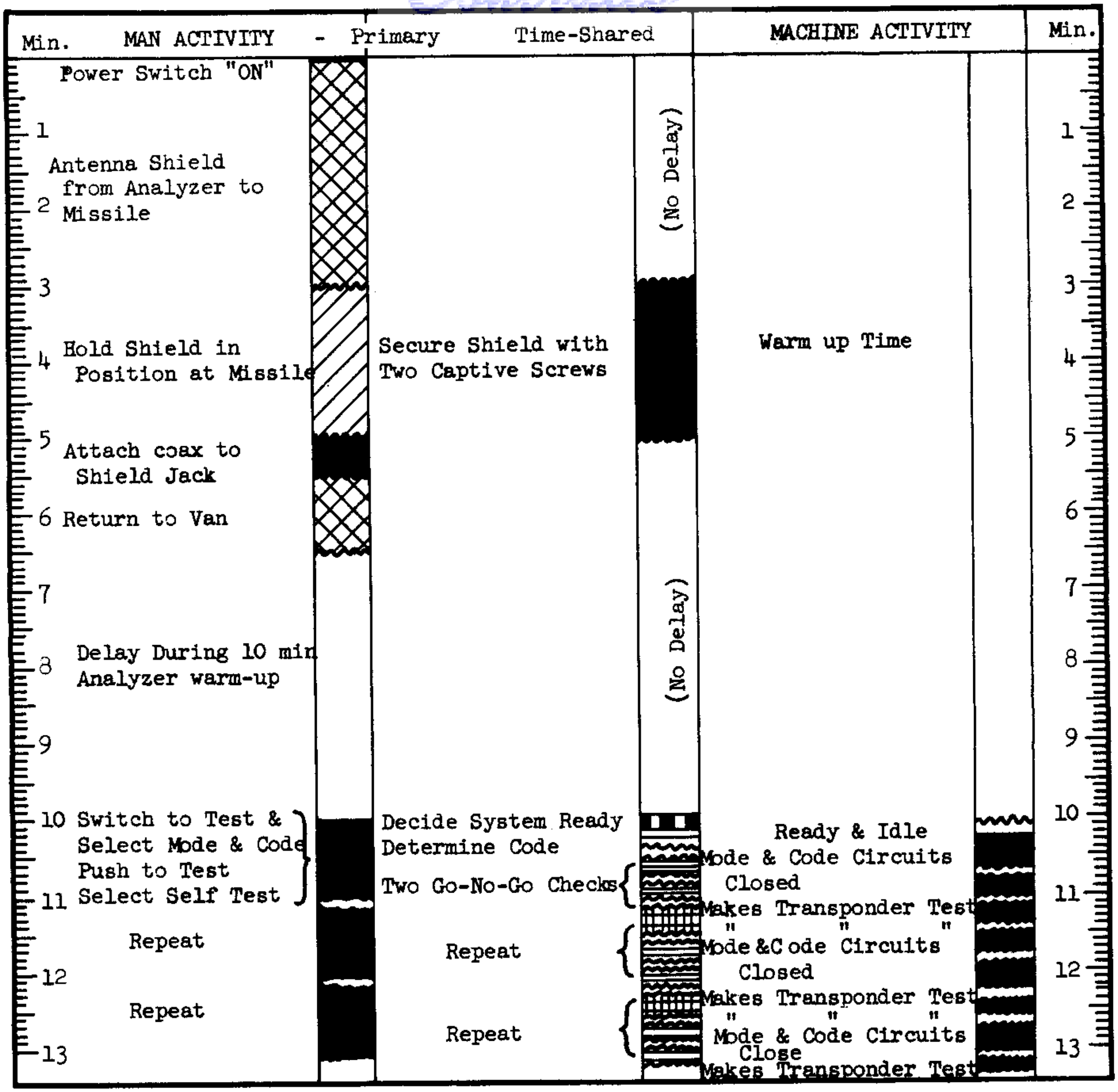

FIGURE 1

SAMPLE TIME LINE ANALYSIS MAN-MACHINE TIME CHART FOR AIRBORNE RADAR TRANSPONDER UNIT ANALYZER OPERATION

Straight lines across bars indicate definite start and terminal times; saw-toothed lines indicate indefinite starts, terminations and duration. Note that most of "machine down" and "man idle" time results from ten minute machine warm up requirement.

<u>Recommendations</u>. The following problem areas were identified as requiring further study:

1. How can the difficulty of task (and job) performance, as required by specific weapon systems operational programs, be objectively determined?

2. How can the validity and reliability of the following aspects of functions and task analysis be determined?

   a. Representativeness of selected operational and environmental programs.
   b. Identification of critical stimulus inputs.
   c. Estimates of human information channel loading.
   d. Evaluation of difficulty levels of required decisions.
   e. Identification of necessary feedback data.
   f. Estimates of task performance time requirements and over-all operator time stress.
   g. Investigation of task analysis as a means of determining operational sequences and task performance times.

Folley, J. D., Jr., & Miller, R. B. Summary comparison of job requirements for line maintenance of three complex electronic systems. Lowry Air Force Base, Colo.: Armament Systems Personnel Research Laboratory, Air Force Personnel and Training Research Center, September 1955. (ASPRL Technical Memorandum 55-17) (Contract No. AF 18(600)-600)

Purpose

This study, an extension of the study reported in Miller, Folley, & Smith (1954), was directed at finding some common denominators among line maintenance jobs, using the Q-24, K-1, and A-3A electronic systems as samples. The study had three purposes. One was to provide data useful for establishing the content of a fundamentals course preceding specialized training. A second purpose was to suggest how training, either fundamental or specialized, could be slanted to the transfer of the skills and knowledges from performance on one equipment to another. The third purpose was to identify, if possible, bases for anticipating transfer of training among the sample jobs.

Results

Tasks previously identified were compared by behavior categories (Miller, Folley, & Smith, 1953a) for the three equipments. The following general results were indicated.

Comparison of the specific job behaviors, as "reading dials," indicated a high degree of similarity among the three equipments. These specific behaviors seemed highly transferable from one equipment to another. However, major differences existed in the organization and sequences of the behaviors into procedures. If the mechanic had performed the procedures by direct reference to job instructions, the transfer would be greater than if he had memorized them, but in either case transition time was expected to be almost the same as initial training time.

The "information content" of the jobs differed substantially, including the nomenclature and location of components, and this material appeared to have very low transferability.

Within the category of "Mental Skills and Abilities," transfer of inferring and interpreting behaviors, as well as the use of block diagrams or job instructions, depended on the type of training received and the format organization of the materials. If training emphasized the method of tracing signals from one diagram to another, transfer to other equipments should be quite high.

As a result of these considerations, the following list indicates the more important skills and knowledges believed to be transferable to varying extents over the three equipments studied.

Discriminations and Perceptions

1. Reading dials.

2. Comparing and recognizing wave shapes on an oscilloscope.

3. Noting various kinds of defective electronic parts by external signs.

Knowledges

1. Recognition of common electrical symbols as given in diagrams.

2. Knowledge of principles of data flow in electronic equipment.

3. Knowledge of the maintenance procedures in general of such components as power supplies and servomechanisms.

4. Knowledge of control settings on the common test instruments.

5. Knowledge of precautions in the use of complex electrical and mechanical equipment.

Mental Skills and Abilities

1. Making arithmetic computations.

2. Drawing logical inferences about possible malfunction sources with data flow diagrams as aids.

3. Interpreting signal flow from block and circuit diagrams.

4. Reading and interpreting Technical Orders and other written instructions.

Manual Skills and Operations

1. Putting together electrical and mechanical fittings.

2. Soldering.

Conclusions

Content of a Fundamentals Course. The fact that these transerable skills and knowledges exist does not warrant the assumption that a common course of "fundamentals" training is desirable. These might be more effectively learned in the context of the specific equipment with which the men will be dealing, with emphasis on the generalizable aspects of maintenance. In this case, the common items were relatively simple behaviors. A fundamentals course should probably contain material which is not only common to a class of equipment, but which is also taught more efficiently in a separate course. Material meeting this second criterion includes that which takes a long time to learn. A study of these equipments does not yield any appreciable amount of material meeting both these criteria.

Training Emphasis for Transfer from One Equipment to Another. As above, simple behaviors may be expected to transfer readily. Procedures and information content would not be expected to have a positive transfer effect. However, emphasis on some of the general similarities of procedures such as checking could promote transfer, where the data flow being checked is operationally the same and the variables are checked by similar means in the same order. To the extent that troubleshooting procedures are based on data flow and the use of block diagrams, transfer can be expected, varying as the problem varies.

Transfer of Job Competence from One Equipment to Another. It was found that transfer of proficiency could be realized on relatively simple behaviors requiring little training. However, the bulk of maintenance procedures and information content are specific to each equipment. Therefore, the things which would transfer were skills like following written procedures and making logical inferences in troubleshooting.

It was felt, however, that greater transfer would be realized than indicated here due to an appreciable transfer of nonspecific habits, such as learning what to search for in the job environment, and enhanced distinctiveness of job cues.

Comments

This comparison of training requirements for three electronic systems represents a useful starting point in trying to anticipate the training requirements for a new system, since it indicates general types of training which may transfer from one related job to another. In recommending AFS's for a new system, a review of capabilities as indicated in a thorough Job Training Standard and/or Training Syllabus, keeping in mind the implications of this study, would help to suggest those skills and knowledges for which he would require transition training, as well as those requiring "initial" type instruction.

See Miller (1957) for a later study in this area.

French, R. S. Functional characteristics, utilization, and procurement of a MAC trainer: K-system TEA form for MAC trainer. Appendix: Description of K-system task characteristics analysis form. Lowry Air Force Base, Colo.: Air Force Personnel and Training Research Center, February 1957.

Purpose

To set down the procedure used for translating technical information on the K-1 Bombing-Navigational system into the most usable form for incorporation into training devices or techniques. Task Equipment Analysis (TEA) was used for summarizing information about the Post Flight Maintenance Check on the K-1 system. The Task Equipment Analysis format is illustrated and described in detail.

Rationale

The mission of the military psychologist is defined: Data for TEA is gathered from such sources as technical orders, manufacturers, etc., by either the psychologist or by a company representative with the military psychologist advising. Before this TEA technical information can be used it must generally be translated into psychological units or categories. For example, Miller & Folley (1952) proposed to analyze checking and adjusting procedures on the Q-24 Bombing Navigational system. A breakdown of these behaviors into such psychological categories as "discriminations and perceptions, knowledges, skills, and abilities" was used to compare the per cent frequency of occurrence for these behaviors for the prototype and production models.

The categories are not a source of information in themselves, but are a means of storing and transmitting special information. Categories used arose from needs of the situation, i.e., the development of a simulator.

In determining the degree of specificity desired in defining categories, care should be taken not to be so broad as to transmit no information in context of the specific analysis, or so narrow as to apply to only a few steps. The middle ground desired is to structure categories applicable to roughly one half of the procedures. The system of analysis used here provides information regarding:

1. Physical make-up of the planned devices.

2. Where in the design of the device the critical discriminations should be provided for.

3. Procedures and tasks which might introduce scoring and reliability problems.

4. Factor content of the task. (Many complex procedures are actually combinations of simpler procedures which can be trained for separately.)

Phasing

The analysis was performed preliminary to development of a panel-type simulator, but with a thought that it might suggest techniques applicable to related problems in subsequent equipment stages.

Summary of Method

Figure 1 shows a sample page from the K-1 analysis. The form has two parts. The left side has space for a statement of the general subtask area and below this is space for a step-by-step procedure of the subtask, e.g., "C-413 power switch OFF." In addition, ten dimensions or categories believed to be relevant to simulation of the task are listed. On the right side of the form, descriptions are given for a number of subcategories within each of the major categories. Table I indicates the training function implications of the subcategory ratings. The categories and ratings are described below.

1. Memorization. The ratings of this category distinguish between procedural steps one might expect the mechanic to recall without reference material and those which are so difficult or technical, particularly those involving actual number values, that they should be asked for in a test situation only if reference material is available.

2. Training. These ratings provide information as to whether or not the student should be expected to accomplish a practical check on a particular procedure.

3. Difficulty. (Misleading) The purpose is to indicate certain, rather than specific characteristics of the item which might predict its relative difficulty. The following ratings are made:

TASK	1. Memorization	2. Training	3. Difficulty	4. Uniqueness	5. Criteria	6. Special ability	7. Sequence	8. Manipulation	9. Supplementary Equipment	10. Simulation
RAI Presentation										
Turn Bombing Mode Switch to SYN	a	a	c	a	a			b		c d
Turn Radar Power Switch to SCAN FAST	a	a	c	a	a			b		c d
Coordinate converter power supply check										
Check that coordinate converter power supply light is lit	a	a	b	b	a					c d a
Meter is in the GREEN	a	a	b	b	a					c d a

LEGEND

Measurement

1.a. Task is easily memorized; quickly becomes habitual.
b. Task is hard to memorize; technical reference material usually used.
2.a. Some practical experience provided by present school training.
b. Familiarity only provided by school training.
3.a. In the given context correct behavior is obvious.
b. Correct behavior might be deduced without specific training
c. Correct behavior unlikely without specific training.
4.a. Knowledges and/or skills required for task are unique.
b. Some or all elements of the task have been presented in a different context.
5.a. Observation or adjustment: made with reference to clearly defined positions, states, or motions.
b. Made with reference to known scale.
c. Estimated proportionally.
d. Made in terms of subjective criteria.
6.a. Above average perceptual or motor ability desirable.
b. Above average reasoning ability desirable.
c. Superior motivation or application desirable.

Design

7.a. Step must be done at this time as precautionary.
b. Step is a necessary antecedent within the subtask.
c. Step should be done in fixed sequence relative to one or more other steps.
8.a. Manipulation of test equipment
b. Manipulation of equipment controls
c. Manipulation of parts of system other than controls.
9.a. Special test equipment needed.
b. Common test equipment needed.
c. Hand tools (wrench, screw driver, etc.) needed.
10.a. Mechanic verbalizes to supplement, or substitute for action.
b. Component or part represented by conventional symbols, names, block diagrams, etc.
c. Component or part represented by a photograph.
d. Knobs, indicators, etc., inserted on photograph or dummy object.
e. Component or part represented by dummy object.
f. No simulation practical; actual equipment should be used.

Figure 1. K-System Task Characteristics Analysis
(Checking, Aligning & Adjusting)

a. A rating of a means the procedural step is so well cued by its context that the correct answer will be obvious even when specific requirements and knowledge have not been retained by the student. This rating would discriminate very little if at all among students at the end of training.
b. This indicates that the procedural steps are partially cued by their context. Correct response might be deduced without retention of the appropriate skill or knowledge.
c. The correct response is very unlikely without retention of the appropriate skill or knowledge. Procedural steps so rated should discriminate well among mechanics.

4. Uniqueness. These subcategories indicate tasks peculiar to the system, as opposed to tasks involving circuitry, equipment, or procedures encountered in general electronic training. Information supplements 3, above. If the task has many elements common to basic or fundamental tasks, the possibility of generalization or transfer without specific retained knowledge is greater.

5. Criteria. Particularly relevant to the reliability of a measure.

a. Those observations or adjustments made with reference to objective criteria other than calibrated scales; e.g., labeled switches, switches with definite detent, etc.
b. Tasks concerned with calibrated values.
c. Tasks where adjustments are estimated proportionately with clearly defined limits, e.g., adjusting a scale to a point midway between stops.
d. No clear-cut criterion exists in the task; e.g., in radar, adjustment for best scope presentation.

6. Special Ability. This was included to make note of those tasks which might better be performed by persons with somewhat greater ability. Most tasks can be done by the average individual. The entry, without experimental evidence, must represent best subjective judgment. The following ratings are made:

Table I

DESCRIPTION OF CATEGORIES USED IN K-SYSTEM TASK CHARACTERISTICS ANALYSIS

	Characteristics	Converse
1.	Usually memorized	SOP followed - too complex to memorize
2.	Acquired by OJT	Presented in formal training
3.	Correct behavior is obvious or "common sense"	Several reasonable alternatives possible
4.	Behavior can be elicited with simple dummy panel (if necessary with associated meters & dials)	Complex circuitry required to simulate task
5.	Proper sequence is essential	Within general task area sequence not important
6.	Task best presented in panel form	Task so complex verbal presentation would be necessary
7.	Pictorial presentation would be desirable in place of actual component or indication	Dummy control or actual equipment could be used
8.	Task may be presented using actual equipment only	Some kind of simulation possible
9.	Test equipment or tools required	No tools required
10.	Special skills, aptitudes, or motivation desirable	No special abilities needed
11.	Task could be self-monitoring and self-scoring	S's performance must be scored by observation
12.	Correct behavior might be deduced without specific training	Special knowledge through training required
13.	Time consuming on actual equipment	Practical to use actual equipment

Table I (cont'd.)

DESCRIPTION OF CATEGORIES USED IN K-SYSTEM TASK CHARACTERISTICS ANALYSIS

	Characteristics	Converse
14.	Actual manipulation by S is possible and desirable	Impractical for S to manipulate
15.	Requires specific knowledges or information from TO's, schematics, etc.	General principles or theory are sufficient
16.	Knowledges required for the task are unique, little transfer from related training may be expected	Task involves elements common to training in a different context
17.	Manipulation is made to subjective tolerances or criteria	Manipulation is made on calibrated dials or in terms of other objective criteria

a. Requires complex eye-hand coordination.
b. Involves more than routine reasoning and problem-solving behavior.
c. Includes routine tasks which might be overlooked by the average individual; e.g., checking that all units were "safetied."

7. Sequence. Sequence is often as critical as the step itself. Ratings a through c are made.

   a. Procedural steps which must be performed at specific times to prevent possible damage to equipment or operator personnel.
   b. Step must be performed before certain other steps.
   c. Task must be performed in a fixed sequence.

8. Manipulation. The ratings (see form) indicate where manipulation by controls, test equipment, or parts of equipment other than controls is necessary.

9. Supplementary Equipment. Specific requirements for supplementary equipment for the maintenance operation. Ratings a and b distinguish common and specialized test equipment. In general, common is multi-purpose. Special is for a single piece of equipment only.

10. Simulation. Judgment as to most practical means of simulating the task. Except for f, the following subcategories or considerations are not mutually exclusive.

   a. Complex panels should be avoided where simple dummy-like displays are thought possible.
   b. Actual system components are difficult to procure. Use standard meters with specially designed faces.
   c. Highly complex circuitry required to obtain realistic functioning. Often defeats the purpose of simulation.
   d. Knobs, indicators, etc. on photograph or dummy object.
   e. Component or part represented by dummy object.
   f. No simulation practical; actual equipment used.

Comment

While specific to a simulator development problem on the K-1, the TEA procedures here could be adopted to other systems and problems. For further analysis of the K-1 system, applications of the Miller-Folley technique to other systems, and additional studies relating to this technique, see references (Miller, Folley, & Smith, 1953a; Miller & Folley, 1951a; Miller & Folley, 1952; Miller, Folley, & Smith, 1954).

Gagne, R. M. Training devices and simulators: Some research issues. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1954. (Technical Report 54-16) (Project No. 509-020-0009)

Purpose

This paper attempted to describe and clarify some research issues which occur in connection with the development, use, and evaluation of training devices. The purpose was to see whether clarification can reveal a framework for psychological research in the training area.

Conclusions

It was maintained that the kinds of utilization of training devices are two: performance measurement and performance improvement, distinguished particularly in the characteristics of the device essential to each purpose. When the device is used for performance measurement, the important characteristics are reliability and validity. When it is used for improving performance, the important characteristic is the amount of transfer of learning to an operational task. In either case, the degree of simulation becomes a secondary consideration.

Among the problems identified which require further research and which are related to the present survey are the following:

1. The differentiation of critical job activities from those which are routine and easy is one of the central problems faced in designing training devices. Related to this is the problem of how the characteristics of an operational task should be altered to optimize training on a training device. One training situation deliberately changed from the job situation to emphasize critical aspects, showed transfer to the operational task greater than that produced by practice in the job situation itself.

2. It is impossible to design a trainer unless one knows what behaviors are included in the job, and which are the critical behaviors to be trained. Training equipment requirements therefore, are based on categorization of the kinds of equipment-oriented behaviors and skills involved in the job. Not only was need seen for such a taxonomy, but a bigger need was seen to be the development of a

theoretical system relating physical task variables to performance variables by means of conceptualized intervening processes. Such a theory would permit the evaluation of similarities between related tasks, such as flying forward in a plane and driving forward in a car.

Discussions of research problems included proficiency measurement, criterion development, the determinants of human variability, relationship of set and motivation to learning, and the mechanisms of transfer of learning. These topics are not reviewed, since they are less directly related to the present survey.

Comments

The two research problems identified in this abstract are significant because of their implications for the type of information QPRI documents may be called upon to provide.

Gagne, R. M. Methods of forecasting maintenance job requirements. Symposium on Electronics Maintenance (Asst. Secretary of Defense, Research and Development). Washington, D. C., August 3-5, 1955.

Purpose

This document reports a symposium presentation of current QPRI methodology and thinking.

Conclusions

QPRI is needed for selection, classification, training and assignment programs for new systems.

Some of the major problems to be resolved are:

1. How do we get from equipment descriptions to job descriptions?

2. Can job requirements be derived from equipment in development stages, and if so, will they be reliable?

3. How can jobs be described in a way that is both reliable and meaningful?

Equipment analysis is a technique developed by Robert B. Miller and associates for obtaining job information early in system development. Miller found:

1. The designer of equipment has a human in mind, though he may think of his functions only in general terms. Further, he may not think of him consistently, especially with respect to maintenance.

2. The designer is able to describe verbally what the human is to do in maintenance functions. However, he probably won't have it written down.

3. Basic data for job prediction are the conceptions which the designer has. These concepts are incorporated into the equipment and can to a certain extent be derived from it.

4. The designer's conceptions tend to be in terms of man-machine interrelations such as "check," "repair," "assemble," and "replace," which form a basic framework for behavioral description.

5. To get the design engineer to describe not only these operations, but also the behavioral activities required to carry out these activities, we must provide an objectively defined set of terms for human behaviors - - externally observable events.

Task description must be timely and dependable. The Q-24 and K-1 studies by Miller, Folley, and Smith (Miller & Folley, 1951a; Miller & Folley, 1952; Miller, Folley & Smith, 1953a) go far in the direction of establishing sound operational definitions of behavior. Their categories were:

1. Discriminations and perceptions, e.g., observing gross indications, noting defective parts.

2. Knowledges, e.g., locations, nomenclature.

3. Mental skills and abilities, e.g., arithmetic, interpretation of circuit drawings.

4. Manual skills and operations, e.g., adjusting controls, assembling.

In the Q-24 and K-1 studies, task descriptions developed from early prototypes showed high stability and corresponded to those developed from production models of the same equipments.

How is a job described in terms which are convenient, understandable, subject to only one interpretation, etc? Two examples of descriptions which are inadequate are:

1. Those which make immediate inferences from observations to underlying abilities and describe jobs in terms of numerical facility, verbal fluency, etc. These are subject to different interpretations and not reliable from job to job.

2. Time and motion studies which employ such terms as transport load -- transport empty. It provides no description of the behavior at the beginning and end of the movement.

Describing jobs in terms of the basic framework, noted above, is also unsatisfactory since it provides a job-to-job reliability of practically zero. To go one descriptive level lower by adding an operation work such as "inspection" to the name of the equipment part, e.g., inspects the scrimbob, still provides little reliability since the meaning might differ among equipments. The categories suggested by Miller go still one step further and do achieve reliability.

The author, Gagne, suggests the following categories of behavior:

1. Discrimination (e.g. reading dials, aligning dials).

2. Recall (e.g. remembering procedures).

3. The use of symbols (e.g. interpreting charts).

4. Decision making (making complex judgments of different courses of action).

5. Motor skill (tool using, etc.).

Recommendations

We need to develop an adequate set of operational definitions of behavior categories. Points of correspondence between predicted and actual job behavior need to be explored. See Miller, Folley, and Smith (1954), and Folley and Miller (1955).

Ghiselli, E. E., & Brown, C. W. Personnel and industrial psychology. New York: McGraw-Hill, 1955. Chapter 2.

Purpose

This chapter, Job and Worker Analyses, presents various approaches to the operational description of exisiting jobs (job analysis) and personnel requirements (worker analysis).

Conclusions

Job analysis as described here is essentially oriented to the consideration of existing, more or less standard jobs, and so is not especially relevant to the present study. However, the early thinking described here does indicate the origins of techniques later applied in the task analysis, qualitative personnel requirements areas.

For instance, activity analysis (Miller & Folley, 1951a) and the Standard Maintenance Form may be outgrowths of such recommendations for job analysis techniques as observation of personnel at work, interviews, and "questionnaires"; consideration of work materials, tools, and manuals; and the analysis of operational procedures and situations (missions and contingencies).

The review of early worker analysis techniques is somewhat more related as a predecessor to task analysis procedures. In addition to considering the skills, knowledges and abilities of job incumbents, worker analysis at this early date also considered these characteristics as anticipated for a new job.

Early listings of job "traits" were too general and subjective. A subsequent refinement was the recognition that the relative importance of some traits (criticality) was important in describing a job and that the amount of each trait required (skill level) was also significant. With these refinements, the desirability of defining the minimum qualifications for a job became apparent (Miller, 1953b).

Among the qualitative techniques described as used in worker analysis, the technique employed by the U. S. Employment Service[1]

[1]Stead, W. H., & Shartle, C. O. "Occupational Counseling Techniques" pp. 175-183, American Book, 1940. For a later revision see War Manpower Commission "Job Analysis." U. S. Government Printing Office, 1944.

appears to be the basis for some later technique suggestions for task analysis. This early method developed to describe personnel requirements, involved rating by an analyst of a list of forty-five "traits" on a three-step scale, measuring the "quantity" of each trait required.

The "traits" employed are given below. Compare with the behavior categories of Miller, Folley and Smith, (1953a). In practice, each trait is also carefully defined and illustrated.

1. Work rapidly for long periods
2. Strength of hands
3. Strength of arms
4. Strength of back
5. Strength of legs
6. Dexterity of fingers
7. Dexterity of hands and arms
8. Dexterity of foot and leg
9. Eye-hand coordination
10. Foot-hand-eye coordination
11. Coordination of independent movements of both hands
12. Estimate size of objects
13. Estimate quantity of objects
14. Perceive form of objects
15. Estimate speed of moving objects
16. Keenness of vision
17. Keenness of hearing
18. Sense of smell
19. Sense of taste
20. Touch discrimination
21. "Muscular" discrimination
22. Memory for details (things)
23. Memory for ideas (abstract)
24. Memory for oral directions
25. Memory for written directions
26. Arithmetic computation
27. Intelligence
28. Adaptability
29. Ability to make decisions
30. Ability to plan
31. Initiative
32. Understanding of mechanical devices
33. Attention to many items
34. Oral expression
35. Skill in written expression
36. Tact in dealing with people
37. Memory of names and persons
38. Personal appearance
39. Concentration amidst distractions
40. Emotional stability
41. Work under hazardous conditions
42. Estimate quality of objects
43. Work under unpleasant conditions
44. Color discrimination
45. Ability to meet and deal with public

The three ratings, later adapted by Ray, Passey, Adams, Smader, & Simon, (1957b) are:

"A" indicates that a high degree of the trait in question is demanded by the job, an amount of the trait such as is possessed by only 2 per cent of the general employed population.

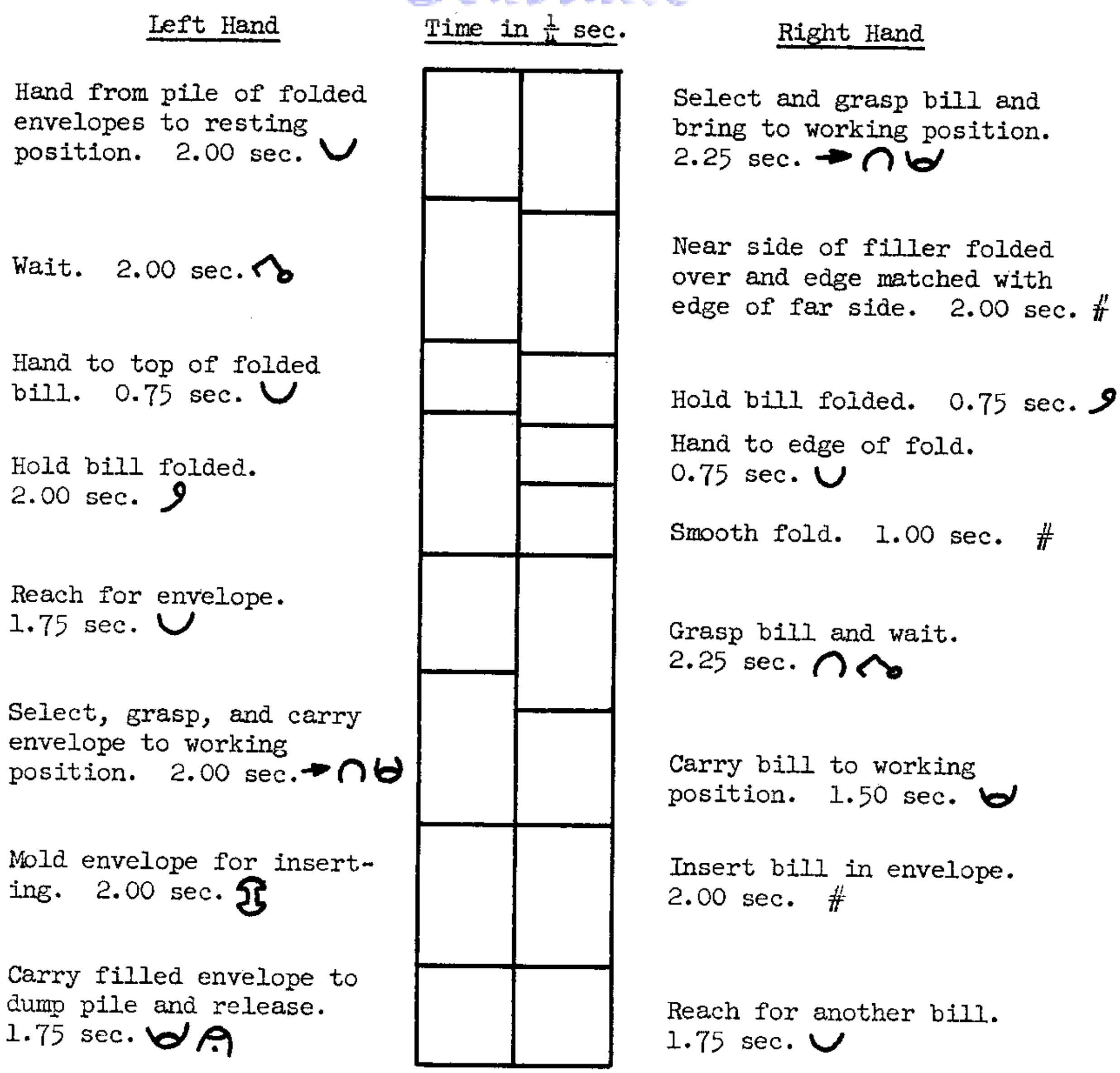

Figure 1. Analysis of the movements made by a mail clerk in folding a bill and inserting it into an envelope.

"B" indicates that the workman should have more than an average amount of the trait, not as much as indicated by a rating of A, but more than is indicated by a rating of C; an amount such as is possessed by the next 28 per cent of the general employed population.

"C" indicates that an amount of the trait such as is possessed by the lowest 70 per cent of the general employed population is adequate for the job.

In establishing the "Dictionary of Occupational Titles," this rating method was employed. The emphasis was on worker specifications, so that jobs requiring the same experience, abilities and methods of work are classed together. In addition, duties, types of equipment used, nature of materials worked with, nature of articles produced, and working conditions were also considered.

It was judged that this U. S. Employment Service approach is more practical when one is interested in the extent to which jobs can be interchanged.

Another technique for analyzing jobs is "time-and-motion" study, based on early work by Gilbreth and Taylor. Figure 1 is an example of this combined analysis. This mode of simultaneous activity representation incorporating behavior coding is echoed in Erickson & Rabideau (1957).

Comments

This article is abstracted more for the purpose of showing some of the origins of more current task analysis and position description procedures and rationale than as a source of new or alternate methodology.

Glaser, R., Hahn, J., & Phillips, J. C. (UNCLASSIFIED title) Collecting and compiling task information for newly developed guided missiles. Guided Missile Personnel Research Report No. 2, Part 1. Pittsburgh: American Institute for Research, August 1953. (BuPers Bulletin 53-2) (Bureau of Naval Personnel Contract No. N7onr-37008, NR-152-079) (CONFIDENTIAL report) (a)

NOTE: This abstract omits reference to classified equipments and is unclassified.

Purpose

Part 1 of this report presents recommendations and considerations for the collection and processing of task data by a method applicable to newly developed weapons in general. The processing and organization of task data is discussed in the following steps:

1. An over-all categorization and description of the activities involved in the operation and maintenance of the new weapon.

2. Specification of the overlap between the activities of existing Navy ratings and activities required by the new weapon.

3. Identification of the non-overlapping activities of the new weapon that require detailed personnel research and analysis.

4. Organization and presentation of task analyses and task information for the non-overlapping activities.

Phasing

The missile on which this study was based was in the test and evaluation stage, and it was necessary to investigate the contributions of all possible data sources, to produce a stable analysis of the required operation and maintenance tasks. Various procedures for obtaining task information were employed.

Summary of Method

Collecting Data for Newly Developed Weapons. In collecting data, two considerations should be kept in mind. The first is that aspects of task performance unique to the test and evaluation phase which will not be part of the operating situation should be identified as such, and eliminated from the task information. Instrumentation, monitoring and test devices, and temporary procedures are examples. The second consideration is that one-shot data collection is not enough; arrangements should be made for a continuous flow of job information to the contractor and military agencies concerned.

Four primary sources are available for collecting data during the test and evaluation phase. (See Miller, Meister, & Feroglia, 1955.) The first is the cognizant Navy bureaus, which can supply initial preliminary and orientation information, and a list of the system contractors.

The second source is the activities of the design and production engineering contractors. The following data may be obtained from each of the indicated contractor functions:

Design Engineering Dept.: Basic blueprints, redesign changes, equipment specifications, informal equipment manuals.

Service Publications Dept.: Preliminary field manuals, useful in job and task analyses.

Test and Servicing Equipment Dept.: Test equipment blueprints, philosophy of maintenance. These data largely define the line maintenance task.

Technical Procedures Dept.: Standard test procedures, checklists.

Reliability Study Dept.: Lists of component malfunctions and associated unit failures or personnel malpractices.

Field Operations Dept.: Operating and maintenance procedures and checklists used in the field; compilations of operation and maintenance problems.

Factory and Customer Training Dept.: Factory training curricula, training materials. These may contain a core of material useful in developing service training.

Quality Control Dept.: Analyses of production failures, providing material for the development of troubleshooting and repair training exercises.

Production Supervision Dept.: A list of frequent personnel malpractices in production testing and checkout procedures, and information on how these tasks are performed. Because the production workers have similar backgrounds to service personnel, their mistakes suggest areas for service training emphasis.

The third source of data is the activities of the field units testing and evaluating the weapon. Task information may be obtained here by planned observations and interview, and by systematic collection and analysis of maintenance records.

The interviews are conducted on the basis of and subsequent to the compilation of Task Analysis Forms by the field personnel. This form gathers the following data:

Task. The task title, such as "Assembles the missile sections." "Task" is used here in a somewhat broader sense than usual.

Operations Involved. The work activities (subtask) performed to accomplish each task. Each operation is designated by a number. Infrequent operations are accompanied by qualifying remarks.

Behaviors. Behaviors (elements) describe the personnel action taking place (unscrewing a bolt) and how personnel perform the action (unscrewing bolts with a pneumatic wrench). The group of "behaviors" applying to each operation (subtask) bears the same number as that operation.

Cues Available for Task Performance. Indications of how something has been done or what should be done next. It should be specified how each cue is perceived; visually, tactually, by ear, etc.

Time required. Time required to perform the entire task, including preparation for and completion of the task. Conditions causing time variations are linked to their consequences.

Tools and Equipment. The equipment worked on, tools, checklists, diagrams, and auxilliary equipment.

Precautions. Procedures for avoiding injury to personnel, damage to equipment, or task inefficiency.

Personnel Malpractices. Incidents of incorrect performance or omission of operations, or violations of precautions which have occurred on the task.

Team Structure. Number of men involved in performing the task, the operations performed by each man, and identification of the team supervisor.

Sources of Information. Training, operating, and maintenance manuals and technical material pertinent to the task.

Comments. Additional information, including an estimate of the completeness and stability of the task data reported.

Record of Personal Data. A separate form supplementing the Task Analysis Form, describing education and work experience of the respondent, as an aid in evaluating the task data and providing means for a follow-up interview, if necessary.

In order to obtain data from maintenance records on a continued-flow basis, the Maintenance Data Form was developed for incorporation as a regular part of maintenance report procedures and forwarding to the appropriate agencies. (See Miller & Folley (1951a) for a similar but more detailed data form.) It covers the following data:

Equipment. The name, mark, and model of the equipment.

Casualty. The malfunctioning component.

Symptom. The malfunction indication.

How Detected. Detected during a particular operation or visual or test equipment check.

Specific Defective Parts. A defective tube, broken lead, parted solder joint, etc.

Troubleshooting and Repairing Activities. The steps the technician takes in identifying and correcting the malfunction. The categories of data to be obtained are: Sequence of checks performed, the reason for each check, the instruments, tools, diagrams and checklists used for each check, the indication provided by each check and the action taken as a result of each check.

Equipment logs kept by field units may also provide task information.

The fourth major source of task data is in the area of related tasks and ratings. Overlapping duties may be identified by comparison of preliminary task data for the new weapon with information about existing ratings and duties. This information may be obtained from training curricula, training and field manuals, the qualifications for advancement in rate, and the organization of duties of a particular rating. Information about the differences between existing equipment used in activities related to those of the new equipment may be obtained from interviewing operating personnel and from equipment manuals.

Processing and Compiling Task Data for Newly Developed Weapons. In achieving the four purposes of the study identified at the beginning of this report, the following procedures were developed:

Step 1: Over-all categorization and description of the activities involved in the operation and maintenance of the new weapon. In the case of a missile, the tasks were grouped into the equipment categories of the missile guidance and control activities or the missile test, servicing, handling, etc., activities. The tasks listed in each of these categories were then divided into subcategories of operations, operational maintenance (routine checking, aligning, and servicing), and technical maintenance (complex troubleshooting and repair).

This step should be accompanied by an over-all description of work flow, from production line to firing.

Step 2: Specification of the overlap between the activities of existing Navy ratings and activities required by the new weapon. In this step, the tasks described in Step 1 are compared with the tasks accomplished by related Navy ratings. The resulting comparisons are presented in a series of tables, one table for each related rating. Each table includes the following information (See Figure 1):

1. Duties performed by the existing rating that are related to new weapon activities.

2. New weapon activities related to the duties in Column 1.

3. Differences and similarities between the duties identified in the first two columns.

4. The kind of additional training (none, OJT, or transition training) required for the existing rating to perform the new related duties.

The results of Steps 1 and 2 for this weapon system are given in "Guided Missile Personnel Research: Report No. 1."

OVERLAP TABLE -- GUNNER'S MATE (GM)

Duties Related to New System Activities	New System Activities	Differences and Similarities	Additional Training Required
Handling, transfer, & storage of ordnance material.	Handling transfer, and storage of ordnance components.	No essential job difference between the procedures generally employed.	Adequate experience from OJT should make personnel proficient in handling & storage.
Operation and maintenance of X and Y gun mounts and drives.	Operation and maintenance of A and B launchers and drives.	A launchers use X mounts and drive mechanisms; B launchers use Y mounts and drive mechanisms. Train and elevation drives used on mounts are reversed on new system.	OJT is adequate for both operation & maintenance procedures. Familiarization oriented toward system. Unique problems could be appended to present gunner's mates' training courses.
Operation and maintenance of ammunition hoists.	Operation and maintenance of ready-service ring & hoist.	The ready-service ring & hoist is a complex conveyor and hoist. Complex timing circuits are involved in operating the ready-service ring.	Transition training on intensive OJT is involved here.
Battery alignment.	Launcher alignment.	Gun "bore sighting" equipment is modified for system installation.	Brief OJT should suffice here.
Use of standard electrical and hydraulic test equipment.	Checkout, alignment, and servicing of system components.	Both special and standard test equipment and procedures are used.	Transition training in use of system checkout, alignment, & servicing procedures, and familiarization with the operation of system components.

Figure 1. Overlap Table Format

Step 3: Identification of the non-overlapping activities of the new weapon that require detailed personnel research and analysis. In the case of the system analyzed in this study, the special test equipment, the missile itself, and the activities concerned with preparing the missile, were unique. The activities concerned with preparing the missile for firing, including the activities of missile operations, missile operational maintenance, and missile technical maintenance formed a group of tasks not readily incorporated as a group into present Navy ratings.

Step 4: Organization and presentation of task analyses and task information for the non-overlapping activities. The product of this step is a reference source containing the following job information:

1. Specification of scope and content. Introduction and overall description of system activities, standard and unique.

2. Analysis of the tasks involved. The categories recommended for the analysis of each task are given below. They are similar to those of the Task Analysis Form described earlier.

   Task Summary. A synopsis of the task; it explains the nature of the task in terms of what is accomplished, the type of equipment involved, and the type of work performed. It may also indicate the difficulty level of task behaviors, stability of the task, etc.

   Sub-Tasks and Behaviors. Sub-tasks are the major division within the tasks, formed by dividing the operations into meaningful, independent mission groups, such as "setting up the equipment." (Behaviors were defined earlier in the report.)

   Cues Available for Task Performance. This category is defined the same as its counterpart on the Task Analysis Form.

   Major Decisions. The critical decisions a man must make that determine the successful accomplishment of a task. These include decisions which determine the next task to be performed, and decisions to alter the sequence of operations or perform operations not usually required for the task. Both the decision and the ones on which they are based are described.

Special Precautions. Precautions are defined as in the Task Analysis Form. Unique precautions for that task are described in detail; standard Navy precautions are listed separately.

Personnel Malpractices. Defined the same as for the Task Analysis Form.

Tools and Equipment. Defined as for the Task Analysis Form.

Time Required. Same as for the Task Analysis Form.

Team Structure. Identified as for the Task Analysis Form.

Skills and Knowledges. A summary listing of the kinds of skills and knowledges required for adequate performance of the task, inferred on the basis of analysis of the task behaviors presented in the previous categories. This list offers information for inferring aptitude and for identifying skill levels, etc.

Sources of Task Information. Same as for the Task Analysis Form.

3. An index of all the technical material gathered in the data collection process. The index categories found useful in this study are given.

4. A technical summary is appended, including a non-technical description of the total system, and a specific, technical description of the system, broken into functional units and described in terms of signal inputs, outputs, check points, and tests. A list of the basic principles used in each functional group is included.

5. Comparison of the subject matter of the new weapon with standard curriculum material. In the case of a primarily electronic system, this comparison specifies whether the circuitry involved is special or is covered in the general Navy electronic core curriculum. Each functional unit is judged. Those which are similar are classed as "basic." The classification "special" is used for functional units which should be emphasized by review or introduction in a course designed specifically for that system, assuming a "basic" background. Units which are basic but have unique uses in the system are called "basic with special uses."

The task analyses, technical data index, technical summary format and comparison of system subject matter with standard curricula, are all given in Part II of this report (Glaser, Hahn, and Phillips, 1953b,c).

Hahn, C. P. The identification and description of some critical air-crew job requirements. Randolph Air Force Base, Tex.: USAF School of Aviation Medicine, February 1954. (Project No. 21-29-014, Report No. 2)

Purpose

This study was the second step in a long-range research program to facilitate the analysis of air crew specialties and classification of air crew personnel. The aim of this step was to refine by statistical means the job elements and their component behaviors previously developed for various aircrew positions. It describes an approach to the categorization of behaviors into comprehensive and homogeneous groups. The initial step developed a job analysis procedure based on the critical incident technique.[1]

Procedure

Eighteen job elements had been identified in the first study. These were reported in the "Job Element Record Form." (JERF) The procedure for analyzing these for homogeneity and independence consisted of three steps:

1. Construction of short tests to measure specific behaviors in the JERF.

2. Administration of the tests to a representative sample of male high school seniors. (Five hundred and sixty-two students were used.)

3. Correlational analysis of the performances on the tests.

Results

The section of the study concerned with test development is not reported in this abstract. Table I shows the revised grouping of behaviors which resulted from the study.

[1] Wagner, W. F. Development of standardized procedures for defining the requirements of aircrew jobs in terms of testable traits. Randolph Air Force Base, Tex.: USAF School of Aviation Medicine, Jan. 1951 (Project 21-29-010, Final Report).

Conclusions

Eleven job elements involving ability factors and four job elements involving nonability factors (dealing with motives, temperament, and leadership) were identifiable. All of these may be satisfactorily tested by paper and pencil tests.

Recommendations

1. Further analysis should be made for the one element tentatively identifiable.

2. The extent to which available aptitude tests measure the refined job elements should be determined.

3. Aptitude tests should be constructed for the elements identified and then validated against training and operational criteria.

Table I

SUMMARY OF REVISED GROUPINGS OF BEHAVIORS ON BASIS OF STATISTICAL ANALYSIS

Element[2] and Category

Element 1--UNDERSTANDING VERBAL MATERIALS

- 1A Quickly understood regulation, directive, order, flight plan
- 1B Understood difficult regulation, directive, order, flight plan
- 1C Quickly understood technical or theoretical material
- 1D Understood difficult technical or theoretical material
- 1E Quickly understood instructions for equipment, use or repairing
- 1F Understood difficult instructions for equipment, use or repairing
- 1G Quickly related new materials to old knowledge
- 1H Related difficult material to old knowledge

[2]Item codes refer to original classification.

Element 2--LEARNING AND REMEMBERING VERBAL MATERIALS

2A Quickly learned nontechnical, nontheoretical material
2B Quickly learned theoretical or technical material
2C Quickly learned equipment operating instructions
2D Accurately remembered nontechnical material
2E Accurately remembered theoretical or technical material
2F Accurately remembered equipment operating instructions
2H Remembered which materials or equipment to use
2I Remembered all items in a complex inspection
2J Remembered all steps in complex safety procedure
2K Remembered time or sequence for performing operations

Element 3--MAKING NUMERICAL COMPUTATIONS

3A Performed series of simple computations without error
3B Quickly performed simple computation

Element 4--USING MATHEMATICAL REASONING

4A Included all relevant factors or steps
4C Quickly solved problem using mathematical reasoning
4D Correctly solved unusually difficult problem using mathematical reasoning
4e Accepted an obviously impossible result

Element 5--RECOGNIZING AND DEFINING PROBLEMS

5C Analyzed difficult problem into component parts
5D Used relevant information from past experience
5g Substituted less adequate method for satisfactory one

Element 7--PLANNING AND ANTICIPATING PROBLEMS

7A Memorized materials or procedure for future use
7D Prepared for changes in conditions
7E Planned to take advantage of a "break"
7F Conserved equipment and supplies
7H Effectively planned for changes in conditions
7I Effectively planned for conserving materials
5f Didn't see adaptability of a procedure

Element 8--MAKING SOUND DECISIONS

8B Chose action giving desirable results
8C Chose appropriate time for action
8D Decided on most appropriate procedure
8E Chose appropriate materials for equipment

Element 10--ESTIMATING AND IDENTIFYING: (Visualization--Spatial Perception--Induction)

10B Estimated distance or angle closely
6DEF Adapted, improved, and devised or improvised tool, equipment or part
7J Effectively planned for use of own time and time of others
12C Accurately integrated graphic information
12M Visualized position of aircraft from instrument or other data
13D Maintained orientation with few references
13Q Visualized object from instrument readings or other source
14A Explained normal functions of equipment
14B Determined effects of maneuvering

Element 11--READING AND RECORDING DATA

11A Accurately extracted graphic data
11B Quickly extracted graphic data
11C Accurately read simple instrument
11D Quickly read simple instrument
11EF Recorded data quickly and accurately

Element 12--INTERPRETING DATA FROM RECORDS AND INSTRUMENTS

12A Accurately interpreted graphic information
12B Quickly interpreted graphic information
12D Matched graphic information to actual object
12E Matched graphic information with instrument reading or other visual representation
12H Integrated several instrument readings
12I Used minimum number of instruments

Element 13--INTERPRETING SPATIAL PATTERNS

13FG Accurately, quickly interpreted graphic representation
13H Integrated information from graphic representations
13J Matched graphic information to instrument reading
13KO Identified difficult scope return
13M Determined relative position from scope return
13N Accurately integrated scope readings

Element 14--VISUALIZING MECHANICAL RELATIONS

14C Predicted effects of equipment controls
14D Found cause of equipment malfunction

Element 20--ACCEPTING PERSONAL RESPONSIBILITY

20B Took action beyond his responsibility
20C Improved his own proficiency
20E Checked accuracy of own or others' work
20F Admitted his mistakes
20G Was scrupulously honest

Element 20--ACCEPTING PERSONAL RESPONSIBILITY ... (continued)

20I Cared for equipment or conserved supplies
20J Carefully obtained, recorded, or transmitted information
20K Carried out required physical operation well
20L Carried out required nonphysical operation well

Element 21--ACCEPTING ORGANIZATIONAL RESPONSIBILITY
21B Accepted and carried out orders promptly
21C Considered ideas or decisions of others
21D Willingly did job beneath him
21F Disregarded personal convenience
21G Followed necessary rule or SOP

Element 23--MAINTAINING PROFICIENCY UNDER PHYSICAL STRESS
23D Efficient dispite loud or continuous noise
22b Reluctant to work in small space

Element 24--WORKING EFFECTIVELY WITH OTHERS
24B Organized work of others well
24C Assigned best qualified to task
24E Got cooperation of others
24F Stimulated others to increased effort
24G Raised morale of others
24H Appreciated efforts of others
24I Considered others
24J Maintained friendly relations
20D Stayed with problem
20H Was commendably self-reliant
22E Made quick and adequate readjustment

Indiana University Institute for Educational Research. Task-oriented analysis of the K-system and its relationship to the development of the K-system fundamentals proficiency tests. Annual report. Air Force Personnel and Training Research Center, July 1953. (Contract No. AF 18(600)-306)

Purpose

This report describes a detailed analysis of the K-system equipment and discusses the relationship between such a detailed equipment analysis and the logical development of proficiency tests. The specific use discussed is the development of a Systems Checker or Mechanic Level-of-Performance test.

Rationale

The function of the psychologist was established as that of coordination with a technical expert, and translation of the equipment analysis into tests oriented to behavioral categories. It was stated that the design engineer and the technical expert, not the psychologist, should do the task analysis.

The assumptions upon which the basic equipment analysis was based:

1. Job requirements can be validly specified by this process.

2. Content can be analysed by a technical expert.

3. Other technical experts will corroborate the equipment analysis independently.

The equipment analysis was done first, then a task analysis. Following the task analysis (see Figure 1), the tasks were ordered on a concrete-to-abstract continuum.

Concrete. Refers to "routine" task. A person is not required to classify objects in accordance with a principle. The behavior is determined by characteristics of objects as perceived at a given moment.

Abstract is complex. The individual is required to organize objects in terms of properties they have in common. He responds to a class or category.

From this continuum the tasks were classified into four categories or levels of complexity. These were:

Identity. Mechanic brings together objects on the basis of exact seonsory attributes.

Partial Identity. Similar in some ways or in terms of one sensory attribute.

Co-junctionality. Objects which seem to belong together in a given situation on the basis of being used together.

Categorical similarity. Objects belong in the same general category.

The basis for this classification is that of Bolles "basis of pertinency," established in a study of test performance of aments, dements, and normal children of the same age.[1] If one accepts the categories defined, the task oriented analysis is reducible to four basic classes of tasks:

1. Tasks of reading dials and indications.

2. Knowledge of what happens when certain controls are manipulated.

3. Knowledge of the rudiments of data flow.

4. Knowledge of the bombing problem.

Because the categories were mutually exclusive, it was easy to classify each task.

Summary of Method

Sources of information were the equipment analysis and SAC maintenance requirements. Resources required were a technical expert and reference materials, including technical orders, military specifications, maintenance manuals, engineering reports, and analyses.

[1]Bolles, M. M. The basis of pertinence. New York Archives of Psychology, 1937, 212, 51 ff.

The task analysis was completed with use of a Task Oriented Analysis Form shown in Figure 1. In the first column the analyst recorded the task to be performed. In the second column the skill and knowledge required to perform the task was recorded.

TASK ORIENTED ANALYSIS

PREFLIGHT CHECK, WCKG 391 PRE-FLIGHT TASK TO BE PERFORMED.	KNOWLEDGE OR SKILL REQUIRED

Figure 1. Task Oriented Analysis Format

The following steps were carried out in preparing the task analysis.

1. The first cut was made by the technical expert on the basis of equipment only.

2. The first cut was then reviewed by the psychologist.

3. The resulting task descriptions were then compared with the SAC maintenance requirements.

4. Six SAC maintenance technicians were invited to visit the installation and review the material in detail.

Comments

Use of the procedure in the complex task area is not really tested. There are areas where the analyst would have much more difficulty than appears to have been encountered in this study. The report states that a concrete-to-abstract continuum should range from routine maintenance requirements to complex troubleshooting. The equipment analysis conducted was concerned only with lower level tasks--"rote memory and principle habit formations." Even for this level the report states that it was necessary to find "broad classes for the material isolated in the task analysis since a complete report would have taken thousands of pages." While a "scale" along which to rate skill and knowledge content of each task is suggested, no widely usable scale evolves.

Although the task analysis format is shown, no comment indicates the rationale or method for determining the skills and knowledges required nor the level or manner in which the tasks are stated.

No indication is given of the equipment analysis methodology, and of how the tasks were derived in the first place.

While various classifications of tasks are given, no indication is made of how or why they fit into the total sequence of analysis.

Jones, Edna M., & Miller, R. B. The use of pictures and diagrams in job descriptions. Pittsburgh: American Institute for Research, September 1956. (Project No. 7709, Task No. 77150, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1203)

Purpose

This report suggests principles and technique applications for the preparation of pictorial and diagrammatic materials to support job descriptions in the Air Force Qualitative Personnel Requirements Information program. It is anticipated that the contents may also be applicable to the preparation of job instructions and related training aids.

The report reviews the theoretical considerations in the use of illustrations to support written text, available illustration techniques, and the types of illustrations appropriate to specific areas of job descriptions. The latter area of consideration is emphasized in this abstract. The reader may refer to the document for a more thorough review of the theoretical considerations and greater detail of the illustration techniques.

Conclusion

Briefly, eleven principles and ten tentative hypotheses were evolved from the theoretical considerations which guided and supplement the specific recommendations.

Recommendations

Illustrations in Support of Operator Positions. The following suggestions parallel the steps for determining position-task requirements of operators as outlined in Miller (1956a).

1. Determine criterion outputs of the man-machine system. Machine output factors and their relationships may be shown diagrammatically in the form of block diagrams. Brief statements may be added to the output blocks showing the operator's role in controlling the output, i.e., "fully automatic, automatic following operator initiation," etc.

2. List the kinds of input conditions (program variables) with which the program must cope. Diagrams, especially of the block type, are an excellent means of summarizing contingencies under which a given requirement must be performed. Diagrams are a useful supplement in showing the interactions of variables and conditions, either quantitative or qualitative. They are especially useful in showing the geometrical relationships in a problem a given system must solve. Ribbon-type arrows to schematize three-dimensional flow of events and abstract pictures may be helpful.

3. Enumerate duties in a typical mission cycle. The flow chart provides a desirable summary of activity sequences in a form readily grasped and recalled. Each block may represent a duty or time segment of a work or mission cycle. Alternative segments and contingencies may be shown by a dotted block beside the main series and connected by a dotted line to the point where the contingent action might occur. See Snyder (1959).

4. Enumerate the tasks in a typical mission cycle. Flow diagrams are an excellent means for schematizing relationships of activities and events such as sequence and overlapping. Blocks may be stacked above each other and overlapped to show in gross terms the concomitant tasks, the right-to-left length of the block indicating the relative task duration.

5. Differentiate continuous (tracking) tasks from discontinuous (procedural) tasks. Continuous tasks may be represented by continuous lines, discontinuous tasks by broken lines.

6. Write out the position elements contained in respective discontinuous (procedural) tasks. Task programs may be diagrammed as in Step 2.

7. Describe continuous position duties. Most tracking tasks include time-shared activities, if none other than monitoring equipment operation. A series of time charts is practically essential in grasping the complex possibilities of job demands under operational conditions. See Erickson & Rabideau, (1957). Miller (1956a) suggests a simplified schematic which is relatively inflexible in showing how a particular set of contingencies would affect the bunching of behavior requirements. This inflexibility is overcome in Weislogel & Jacobs (1956) by the use of multicolored transparent overlays, which provide different color codes for perceptual, recall, and

manipulation demands. Overlays representing different contingency situations may easily be combined with the various segments to indicate loading problems.

It cannot be too strongly emphasized that the characteristic limitation in task descriptions is in the account of the stimulus complexities and contingencies which must be dealt with simultaneously. Diagrammatic treatments may aid, far more than words alone, in organizing and revealing these complexities.

Illustrations in Support of Maintenance Position Descriptions. Special uses of illustration in maintenance position description are discussed below.

Typical work cycles. Work cycle flow charts may be given an additional context by schematizing the route the mechanic must characteristically take in performing the work cycle. Blowups, using representational sketches, may be made of the various work stations or portions of the route. Forms of the flow chart map may be adapted to what has been called the "blackboard testing" of provisional position structures (Miller, 1956b). Contingencies may be added to the work cycle map to indicate potential obstacles.

Locations of portions of the equipment. A phantom view of the total system may be shown, with the subsystem relevant to the position emphasized in silhouette, darker rendering, or color. Access hatches may also be shown.

Identification and nomenclature of components of an equipment. Retouched photographs or line drawings can show the external and internal appearance of components. Internal appearance need only be shown when the mechanic must work within the shell for servicing, adjusting, etc. For QPRI purposes it is not necessary to show the appearance of every chassis and subassembly. If QPRI were to be used directly for specific training content, it would be necessary to show series of pictures in which every part to be serviced, checked, adjusted, disassembled, or replaced is identified either by labelling or call-out. Test equipment and unusual tools should also be illustrated, with expected points of difficulty blown up to show the problem details.

Detection and identification of out-of-tolerance conditions. Where a variety of qualitative factors must be taken into account in determining tolerance conditions such as determining the camber, caster, and balance of a steering wheel, a semi-pictorial diagram may be used. The wave shape output of an oscilloscope is an especially important type of information to illustrate.

Aids to troubleshooting. It should be stressed that for troubleshooting diagrams, only objects that provide for a given position check values, adjustment capability, and replacement as a unit, should be shown. The same applies to diagrammatic aids for "principles of system operation."

Description of precautions. Verbal precautions can often be given meaningful context through diagrams, especially if identification confusions are anticipated. It is important to represent the proper action, not the improper one; the text should describe the nature of the improper action.

Special Features

A 41-item annotated bibliography of literature in the field of illustration of technical and training material is included.

Kershner, A. M. A report on job analysis. Washington, D. C.: Office of Naval Research, 1955. (ONR Report ACR-5)

Purpose

This report provides a critical review, with the assistance of an extensive bibliography of (1) purposes or uses for which job analysis is performed, (2) terminology and definitions of job analysis, (3) methods of job analysis, (4) research on methods, (5) some recent studies concerned with job analysis procedures, job evaluation, and factor analysis, and (6) discussions and conclusions.

Conclusions

This report is not systematically abstracted because in job analysis, the focus of attention is usually "the job as it now is," an orientation unsuited to the purpose of this survey. However, some of the criticisms, conclusions, and comments have some bearing on the problem of anticipating, describing, and structuring new positions. These are indicated here.

Job analysis methods are varied, but generally they consist of one or more of the following: observation, interview, questionnaire, work participation, and literature (including training manuals) review.

Of all the studies reviewed, the author felt that only one completed a serious attempt to attack the problem of job analysis methods: "Research into Basic Methods and Techniques of Air Force Job Analysis" (Rupe, 1951, 1952; Rupe & Westen, 1955a, 1955b; Rupe, 1956). "It is safe to say that future researchers in job analysis should not proceed without an exceedingly careful examination of this pioneering effort into research on job analysis methods." Among the studies conducted in this project was an analysis of overlap, unique items, and of the skills, knowledges, and physical demands sections of the Work Performed and Tools, Equipment, and Materials Worked Upon checklist schedules. These schedules all reported elements within each of four jobs as analysed by five different job analysis methods. One of the conclusions of the study was that the ability of the type of analyst used on this project or, in fact, any operational job analyst, (not a psychologist) to make dependable, useful, and psychologically meaningful estimates of skill and knowledge requirements of existing jobs was held in question. See Wiley, Harber, and Giorgia (1959).

Among the job analysis methods studied in other projects, the group interview procedure appeared to be one of the most satisfactory; at any rate, no serious disadvantages to the method were stated.

Considering over-all job analysis techniques, it was concluded that job analyses which are all-purpose are just that--they serve everyone in general and no one in particular. If the analysis is being made for the development of training curricula, it should produce information useful to such a purpose. If the purpose is the development of selection or proficiency devices, the job analysis should provide the user with what he needs.

Evidence of dissatisfaction with conventional job analysis is not difficult to find. An internal Air Force paper (Rupe & Demaree, 1953) criticizes conventional job analysis on the following points:

1. The job duties of conventional job schedules are not easily combined into inventories of tasks performed by given levels of incumbents.

2. The frequency of task performance is not obtained in a suitably structured manner to assume reliability or validity of results when statistically analysed. (Christensen, 1949)

3. There is no procedure in conventional job analysis for identifying critical tasks in the sense here defined.

4. There is no procedure in conventional job analysis for objectively determining the existence of specialized assignments within AFSC's.

5. The final results lack comprehensiveness.

6. Conventional job analysis does not appear to be effective in identifying the skill and knowledge requirements of jobs.

Among the difficult questions facing job analysis are what are the appropriate units or aspects of jobs for consideration, and what are the pertinent levels of detail for different classes or types of jobs and for the different kinds of users of job analysis products. See Erickson and Rabideau (1957). Obviously, "complete" description cannot be done away with where the occupational information function, training functions particularly associated with activities that must be learned on the job, and various currently used job classification schemes are to be served by analysis. But it does appear that there are a whole host of work activities that can be reflected more advantageously in terms of what is required of the worker than in so-called job-oriented language. It is time that attention be focused more fully upon the worker--the knowledge and skills required of him directly.

Recommendations

In reviewing the work done in this area, one source of development work is noted as being absent from the literature and generally unobtainable--recent work done for industry, especially in the analysis of higher level supervisory, scientific, and executive positions. This area of study would be well worth investigation, and might similarly yield results applicable to the qualitative personnel requirements program, as well as for job analysis.

Special Features

This survey report reviews the various definitions that have been applied to such terms as job analysis, worker analysis, position analysis, position evaluation, qualifications analysis, duty, responsibility, task, position, job, occupation, job evaluation, position classification, element, and position type. Rather than arriving at a best list of definitions, the review is a critical summary of the various usages and their evaluation. The bibliography of this report lists 79 items.

Comments

This report does not attempt to enumerate the many good points or satisfactory applications of the methods reviewed, although it acknowledges their existence. Its principal aim is, by critically identifying possible or proven weak spots, to stimulate further research in this area.

Knowles, W. B. Automatic and personnel requirements for guided missile ground support functions. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, May 1959. (WADC Technical Report 59-240) (Project No. 7185, Task No. 71584, Contract No. AF 41(675)-170)

Purpose

The study was conducted to investigate the relationship between automated systems and personnel requirements for guided missile support systems, especially as required for the preparation of QPRI material. The study concerned itself principally with organic level maintenance on the Mace, Snark, and Bomarc missiles. The QPRI approach was developed only as an idea, and tried out on the Mace system.

Rationale

The development and special applicability of "logical elimination" troubleshooting techniques to automated electronic systems led to QPRI reports derived from this sort of step-by-step equipment-oriented task approach. While data prepared in this manner are useful for handbooks, or for gaining insight into human engineering problems, they are of little value as a basis for recommendations in the areas of manning, selection, training, etc., since the psychological makeup of the task is never considered.

The problem was how to go from a task analysis, stated in terms of "turn knob X," "read waveform Y," to the identification of the required electronics aptitude index, and knowledge and skill requirements. Or, if a job is specified as intended for a 3-level operator with less than a high school education and an electronic aptitude index of 60, what does this tell the designer about that man's capabilities in terms of the knobs he can turn or the scopes he can read, by way of design evaluation.

Summary of Method

One approach to the problem has been to categorize tasks into such psychologically meaningful groups as simple discrimination, complex manual task, etc.

The approach suggested here is a direct outgrowth of the equipment under consideration; it was proposed that tasks be categorized in one of five general areas, these areas coded, and the coded tasks diagrammed much the same way as computer functions are diagrammed for programming. The operating and maintenance handbooks for the Mace guidance system checker illustrate this process—a shorthand for summarizing personnel operations. See Snyder (1959) for a similar but more comprehensive technique.

Procedure

The following categories and codes were used:

1. Very simple manual operations such as operating switches and knobs were counted, and numbers used to designate these operations.

2. Manual operations requiring some motor skill, such as nulling out sensitive servos or dismounting heavy assemblies, were designated by the letter "M".

3. Operations requiring mainly sensory discrimination such as meter reading were identified by the letter "S."

4. When the technician had to use information acquired earlier, these points were labeled "R" for Remember.

5. When the choice of alternative succeeding tasks was conditional on a specific meter reading, the accomplishment of an adjustment or the combined results of several previous steps, the point was labeled "C", conditional, and the alternatives were then shown.

Sample diagrams of tasks described this way are illustrated.

1. Checks crystal currents: 2-S-2-S

2. Adjusts antenna yaw gain: 3-M-M-C$\begin{smallmatrix}\nearrow 1\\ \searrow 1\end{smallmatrix}$

3. Align cathode ray tube sweep:

5-M-2-M-S-S-1-$\overset{1}{C}$-S*   -1-S*   -1-M-$\overset{M}{C}$-1-2-1-S-1-2-S-1-S-1-S*

-S-C†   -1-$\overset{M}{C}$-S*   -1-C‡   -2

*No instructions covering this sequence.

†If the condition is not met the operator goes back to Step 6 and repeats.

‡If the condition is not met, the procedure is repeated from the beginning to this point. If it is still not met, one of three units is replaced and the procedure repeated. This process is repeated until the condition is met.

Conclusions

It can be seen from the illustrated diagrams that this procedure readily indicates to the designer the structure of tasks he has created, and any blind alleys, closed loops, or other incomplete procedures.

For the purpose of task simplification, an a priori ranking of the categories from difficult to simple, C-R-S-M-1, would indicate at least one basis for a sequence of elimination. In the application of this diagram system to the Mace, the designers found that this technique did suggest simplifications.

Recommendations

It would be most desirable if this technique could be developed to predict aptitude requirements for the performance of the tasks worked out. Considerable research would be required to accomplish this, however. The present task categories are neither independent nor exhaustive. A means of summarizing the data needs to be developed. A factor analytic or multi-variate analysis needs to be done to develop the task description, followed by a series of correlation studies to relate the structural descriptions to measures of personnel abilities.

Comments

This technique appears less suited to the development of QPRI than it is to the "debugging" of the operational or maintenance procedures. General Electric, Cornell Advanced Electronic Center, (no date) presents the fourth quarterly report on this study.

May, R. V., Jr. The use of job analysis schedules in preparing job requirements check lists. Lackland Air Force Base, Texas: Human Resources Research Center, June 1951. (Technical Research Note 51-2) (Project 21-07-015)

Purpose

This report presents a review of difficulties encountered in utilizing existing job analysis schedules to develop a standard job requirements check list. The purpose of the project was to develop a check list of skills, knowledges, and abilities which could be used by a job analyst to report the requirements of Air Force jobs. The original plan was to examine 2170 job schedules on file, compiled between 1946-48. They were to first analyse the jobs and describe the duties and tasks, and then set down statements of skill, knowledge, and abilities required. The analysis produced 70,000 such statements.

Procedure

1. Twenty-five hundred skill, knowledge, and ability statements, taken from a five per cent sample of the job schedules, were used.

2. Discarded from the data were:

   a. Those statements obviously peculiar to a single Air Force job, e.g., "must know the temperature tolerance in making dentures."
   b. Those having no apparent psychological significance, e.g., "must have some ingenuity in using scotch tape."
   c. Those obviously paraphrasing military requirements in general, e.g., "must be able to read and write common words."

3. On the basis of similarity and overlap, the remaining items were reduced to 90 general statements or categories. (These are presented in Table I of the report.) Examples of knowledges: Decimal file system, bookkeeping, hydraulics. Examples of abilities: Compare numbers rapidly, read blueprints, lead others. Examples of physical or psychomotor skills: Far vision, hearing, leg strength.

Conclusions

1. The skill and knowledge statements contained in the available job schedules failed to provide an adequate amount and variety of useful psychological information for research purposes. Inadequate emphasis was placed on skill and knowledge requirements in the original job description and the analysis was not designed to provide data in a form immediately valuable for personnel research purposes. The original job schedules were prepared for the purpose of job descriptions for revision of the classification system.

2. The majority of the statements were too specific to the job being analysed, to be classified into useful psychological categories and placed in a job requirements check list.

3. Many of the statements not specific to a given job were too broad in concept to be of much value.

4. There were many areas of skills and knowledges which were not identified by this system.

5. The data available was so inadequate that even a tentative systematic arrangement of knowledge, aptitude, skill, and ability classifications did not seem feasible.

Recommendations

A different approach is therefore required for development of the proposed job requirement check list. Further research, or review of research, needs to be done on the isolation and classification of human knowledge, aptitude, skill, and ability.

Special Content

Table I of the report presents the 90 skills, knowledges, and abilities isolated. Appendix A shows the type of verbatim statements used as data. Appendix B is a sample job schedule.

Comments

This report indicates one approach to the identification of skills and knowledges which did not yield useful information.

Miller, R. B. Anticipating tomorrow's maintenance job. Lackland Air Force Base, Texas: Human Resources Research Center, March 1953. (HRRC Research Review 53-1) (Project No. 507-008-0001, Contract No. AF 33(038)-12921) (a)

Purpose

This document was published as a general review of the project to date, and especially covers Miller, Folley, & Smith (1953a), Miller & Folley (1951a), and Miller & Folley (1952). Because it is such a general review of basic material abstracted, the body of this document is not reviewed. Revision 4 of the Standard Maintenance Form, published in the Appendix, has been included in the abstract of Miller & Folley (1951a), where development of the form is detailed.

This abstract covers only the remaining part of the Appendix, "An Outline of the Logic in Functional Analysis," taken from a paper presented by R. B. Miller to the American Psychological Association convention, September 1952. The equipment analysis used in this project (Miller & Folley, 1951a) was based on this work on man-machine analysis.

An Outline of the Logic in Functional Analysis

The following steps trace the relationships between the over-all purpose or objective of the equipment and the job actions which must be performed on the equipment. The "job" of the machine is shown as interlocking with the job of the man. This analysis may be carried down to extremely specific man-machine tasks. Although the present context is that of the maintenance job, the same scheme might also be applied in determining the job action requirements of the operator of the equipment.

A detailed extension of this scheme provides a basis for integrating equipment design and job design during their formative stages. It also provides for a systematic job analysis.

1. What is the operational function of the equipment? The operational objective and its limits are determined by military specifications. For example, AN/X radar bombing equipment has as its function the dropping of bombs with 50 mil accuracy on the basis of specified kinds of input information to the equipment. Fifty mils is the "tolerance limit" set for the equipment as a whole.

2. What are the variables in the operational function which are controlled by the equipment? These variables usually arise from natural phenomena. In equipment AN/X these variables are the variables of the "bombing and navigational problem" such as distance from target, wind direction, wind velocity, air or ground speed of aircraft, bomb ballistics, and so forth. Subsystems of the equipment control each of these variables with specified tolerance limits of accuracy. The tolerance limit of all subsystems together is determined by the tolerance limit for the operational function.

3. What are the interaction requirements of the parts of the equipment to each other within subsystems? This requirement is defined by the tolerance limits permitted for the specific subsystem in question. In the AN/X subsystem, for the control of "angular distance from target" the output from each component must vary with specified limits in relation to the data fed into the components of the subsystem. These equipment interaction requirements involve the engineering problems which the design of circuits and mechanisms must solve. A sample statement would be: "When shaft A is rotating at x, the charging rate of the generator must be within 2 amperes of value y or the equipment will tend not to control for angular distance from the target within allowable tolerances."

4. What are the indicator requirements of the equipment? These are provided by the engineering designers. They offer direct or indirect evidence of the adequacy of operation of the set and its components. For example, "When the Revolution-per-Minute indicator is 100 plus or minus the width of the needle, the Rate-of-Charge meter must read 25 plus or minus 2 units."

5. What are the mechanic's information requirements? In other words, what must the set tell the mechanic so that he will know if it (or some portion) is performing adequately? This set of requirements is made up in part from what can be done by the mechanic to correct the component's action and in part from what needs to be known in order to decide whether the equipment should or should not be used in a mission. The characteristics both of the mechanic and of the equipment make up this requirement. Pointer indications on the RPM and Rate-of-Charge indicators require that the mechanic tell the difference between an in-tolerance and out-of-tolerance reading.

6. What are the mechanic's action requirements? What does the mechanic have to do, and do it with, and to what, in order that the set will operate properly? Both the equipment and the mechanic together pose these requirements. They involve the ways in which the mechanic can control the change of action of the set or portions of it. Thus, he may have a "Rate-of-Charge" adjustment screw. When he turns it to the right, the charge rate increases; when he turns it to the left, it decreases.

7. What are the mechanic's feedback information requirements? What will tell the mechanic that his attempted corrective action was adequate or inadequate? If his first response fails to be adequate, other actions which he may take to bring the needle into the correct position may be spelled out. These alternatives become subtasks in the job.

Note that steps 5, 6, and 7 tie the job of the mechanic into the job which the equipment has to perform. Steps 4 and 5 link the action of the equipment to the action required of the mechanic and are the steps where engineering design and job design come together. This is also true in Step 7. In the engineer's language, the functions of the mechanic plus the function of the equipment form a "closed loop."

Comments

See Miller (1953b) for further development and refinement of this functional analysis approach.

Miller, R. B. A method for man-machine task analysis. Pittsburgh: American Institute for Research, June 1953. (Preliminary draft of WADC Technical Report 53-137) (Aero Medical Laboratory Contract No. AF 33(038)-22638) (b)

Purpose

The procedure described here was designed to specify training requirements for equipment operators in detailed and unambiguous psychological terms. It was intended for use in the blueprint and breadboard stages of development, as well as later on. Task analyses of equipment would identify the tasks to be trained by a proposed training device and guide design specifications for the device regarding the functional characteristics of its hardware make-up. The task analysis would also be applicable to the training device to derive student and operator task requirements. The extent to which a comparison of the two task analysis applications indicated behavioral overlap would represent the transfer of training to be expected from trainer to operational equipment. A task analysis also provides a basis for developing training syllabi and training aids. This formal task analysis procedure identifies the sufficient and necessary tasks in the man-machine functional system.

Rationale

Task analysis is both a rational and empirical method. It can be used without empirical data about job performance because the behavioral requirements of a man-machine task may be given by the equipment displays, available response alternatives, and controls. An assumption of this presentation is that the operational equipment is taken as a given. (See Comments).

The criterion output of a man-machine system normally consists of several variables. Each of these is a functional chain in which the man is frequently a critical link. Task analysis consists of the enumeration of discriminations, decisions, and action behaviors which are necessary and sufficient to operate the system within the tolerances allowed. These behaviors are grouped both by system purpose and by temporal relationship. Some task requirements overlap in time, and these must be identified to indicate the psychological load required of the operator in the performance of his job. Task analysis should therefore provide both a longitudinal and cross-sectional analysis of job behaviors with respect to time. It is recommended that this behavioral analysis be supplemented by observations of "critical incidents" of operator error, such as those arising from built-in human characteristics, individual experience, previous training, and methods of approach to the task, which cannot readily be forecast from a systematic analysis. See Miller & Folley (1951a). Such data would aid selection and training planning.

Summary of the Method

The following definitions are among those presented in this report:

Subtask. A form of task in which the occurrence or conclusion of one response is the cue for a second response which may in turn be the cue for the next response in a relatively invariant sequence. Example: "Put gear shift into NEUTRAL position."

Proximal Stimulus. Stimulus indicating the presence, location, or identity of a given task. Example: An identifying knob shape.

Distal Stimulus. Stimulus which incites a task performance by or through a machine.

Procedural Task or Procedure (Discontinuous task). A kind of task in which discrete (principally all or none) responses are made to cues or specific values of cues in a continuous series of stimuli. In early learning stages they tend to be verbally mediated and are rather highly generalizable among varying situations. When the procedures are invariant, practice makes them automatic or unmediated, and transfer is more difficult, especially if the work load is heavy.

Continuous Feedback Skill. A performance involving a continuously changing response to a continually changing stimulus. These skills vary depending on the extent to which an operator can anticipate the extent and nature of response required. Example: Tracking a sine wave can be entirely anticipated; tracking a moving target is more difficult to anticipate.

Because "procedures" and "continuous feedback skills" show different transfer of training characteristics and pose different training problems, different methods and formats for task analysis have been developed for each.

The general approach in the proposed task analysis method is that a behavior can be defined by the stimuli, response alternatives, and effector activities involved in that behavior. If the operator uses equipment, the task-relevant discriminations will be based on displays or cues, and the task-relevant responses will be control activations. If it is possible to determine the critical figure-field differentiation which the operator must make in a given behavior, the discrimination which he must learn and make is defined.

Two supplementary procedures for task analysis are presented. The second format, for analysis of continuous tasks, is the more general procedure and could be applied to analysis of procedural tasks with the omission of various categories.

The task analysis procedure involves the following:

1. A simple statement of the man-machine system output, including a criterion of over-all quality.

2. Determination of the system functions, or the necessary and sufficient man-machine activity variables.

3. Tracing each system function to the input or operator control. Description of this control and the manipulations required to achieve the desired results.

4. Determination for each function of the information displayed by the machine which the operator must discriminate to accomplish the function.

5. Identify the indications of response adequacy presented to the operator which he must also discriminate.

6. Identify environmental data available and necessary to the operator including stored information, contingencies, etc.

7. Identify functions which must be modulated by the operator at the same time, in sequence, or in cycles. These behavior groups are tasks.

8. Review the analysis to insure that each stimulus is linked to a response, and vice versa. A statement of the response adequacy criterion, related to the system adequacy criterion, will help insure the relevance of each task.

The task analysis of procedures is divided into two sections: analysing system and job functions, and analysing tasks and subtasks within job functions. One group of job functions are those of starting and stopping procedures. These functions, including pre- and post-operative checks, are normally specified in Technical Orders. The other group of job functions are operating procedures. Following a definition of the criterion of system output, list the system functions, or system variables which go to make up the system output. These functions or variables may be identified by reviewing the equipment controls, or by considering such necessary activities as aiming a rifle, for which "controls" are not used. Job function analysis formats are illustrated in the report, but omitted here because of their length.

GROSS TASK ANALYSIS

TASK	DISPLAY		DECISIONS	SUBTASKS LISTED	CHARACTERISTIC ERRORS OR MALFUNCTIONS
	DESCRIPTION	CRITICAL VALUES			
A. Set up before first run	Position of brake	Not in 9 o'clock position	Release brake - move to 9 o'clock position	1	
	Recall of last inking	Copy light since last inking(est.)	Measure ink - add if necessary	18, 19, 20, 21, 22	

ANALYSIS OF SUBTASKS

SUBTASK OR TASK	DISPLAY - CONTROL DESCRIPTIONS	CONTROL ACTION	INDICATION OF RESPONSE ADEQUACY	OBJECTIVE CRITERION OF RESPONSE ADEQUACY	CHARACTERISTIC ERRORS OR MALFUNCTIONS
A. Re-lease brake	Brake	Turn clockwise (up)	Brake stop in 9 o'clock position		
B. Attach the stencil	Wheel	Turn	Stencil head clamp avail-able		
	Stencil head clamp	Lift left end	Stencil head clamp loosens		

Figure 1. Task Analysis of Procedures

The analysis of tasks and subtasks within job functions uses two formats. The Gross Task Analysis covers the major tasks required and emphasizes the display or situational behavior features. The Analysis of Subtasks format emphasizes the control or response behaviors. A description of the purpose and use of these formats is given below.

The Categories in Gross Task Analysis

Task. The name of the task will usually be stated as some purpose within the job, calling for a group of procedural tasks instrumental in achieving the purpose. These are listed in the columns and rows to the right of the Task column.

Display/Description. Those task-relevant cues which initiate each task or present the requirements of a control action to help achieve the Gross Task. The "display" or cue may also be information recalled by the operator. If the operator must search in the display context for the critical cues, the word "search" should be written in the box with the display description.

Display/Critical Values. The specific and essential feature, value, or stimulus difference which provides the basis for a discrimination leading to correct control action. If the discrimination involves estimates of size or qualitative differences, the word "estimated" should be written in the Critical Value column. Tolerance limits for these estimates will be provided in the "Analysis of Subtasks" in the columns Indication of Response Adequacy or Objective Criterion of Response Adequacy, or both.

Decisions. The principal alternate choices which the display situation may present. These choices of response may be considered as tasks or subtasks. Often only one response is appropriate to the situation and only that one is noted.

The decision is a mediating action in the chain of psychological events between the display and the response. These mediating actions have an important bearing on training and must be recognized in the task.

Task Operation or Subtasks. The code designation of the response or response group necessary to complete the task requirement. This code designation is obtained from the format of "Analysis of Subtasks," where control actions are analysed.

Characteristic Errors or Malfunctions. Ways in which the human operator may tend to make errors or the equipment may malfunction. These data would be provided by operational log books and malfunction records. This column also includes precautions in making a decision or performing the task.

Analysis of Subtasks Format

The "Analysis of Subtasks" form is separated from the "Gross Task Analysis" form only for convenience. It is a supplementary and not an alternate form. Its purpose is to record the response details of tasks, subtasks, or both. It contains the following categories:

Task or Subtask. The title of the task or subtask which is to have its response analysed, and an identifying number which can be used on the "Gross Task Analysis" sheet for reference.

Display. This column will frequently not be used because the control level will usually be the proximate stimulus for the control action. (The distal stimulus initiating the subtask or task will usually be described on the "Gross Task Analysis" form.) Occasionally, some distal display feature may intervene in the performance of a subtask and require modification of that subtask. The column for Display provides for this contingency.

Control Descriptions. The control or controls instrumental in the execution of the subtask or task. Where a photograph or specifications are available, they should be used for references.

Control Action. The human action required on the control to get the appropriate machine activity. The description should be sufficiently explicit that a person could perform the control action on the basis of that description.

Indication of Response Adequacy. A stimulus which shows the operator that the control action he has made is effective. This indication of response adequacy should usually be the cue for the next step.

Objective Criterion of Response Adequacy. This column is used when some criterion independent of the immediate subtask or system is available; i.e., the number of parts rejected by an inspector is an objective criterion of the adequacy of a worker's performance.

Characteristic Errors or Malfunctions. Information which will guide training to minimize sources of human error which are especially prone to occur.

Some equipments are more likely to fail on certain operations than on others. This information may be used to determine additional subtasks which will prevent or alleviate the problem.

Continuous Feedback Functional Analysis

The first step in feedback task analysis is to define the major functions of the job under investigation. The first order of major functions may be very few in number. Thus, the major functions in driving a car (with respect to feedback performances) consist of accelerating, stopping, reversing, changing direction right or left. From these functions may be analysed, by a combination of empirical observation and rational method, the tasks required to perform these functions. A sample function analysis for feedback procedures is given in the report, but omitted here because of its length.

Continuous Feedback Task Analysis

The following categories are included on the "Task Analysis of Continuous Feedback Skills" form as shown in Figure 2. If a task includes a procedure, the procedural behaviors may be specified on the form for "Analysis of Procedural Tasks" and referred to by code number.

Task. State the task in terms of some goal outcome.

Display/Problem. A representative sample of the task problem should be described here.

Display/Critical Stimulus Variables. The essential stimulus components generic to the display problem and the task. These variables will provide the basis for determining the discriminations which the operator must make. In this space should also be set down whatever "preparatory situation" may lead up to the display problem, e.g., dark adaptation preceding glare of oncoming headlights. Time values as they affect rate at which the stimuli must be perceived and integrated should be given separate consideration.

Display/Noise. The kinds of interference, outside the operator, which may disturb the operator's reception of the information conveyed by the display.

Decisions. Gross response alternatives which may be available to the operator.

Controls/Description. The appearance, location, and other cues relevant to the identification of controls involved in the task. Reference may be made by part number, etc., if available.

Controls/Activation. What the operator has to do to the controls to achieve the goal of the task. Direction of movement, rate of movement, magnitude of movement, sequence of movements, and combination of movements should be recorded. Preparation for movement should also be included.

JOB Driving 1950 Pontiac Hydramatic

TASK Tracking toward a variable aperture: three rates problem (Passing a car with an oncoming car in the passing lane).

DISPLAY

Problem: Path ahead with oncoming car; competing car ahead and to the right. Assume competing car will not accelerate.

Critical stimulus variables:
(1) The absolute rate of competing car (X).
(2) The absolute rate of oncoming car (Y): cars of variable size and speed.
(3) The absolute momentary distance between X and Y.
(4) The acceleration potential of O's car at that speed (Knowledge requirement).

Time values: Critical since a time of no return will be reached when it is too late to get into aperture or to brake; this is a function of 1, 2, 3, and 4 above.

Noise: (1) Stress may occur (2) Worry that X will increase speed while passing

DECISIONS Pass now or pass later

CONTROLS

Description: Accelerator — Steering wheel

Activation: For rapid access of power, press all the way to floor board past a resistance detent.

Action: Drops transmission from 4th to 3rd gear below 50-55 mph. More power from faster engine-to-wheel ratio.

FEEDBACK

Cues: Same as display but as X, Y, and O approach, the success of the solution or lack of it becomes more apparent.

Time delay: Function of acceleration of car.

Criterion of response adequacy: Getting back into right lane with "safety margin" (50' plus) depending on speed. (Better criterion would be in terms of time between turning into right lane and collision: 5 seconds).

Critical values: Collision course perceived imminent.

Corrective action: Brake and return to right lane; ditch on left side.

CHARACTERISTIC ERRORS AND MALFUNCTIONS

(1) Getting too close behind X before accelerating and passing X.
(2) Failing to take into account slight grade.
(3) Failing to take into account cars behind O which may prevent return behind X in emergency.
(4) Not returning to right path as soon as safe to do so.

Figure 2. Task Analysis of a Continuous Task

Controls/Action. The machine functions modulated by the control--the ratio of movement of the control to the magnitude of machine output.

Feedback/Cues. Those cues directly fed back to the operator from the initial grasping of the control, and those fed back from changes in the machine outputs with respect to goal requirements.

Feedback/Time Delay. The time relations between activation of the control and the onset or availability of the respective feedback cues.

Feedback/Criterion of Response Adequacy. Cues available to the operator which show that his response is achieving the criterion demanded. It should also include signs which, although not available to the operator, may show to an instructor whether the response is adequate. Tolerance limits should be specified.

Feedback/Critical Values. Cues which indicate to the operator that the system is appoaching a "discontinuity" in action. Thus, the screech of tires and tipping of a car rounding a curve at high speed is a cue that the car may skid or overturn.

Feedback/Corrective Action. Corrective action against the consequences of reaching or exceeding critical values of machine response.

Characteristic Errors and Malfunctions. Same as similar columns on the other forms.

There should be a sufficient detail of the stimulus conditions which influence performance to establish what and how many concurrent signals are being fed the operator (including both Display and Feedback Cues categories) and the frequency at which perceptual responses, decisions, and motor adjustments must be made under conditions up to maximum difficulty for that job. If the complexity of the job makes this integration difficult, one more step may be required called "program analysis."

Program Analysis

The purpose of program analysis is twofold. One is to determine what activities, tasks, and behaviors are time-shared. The other is to identify the situations to which the man-machine system will have to adapt.

If empirical data are available about sample situations to which the system is subjected, they should be used. If not, then informed conceptualization will be required.

Equipment malfunction or interference within the system which still tolerates operations may be included. Noisy channels of communication should not be disregarded.

From these contingencies may be deduced the behaviors which overlap in time or are in close temporal contiguity. A sheet of paper may be marked off with a time-scale along one margin. On this time-scale indicate what tasks are concurrent as a standard matter of course. At another level of the paper indicate tasks or behaviors which are not necessarily correlated in time with other tasks. By stacking the nonstandard (with respect to time) tasks above the densest layers of time-shared activities, the maximum behavioral load required of the operator is suggested. By combining time lines for all members of a team, crew, or system, the total pattern of operations and interactions may be analysed. See Murphy, Fairman, Lindner, Smith, and Purifoy (1959) for an application of this type of technique.

Comments

While this presentation was apparently aimed at analysis of existing equipments, there should be pointed out the even greater value it has when applied to development equipment. The sequence and approach outlined, while operationally applicable to production equipment, is logically in reverse order. Ideally, system and job functions should not be determined by the controls and displays presented, but by the system requirements or criteria, without reference to the equipment. It should be system requirement based, rather than equipment based.

Some of the definitions used and detailed procedures suggested are simplified or superceded by later thinking in this area and applications of the general method of approach.

Miller, R. B. Suggestions for shortcuts in task analysis procedures. Pittsburgh: American Institute for Research, December 1954. (Aero Medical Laboratory, Contract No. AF 33(616)-2080) (b)

Purpose

This report is the result of a study of methods for reducing the time and effort spent on task analysis prior to making training device design recommendations. Normally, a task analysis is expected to make inputs to many areas, such as the effective use of training equipment, selection and proficiency determination, human engineering, operations analysis, job design and job procedures, and job instructions. This study attempts to identify the shortcuts possible if all the purposes for a task analysis were eliminated except that of designing training equipment.

The task analysis procedure taken as a point of departure is described in full in Miller (1953b).

Conclusions

Several areas of consideration are related to the isolation of training equipment information. They are reviewed briefly below.

Assuming that the task analyst is the one who makes the design recommendations, he might avoid writing down task analysis data if he were thoroughly familiar with the job being analysed. If either of these conditions were not met, ordering and writing down job data at the behavioral level would be essential.

To the extent that performance of a task does not require the presentation of stimuli or the identification or manipulation of controls (or other physical supports for action), the inclusion of such a task in a "task identification" list is irrelevant to trainer design and may be omitted.

If it is decided in advance that the insturctor will provide the trainee with knowledge of results and scoring of his performance on the trainer, rather than by automatic presentation, detailed behavioral analysis is unnecessary for the design of the trainer. (However, this analysis still would be needed for determining job and task performance criteria.)

Skills acquired to certain stimuli may not meet performance requirements under different stimuli, and compounding tasks may have peculiar interaction effects on behavior. A program analysis should, therefore, be performed, indicating what tasks will or will not have been acquired in a given training (equipment) context.

The injudicious partition of a job into training segments risks inefficiency and limited transfer when the segments are brought together, especially when the job involves complex time sharing, interlocking anticipations, memory storage, and scanning behaviors. Where a separate part-task trainer may not be called for, provision may be made for part practice on a complex trainer. Because maintenance tasks usually occur in sequence rather than overlapping, tasks may be grouped according to hardware as a basis for trainer requirements.

In some circumstances, particularly for procedural tasks, such existing job data as technical orders, maintenance and logistics plans, standard operating procedures, or prepared operations analysis data, may be substituted for detailed task analysis behavioral statements.

The analyst's insight and experience with the special difficulties in learning and performing discriminations, recall, decisions, manipulations, etc., may take the place of organizing behaviors in a specific format. For a system of some complexity, however, this insight would not suffice.

Below are suggested some amendments to the normal task analysis method for recommending training equipment design in terms of psychological requirements. It is not essential, but very helpful, to follow the steps in the order listed.

First, a limited system function analysis should be performed, conceptualizing the system as a process changing inputs into outputs, and operating within predetermined or arbitrarily identified requirements, which must be stated as a reference for the whole man-machine operation. Despite the methodological utility of systems functions to the broader applications of task analysis, most of its formal aspects may be omitted from task descriptions applied to training device design. Four steps of functions analysis, however, _should_ be performed.

1. Analyze final machine output variables as a basis for studying the provisions for guiding or monitoring the machine by the operator.

2. Enumerate job segments, if a regular serial order can be established. Within each segment will be a group of tasks which may or may not be performed in standard order, plus emergency procedures, and alternative tasks for contingencies. Organizing tasks in this way is quite relevant to the design of training equipment, assuming that identifiable job segments may also be training "segments" or units.

3. Obtain criterion values and tolerances of outputs and rate values, as objective indications of operator proficiency. In some cases, the minimum acceptable _rate_ of performance is dictated by the work or machine environments of the operator.

(Performance rates are seldom applicable to maintenance tasks.) If such criteria are not available, design recommendations should include specific statements of the tolerance values required, and how they are to be incorporated in the functional characteristics of the training equipment.

4. It is desirable to identify and study the major program variables before starting task enumeration and behavioral analysis, and re-examining them when the task analysis is completed, to include recommendations covering the operational implications of all contingencies.

The task analysis should then be performed, consisting of the following steps:

1. Identify and list the names of tasks either in the entire job for which training equipment is to be prepared, or for those job segments for which some specific device is intended. In this process, it will save effort later on if it is indicated how each task is related to other tasks in terms of temporal proximity, carry-over of information, commonality of knowledge, anticipations, or other characteristics which may establish psychological commonality either in learning or in performance, or both. It should be remembered that it is the operational and behavioral content denoted by the task name which is significant.

2. It is in this step that the principal departure is taken from the full-length task analysis. Instead of identifying all behaviors and writing them out in format, the analyst selects only the data he considers critical to the training problem, or which cannot be obtained from sources of task information planned for use with the training device. He identifies the following information essential to training device design:

   a. Display-control hardware task supports, considered in their broadest sense; selecting a tool is a display problem, using the tool, a control problem. He should specify what physical elements may be omitted, and what dummied in the trainer. Special functional and physical features as required for training may be specified when actual recommendations for the trainer are being made.

   b. Special difficulties known or anticipated in learning or performing behavioral task elements, in terms of the categories of perceptions and discriminations, decision-making and problem-solving, recall of stored information, and motor response.

      In checking a tolerance condition, is his reference standard objectively present, or is an "absolute" judgment based on a standard present during training?

When consummatory responses are functions of several stimulus components staggered in time, it is essential to identify the preparatory and triggering cues, so their provision will be considered in training equipment.

Problems in motor response may include brief reaction times, difficult access to controls or cramped quarters for control movements, timing and coordination of control movements, manipulation "tricks of the trade," etc. Operational demands frequently require less in the way of actual tracking behavior, for instance, than the anticipation of how much control force is required. Whether a control can be located visually in operational conditions or must be located kinesthetically is another important factor. Restraints such as G-suits, gloves seat belts, or movement up ladders, on slippery surfaces, against strong wind, etc., are also important.

c. Inferred or observed human error or malpractice. For example, the recognition that under emotional stress an operator's perceptual field becomes restricted has led to practice in broad scanning of the field, persistently throughout pilot and gunner training. It is also well known that when the inciting cue to a behavior must be recalled rather than recognized, there is relatively high probability of occasional forgetting.

d. Needs for specific knowledge of results to trainees. If it is explicitly stated that the instructor is to be the principle source of response evaluation and knowledge of results to the trainee, minimum additional data need be given in this category of task description. Knowledge of results is particularly essential to task situations in which the trainee himself lacks a specific criterion for response adequacy, or where it is not directly provided by the immediate consequences of incorrectly operating or dealing with equipment.

e. Reference sources for task description. Reference material used in lieu of a detailed behavioral analysis should be clearly cited.

3. Identify rate- or time-critical tasks and their task contexts. Tasks in which time and rates play critical roles should be identified. If performance of these tasks is in the context of performing other tasks which may not have time-critical elements, it is essential to determine these contexts. Time values and their tolerance values should be obtained, if possible.

4. Chart tasks on a time base and show time-shared activities. Individual task information is organized into a pattern above a time base line. Operations analysis charts may provide much of the critical information required. By number coding, reference may be made to points which are highly loaded with error likelihoods and/or performance stress, as when large amounts of data must be sought for and absorbed quickly, many critical manipulations must be performed about the same time, or there is high internal loading as in anxiety. Intensive training is usually necessary for delicate timing processes, especially if the operator moves progressively into danger by performing his task.

   The chart should suggest for these peak loads what types of anticipations should be trained for, and what kinds and degrees of automatic behavior require repetitive training.

5. Identify variables in task programs in detail and specify their interaction with one another. It is from this task program data that the determination of content for specific training exercises can be developed. If training is to be a readying of the trainee for operations, his skills will need to be developed and tested under the range of contingencies and hazards he will find in the real world.

Recommendations

It should be emphasized once again that these shortcuts are expedients for the sole purpose of arriving at human engineering specifications for trainer design, especially insofar as hardware is concerned. The absence of a detailed behavior description may leave some gaps in recommendations for how the training device is to be used, and thus may weaken the rationale for the inclusion or omission of various features.

Such a shortcut is called for only where a thorough task analysis has not been designed to meet some of the other needs for this sort of data, as suggested in the Purpose, or when a quick determination of training equipment requirements is needed. When a complete behavioral analysis is possible, its use is preferable. This report does serve, however, to point out those aspects of the system function analysis and task analysis procedures which can contribute most to the determination of training and training equipment. See American Institute for Research (1959) for a later discussion of the determination of functional training equipment requirements.

Miller, R. B. General processes and terms in behavioral description. Chapter III of draft, Manual for man-machine job-task description. Pittsburgh: American Institute for Research, June 1955. (b)

Purpose

This chapter consists mainly of definitions of terms used in describing man-machine task analysis methods, with special emphasis on the area of decision-making and knowledge derivation.

Conclusions

This abstract lists sample definitions and related considerations. In the text, each definition and its implications are generally discussed in more detail with examples, and greater continuity. Three areas of behavior are defined; perceiving, decision-making, and manipulation.

Perceiving

In man-machine systems, the fundamental perception is the discrimination of an out-of-tolerance condition from an in-tolerance condition.

Reference standards. A stimulus which is used for making a comparison with another or "test" stimulus to discriminate an in-tolerance from an out-of-tolerance condition. Subjective reference standards are yardsticks which are built into the user through training and experience, consist of a knowledge of "stored information," and should be indicated as such in a task analysis.

Natural stimuli versus symbolic stimuli. A natural stimulus is one which reaches the operator from its source with the physical relationships of the source relatively intact. A symbolic stimulus is one which requires interpretation according to established rules. A STOP sign is a symbolic stimulus to stop; a truck across the road is a natural stop stimulus. A map provides both types of stimuli. To use symbolic stimuli, knowledge must be acquired and recalled to translate the symbol into an action requirement of the job.

Channels of information. A channel of information is frequently defined physically by some "frame" around a display of job relevant stimuli; i.e., windshield, speedometer, rearview mirror. Nonvisual channels of information are not so well "framed," but are identified by the source of stimuli and the conditions under which they are perceived. It is possible to think of various functional channels of information which may be carried in a single physical channel, i.e., an interphone may relay both verbal and code signals

Rate of signal presentation or stimulus change. A highly important determiner of the nature of perceptual skill is the rate at which discriminations must be made, singly or combined. There is some indication that qualitatively different habit systems must be learned when otherwise similar physical action signals occur more rapidly.

Stimulus discontinuities. When stimuli in a job-task cycle appear intermittently, but not at regular intervals in an expected channel, task difficulty becomes greater, special training is required. When a technician has to remember to do something at a time which is not dramatically indicated to him by a forceful external stimulus, there is a highly error-likely situation which should be identified in a task analysis.

Stimulus patterns. Human beings respond to patterns of stimulus inputs, rarely or never to separate stimulus items as such. Furthermore, with practice, the nature and extent of these stimulus patterns usually changes toward greater economy in the perceptual process--a greater range or quantity of stimuli can be filtered and interpreted. This concept is significant in deciding whether to divide a job or task for part training, thereby possibly limiting the potential pattern development.

Perceptual noise. Any stimulus inputs irrelevant to task demands are perceptual "noise." Specialized perceptual "filters" against irrelevant stimulus inputs may be developed through practice. Tasks with a high signal-to-noise ratio are more difficult than those with a lower ratio; the difficulty increases rapidly with time stress, reducing the opportunity for a "second look."

Programs. A concrete representation of conditions under which, at a given time, a task or job must be performed. Programs are compounds of task-relevant stimuli plus noise. A program variable is a convenient way of classifying groups of programs: the program variable of "visibility" would include daytime, night-time, or twilight conditions. Fog, rain, snow, and glare are, for an automobile driver, program noise variables. All principle program variables should be represented in training or proficiency evaluation situations.

The quantitative terms that identify perceptual requirements consist of the number and spatial distribution of information channels that must be scanned, and the rate and frequency of signals coming through these channels and demanding job actions. The qualitative or actual contents that appear on separate operational occasions are called programs. Major program variables are identified to provide for training, proficiency determination, and evaluation of task difficulty. Human capacities to develop selective perceptual responses permit reduction of noise interference; human capacities to respond to signals in units or stimulus patterns, rather than discrete elements, permits rapidity and flexibility of perceptual response.

Decision making. Decision making is a response consisting of three segments:

1. A group of stimulus-inputs which must be responded to according to some feature they have as a group, rather than individually.

2. Recall of knowledge of supplemental information, the stimulus input, or of procedures, general strategies, or rules.

3. Some inferring or computing process by which stimulus components are responded to as a group rather than as individual items.

Recalling. In short-term recall, information is given and used only within a job performance cycle. Short-term recall requirements are important to identify in a job. Long-term recall involves standard knowledge acquired in training. Standard knowledge is a job requirement when it is a necessary supplement to external stimuli for decision-making. Job task knowledges may be of the following types:

1. Anticipations where a future condition must be predicted from some present set of conditions.

2. Locations of objects perceived or manipulated on the job.

3. Nomenclature of objects used or referred to by the technician.

4. Steps in procedures where the technician cannot or should not follow written instructions.

Job-task inferring. Inferring processes produce decisions through the use of general rules, strategies, or principles. In addition to input data, the process of inferring requires identification and recall of knowledges, the proper "rules" or formula to use for the problem. Problem solving may also consist of imagining or reasoning and may expand a technician's job capability where inventiveness is required.

Interpreting. This consists of transforming one kind of information into another kind of information or action, i.e., decoding.

Requirements for inferring and interpreting are obtained by identifying those job circumstances in which a decision must be made by the technician; that is, a situation where a specific response is not prescribed for the specific stimulus presented to him by the system. Determine what information must be added to that provided by the system, in order for the technician to choose the correct control and manipulate it properly. This would constitute a knowledge requirement for such situations. Then determine what minimum rules or steps to take in reaching a decision in the form of a diagnosis, or the series of checks to make in troubleshooting, or in selecting a tool or test instrument, or which control to move at what time. These minimum rules or steps provide the basis for the problem solving process.

Manipulation

As the term is used in man-machine tasks, the term "control" may refer to any object which in the course of job performance must be adjusted, pressed, twisted, shifted, lifted, or otherwise requires some change of position.

Efficiency in using controls. While achieving the same results, some modes of control operation may be more economical of power or saving of wear than others. These techniques should be identified rationally, not on hunches.

Accessibility to controls. Accessibility may be an important factor in the allocation of duties to one job or another, especially if the degree of accessibility imposes time demands incompatible with task time requirements--heavy clothing and accessory gear may also create situations incompatible with operational requirements.

Reaction time. An interacting product of perception time, decision time, and muscular response time. The absence of distinctive warning signals preceding a stimulus for a short reaction time response makes a task more difficult from the perceptual-motor standpoint. Erratic "fore-periods" tend to make a task more difficult than standard fore-periods.

Rate and accuracy of control movement. The more rapid and accurate the movement of a continuous control must be, the more difficult the task. This difficulty is also a function of the length of control travel from one setting to another, and the fineness required of the terminal adjustment.

Shifting from one control to another. Rapid shifts from one control to another increase the probability for error, especially if these shifts must be made when eye movements cannot precede and guide the shift. In order for muscle sense to be reliable in guiding the body member to the proper control, high degrees of training are necessary. Accuracy in finding controls through muscle sense is greatly reduced as the controls are located further from directly in front of the operator.

Control coordination. Where tasks require not only rapid shift from one control to another but also the coordination of control action, the task difficulty mounts disproportionately.

Verbal response. There are few jobs in which verbal or other symbolic communication is not required as a vital link which must be identified as an integral part of a job-task description.

Miller, R. B. A suggested guide to position-task description. Lowry Air Force Base, Colo. Air Force Personnel and Training Research Center, April 1956. (Armament Systems Personnel Research Laboratory Technical Memorandum 56-6) (Project No. 7709, Task No. 77150, Contract No. AF 18(600)-1203)(a)

Purpose

This guide details methods for describing job requirements for operation and maintenance of new Air Force weapon systems, as part of a Qualitative Personnel Requirements program. Position-task analysis provides data, not answers to problems: it shows what has to be trained, but not the best way to do the training; it may suggest, but not direct, changes in procedures or equipment design. Position description is not an end in itself; it is information permitting old and new positions to be compared with a view to selection requirements, and to determine training and other personnel requirements. The critical information is usually contained in the description of position elements within tasks, rather than in task names and duty titles.

The more specific the description of human requirements, the more precisely can habits, skills, and abilities be modified or built-in to meet the requirements. The purpose of a description determines the level of specificity needed.

Rationale

The method of position-task description outlined here is based on the following concept of position composition and characteristics.

The position is the total set of activities assigned to one man in an operational situation, as defined by operational and maintenance plans and standard operating procedures. Position activities are grouped into duties by one of two principles; position segments, or major groupings of activities contributing to the same end function, as takeoff, and generally occurring within an identifiable time phase; and by position function, or basic form of activity occurring throughout a mission, as inspection, checking, adjusting, troubleshooting, etc. In either method, a duty (a set of position activities comprising a major requirement within a position) is stated in general terms, not specifying any equipment details. Duties are composed of tasks which are discontinuous or procedural activities, which can be marked off into separate stimulus-response steps, and continuous or tracking tasks. The two are distinguished because they pose different training problems. See Miller (1953b). A task is a group of unitary human operations, called position elements, usually occurring at about the same time or in sequence, directed to a common machine output. An element is identified by a specific stimulus on a specific indicator or object and a specific response behavior requirement. The general example is: "When condition X, do operation Y to object Z." The essential items in describing an element are the indicator's indication that activity must be taken, the control and control activity required, and the indication of response adequacy. Frequently, the first and the last are combined, in order not to labor the obvious; where the latter is not obvious, it should be noted. An element may contain one of four types of action; percieving, recalling (long-term and short-term), interpreting and inferring, and performing manual operations. Except where a set of mental procedures is being described as a series of steps, each element must have both an input, display, or stimulus feature and an output, response, manual operation, or control operation.

A behavior is any form of human action characterized by a stimulus and a response.

Scheduling or Phasing

The Qualitative Personnel Requirement Information needed as inputs to the various standard Air Force documents comes from a three-phase QPRI program.

The first phase occurs during the development of the prototype system, and provides manning document information, position definitions, task-sequence charts, and provisional training equipment characteristics. Phase 2 begins with delivery of the first production model. It provides a review of personnel requirements, position-task descriptions, and training equipment characteristics. Phase 3 begins after the start of inventory production and provides QPRI modifications based on activity analysis (Miller & Folley, 1951a) and equipment changes.

Summary of Method

Determining Position Requirements for Maintenance Down to Components.

1. Identify the possible data sources and obtain the data required for determining position requirements (Miller, Meister, & Feroglia, 1955). Forecasts of position requirements may be made in advance of hardware existence from diagrams, specifications, and plans.

2. List the "replaceable units" for flight line maintenance. It is not important that packaging be fixed; it is important that assembly inputs and outputs be identified on a data flow block diagram.

3. Enumerate the tasks to be performed by line maintenance. (Miller, 1953b) If procedures have been prepared by engineers for checks, adjustments, replacements, repairs and servicing, skip steps 4 through 9.

4. Determine how line mechanics will make in-tolerance/out-of-tolerance decisions. Identify the sign or indication by which the mechanic can judge the tolerance condition.

5. a. Determine how line mechanics will identify overall system outputs as in- or out-of-tolerance.
   b. Determine what test equipment will be used. Itemize the test equipment which is not built in under a separate category of "position objects."
   c. Determine how line maintenance will check subsystems and data loops down to plug-in assemblies. Identify all check points and their out-of-tolerance indications. If a check point is not available between one replaceable assembly and another, inquire from the manufacturer how that assembly may be checked. If a feedback loop or parallel circuit involves several assemblies, determine how the loop may be broken and the component assemblies tested on the line.
   d. Determine any other equipment items to be checked by the line mechanic, and their tolerance indications. Note signs of mechanical damage, as below, and a quantitative tolerance value, if possible.
      - Frayed wires or cables
      - Bent or damaged pins in connectors
      - Burned parts
      - Mechanical parts bent or out of alignment
      - Excessive play in mechanical parts

   If a qualitative check must be made, a "barely acceptable" sample should be available for training.
   e. Organize maintenance check points into a list and represent all check points on a block diagram of line replaceable units (Miller & Folley, 1951a), specifying the tolerance indications of each as it will appear to the mechanic. Specify the test set to be used, if possible.

5. For each line check point determine what adjustment control modifies the signal characteristics to be checked. If an adjustment control is not associated with a check point, then the line mechanic's only alternative is to replace the assembly when out-of-tolerance. List each adjustment control opposite the associated check point; if more than one control, indicate the order and mode of use. If checks and adjustments <u>must</u> be done in sequence rather than individually, indicate the sequence on the block diagram.

6. Determine the sequence of checks and adjustments intended for the system in line maintenance. This is done with the help of the engineers. No effort should be spared in designing SOP checks and adjustments which parallel logical troubleshooting sequences, because of the difficulty in teaching separate troubleshooting procedures.

7. Determine the steps to be taken in replacing each assembly replaceable by line mechanics.

8. Itemize repairs to be made by line mechanics and determine the steps to be performed in making each repair.

9. Determine what cleaning, lubricating, and other preventive and servicing activities will be required in line maintenance.

10. Determine the position elements and their proper order within the task procedures. See Miller, (1953b). This is the heart of the position description procedure.

11. Write out the elements for the tasks required of components maintenance.

    a. <u>Position</u>. Write the position title.
    b. <u>Duty</u>. Write the name of the duty or mission segment. Give it a code number such as 1.
    c. <u>Task</u>. Write the name of the task, including its own code number plus that of the segment or duty in which it falls: 1.1.
    d. <u>Time</u>. Estimate the time required to perform the task (not element) in sequence with other tasks, and out of sequence with any normally preceding tasks. These times are often the same. For repair and troubleshooting tasks, times can only be given for specific examples.

       The frequency with which a task is performed is entered under <u>Indication</u>.

e. Task Conditions. Enter under Indication the equipment conditions indicating when the task should be performed. If part of a procedure write "SOP for Procedure X;" if not part of a procedure, it is essential to state the conditions.

f. Control. Name the control to be manipulated. In parenthesis, write the tool or test equipment used. Code the element by number: 1.1.1.

g. Activity. Name the activity to be performed. Typical activity verbs are:

    Perceiving: observes, reads values, notes relative motion, identifies visual patterns, notes simultaneous events.

    Recalling: recalls, takes precautions, locates, recalls nomenclature.

    Interpreting and inferring: makes computations, interprets, draws inferences.

    Performing manual operations: positions, aligns, mounts, assembles, connects, lifts, solders, turns on, writes, uses screw driver.

h. Indication: Identify the indicator (Miller, 1955b), the indication of response adequacy, and the response tolerance limits.

i. Remarks. When alternative actions are indicated note them under Remarks. Write the alternatives out under a new subtask coded to the subject task or element in the Remarks column. Precautions should also be entered here.

12. Determine procedure and aids to be used for troubleshooting in line maintenance.

    a. Determine general troubleshooting procedures. Describe the strategety suggested by the engineers. The final procedure should be based on equipment as packaged in production models.

    b. Determine the supporting aids to troubleshooting. See Miller, Folley, and Smith, (1953a). The data flow block diagram should be adapted to the troubleshooting procedure or strategy for line maintenance. Check lists, symptom tables, and a "theory of operation" are included.

    c. Describe Troubleshooting. This description must be accompanied by a description of equipment packaging and layout. Troubleshooting to the level required by the position is considered a duty or segment. Each task consists of locating the malfunctioning major component. Enough samples of troubleshooting should be described to cover representative decisions required. A subtask is identified by stating the actual malfunction and initial symptom.

Information Needed lists questions which a proficient mechanic would ask in guiding the troubleshooting. Opposite each question in the Behavior column is entered the action taken to answer the questions. The result of this behavior is entered in Indication. The Interpretation column describes the meaning of the indication on the basis of what has been learned so far. The Remarks column identifies critical decisions, special difficulties, and precautions.

If special aids make troubleshooting entirely procedural, the task would be treated as a procedural, rather than a continuous task.

13. Summarize the position information. This summary precedes the position description and contains the following:

a. Position Title.
b. General Features. The working situation, environment, and personnel interactions.
c. Duties and Tasks. Describe each duty or segment; list the appropriate tasks under each. Indicate similarity to existing AFS's by the following rating:
   1. If the task involves a subsystem or component identical to one already in the Air Force inventory, the tasks required on the new equipment may be judged identical.
   2. If elements of a task are similar to those existing in the specialty (AFS) area, but refer to new components or test instruments, the tasks may be identified as similar.
   3. If the task contains elements which do not occur in the specialty (AFS) area, and represent unusual activities for the kind of maintenance personnel employed, these elements should be identified as new.
   4. If the elements of a task and their sequence in the task are common and within the repertoire of the average adult without special training, they should be identified standard. If any indoctrinatory training or practice is required by a normal adult to perform the task it is not "standard."
d. Qualifications. Indicate the required level of aptitude as measured by the Airman Classification Battery. List the specific transferable skills and knowledges helpful to a person, should he have to become proficient in another position after becoming proficient in this one. Example: Ability to interpret schematic and wiring diagrams of electric and electronic circuits.

14. Identify photographs, parts lists, position instructions, check lists, and block diagrams of line replaceable units. If possible, these materials should be supplied with the position description.

Steps in Determining Position Requirements for Maintenance Within Components.

The method used to obtain a detailed description of within-components (shop) maintenance follows the same sequence of steps as the procedure for components (line) maintenance; only the shop-relevant variations are abstracted here.

1. Obtain sources of data for determining shop position requirements. The additional system products related to shop maintenance are:
   a. Method for checking line replaceable units when removed from normal installation.
   b. Procedures for checking, adjusting, and troubleshooting each line replaceable unit.
   c. Shop test equipment.
   d. Tools needed for work on and within line replaceable units.
   e. Diagrams showing functional connections of parts within line replaceable units.

2. List the components with which shop mechanics will work, including all line replaceable components plus such within-component parts as condensers, resistors, and coils, which must be maintained. Parts such as resistors, of which a system contains many, may be listed as classes, rather than each resistor individually. Parts may be classified by electrical function, as resistor, or by method of connection within the component; soldered, bolted in, plug-in, etc.

   The main shop maintenance functions are checking, replacing and a smaller amount of repairing. Parts are seldom adjusted; a plug-in is adjusted by manipulating a part. Troubleshooting is done on a plug-in, not a part, to determine which part needs to be repaired or replaced. There is little servicing of parts.

   For the checking function, therefore, parts should be classified by electrical functions, since they are usually checked the same way. For the replacing function, parts should be classified by means of fastening.

a. Classify all the parts from one line replaceable unit. Test the classes of components according to each of the schemes above. The important factor is the similarity of the checking operations required.
b. Analyse each of the other line replaceable units and add whatever additional classes of parts are necessary to encompass all parts.
c. Prepare a composite list of components pertinent to shop maintenance. The list will include line replaceable units, parts classified for checking, and parts classified for replacing.

3. Enumerate tasks to be performed by shop mechanics. If procedures have been prepared for checks, adjustments, replacements, repairs, servicing, and troubleshooting, skip steps 4 through 9.

4. Determine how shop mechanics will decide whether components are in tolerance. The same procedure is used as for line checking.

   a. Determine how shop mechanics will tell whether each line replaceable unit is in tolerance. Shop mechanics will frequently check the various line replaceable units by the same procedure, with different settings. In this case, outline the procedure only once, and include the settings in a table.
   b. Determine how shop mechanics will decide whether parts in the various classes are in tolerance. Same procedure and considerations as for line checking.
   c. List all test equipment used in both line and shop maintenance and determine how shop mechanics will decide whether each item is in tolerance, and how it may be adjusted. Checking and calibrating line and shop test equipment may be a shop function.

5. Determine what adjustments must be made in shop maintenance.

   a. List all adjustment controls and their operations on each line replaceable unit.
   b. In each line replaceable unit determine what indicator is used with each adjustment control and what the indication should be.
   c. For each line replaceable unit determine the sequence in which the adjustments should be made.

6. Determine the means by which shop mechanics will replace line replaceable units and the various classes of parts. Classes of parts derived for replacing are used here.

7. Determine what parts or subclasses of parts within line replaceable units must be repaired by shop mechanics (rather than just replaced); describe the steps to be performed in making these repairs.

8. Determine what cleaning, lubricating, and other preventive and servicing will be required in shop maintenance.

9. Determine the means by which shop mechanics determine which part in the line replaceable unit is malfunctioning and requires replacement or repair.

10. Determine the position elements and their proper order within the task procedures.

11. Write out the position elements for the tasks required of shop maintenance.

12. Summarize the duties and tasks, specifying tasks identical to or different from previously established tasks. These steps are identical to steps 10 through 13 for line maintenance.

13. Identify photographs, parts lists, position instructions, check lists and diagrams pertinent to shop maintenance.

<u>Steps in Preparation of Position Definitions for Operator Positions</u>. The analysis procedure for operator tasks is similar to that for maintenance tasks, except that there is a greater emphasis on the time factor, usually a greater variety of situations in which the tasks are performed, more continuous tasks, and greater emphasis is placed on anticipation of control requirements and results.

1. Determine criterion outputs of the man-machine system. This may be stated in much the same terms as contained in the General Operational Requirement. Reduce from the GOR and information of comparable systems, the principal output variables of the new system. Each output variable should reflect a human control function, a human monitoring function, or both. Determine the maximum capability and tolerances required of each variable. Some tolerances cannot be determined until the operational situations are established by the Operational Plan.

2. List the kinds of input conditions (program variables) with which the system must cope. Program analysis determines what activities are time-shared and what sample situations represent all operational environments. The most extreme conditions

should be identified for each program variable. Programs must include emergency conditions.

3. Enumerate duties in a typical mission cycle. Within a duty, task functions may be identified, i.e., for taxiing, functions of steering and regulating speed exist. A work or mission cycle (segment) begins when equipment is taken from storage or turned on and ends with its return or turning off.

4. Enumerate the tasks in a typical mission cycle. A task title should be directed toward equipment. Each task in the list should have coded reference to programs which provide cues for performing the task or indicate that the task should be done in a special way; i.e., the task of "starting jet motor" has a program for starting on the ground, and one for starting in the air.

   With the list, prepare a functional block diagram of task relationships. It should show the sequence of tasks, which tasks occur at the same time, and the frequency a task is repeated in the mission. It does not need to have a time baseline; it is not equivalent to time charts.

   A preliminary statement of position requirements of QPRI may consist of detailed task listings plus indication of the principal behavioral difficulty for the position.

5. Differentiate continuous (tracking) tasks from discontinuous (procedural) tasks. Different types of training are involved and the procedural tasks may be analyzed with a simpler format, even though the same procedure is used. In the task enumeration write "C" for continuous or "D" for discontinuous tasks.

6. Write out the position elements contained in each procedural task. Diagrams, photographs, or physical mockups of displays and controls in the operator work space will be referenced if available.

   a. Position. Write the position title.
   b. Position Duty. Name the position duty or segment if it will help organize the analysis, and code it as 1.
   c. Task. Name the task and its code number, with that of the segment in which it falls, 1.1.
   d. Time. Under the task title write the time required to perform the task, including transition and make ready time from adjacent tasks.

e. Task Program Under Indication. Write the equipment or situational condition calling for performance of the task. If the task is part of a standard procedure write "SOP." When different programs require the task to be performed different ways enumerate first the elements required under Program A, and then those required for Program B.
f. Control. An item written here implies that the operator identifies and selects this control as the first requirement of that element. Each element should be coded, 1.1.1.
g. Activity. Usually a manual activity but it may also be recall of knowledge, a mental process such as computing, planning, or interpreting, or a perceptual process such as scanning and estimating. An element may be complete with only an Activity entry if it is a mental process leading to a decision.
h. Indication. The cue and source or channel of the cue indicating the adequacy of action taken. The immediate indication is usually feedback from manipulation of the control, and the remote indication (Miller, 1953b), comes from the system output resulting from control activation. This column may include any condition affecting the position element(s).

7. Describe continuous position duties. Because continuous tasks usually deal with more complex stimuli, they are considered separately. See Miller (1953b). Piloting any vehicle is an example.

Prior to determining the elements of continuous tasks, the mission will have been divided into segments, tasks will have been enumerated within duties, and the programs under which the duties and tasks may be performed will have been identified.

a. Position. Write the position title.
b. Mission Program. Identify the program or purpose of the mission from which the duty is taken.
c. Duty. Write the title of the duty or segment.
d. Task Enumeration. List all tasks in the duty, continuous or discontinuous.
e. Programs. Enumerate program conditions under which the duty may be performed.
f. Problems. Describe problems the operator must solve and information provided.
g. Triggering Signals. Describe the signals demanding decisions for major action by the operator.

h. Decisions. Describe decisions which must be made during the duty, time in the mission when decisions must be made, and major alternatives (subsequently treated as separate tasks).

i. Control Action. Identify the action required and whether the control has synthetic feedback, is power-boosted, etc.

8. Prepare task diagrams and time charts of duties and mission cycles. A time chart is a task diagram on a time baseline, showing duration of task or element, when it occurs in the mission, and which other tasks it overlaps. Separate charts may be prepared for different programs. It will show when the operator is heavily loaded, requiring extra training. If it contains the undifferentiated requirements for a whole crew, it provides a basis for allocation of tasks to different positions. The frequency and length of a task help plan manning levels.

   List the tasks in the duty down the left side of the chart. Provide for overlap from one chart to the next, to show the anticipations necessary for the operator. Detailed data may be coded and referenced elsewhere. Overlays may help show complexities arising from overlapping activities (Weislogel & Jacobs, 1956).

9. Examine position elements, tasks, and duties, for anticipating training and performance difficulties. Review the data resulting from equipment analysis, activity analysis (Miller, 1953b), time charts, direct observations, etc. The context of an airborne emergency is an example, where cues differ from those occurring in normal flight.

10. Summarize the position information. This is the same as for maintenance poisitions, except that General Features includes operator interaction with other personnel.

Steps in Preparation of Position Definitions for Operator-Type Positions. The following position description may be prepared prior to the availability of detailed task data.

1. Name the position.

2. List the criterion system outputs.

3. List the input conditions (program variables) with which the man-machine system must cope.

4. Enumerate duties (segments) in a typical mission cycle.

5. Enumerate the tasks for each duty, identifying continuous and discontinuous tasks.

6. Analyze into elements tasks unique to the particular position.

7. Concentrate on getting data about tasks which require high speed in perception and judgment, complex coordination at the same time or in rapid succession, or a lot of remembered information.

8. Position information, as outlined for line maintenance.

Revising and Supplementing Qualitative Personnel Requirements Information for Operators. Activity data (Miller & Folley, 1951a) from personal observation, suitable operational records, and structured interviews, add to the analyst's data, especially in the areas of operational errors, difficulties, and program situations. QPRI should be regularly revised on the basis of these data.

Special Features

This document contains an especially good glossary of terms drawn from four companion guides, this and Miller (1956b) being among them.

Comments

This report reviews and draws together many of the techniques of analysis and presentation developed at earlier times, and weaves them into a logical, comprehensive, and smooth-flowing whole for the presentation of qualitative personnel requirements information. This is certainly one of the key items in the survey.

Miller, R. B. A suggested guide to position structure. Lowry Air Force Base, Colo.: Air Force Personnel and Training Research Center, May 1956. (Maintenance Laboratory Technical Memorandum 56-13) (Contract No. AF 18(600)-1203) (b)

Purpose and Phasing

The purpose of this guide is to provide guiding principles for the development of position structures and Position Organization Tables at about the time a newly developed weapon system reaches the stage of the Operational Concept and Plan. Although the considerations and techniques for position structure offered here are relevant to very early hardware stages of system development, they are especially directed to the stage called Mock-Up Inspection. Position requirements are largely, but not entirely, set by equipment design, especially for aircrew activities.

Position structure is the assigning of all tasks and groups of tasks within an organizational unit to individual positions on the basis of requirements of the organizational unit to accomplish a goal, and the psychological factors going into individual training and performance. The product of this structuring is a Position Organization Table which will provide the data for Tables of Organization and Manning Tables.

Summary of Method

The Structure of Operator Positions. Operator positions are largely predetermined by the information which can be displayed and the controlling actions which have been built in at this stage. Also, aircraft interiors limit crew sizes and the reshuffling of work-space configurations. One trend in the opposite direction is the shift of operator positions from aircraft to ground, permitting greater flexibility.

Because of this general situation for operator positions, this section is mainly concerned with means for testing in advance of operations, the practicability of the provisional position structure, and perhaps to make the structure more explicit as well as reveal shortcomings. Three techniques for testing position structure are suggested: a "Blackboard Test," use of a simulator, and utilization of the Operational Suitability Test situation.

Blackboard Test of Position Structure Practicality. The following data are required:

1. Hardware design of the equipment with respect to work-space configuration for each crew member, physical arrangement of displays and controls, display linkages, special response feedback channels, and supporting equipment used by each crew member.

2. Tasks allocated to each position in the provisional plan for position structure, including operating procedures for the performance of each task, and estimates of time required to perform tasks and the point in the mission cycle where the task occurs. See Miller (1956a) for derivation of these data.

3. Information as to who makes what decisions in the course of a mission cycle, in each type of mission cycle. Different allocations of responsibility may be made for different types of missions.

4. Communication facilities between coordinatively active positions during a mission.

5. Detailed statements of the conditions under which the system must operate. See Miller (1956a) for derivation of these data.

To perform the "Blackboard Test," a Proponent, Opponent, and Umpire are chosen. All must be familiar with system operation. The Umpire must also be able to recognize likely conditions of human error.

The Opponent poses specific program conditions for each phase of the hypothetical mission, and specifies operator error. The Proponent tries to accomplish the mission objective by responding to the challenge of each program condition, within the specified capability of his manpower as defined by the tasks, task performance times, communication facilities, and decision-making centers. The Umpire rules out unrealistic programs or ones the system is not designed for, keeps time data of the response actions, and notes the following:

1. Emergencies not likely to have been perceived or coped with.

2. Estimated information overloads on the crew or an individual.

3. Incompatibility of time and/or duty requirements.

4. Likely human errors, especially those not covered by supervision.

5. Estimated proportion of mission failures based on given performance breakdowns.

The results are limited principally because the procedure deals with symbolic rather than actual events, and depends largely on the astuteness of the players. Time estimates of operator interaction and estimates of maximum load are necessarily very gross. A given stimulus does not exist, since all stimuli are announced verbally. Because of these limitations, results from this test should be accepted cautiously. Perhaps its principal use may be the identification of possible problems to be tested in the simulator and Operational Suitability Test situation.

The simulator test may be used to check the position structures developed in earlier phases. It presumes that all positions and their functional interrelationships in a crew are represented in the simulator. The fullest range of stimulus inputs of which the simulator is capable should be exploited in determining the crew's capability within the human engineering and position structure limits imposed on them.

The Operational Suitability Test provides still greater realism, in some respects than the simulator. It is less useful than the simulator only in that it is less flexible in presenting stimulus inputs and in representing emergency conditions. In both simulator and Operational Suitability Tests, the same categories of data are required as for the Blackboard Test. Data from system simulations are likely to be far more valid as bases for inference and recommendations than from the Blackboard Test.

Unless human engineering redesign is permitted, these tests will be most important in identifying overloading and reallocation of tasks or specification of such standby capability as man-to-man monitoring or function sharing. Overload may be caused by any of the following:

Number of signal sources to be scanned.

Spatial distribution of signal sources.

Rate and variety of signals demanding responses.

Amount of short-term information to be noted, recalled, and integrated into decisions, especially when arriving through different channels.

Number and rate of quantitative and/or qualitative calculations required.

Number of controls operable during the time examined.

Rate, frequency, and precision of responses required.

Extent to which activities are "task-paced" or "self-paced."

Determining Maintenance and Support Positions. The following steps consist of getting and organizing information essential to developing a Position Organization Table:

1. For a typical operational unit of the system, describe the typical flow of maintenance vents, including servicing and emergency maintenance of test equipment. The block diagram form of description is perhaps the simplest way of representing and interpreting these operational relationships. The description should cover the aircraft and all its parts from the moment it enters the hangar or ramp until it is ready to go again. See Jones and Miller (1956).

   Determine the locations in a typical Air Force establishment at which maintenance operations will be performed.

   Itemize the classes of maintenance operations to be performed on each subsystem at each location, and the assemblies or units on which the respective maintenance operations will be performed. See Miller (1956a) for the derivation of these data. From this information a master flow chart may be prepared, with one dimension indicating the various "stations" where maintenance is performed and the other dimension listing the maintenance operations, referenced to equipment units, at the station. Transportation requirements between stations should also be identified, as well as preventive maintenance positions.

2. Determine the numbers of aircraft constituting the organization for which the Position Organization Table will be prepared. This is usually a squadron.

3. Determine maximally permissible turn-around time under combat conditions. This may be an operational requirement of the Air Force, in which case capability must be developed to meet it. Or, it may be the outcome of the development of required capability. (Ray, Passey, Adams, Smader, & Simon, 1957a).

Determine the expected maximum number of missions the operational unit will fly per week. It is essential to differentiate time-critcal, time-limited activities from nontime-critical activities, as a basis for determining priority. consideration.

4. Enumerate human activities or tasks required for each operation identified in the flow diagrams.

5. Estimate for each task the frequency of its occurrence in a typical operational day. This is a multiplication of missions per day times task occurrence per mission. Include a safety margin for human error. In some instances, these casualty data are kept during development, prototype and production testing (Miller & Folley, 1951a).

6. Estimate the performance time for each task. Especially in time-critical tasks include a safety margin.

   Indicate activities requiring simultaneous, coordinated team action.

7. Determine the specific logistic support provided (number and kind of supporting equipment) for maintenance operations.

8. Estimate the human activities which, omitted or faulty, are most critical for mission operations, as when the whole squadron depends on one man's capability. The more men performing an operation, the less vulnerable the unit is to being knocked out by any pattern of loss.

9. Determine by inference or review of similar systems the relative vulnerability to use for men performing respective tasks. A vulnerable man performing a critical task should have standby capability reflected in the Position Organization Table.

Grouping Tasks Into Positions. Synthesis of tasks into positions should be guided by the following principles:

1. Activities assigned to a position should keep the man busy for a typical work period of unit operations.

2. Tasks should be grouped so they contain similar knowledges and skills. Training requirements are thereby minimized. Groupings of similar knowledges and skills might be: same

equipment used, same procedures followed, same type and level of knowledge or principles of operation required, same nomenclature and location of parts, and the same man carrying through a related series of actions.

3. If otherwise appropriate, the tasks grouped in a position should resemble the groupings of comparable positions on existing, obsolete systems.

4. Technical supervisory positions can be established through the following collective considerations:

   a. Who decides what men will do during a mission?

   b. Who decides the distribution of material, equipment, etc., to maintenance and support units?

   c. Who allocates maintenance and support activities in an emergency?

   d. Who monitors the quantity and quality of maintenance and support work?

   Tasks of responsibility should be combined into technical supervisory positions. When the workload exceeds one person, it should be divided, using steps 1 through 9 and principle 2.

5. In assessing the relative level of a position, the following factors should be considered:

   a. Relative amount of routine versus nonroutine activities.

   b. Relative range and complexity of situations requiring nonroutine activities.

   c. Numbers of factors entering into problems and decisions.

   d. Need for proper judgment and action on basis of incomplete data.

   e. Amount of irreversible commitment depending on decisions.

6. Special factors may override these considerations, as when a highly specialized skill is required, or when team action suggests the incorporation of all tasks into team training.

Based on the principles above, a Summary of Organization Table, containing position title, man hours/day of unit operation, and total number of men required. This provisional Organization Table may then be tested by the "Blackboard Test," as suggested earlier.

Early Forecasting of Tentative Position Structures. Forecasts of position definitions must be made prior to the Operational Plan. This can be done as much as a year beforehand (ASPRL-TM-55-15). The following steps are suggested for determining tentative position descriptions at early dates of development. Such descriptions will necessarily be very gross.

1. Prepare over-all position requirements for maintenance or support in the form of position descriptions (Miller, 1956a).

2. Obtain from the using command and other appropriate Air Force agencies available information on maintenance policy. Classes of maintenance operations performed at various locations may be inferred from plans for test equipment, hoists, tools, etc.

3. Apply principles 2 through 6 to the available data, wherever possible, to group activities into tentative positions.

Comments

This report is a companion guide to Miller (1956a). In both cases, the original documents should be referred to for more specific instructions and for the implications of the various procedures.

A 66-item glossary (similar to that in Miller, 1956a) is included in the report.

Miller, R. B. Derivation of skills and knowledges in electronic maintenance. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, January 1957. (AFPTRC Technical Note 57-5) (Project No. 7709, Task No. 37300, Contract No. AF 18(600)-1351)

Also in:

Finch, G., & Cameron, F. (Ed.) Air Force human engineering, personnel, and training research symposium report. Washington, D. C.: National Academy of Sciences, National Research Council, 1958. (Publication 516) (Symposium November 15-16, 1956 by WADC)

Purpose

To derive a behaviorally oriented method of developing generalizable training content. The scientific problem was to systematize the abstraction of generalizable course content based on actual job behaviors, rather than on the conventional theory of design and operation of equipment. The practical purpose was to develop training which would permit cross-trainability among six electronics maintenance positions for the F-86D aircraft.

Procedure

The procedure, adapted from a previous research development (Miller & Van Cott, 1955) consisted of four principal steps:

1. Making explicit the assumptions and conditions on which the training was to be based. These were that the structure of the six positions being considered was not to be altered, that trainee capability included about two years high school and no previous electronic training, and that the training time allowable could not exceed twenty weeks.

2. Identifying and describing the position requirements in sufficient detail that inferences could be made about common skills and knowledges. Task summaries were prepared in which essential behaviors were briefly described, error tendencies noted or predicted, and tools, test equipment, job objects, symbols, and processes were identified. Each position description was organized around a "characteristic maintenance work cycle."

3. Inferring the skills and knowledges common to two or more positions. Skills common to two or more positions were identified by identity of job supports, such as tools, test instruments, forms to be filled out, etc., and the behaviors for using these supports.

However, deriving common knowledges was the key problem in the study. Knowledges were thought of as "symbol-mediated" similarities, because the mechanic may be able to form and generalize a capability by means of ideas, concepts, and symbols. In identifying common knowledges the approach was not to general background theory and information, but to specific behavioral requirements--the range of job situations and conditions under which required responses had to be made. From these behavioral data were induced conceptual content and knowledges. These data were generally based on non-standardizable job situations such as troubleshooting, taking general precautions, planning a work space, etc.

In selecting generalizable knowledges, two criteria were kept in mind. First, a concept or knowledge to be used in job operations must be tied down to those operations in terms of both stimulus and response. Second, the concept or symbol should be relatively concrete to the trainee--ideally, the concept would be no broader than the job conditions likely to arise within the position using the knowledge. An attempt was also made to use symbols and ideas likely to be already in the trainee's repertoire.

In order for a job knowledge to be useful, the mechanic must discriminate the job situation calling for the knowledge, remember the knowledge content, and make some job-oriented response as a consequence of recalling the knowledge. If there are any breaks in this sequence, the knowledge is inoperative. In identifying knowledges for training, the problem is to find the point of diminishing returns between the training input of knowledges and the performance output gained thereby.

Generalizable knowledges are most called for in nonroutine tasks where decision making is required. Troubleshooting provided the most complex grouping of knowledges. Decision making in troubleshooting consists of recalling or generating an efficient strategy for making a series of checks leading to the malfunctioning component. The factors in this strategy may be taught as such and be given practice in a variety of problems.

It was also recognized that the more appropriate the diagrams and handbooks for a given position, the less the need for knowledges in the head of the mechanic. As it is, learning how to use Technical Orders and diagrams (in other words, filtering them) constitutes a sizeable part of the core knowledges.

4. Translating the common skills and knowledges into characteristics for core training. The final step consisted of organizing the derived skills and knowledges into a training course. The general consideration was to provide optimal practice conditions, devices, and procedures for learning the content in such a way that the trainee would generalize what he learned both to specialized training for a given position, and to cross training. Sequence of training content largely paralleled the typical maintenance work cycle to provide an operational context. Care was also taken to specify forms of "knowledge of results" quickly deliverable to the trainee during practice.

Results

The generalizable skills and knowledges identified were the following types: use of test instruments and mechanic's tools, how to strip wire and solder connections, characteristics of making checks, adjustments, trouble diagnosis, replacements and precautions for avoiding personal injury or equipment damage. Brief explanations of "why" were given when it was felt they would promote recall or motivation. The rest of the content was based on position requirements and human errors. A few simple abstract concepts were presented.

Conclusions

The principal conclusion not reached was whether such generalizable skill and knowledge content can be most effectively taught in a basic "core" course or whether to train for generalization while teaching a specific job.

Comments

See Folley and Miller (1955) and Peterson (1956) for earlier studies in the same area.

Miller, R. B., & Folley, J. D., Jr. A study of methods for determining skill, knowledge, and ability requirements for maintenance of newly developed equipment. Technical Appendices I-VII. Pittsburgh: American Institute for Research, June 1951. (Project No. 21-07-016, Human Resources Research Center Contract No. AF 33(038)-12921) (a)

Purpose

This document, the second report of the study of methods for determining skill, knowledge, and ability requirements for maintenance of newly developed equipment, sets forth the formats and rationales of the two methods developed to obtain, record, and organize the behavioral data needed to anticipate the personnel requirements of the equipment under development.

One section of the report, dealing with the influence which equipment design exerts on the subsequent job requirements, and offering some elementary guide lines whereby training for maintenance and maintainability may be aided, is not reviewed in this abstract.

The rationales for the two analytical procedures and their accompanying forms are abstracted briefly. A detailed rationale of the individual items of the Standard Maintenance Form is omitted here, because of its length.

Rationale and Summary of Method

The way equipment is built and operates defines many of the tasks of maintaining it. Check and test points, test equipment, stability of parts, packaging, tolerances, and accessibility of parts illustrate these maintenance implications. Assuming that any component may become defective, the design and assemblage of equipment offers an exhaustive list of maintenance operations.

The second major source of information for setting up the job requirements of maintenance personnel are malfunction incidents. Their relative frequency will indicate the relative importance of various phases of training and skill. Malfunction during operation may identify problems or contingencies not anticipated earlier. The problem is to get systematic information specifying the symptom and corrective responses. Such information should be available not only during design and prototype phases, but also from the operational phase to feed back changes in operational use and maintenance requirements as inputs to training content and procedures.

The equipment block diagram is taken as the basis of this approach to the anticipation of line maintenance job requirements. It serves to identify to the appropriate level the critical equipment functions or data flow channels for which maintenance will be required. (For a similar analysis of shop maintenance functions, the circuit diagram would replace or supplement the block diagram.) In this study, the functional block diagram is the common denominator of recommendations for coordinating equipment design, writing technical orders and standard operating procedures, maintenance training, and maintenance operations.

In addition to the previously established technical maintenance functions of checking, adjusting, troubleshooting, replacing, and repairing[1] (lubricating was not deemed appropriate to the electronic equipment in this study), several psychological behaviors are involved in the technical aspects of maintenance: following standard operating procedures, as in checking and adjusting; using logical procedures, as in troubleshooting; and manual and discriminative skills, as in replacement and repair and discrimination in troubleshooting and checking. The extent of each of these behavior types is defined, in this case, by specifying their performance at the line level of maintenance. Each of the abstracted technical maintenance functions may be defined within these psychological terms, with the addition of mental skills and knowledges, and decision making.

The Job Behavior Forms reproduced here were prepared to expedite the compilation of job behaviors in the course of the <u>equipment analysis</u> procedure.[2] The lists should be started in the breadboard stage and extended or amended as required by changes in the design or construction of the equipment or by malfunction data. Ideally, these forms would be prepared by the design engineers, working with the human engineering and training specialists.

The rationale for determining the categories is that the conditions for a given behavior (assuming a motivated individual) can be specified by identifying the discrimination the man must make, when he must make it, the instrument or means he must use, and the alternative responses (and their sequence, if any) from which he must choose with respect to the discrimination he makes.

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1 Defined in the abstract of Miller, Folley, and Smith (1953a).

2 A revised Job Behavior Form for Checking and Adjusting is illustrated in the abstract of Miller, Folley, and Smith (1953a).

The total list of job behaviors, however, would be the basis for the minimum technical training requirements.

The Standard Maintenance Form was developed and used for the collection of data for activity analysis. By the fourth revision[3], presented here, it had been expanded to assist in the following additional functions:

1. Predicting maintenance job requirements of a given equipment to determine training requirements and training criteria (tests of job fitness).

2. Guiding the modification of equipment, testing devices, and procedures.

3. Designing maintenance jobs.

4. Organizing maintenance operations for efficiency.

5. Simplifying recording, classifying, and filing maintenance data.

6. Maintenance job aids.

7. Providing maintenance evaluation criteria at the level of individuals, organizations, fields, and equipment systems.

8. Identifying maintenance operations bottlenecks.

9. Revealing unanticipated maintenance problems.

While the Standard Maintenance Form must be used with other sources of information to do the jobs listed above, it is useful at every stage of equipment development and use. It is designed principally for use by operators and maintenance personnel for the collection of Corrective Maintenance data, but the information obtained has implications for Preventive Maintenance as well.

[3] The fourth revision is illustrated in this abstract, taken from Miller (1953a). Differences between the fourth and the third, which is the one actually reviewed in this report, are slight.

Specify the following:

A. When and under what condition this check is to be performed.

B. The proper sequence of steps in the correct turn-on and turn-off procedures.

List in the appropriate sequence the check operations necessary to determine if the equipment is ready for operational use:

Operation sequence number	Location of check-point, dial, meter, or other indicator	Test equipment required	Indication that equipment checks OK or not OK--specify tolerance limits and other specific indications of adequacy or inadequacy	Action to take if not OK

Figure 1. Field Maintenance: Checking

List in the appropriate sequence (if any) the adjustment operations appropriate to bring the system or subsystem into tolerance limits for the respective conditions:

Sequence of steps	Indication of check OK or not OK	Location of control affecting this indicator	Action to be performed on this control to bring reading into tolerance	Test equipment and tools used to perform this action	Effects on other indicators of changing this control	Action to take to correct interaction effects

Figure 2. Field Maintenance: Adjusting

List all the units and subunits which are subject to replacement at the field level of maintenance:

Designation and location of unit	Procedures for removing unit, including tools required	Procedures for putting in replacement, including tools required	Precautions to be taken in replacement

Figure 3. Field Maintenance: Replacing

List defective parts which are to be repaired at field shops: (groupings should be made on the basis of similarity of repair operation involved)

Designation of defective part	Nature of defect	Tools, instruments needed	Procedure to follow in the repair operation	Special precautions to be followed	Check required to determine if OK

Figure 4. Field Maintenance: Repairing

Job behaviors

1. All behaviors listed under Checking, but not according to standard sequence.

2. All behaviors listed under Adjusting.

3. Behaviors under 1 and 2 in special sequences from "Indication of check not OK" or from gross symptom of malfunction to the malfunctioning "replacement" unit. This should be a logical sequence with respect to the linkages or data channels built into the equipment. (This behavior seems to require some degree of deductive reasoning which can be simplified and thus facilitated by suitable data-flow diagrams.)

Job knowledge requirements

1. List according to groupings by component systems or subsystems, (a) malfunction symptoms, (b) diagrams of the linkages of data channels which trace to (c) the cause of the respective malfunction symptoms.

   Source of data: Engineering diagrams, specifications, operational equipment.

   Note: This list may be too extensive and cumbersome to be practical. It is hypothesized that a job requirement for troubleshooting is the ability to trace component systems in the equipment down to the replacement components at line maintenance level and distinguish the function of the respective components on the basis of their outputs.

2. List frequently occurring symptoms paired with likely malfunction sources.

   Source of data: Standard Maintenance Form data at various stages of development of the equipment.

   Note: This information will facilitate troubleshooting, but is not essential to it.

3. List symptoms paired with likely malfunction sources which are particularly difficult or subtle to diagnose:

   Source of data: Standard Maintenance Form data.

Figure 5. Field Maintenance: Troubleshooting

Designed as a master form to cover maintenance conditions, it is not only a recording device but also the outline of a maintenance procedure. It is desirable that it be used in maintenance training, therefore, as a training aid and for indoctrination in its use and philosophy: the importance of recording maintenance experience so that maintenance can be continually improved.

The SMF is used to record maintenance incidents and behaviors not anticipated from equipment design, and to indicate special maintenance difficulties. It also provides frequency data with respect to given kinds of maladjustments and malfunctions, emphasizing the importance of certain maintenance behaviors by a simple tally. SMF data for field maintenance can be obtained as soon as any portion of the equipment is at a stage permitting tests and operation. This early data should initiate consideration of training equipment requirements, beginning in the breadboard stage. "Troubles" for troubleshooting trainers can be tentatively obtained from SMF prototype data, since most changes beyond the prototype state are within line-replaceable components. The best solutions to maintenance problems identified in the prototype stage can be worked out by engineers for incorporation in training courses. Specific procedures such as adjusting and checking, however, cannot be specified until after the equipment has been in operation and actual operational tolerances, etc. are determined.

SMF data on production and operational equipment can contribute to revisions of course content and training material. The rationale for each item of the SMF (Revision 3) is given in this report along with instructions for its use, but these are not abstracted here, due to length.

Summary

The list of Job Behaviors as made from the equipment itself and supplemented and amended by SMF data will be an exhaustive list of over-all maintenance at a given level. This list identifies the essential tasks, which constitute the minimum training requirements for job effectiveness: if the trainee is taught these things he will be effective in his job; if he is not taught them, no matter how much else he is taught, he will not be effective until he learns them.

Recommendations

The sum-total technical job requirements still need to be organized into individual jobs. The best way of ordering, organizing, and integrating behaviors within an individual job constitutes a separate task. This report does not cover these problems.

Comments

Two applications of the Standard Maintenance Form and Job Behavior Form procedures, along with a tryout of the malfunction probability technique, are reported in Miller and Folley (1952) and Miller, Folley, and Smith (1953a). At the time this report was prepared, it was felt that the SMF would be the most valuable tool. However, the tryouts showed the Job Behavior Forms accompanying the equipment analysis procedure to be generally superior in obtaining and handling data for the anticipation of personnel requirements. See Miller, Folley, and Smith (1953a) for a summary of these results.

The original outline of the systems functions analysis technique, applied in this project, is described in Miller (1950).

STANDARD MAINTENANCE FORM

A. 1. A/C Number ______ 2. A/C Type ______ 3. Equipment ______

4. Abort: ☐ Yes ☐ No 5. Scope pictures taken: ☐ Yes ☐ No

B. Work Order 1. Number ______ 2. Date ______ 3. Hour ______

C. Malfunction Symptoms Observed: 1. Date ______

2. Symptoms observed by ______ 3. MOS or AFSC ______

4. Symptoms first noted:
- ☐ in flight, before bomb run
- ☐ in flight, during bomb run
- ☐ in flight, after bomb run
- ☐ during Performance Check
- ☐ during Pre-flight Check
- ☐ during Post-flight Check
- ☐ during Non-routine Check

5. Computer - Crosshairs - Syncronization ______

6. Stabilization and Optics ______

7. Dials and Indicators ______

8. PPI and B Scope Presentations ______

9. Power and Power Supplies ______

10. Others ______

D. 1. Symptoms Verified: Yes / No

E. Line Maintenance Work Begun: 1. Date 2. Hour

F. Adjustments Made: 1. By ______ 2. MOS or AFSC ______ 3. Adj Control Used 4. Test Instrument Used 5. OK

G.

H. Record on the inside of this folder the steps taken in isolating the malfunction causing each symptom.

D. 2. Test flight needed: ☐ Yes ☐ No 3. Test flight made: ☐ Yes ☐ No

Fold — — — — — — — — — — — — — — — — — — Fold

Malfunction symptoms	J. Units Replaced 1. By ______ 2. MOS or AFSC ______ 3. Serial number OUT	4. Name of replaced unit	5. Serial number IN	6. Hours on unit before malfunct.	K. Symptom Cleared in Aircraft 1. Date	2. Hour	3. Mech. initials	N. Repair Work Done 1. Name of defective part within unit, Nature of defect and Repair work done.— Include lubrication.	Repair work completed 2. Date	3. Hour	4. Name of repairman doing each repair job.
C5											
C6											
C7											
C8											
C9											
C10											

L. Ground operating hours used in line maintenance ______

M. Work to this point released by ______

O. What would have simplified any of these jobs?
- ☐ Training (specify) ______
- ☐ Test equipment or tools (specify) ______
- ☐ Modification (specify) ______

P. 1. State reasons for any long delays: ______

2. Other comments ______

TROUBLE-SHOOTING DIAGRAM

G. 1. ☐ All plugs checked and tightened 2. ☐ All fuses checked and OK 3. ☐ All power supply voltages exactly on value

[H] KEY and INSTRUCTIONS

In the space below record the steps you take in finding each trouble.

a. In the left-hand margin opposite box A. write the C-number showing which trouble you are working on (C5, C6, etc., from page 1.)

b. In box A. write the name of the unit in which you make your first check in trying to locate that trouble.

c. In the lined and numbered data box attached to box A. record the required information about this check. (see key)

d. Use box B in the same way for the second check, box C. for the third, etc. until the first trouble is cleared. Put an X through the name of the malfunctioning unit.

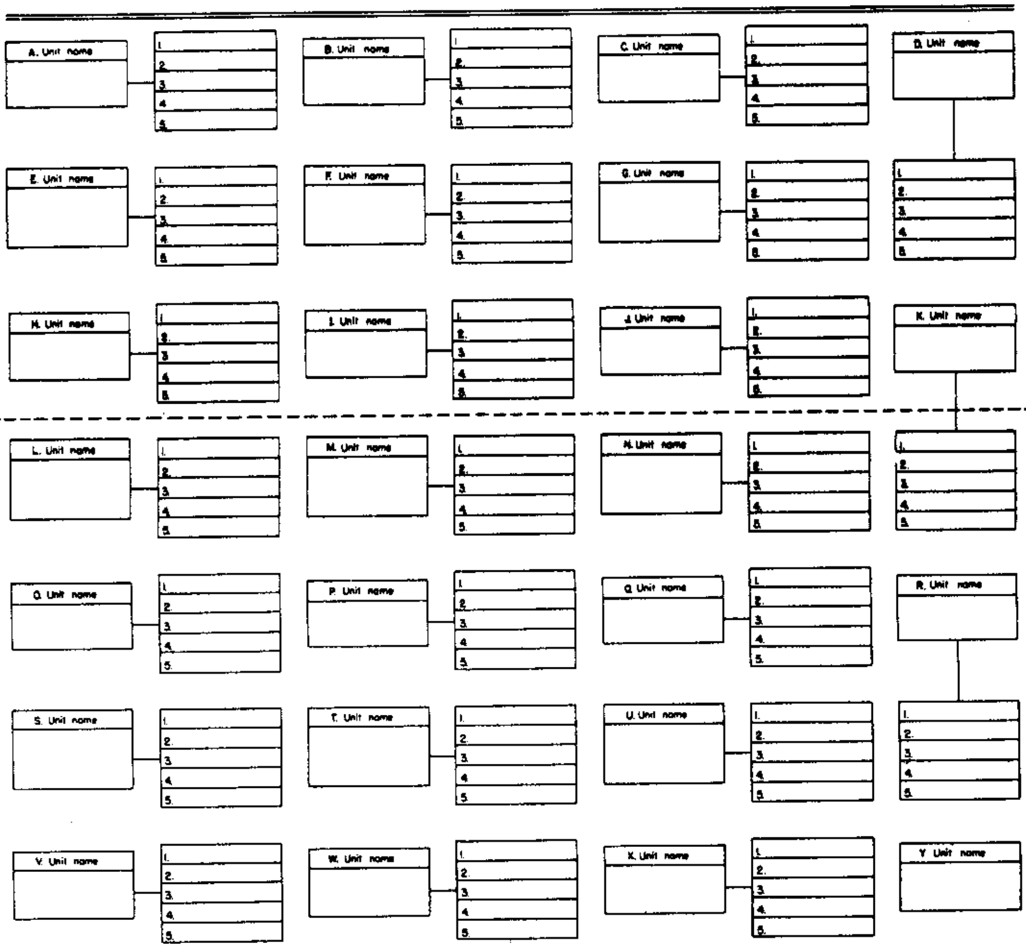
e. When you start on the second trouble, write its C-number to the left of the box in which you record the first check made in trying to locate this trouble. Then use the boxes in order to record the information about each check made.

f. Continue this recording procedure until all the troubles have been cleared and recorded.

CHECK DATA TO BE RECORDED

1. Check point used
2. Test instrument used
3. Reading obtained
4. ✓ if reading within tolerance, X if out of tolerance
5. Adjustment control used if any

Fold



Fold

[I] Trouble-shooter's Recommendations For Clearing Symptoms.

Numbers refer to corresponding symptoms under C, Page 1.

Malfunction Symptom	
C.5	
C.6	
C.7	
C.8	
C.9	
C.10	

SMF - experimental Revision Number 4, April 1952

Developed by the American Institute for Research under the sponsorship of Human Resources Research Center

Miller, R. B., & Folley, J. D., Jr. The validity of maintenance job analysis from the prototype of an electronic equipment. Part I: AN/APQ-24 radar set. Technical Appendices I-V. Pittsburgh: American Institute for Research, June 1952. (Project 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921)

Purpose

This report precedes Miller, Folley, and Smith (1953a), as the first application of a method for anticipating line maintenance job requirements from prototype development data. The job analysis of the AN/APQ-24 was secondary in this project to the testing of the job anticipation procedures. These procedures, covered in this document, are reported in full in Miller, Folley, and Smith (1953a), Miller and Folley (1951a), and Miller and Folley (1951b). The text of this document is therefore not abstracted.

Special Features

The report, stressing the equipment analysis of the AN/APQ-24, provides substantial coverage of the technical aspects of the line maintenance job, especially for the troubleshooting techniques and behaviors involved. Sample comparative formats of line and shop troubleshooting procedures using the logical elimination technique are presented, and include sample inferences of the troubleshooting skill and knowledge requirements. The first part of this troubleshooting behavior analysis format is included here.

Comments

This type of analysis may be useful in the preparation of Technical Orders and training courses.

TROUBLESHOOTING TO ASSEMBLIES. PART A. GETTING THE SYMPTOM PATTERN

Procedure	Interpretation of Results and Rationale	Example	Inferred Skill and Knowledge Requirements
1. Do as much of a performance check as can be done according to the following requirements:			
a. When in performing the check a given reading is out-of-tolerance, attempt to bring it within tolerance by making the proper adjustment. If it can be adjusted to within tolerance do so, and then continue with the performance check.	1.a. The first out-of-tolerance reading which cannot be brought into adjustment indicates that the chain in which the trouble probably lies is the one containing the check point used in that check.	1.a. Performance check is begun and runs smoothly until output 1 is checked. This is found to be out-of-tolerance. B_1 is adjusted and output 1 is then within tolerance.	1.a. Performance check behaviors as specified in the Check-Adjustment portion of the job analysis.
b. If the out-of-tolerance reading cannot be brought within tolerance by adjustment, make a note of this condition. Proceed with the remaining parts of the performance check which are not affected by that particular out-of-tolerance condition. Results: By the Performance Check we have determined which data chains of the equipment are in-tolerance and which are out-of-tolerance. We are now ready to start making some inferences.	b. The chains in which other out-of-tolerance readings are noted probably also contain the malfunctioning component. **Warning: It should always be remember, however, that there may be more than one defect or malfunction in the equipment at one time.**	b. Output 2 is then checked in the normal sequence of the performance check. B_2 is adjusted, but output 2 will not come within tolerance. Since the malfunction causing output 2 to be out-of-tolerance obviously will have an effect on 2a, the step in the Performance Check which checks output 2a is omitted. The steps which check the other outputs are performed.	b. Interpretation of the block diagram to determine which chains derive certain inputs from the out-of-tolerance chains. A check of the output of these chains would not give a valid indication of their operation, since it would be influenced by the out-of-tolerance inputs. (NOTE: 1. Interpretation of the block diagram as used in this section will also imply Knowledge of Locations and of Nomenclature. Recording or remembering results of checks is also a requisite for practically all troubleshooting behaviors.)

Figure 1. Troubleshooting Skill and Knowledge Derivation and Rationale

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. The validity of maintenance job analysis from the prototype of an electronic equipment. Part II: K-1 bombing-navigational system. Pittsburgh: American Institute for Research, Feb. 1953. (Project No. 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921)(a)

Purpose

This report reviews the second application of a procedure developed earlier in this project (Miller & Folley, 1951a; Miller & Folley, 1952), for the anticipation of maintenance job requirements of an electronics equipment for data available at the prototype stage of equipment development. The purpose of this second application was to provide a second check on the adequacy (validity) of the procedure.

The project was concerned with two principal objectives. One of these was to determine the extent to which job behaviors of maintenance personnel can be predicted from preproduction data of newly developed equipment. The other was to devise relatively simple, practical methods for getting this job information during preproduction phases of equipment development, since the earlier that job requirements can be anticipated, the sooner a training program can be prepared and support provided for the equipment in the field.

Procedure

The general approach used in this project was the comparison of maintenance job requirements data available at the prototype stage of development with similar data obtained from the early operational equipment. (Later operational equipment was not included, since training for modifications of the later models should keep pace with these modifications as they are made, through Technical Order channels.)

In order to talk about maintenance job requirements of an equipment, it was necessary to divide all of the system maintenance requirements into tasks being studied and compared. The first report in this project (Miller, 1950), suggested the division of all maintenance tasks into the broad classes of flight line maintenance, shop maintenance, and dock or periodic maintenance, basically a combination of tasks included in the first two classes.

Line maintenance consisted of operations usually performed in the airplane on the flight line. It was defined as being concerned with the entire system, and dealt with no component smaller than the assemblies known as plug-ins or subunits. It does not include troubleshooting or repairing within the plug-in unit with the exception of tube replacement and minor cable connector repairs.

Shop maintenance was defined as those operations performed within the plug-in assembly and involved the parts which make up that assembly.

To simplify this project, only the line maintenance families of tasks were analyzed and compared as predictors of job requirements.

Preliminary to the analysis of the AN/APQ-24, five broad maintenance functions were distinguished to simplify the observation and classification of behaviors. These functions are checking, adjusting, troubleshooting, replacing and repairing, and are defined below as performed at the line level. The functions are not entirely exclusive or independent of one another; however, they are considered to be exhaustive of the total job.

Checking. Any observations involving comparison of standard inputs and outputs of systems or subsystems to determine if they are within tolerance limits. These tolerance limits may be quite exactly specified, as by readings on meters, or they may be less exactly specified in terms of some standard of excellence such as the appearance of the radar scope. Where appropriate, separate criteria for judgment should be specified for outputs with inexact tolerance limits: For example, extraneous signals such as noise (or grass), brightness, sharpness of image, and so forth on the radar scope.

Adjusting. Any manipulation of a part of a system or subsystem which was specifically designed for adjusting in order to bring the system into tolerance limits.

Troubleshooting. Diagnosing and localizing malfunctions through observations of symptoms and performance of necessary checks by logical and systematic procedures or from probability data[1]. Isolating malfunctions when simple direct adjustments fail to eliminate them.

Replacing. Any substitution of an operative unit or subunit for an inoperative one. Here a unit is defined as a portion of the equipment which is contained within its own case and connected to

1 A history of the equipment showing what corrective actions have been successful in clearing given malfunction symptoms in the past.

adjacent parts of the system by means of cables. A subunit is defined as a smaller portion of the equipment which is housed within a unit and connected to the main chassis and to the wiring of the unit through multi-pronged plugs.

Repairing. Mending a damaged or broken circuit or mechanical part; replacement or servicing of circuit components of a functional size smaller than a subunit.

The basic procedure developed in this project to permit comparison of prototype and operational maintenance job requirements was "Equipment Analysis." The method consists of analysis of the equipment or equipment data (the type of which occurs in Technical Orders) to determine what information the equipment itself can provide as to whether it is operating within specified tolerances. On the basis of these data, job behaviors can be specified which are necessary and sufficient for its maintenance. Input and output check-points of assemblies, the values required of them and the test equipment required specify the list of line level checking behaviors required. Adjustment points, the tools required for them, and the human responses required make up the line level adjusting behavior requirements. Troubleshooting, replacing, and repairing are similarly specified by equipment data.

In order to obtain the data required for the Equipment Analysis, a Job Behavior Form was devised to obtain data on the checking and adjusting maintenance functions.[2] The categories of this form were established from (1) the displays, cues, or stimuli involved and the discriminations to be made for a given job behavior--what the mechanic has to distinguish from what; (2) the response and response components appropriate for corrective action--what the mechanic has to do, and what he has to do it with; and (3) a criterion of the effectiveness of the response--what signs can tell the mechanic whether he did the right thing. The categories of the Job Behavior Form are:

Step Number. To provide an accurate sequence of behaviors, in the order in which they are to be performed.

Control Name or Description and Location. Designates the unit, subunit, switch, or adjustment point on which the action is to be performed.

Control Action. Designates what essential action is to be taken by the mechanic performing the step.

[2] Earlier format variations are illustrated in Miller and Folley (1951a).

Indicator Name or Description and Location. Designates what indicator is to be observed in order that a correct control action can be made.

Indication of Response Adequacy. Describes the sign or cue available to the mechanic, telling him if his immediately preceding action on the control(s) was adequate.

Critical Discrimination in Display and/or Decisions Required. Designates what discriminations must be made by the mechanic in order to determine if an indicator, scope, or other instrument is indicating within specified tolerances. For example, noting that the periscope cross-hairs are bright enough or not. Also included are the decisions required on the part of the mechanic to bring the equipment within proper tolerance values.

Supplementary Actions and/or Precautions and Characteristic Malpractices. Additional actions or manipulations which are necessary to complete the step. Also included are any precautions which are to be observed during the performance of a particular step in the task. Data for this column are supplied from observations and/or records such as the Standard Maintenance Form of incorrect or inadequate practices of mechanics on other similar equipment, and from data obtained during prototype testing of this equipment.

An example of the Job Behavior Form for the task of adjusting the picture position and focus of a television set is shown in Figure 1.

In addition to the data supplied by Equipment Analysis, it was felt that supplementary data from the field would be useful in completing the analysis of the line maintenance job. Activity Analysis and the Standard Maintenance Form were developed earlier in the project (Miller & Folley, 1951a; Miller, 1953a) to standardize collection of the data from field maintenance personnel. The SMF serves two unique functions: it records frequencies of malfunctions for construction of malfunction probability tables, and it records "characteristic malpractices" in maintenance operations.

Equipment Analysis alone is intended to provide necessary and sufficient behaviors and requirements for the line maintenance job. Activity Analysis alone does not give a complete statement of the job. Taken together, however, they may give a more complete picture of the job than either one alone. Each contributes as follows:

Equipment Analysis:

1. A complete statement of the sufficient and necessary specific behavioral requirements for checking, adjusting, replacing, and repairing as defined.

JOB BEHAVIOR FORM FOR
CHECKING AND ADJUSTING
REVISION A.
14 February 1952

NAME OF SUBTASK	Code No.
Adjust Picture Position and Focus	TV-1

Step No.	Control Name or Description and Location	Control Action	Indicator Name or Description and Location	Indication of Response Adequacy (Give Tolerance for Quantitative Values)	Critical Discriminations in Display and/or Decisions Required	Supplementary Actions and/or Precautions & Characteristic Malpractices
1.	OFF-ON Switch	Twist Clockwise	Switch Dial	Dial indicates ON		
2.	(Wait five minutes to warm up set.)					
3.	Channel Selector	Twist CW or counter CW	Switch Dial	Indicates "3"		
4.	FINE TUNING	Twist CW or CCW	Picture Screen	Picture Appears, is steady	Point in tuning of dial at which picture is steadiest.	*Note: First twist knob back and forth in wide arcs through point of maximum picture steadiness; decrease range of control movement around this point until range is found within which no change in picture steadiness can be detected. Set control at center of this range.
5.	Focus Knob	Twist CW or CCW	Picture Screen	Picture changes in focus (clearness)	Leave knob at point where picture is sharpest.	
6.	Hor. Ctr.	Twist CW or CCW	Picture Screen	Picture moves so as to be in center of screen.		
7.	Vert. Ctr.	Twist CW or CCW	Picture Screen	Picture moves so as to be in center of screen.		Steps 6 and 7 may interact with Step 5. If necessary, repeat Step 5.

Figure 1. Sample Page from a Job Behavior Form

2. A technique for troubleshooting based on the flow of information through the equipment and logical methods of isolating disturbances in that flow.

3. Categories of line job behaviors such as "reading values on dials", "reading radar scope and oscilloscope", and so on. These can be abstracted from the behaviors in equipment analysis.

Activity Analysis:

1. From prototype testing, a first approximation for emphasis of certain requirements in training and selection.

2. From prototype testing, sample maintenance problems to be used in early training.

3. From prototype testing and/or operational use, patterns of symptoms and probable causes, special precautions to be observed, and characteristic malpractices which should be avoided, all of which can be incorporated in training.

Referring to the definition of troubleshooting, to "localize malfunctions" implies a degree of fineness of localization, or level of troubleshooting. Two levels of troubleshooting have been specified in this project for the K-1, troubleshooting to assemblies and troubleshooting to parts. Since this study is concerned with line maintenance, the appropriate level of consideration is troubleshooting to assemblies. (Shop maintenance is concerned with the troubleshooting to parts.)

The equipment or task analysis system of job anticipation does not permit anticipation of troubleshooting tasks, since at present these particular tasks are not developed for a prototype. However, the subtasks involved appear to be merely a rearrangement or new sequence of regular checking and adjusting subtasks.

As indicated in the definition, two troubleshooting techniques were considered in the study; troubleshooting by logical elimination (Miller & Folley, 1952), and troubleshooting from probability data. Troubleshooting to assemblies by logical elimination requires a functional block diagram of the equipment, (troubleshooting to parts uses circuit diagrams) written procedures for checking and adjusting the equipment, skill in interpreting the diagram, performing rather simple logical deductions, and the skills and knowledges involved in making checks and adjustments. The functional block diagram can be prepared during the design stage of development, and training in its use in eliminating possible sources of malfunction by logical deduction can be done at any point during prototype testing or before. Behavior requirements involved in checking and adjusting can be obtained through Equipment Analysis at the prototype stage.

Troubleshooting by probability requires an adequate history of equipment performance in terms of symptoms and a table of reliable relative probabilities of corrective actions effective in the past for eliminating a given symptom or pattern of symptoms. Skill and knowledges required for making checks and adjustments are also necessary.

The skills and knowledge requirements for probability troubleshooting can be obtained through equipment analysis of the prototype. However, the quantity of accurate data necessary for the construction of reliable probability tables of malfunction correction actions is quite large, partly from the statistical assumptions involved in probability distributions, and partly because of the very large number of malfunctions which can occur in a complex equipment. Experience indicates that at the prototype testing stage, the amount of detailed information about malfunction incidents tends to be smaller than is required.

The logical elimination technique was used in this project. Comparisons were made between the troubleshooting behaviors as identified by block diagrams of the prototype and production models, as well as the manual skills involved in troubleshooting on the two models.

The replacing job function was analyzed, using the Job Behavior Form, much the same way as the checking and adjusting functions were analyzed.

The job behavior analysis for the function of repair on the production model was submitted to the manufacturer's engineers. These engineers reviewed the analysis and noted points which were different from the line repair activities on the prototype, according to their recollection. They also noted items which should be deleted or added to make the production model analysis of this task the same as that which could have been performed on the prototype.

In presenting the results of the task or equipment analysis, the level of behavior description to be reported was considered. Job requirements may be stated in specific behaviors which, together and in sequence constitute the job of line maintenance for an equipment. A behavior is a composite of discriminations (perceptions), decisions, and motor activities. Such a complete job statement would be the basis for training of a line maintenance mechanic for taking over maintenance duties on that equipment immediately after completion of training.

TABLE I

Definitions of the Behavior Categories

Discriminations and Perceptions

Observing gross indications: noting the presence of mechanical motion, or of an indicator light being on or off.

Reading values on dials: noting quantities registered on dials. Types of dials have been classified as:

Position-marked dials: Positions are marked in discrete steps requiring no interpolation by the observer.

Calibrated dials: A continuous scale marked off in units; readings require interpolation.

Meters: Several scales may appear under one pointer. The appropriate scale must be selected for the purpose at hand; little, if any, interpolation is required for adequate accuracy in reading values.

Noting relative motion of dials, scope presentation: noting gross differences in rates of movement of a dial or pointer, or in a scope presentation.

Reading radar scope and oscilloscope: comparing wave shapes, visual patterns in terms of configurations, standard brightness, sharpness of definition (focus), waviness of lines.

Noting defective parts by external signs: such as physical damage, lit or unlit tube filaments, burned parts, chafed insulation, presence of smoke, presence of burnt odors, sounds of operation, temperature, and so on.

Carrying sufficient speed and load in perception and response: as in noting or doing several things at once or in rapid succession. These tasks in line maintenance are the following: (1) holding a button down while operating a switch; (2) reading calibrated dial and stop watch practically simultaneously; (3) releasing a button, starting a stop watch, turning a switch at the same time. (The decision to put this category under discriminations rather than under manual skills and operations where it could also have been included was based on the seemingly greater difficulty to learn the specific perceptual load problem than the motor load problems in this job.)

Knowledges[3]

Nomenclature: knowing what objects, observations, and functions are referred to by the symbol used in the Technical Order or directive; knowing how they can be identified; being able to recall what name goes with what object or situation in the job context.

Locations: knowing where the objects are located which are referred to by instructions or directions.

Principles of operation: being able to recall what actions of one component of the equipment are related to the actions of other component parts of the equipment insofar as this recall aids in making critical job decisions.

Setting up test instruments: making proper control settings on test instruments in order to obtain a correct representation of the input to the test instrument.

Precautions: knowing what actions to take in specific job situations which will minimize risk of inefficient job performance or of damage to the equipment. (Note that the knowledges or recall of precautionary procedures may be sufficiently practiced so that, in given job contexts, they become habitual, in which case this behavior might be classified as a manual skill or operation. Since this analysis is directed toward training requirements in which the knowledge of what to do generally precedes the stage of automatically doing the required action, the present principle of classification will be used.)

Mental Skills and Abilities

Recording or transcribing information: setting down on standard check sheets readings from instruments; making check marks to indicate in-tolerance operations; writing down results from arithmetic computations.

Making arithmetic computations: performing addition, subtraction, division, multiplication of whole numbers and decimals; solving single-variable linear equations.

[3] The knowledge of nomenclature, locations, and principles of operation is common to all maintenance job behaviors; therefore, no attempt has been made to tally them either in detailed job statements or in grouped job statements.

Making logical inferences: drawing conclusions from premises. The premises consist of a statement of symptoms of malfunction plus knowledge of signal flow and transformation within the equipment. (This knowledge may be recalled or it may be obtained by interpreting signal flow and transformation from a symbolic diagram.) The conclusion consists of a decision as to the next step to take.

Using block diagrams to determine signal flow: interpreting from a block diagram the flow of a signal or signals through portions of the equipment, or interpreting from a block diagram the changes a signal undergoes in a given component of the equipment as these changes would be shown on a suitable test instrument.

Using circuit diagrams[4] to determine signal flow: interpreting from a circuit diagram the flow of a signal through parts of a circuit, or interpreting from a circuit diagram the changes a signal undergoes in a given part of the circuit as these changes would be shown on a suitable test instrument.

Following standing operating procedures: translating verbal or written instructions into the action denoted. Performing the action may also involve other knowledges and abilities listed as part of the job.

Manual Skills and Operations

Adjusting controls: (nontracking) matching adjustment as in turning a control until a pointer indicates a given value; twisting a knob to a given switch position.

Depressing or releasing a button, knob, or switch

Screwdriver adjustments: using a screwdriver inserted in slot as a control handle by twising clockwise or counterclockwise to effect an adjustment.

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[4] The essential difference between a block diagram and a circuit diagram is that the block diagram shows primarily the interconnections and interactions between functional groups of parts. These groups are usually represented by a block which carries a descriptive name, such as "video amplifier." The circuit diagram, on the other hand, shows the interconnections of parts within these functional groups. Use of circuit diagrams is required in shop maintenance. Evidence has not shown that the reading of circuit diagrams is required in line maintenance.

Putting together mechanical fittings: pre-positioning and positioning mechanically interlocking parts such as clamping parts together; putting nuts on bolts (only shop maintenance includes assembly and disassembly of mechanical gear trains and clutches.)

Putting together electrical connections: putting together male and female plugs, multipronged connectors; joining plugs by hand or with the assistance of tools.

Moving or shifting components by hand: as in sliding an assembly or other unit off a mounting base. Components can, in most cases, be moved by one man and sometimes require lifting out of or into relatively inaccessible spots.

Soldering electrical connections: line maintenance involves only the soldering of cable connections, and this very infrequently. (Shop maintenance requires soldering and unsoldering of parts in small places, and making of delicate connections.)

A job anticipation technique which predicts the generalized technical job requirements for maintaining an equipment obviously would have much value. But this technique would have even greater value to the extent that it could predict precisely what the student must learn in a specialized course for a given equipment.

A further advantage of a detailed job statement, if made in psychological terms such as discriminations, decisions, and motor activities would be that any abstractions of job requirements or factors would be referred to these detailed statements as raw data. Such data also provides information essential to proficiency testing in training and on-the-job data.

However, presentation of this detail is not only overwhelming in bulk, but it may be desirable to abstract and generalize psychological factors which seem to be common to groups of superficially different job behaviors. Depending on their validity, such abstracted job requirements would also be valuable in setting up generalized or background training courses.

With this in mind, the specific line maintenance data was grouped into the behavior area headings of Discriminations, Knowledges, Mental Skills (functional knowledge) and Abilities (static knowledge), and Manual Skills and Operations. Job behaviors were grouped under one item such as "Screwdriver Adjustments" on the assumption that any screwdriver adjustment in the Q-24 could be performed on the basis of a single ability, or could be readily transferred on the basis of a common training in "making adjustments with a screwdriver." The principal underlying this division was that behavior may be described by specifying the stimulus and the essential discrimination or perception required; the motor response or essential human output required; and the intervening symbolic or mental processes. The goal, or criterion of response adequacy is implied in these summary statements, but is made explicit in the detailed behavioral analysis for an operationally exhaustive definition of each category title. Cumbersome as this would be, it might be practical in the preparation of a K-1 training course.

Results

The purpose of this section of the study was to validate the techniques developed and tried out once before. The results, repeating those of the first trial (Miller & Folley, 1952) indicate that the procedures were indeed valid. Comparisons of the occurrences of checking, adjusting, and replacing behaviors between prototype and production equipment indicated differences in per cent of behavior occurrence ranging from 2 to 3.3 per cent.

Comparing prototype and production troubleshooting behaviors, the block diagrams were identical, the manual activities involved (checking, adjusting, and replacing) showed the similarity mentioned above, and when the logical elimination technique was used, few equipment changes affected line troubleshooting.

Manufacturer's engineers' comparisons indicated that the repair behaviors were identical. Comparison of test equipments showed that all but two equipments were used on both models.

Conclusions

The degree of "prediction" of the line maintenance job for the K-1 emerged as high as that for Q-24 (Miller & Folley, 1952) when the logical elimination technique was used and the maintenance behavior types were described in task analysis terms and gives reason for optimism that good anticipation can be made of maintenance job requirements on other equipment.

The analysis of the K-1 job requirements based on the prototype was made without SMF data or other malfunction records. Even in the absence of such records the job was spelled out by the use of Equipment Analysis techniques. The prototype job analysis made in this study fitted all the information obtained on the production model by Equipment Analysis plus the Standard Maintenance Form data except for the relative frequencies of various kinds of occurrences and the recording of malfunction symptoms and corrective actions.

The frequency data obtained by SMF's may be used to construct tables of likely causes of given malfunctions. But the number of malfunctions occurring on one equipment during all of prototype testing is so comparatively small that a reliable table of likely causes could not be prepared. Furthermore, the more desirable procedure of trouble-shooting by logical elimination makes unnecessary the preparation of such tables.

Ideally, if mechanics and engineers doing the prototype testing wrote down all the mistakes made in performing their jobs, valuable data on "characteristics malpractices" would be provided. This is obviously an unrealistic approach, and the same data can be obtained during the first training course if instructors are trained to note and record such malpractices observed in their students.

Activity Analysis seems to hold greater promise in production model operations and during training. For instance, these data can be useful in detecting trends of equipment failure indicating a need for technical equipment changes. They may bring to light procedures developed in the field which should be made part of standard procedures and training. They can provide evidence of common malpractices against which students may be warned or trained. They may provide a proficiency measure, valuable in training.

From these considerations it seems that Equipment Analysis is the superior instrument for predicting job requirements from prototype data.

Special Features

A number of areas for future research were identified in the course of the project. While obtaining trial information with the SMF, it was discovered that many of the maintenance tasks being performed were not necessarily those which should be performed for efficient and effective maintenance. The development of Equipment Analysis to get around this problem in data gathering suggests the utility of this technique in developing sound maintenance procedures for training on new equipment.

The most crucial problem is that of deciding what a training course will include. It would seem that the function of at least some stage of technical training is to train technicians to do the job to which they will be assigned. It follows then that the training course should be based on that job. This indicates a definite need for the development of a systematic procedure for translating job analysis into training programs.

Other areas of research identified were the need for improvement of layout and content of Technical Orders for line maintenance use, the problem of planning for maintenance during equipment design (Miller & Folley, 1951a), and the motivation of mechanics to want to go a good job.

Recommendations

The procedure which has been developed has not yet been applied to new equipment in some stage of prototype development. A true test of adequacy should be given the procedure in making a genuine prediction of maintenance job requirements.

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. A comparison of job requirements for line maintenance of two sets of electronics equipment. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1954. (Technical Report 54-83) (Project No. 7709, Task No. 77150, Contract No. AF 33(038)-12921)

Purpose

The purpose of this offshoot from the study of methods of analyzing maintenance jobs was to provide an example of a systematic approach and set of procedures for comparing job activities involved in the maintenance of two or more systems. Such a comparison could provide preliminary suggestions for the following problems:

1. The kinds of transition training appropriate from one equipment to another.

2. The common features of line maintenance jobs in several equipments which would provide the content of a course "basic" to them all.

Procedure and Results

The following program of comparisons was performed:

1. Within-category comparison of behaviors for the Q-24 with those of the K-1. See definitions of behavior categories in abstract of Miller, Folley and Smith (1953a).

2. Between-category comparison for the Q-24 and K-1.

3. Comparison of specific Q-24 procedures with corresponding K-1 procedures. For each equipment procedures having no counterpart in the other equipment are noted. This comparison includes the functions of checking, adjusting, replacing and repairing.

4. Comparison of behavioral requirements for the function of trouble-shooting, and comparison of malfunction symptoms from the Q-24 with those of the K-1.

5. Comparison of test equipment used on the Q-24 with those used on the K-1.

In the application of the job anticipation procedure to the Q-24 and K-1, the degree of function category similarity is indicated in the sample portion of Table I. Comparing Q-24 and K-1 behaviors within a given category, two aspects of similarity and knowledge can be singled out. First, the skill or knowledge believed to be required to perform the behavior on one may be compared with that believed to be required to perform the corresponding behavior on the other. Second, the specific content of the behaviors may require different information for performance on one than for the other, or the specific content may pose different perceptual, conceptual, or motor problems.

The following terms were used in this comparison:

Subtask Step: the cues or stimuli involved and the discrimination which has to be made for a given job behavior, the response and response components appropriate for corrective action, and a criterion of the effectiveness of the response.

Behavior Sequence: the order in which the steps are taken for a given subtask.

Relating subtasks on the procedural level takes into account not only the like, categorized behaviors between jobs, but also the specific procedural aspects of the jobs such as behavior sequence, location of controls and indicators, component nomenclature, and equipment function.

Because in the actual job, these behaviors are performed in specified sequences, a comparison was made between the two equipments on the dimensions of similarity of these procedures (see Table II). First, the subtasks which were either identical for the two sets of equipment or closely related in terms of the over-all purpose of the check or adjustment were drawn from both groups and laid side by side. Where two comparable subtasks existed, the steps were inspected again and behavioral differences were noted in a third column in terms of one or more of the following five kinds of procedural differences.

1. A change in sequence of steps.

2. Addition or deletion of various steps.

3. The introduction of new or substitution of functionally different test equipment.

4. An important shift in location of components.

5. The introduction or deletion of major components resulting from a change or modification of system function or purpose.

For each set of the comparable steps not completely identical, the appropriate numbers from the above five "differences" are placed opposite the set in the third column. Subtasks having no comparable or related subtasks from one equipment to the other were listed at the end of the table. This comparison was made for all the checking and adjusting behavior subtasks. Unlike the checking procedure comparison, few of the Q-24 adjustment subtasks had equivalent counterparts in the K-1 at the procedural level of comparison. This is not to say that equivalent behaviors or procedures are not found in the tasks for the two equipment; however, when the subtasks are inspected at this level, procedural differences become emphasized due to one or more of the causes listed in the numbered list of behavioral differences.

The comparison of replacement behaviors takes into acount the similarities and differences in procedures as well as in behaviors. Several definitions are appropriate here:

Replacing is any substitution of an operative unit or subunit for an inoperative one.

Unit is a portion of the equipment which is contained within its own case and connected to adjacent parts of the system by cables.

Subunit is a smaller portion of the equipment housed within a unit and connected to the main chassis and to the wiring of the unit through multipronged plugs.

The behavior categories involved in replacing are for the most part as follows: nomenclature, locations, precautions, following Standard Operating Procedures, putting together mechanical fittings, putting together electrical connections, and moving or shifting components by hand.

It seemed appropriate first to compare the equipment components for the two equipments in terms of component differences causing replacing behavior differences. Secondly, a comparison of the tools involved in each of the separate job analyses was made. See Tables III, V, and VI for the formats used.

No comparison of the identical radars was needed,but the step-by-step behavior analyses of the two computers were compared and the additional procedures required by the periscope and interconnections were specified.

Procedures for replacing components, units, and subunits in electronics equipment of this type follow a definite pattern of steps with practically no exceptions. Minor differences consisted of such things as changes in bolts,

TABLE I

Comparison of Specific Behavior Content

Between AN/APQ-24 and K-1

Category[1]	Judged degree of similarity between Q-24 and K-1
Discrimination and perception	
(1) Observing gross indications: noting the presence of mechanical motion or of an indicator light being on or off.	Same
(2) Reading values on dials: noting quantities registered on dials. Types of dials have been classified as:	Different dial faces; different values.
(a) Position-marked dials: positions are marked in discrete steps requiring no interpolation by the observer.	
(b) Calibrated dials: a continuous scale marked off in units; readings require interpolation.	
(c) Meters: several scales may appear under one pointer. The appropriate scale must be selected for the purpose at hand; little, if any, interpolation is required for adequate accuracy in reading values.	
(3) Noting relative motion of dials, scope presentations: noting gross differences in rates of movement of a dial or pointer, or in a scope presentation.	Same
(4) Reading radar scope and oscilloscope: comparing wave shapes, visual patterns in terms of configurations, standard brightness, sharpness of definition (focus), waviness of lines.	Radar scope same; different wave shapes for oscilloscope.

[1]See Miller, Folley, and Smith (1953a) abstract for the complete list of categories included in this table.

TABLE II

Comparison of Q-24 and K-1 Subtask Procedures
for the Job Function of Checking (and Adjusting)

Q-24 performance checks	K-1 preflight and postflight checks	Procedural difference code number[2]
PC-1 Energizing system	PRF-2 Initial switch settings	1, 5
	POF-2 Prepower-on settings and checks	1, 5
PC-2 Check input voltages	PRF-3 Stabilization power supply voltage checks	2, 3, 5
PC-3 Check reference voltage	PRF-5 Radar voltage check	1
PC-4 Check + 150 volts	PRF-5 Radar voltage check	2, 4
PC-5 Check + 300 volts	PRF-5 Radar voltage check	1, 2

[2]Number 1 equals a change in sequence of steps; number 2, the addition or deletion of various steps; number 3, the introduction or new substitution of functionally different test equipments; number 4, an important shift in location of components; number 5, the introduction or deletion of major components resulting from a change or modification of system function or purpose.

screws, or other fasteners, a slight difference in the kinds of tools specified, or a very slight change in sequence. The behaviors required to replace the components of the K-1 periscope and interconnections were found to follow the same pattern of steps as seen for the Q-24. There were, of course, additional requirements of nomenclature and location.

TABLE III

Sample Computer Replacement Procedures

AN/APA-44 (Q-24) computer units				A-1 (K-1) computer units			
Unit	Removal procedure and tools	Replacement procedure	Precaution	Unit	Removal procedure and tools	Replacement procedure	Precaution
Tracking Control	1. Remove 2 cables from jacks in rear of unit.	Reverse of removal procedure.	(1)[3]	Tracking Control.	1. Disconnect cable from unit; AN plug wrench.	Reverse	(1)[3]
	2. Remove knurled bolts holding unit to mounting plate; Socket or Crescent wrench.				2. Remove 6 mounting screws; Screwdriver and Open End wrenches.		
	3. Remove unit from mount.				3. Remove unit from mount.		
Power Supply PP-185	1. Remove cable from rear of unit by unscrewing with cannon plug wrench.	Reverse	(1)[3]	Computer Power Supply A-1.	1. Disconnect cable from mount.	Reverse	(1)[3]

[3](1) Plug Precautions: All cable plugs and subunits must be removed carefully to prevent bending pins or pulling pins loose. They should be inspected visually before reinstallation to insure that all pins are straight and in place so that they will enter the sockets properly.

A comparison of the tools required for replacing components of the Q-24 and K-1 consisted of listing side by side the tools appropriate for the computer replacing behaviors and noting the tool requirement differences. (See Table V.) The tools required for the K-1 unique periscope and interconnection were listed separately (Table VI). This comparison showed that no real difference existed between the tools used for each set or the procedural behaviors involved, except for the use of one Allen wrench when installing the K-1, and the difference between adjusting a crescent wrench and selecting an open-end wrench.

The comparison of Q-24 and K-1 repair subtasks involved an inspection of the skill and knowledge requirements determined by the job analysis for each operation of the two equipments. In Table IV, similar repair operations are placed side by side, in two columns. Of the seven repair operations for the K-1 only two had no counterpart activity in the Q-24. No skill or knowledge differences were noted for the matching five, and only procedural differences of nomenclature, as the identification of different type vacuum tubes were found.

In comparing troubleshooting behaviors, the study deals only with troubleshooting to assemblies rather than parts. The logical elimination technique, developed and formalized by the American Institute for Research during this study, is applicable to any equipment, electronic or otherwise, where the equipment functioning depends on process or data flow. Assuming the use of this technique, there are no procedural differences between troubleshooting each of the two sets other than those differences identified earlier of checking and adjusting.

An attempt was made at comparing categorized malfunction symptoms for the two sets, as an indication of the transfer possible if a malfunction probability technique of troubleshooting were used. There was very low similarity of symptoms from one set to the other using this approach, indicating the superiority of the logical elimination technique where training carry-over is desired.

A comparison was also made between the test sets used on the two equipments. Again, a side-by-side listing of test sets was presented, followed by sets used only for one equipment. While there was a large percentage of sets unique to the K-1 system, the differing behavior categories implied were chiefly nomenclature, locations, principles of operation, and setting up test equipment.

TABLE IV

Comparison of Q-24 and K-1 Skill and Knowledge Requirements for the Job Function of Repair

Q-24 Production Model		K-1 Production Model	
Repair Operations	Required Skills and Knowledges	Repair Operations	Required Skills and Knowledges
1. Replace dial illuminating lights.	1. No tools required, only low degree of manual skill.	1. Replace dial illuminating lights.	1. No tools required, only low degree of manual skill.
2. Replace plug-in relays.	2. Use of screwdriver; careful handling to prevent damage to parts.	2. Replace plug-in relays.	2. Use of screwdriver; careful handling to prevent damage to parts.
3. No comparable activity.		3. Service desiccant material.	3. No tools required, care in assembling properly to insure correct seating of desiccant jar; ability to discriminate between fresh and saturated "Drierite" crystals in terms of color.
4. No comparable activity.		4. Service radar pressure system.	4. Use of screwdriver; careful handling to prevent damage to parts (gaskets, waveguide, etc.); care in assembling properly to insure airtight seal.

Conclusions

The individual behaviors required in the perceptual and motor aspects of the job functions of checking, adjusting, replacing, and repairing appeared to have a high degree of psychological similarity. The two sets had little in common in the knowledge of nomenclature and location

TABLE V

Comparison of Tools Specified for Replacement of Units in the AN/APQ-44 Computer and K-1 Computer

AN/APQ-44	K-1
1. Screwdrivers of various sizes	1. Screwdrivers of various sizes
2. Cannon plug wrenches	2. AN connector wrenches
3. Socket wrenches	3. Socket wrenches
4. Crescent wrenches	4. Open end wrenches
	5. Allen wrenches (necessary only for B-36 installation)

requirements, except for the identical components. Because there were several hundred items of nomenclature and locations, this training would be expected to require considerable time. Because the data variables were the same for each equipment, it was felt that, had the variables been represented by common symbols, the nomenclature learning task would have been greatly simplified.

TABLE VI

Tools Specified for Replacing Units of the Interconnection Equipment and K-1 Periscope

Interconnection Equipment	K-1 Periscopic Bombsight
1. AN connector wrenches	1. AN connector wrenches
2. Screwdrivers of assorted sizes	2. Screwdrivers of assorted sizes
3. Socket wrenches	3. Socket wrenches

The knowledge and practice of precautions was found to be about the same for both sets, except that some additional precautions in the handling of mechanical parts would be required.

Because the mental skill capability requirements were judged by the analyst, similarities can be stated only tentatively. However, the activities of transcribing and recording data and making arithmetic computations were identified as being almost identical for the two equipment.

Regarding the behaviors involved in the troubleshooting function, a high degree of carry over was present when block diagrams and logical elimination troubleshooting are taught as a generalizable skill. However, if troubleshooting training were stimulus-bound as in the use of a malfunction probability technique, very little transfer would occur.

In comparing the behaviors of "following Standard Operating Procedures," the nature of the training also determined whether they were relatively transferable or stimulus-bound to a given equipment. In fact, much of the differences between the two jobs probably depends on the conditions of training. The ability to read, interpret, and follow written instruction depends in part on knowledge of nomenclature and locations.

While the individual behaviors were found to be largely transferable between sets, this comparison technique showed the behavior procedures to be largely different. Even when identical test equipment were used, the procedures frequently vary. Standardization of test equipment, however, would facilitate transitioning greatly, and aid in determining course content for "fundamentals" courses.

Recommendations

On the basis of this application of the comparison technique the following suggestions as to what training should be included in a fundamental course for line maintenance mechanics were made. They are indicative of the types of results obtainable from the use of this technique.

1. How to read and interpret technical orders.

2. How to interpret data flow diagrams such as block diagrams, etc.

3. How to troubleshoot by logical procedures with data-flow diagrams as aids.

4. Reading dials.

5. Using oscilloscope and interpretive patterns or comparing wave shapes with reference wave shapes.

6. Noting various kinds of defective electronic parts by external signs.

7. Precautions in the use of complex electronic and mechanical equipment.

8. The variables in bombing and navigational problems.

9. Making control adjustments in dynamic systems as bringing pointers into required alignment.

10. Putting together mechanical and electrical fittings.

11. Soldering.

If training is to anticipate other job opportunities than line maintenance, task analyses should be made of these jobs in order to ascertain their behavioral content and thus justify inclusion of other material.

Comments

In this study the line maintenance job of the K-1 was compared with that of the Q-24, a system which was essentially a predecessor to the somewhat more sophisticated K-1. Because most military system development is a process of evolution rather than revolution, this comparison is especially meaningful. The implication is that as evolving equipment poses requirements for an evolution of maintenance skills and knowledges, these requirements may be defined by a comparison of this sort between the new equipment and their predecessors.

This comparison technique may also be applicable to the measurement of a "new" job against the closest equivalent existing job to determine the differences which must be trained for, assuming that the existing job can be stated in compatible terms. Such a statement might be feasible on the basis of a detailed review of the job background as outlined in the Training Prospectus and Job Training Standards.

Miller, R. B., Meister, D., & Feroglia, W. E. Sources of maintenance job information: IV. Development of information for anticipating maintenance job requirements of new electronic systems. Lowry Air Force Base, Colo.: Armament Systems Personnel Research Laboratory, Air Force Personnel and Training Research Center, August 1955. (ASPRL Technical Memorandum 55-16) (Project No. 7709, Task No. 77150, Contract No. AF 18(600)-1203)

Purpose

This report presents the implications of a study of the kinds and sources of information required for anticipating during early stages of electronic development, the job and training requirements for maintenance of electronic equipment.

Requirements

The maintenance duties to be anticipated are categorized as checking and inspecting, adjusting, troubleshooting, replacing, repairing, and servicing. Servicing and inspecting are defined as:

Servicing. Line: Lubricates and cleans components and parts accessible in the aircraft, replenishes desiccant, hydraulic fluid, ammunition, etc. Shop: Lubricates and cleans components and parts which can be serviced only when disassembled in the shop.

Inspecting. Line: Uses senses for checking parts, cables, lines, oil leakage, etc. Usually a visual check when system is not operating. Shop: Checks connections, burnt parts, etc. Usually a visual check of insides of units replaced on the line, or inaccessible within the aircraft.

The other categories of maintenance job activities are defined for line operations in Miller, Folley, and Smith (1953a). The extension of each definition to the shop context is given in this report, as above, but not abstracted.

The following types of information are required from contractor products for the anticipation during prototype development of the line and shop maintenance activities outlined above.

Information about line replaceable units. Identification of what will be line-replaceable provides one basis for determining the probable usefulness of a job shredout between line and shop mechanics. By revealing the maximum number of "objects" with which the line mechanic must deal, an impression of the magnitude and complexity of the line job is gained. This information will affect the performance of all line duties.

Information about shop repairable units. Basic equipment items down to which the shop mechanic will work, designated by the Air Force as nonrepairable and therefore to be disposed of or sent to depot or factory for repair. These must be identified before the shop mechanic can know how much repairing and replacing is required of him.

Information about access and check points for line maintenance. Access points determine where checking tasks are performed, and the order and length of time required for replacing, repairing, and troubleshooting units. Knowledge of the number and accessibility of check points where signal flow readings can be made, determines where and how test equipment will be used for troubleshooting. Check points for shop maintenance. Both specially designed check points or strategically located connections must be identified, possibly as part of written shop check procedures.

Information about types of check indications. Qualitative or quantitative tolerance indications. Precise data is needed on standards and tolerances for the mechanic to check operating conditions.

Information about adjustment points. Line: Operator controls, knobs, switches, screwdriver, or other adjustment controls which the line mechanic must know the location of and have access to, to perform the adjusting and troubleshooting tasks in returning equipment to tolerance conditions. Shop: Specification of shop adjustment points is essential to the preparation of shop procedures.

Information about maintenance diagrams. Line block diagrams: Diagrams of signal flow between line replaceable units and functional locations of check and adjustment points, needed for troubleshooting. Shop circuit and schematic diagrams: They show signal flow relationships and location of parts within units, and are needed for training and performance of troubleshooting.

Information on nomenclature, configuration, and location of components. Line replaceable units: Determines the manipulations required for removal, replacement, and line repair of parts, and where the mechanic looks for units. Standard nomenclature precedes the final preparation of job instructions and diagrams. Shop repairable items: Serves the same purposes as equivalent line data.

Information about maintenance procedures. Line: Checking and adjusting procedures and sequences require information about the location and characteristics of line replaceable units, access points, and type of check indication. Replacing and repairing procedures require description of use of special tools, precautions for removal and replacement, repairs required, and the conditions and techniques for making them. Servicing procedures require data on units to be serviced, locations, access points, sequence of operations, special tools, and precautions. In addition to the identification of checks and adjustments required, troubleshooting procedures require data on symptoms, built-in or portable test equipment, sequence of units to be checked for each symptom, normal readings and tolerance ranges for each check, possible sources of trouble, diagrams indicating the kind of troubleshooting problem and troubleshooting technique required, and suggested corrective actions. Shop: All available data on shop maintenance procedures should be specified although the shop mechanic's job is not so formalized as for the line. While he knows the problem is within a given unit, the number of possible parts complicates his problem considerably.

Information about maintenance test equipment. Line: Procedures for use and outputs and their interpretation are required data for training, checking, adjusting, and troubleshooting tasks. Shop: Requires special knowledges of procedures for test equipment use and the purposes it will serve in troubleshooting within units.

Information about line and shop tolerance values. Tolerance values are more subject to developmental change and determined at different times than "type of check indication." The data is needed in checking, adjusting and troubleshooting tasks.

Information about line and shop maintenance tools. Specification of standard AF tools implies standard training requirements, plus any special access problems. Special tools require special training and so must be specified to anticipate position requirements and plan training.

Information about the theory of line unit operation. A functional description of system operation at the unit level, required for troubleshooting training.

Summary and Phasing of Method

The following system development products contribute useful information to the derivation of maintenance job information and the determination of training requirements:

Over-all specifications and design objectives. The specifications and objectives provide the basis for a basic system analysis, specifying or implying some of the subsystems to be included and signaling the start of maintenance data collection.

Fundamental equations. These preliminary system representations are too abstract for use in present job anticipation methods.

Functioning diagrams. Completed about six months after development begins, these diagrams show the system data flow between subsystems, and provide a basis for block diagrams and a theory of system operations, for line troubleshooting.

Two-line diagrams and unit specifications. Functioning diagrams, with the addition of signal flow outputs and tolerances between subsystems, become two-line diagrams and are the basis for unit specifications, indicating the operating characteristics of units within subsystems. They may be completed about nine months after the beginning of development, and provide information about line replaceable units, types of check indications, line maintenance diagrams, tolerance values, theory of line unit operations, and line and shop adjustment points.

Breadboards. These circuits or equipment are too preliminary to use in the anticipation of maintenance job requirements.

Schematic diagrams. Emphasizing unit function and signal flow, they specify circuit parts and signal values, shapes, and voltages, and are prepared about twelve months after development begins. Schematics may be incorporated almost directly into maintenance training and job performance for shop troubleshooting. They indicate line access points, adjustment points, nomenclature of shop repairable parts, and diagrams for shop maintenance.

Parts lists. They provide the nomenclature of and access points in shop repairable components.

Preliminary wiring diagrams. These diagrams locate parts within units, but do not show wire or cable locations. They are prepared about twelve months after development begins, and provide the first detailed packaging data. They provide information about line replaceable units, access and adjustment points, line maintenance diagrams, and configurations and location of line replaceable units, for the line mechanic. They provide shop maintenance information about adjustment points, nomenclature of shop repairable components, shop maintenance diagrams, specifications of throw-away units, and the configuration and location of shop repairable units.

Mock-ups. Limited as a data source, they may provide some information about line replaceable units and indicate access problems for checking, adjusting, replacing, and servicing.

Installation and cabling diagrams. Drawings of parts in units, specifically indicating the locations of parts, wires and cables, and adjustment and access points relative to each other and the aircraft, and the packaging of units, determining the accessibility of components and the breakdown of components into line and shop areas of responsibility. These diagrams are completed about twelve months after development begins and provide line information about line replaceable units, access and adjustment points, line maintenance diagrams, configuration and location of line replaceable units, and theory of line unit operation. Additional data on shop adjustment points are also provided.

Layout diagrams and/or brassboards. Extensions of preliminary wiring diagrams prepared about eighteen months after development begins. They include more detail of parts locations, wiring and adjustment and access points, and indicate signal values and direction of flow. Brassboard units are packaged for installation. Most of the above data are available from other products earlier, but these products may verify line maintenance data on line replaceable units, access and adjustment points, line maintenance diagrams, and configurations and locations of line replaceable units.

Additional shop maintenance data are provided on adjustment points, nomenclature of shop repairable components, throw-away unit specifications, shop maintenance diagrams, and configurations and location of shop repairable parts.

Cabling harnesses and/or production shredouts. Layout diagrams of portions of the system to be built for the brassboard do not contribute any new data.

Hardware. Major equipment units, assembled but not cabled together into subsystems, are completed about two years after development begins, and provide the first opportunity to check unit maintenance procedures by observing completed equipment in action. Line maintenance data are provided by observing completed equipment in action. Line maintenance data are provided on line replaceable units, access and adjustment points, types of check indications, procedures, and configuration and location of line replaceable units. Shop maintenance data are provided on tolerance values, adjustment points, procedures, nomenclature of shop repairable parts and points in components, and configuration of parts and physical assembly.

Connected and interacting subsystems. Hardware units are cabled together and tested operationally about two and a half years after development begins, allowing the maintenance demands for the entire system to be evaluated for the first time. Results of operational tests can be systematized into maintenance routines. Maintenance data may be amplified and verified for all line and shop duties.

Test equipment, access points, and tools. Test equipment often vary in design, depending on their anticipated use on the line or in the shop. The number and location of test access points in part determine maintenance efficiency. These products should be designed soon after development starts, and be available for use when the hardware units are constructed. They can be incorporated directly into maintenance training and job performance. They further define the line maintenance job regarding access points and test equipment, and indicate tools, shop test equipment, and procedures which are part of the shop maintenance job.

Procedures. Preliminary procedures, unwritten and not formalized, can be prepared about two years after development begins, and include such activity sequences as installation, preflight, troubleshooting and harmonizing checks, and servicing, telling when, what, and how maintenance tasks are to be performed. They contain maintenance data relevant to all line and shop duties, and are particularly useful for writing job instructions.

Manuals. Consisting of diagrams, procedures, parts lists, etc., they contain both line and shop relevant maintenance data. They are prepared about two and a half years after development begins, and may be used to write job instructions.

Training courses. Preliminary courses for factory maintenance personnel are prepared about two years after development begins, and contain data relevant to both line and shop maintenance jobs.

Nomenclature. Standard names and codes for parts and warnings stenciled on hardware are available about twelve months after development begins. It is useful in preparation of job instructions and procedures.

Tests. Operational performance tests performed by the Air Force about two and a half years after development begins. Maintenance procedures, available much earlier, may be verified here before final incorporation into job instructions. Tests verify data on procedures, tolerances, and test equipment and tools.

Spare parts. Provide information for anticipating maintenance job requirements as they may be related to logistics considerations.

Recommendations

It is estimated that a reliable forecast of both line and shop maintenance job requirements can normally be made eighteen months at the latest after beginning the development model of the system. This data should coincide with the mock-up inspection which usually precedes initiation of the "slow production" model. Assuming no major revisions, minor design changes can easily be incorporated in the on-going maintenance training program. By the time the slow production model is contracted for, most of the developmental products should be available, and the planning for maintenance training should be started.

Miller, R. B., & Van Cott, H. P. The determination of knowledge content for complex man-machine jobs. Pittsburgh: American Institute for Research, December 1955. (Project No. 7714, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205)

Purpose

The purpose of this report is to present the logical development of and procedure for a method of determining the necessary knowledge content for performing, and hence, learning a complex man-machine job, and for translating the results into content suitable for training. Brief consideration (Appendix B) is also given to a tentative approach to the determination of the level of task or job complexity.

Rationale

The rationale for the method is developed at length, logically and step-by-step in the body of the report, in psychological terms. Appendix A summarizes this rationale in operational terminology, and for brevity's sake, it is basically Appendix A which is reviewed here.

Knowledges are not equivalent to job behaviors; they are not operational work outputs. Work outputs are achieved by muscle action and can be trained to occur to overt stimuli. Consequently, although a knowledge may support the selection and mking of a required Response, it is not itself a job requirement. Knowledges are therefore called "conceptual supports" rather than "conceptual requirements," and "learning by rote" is distinquished from "learning by concept." It is conceivable that, given enough time, any job could be learned completely by rote practice without any conceptualizations.

The operational value of conceptual supports is that the information they contain enables the operator to generalize his potential Response capabilities to a variety of work situations for which it is not feasible to provide overt practice, and for which he consequently does not have established S-R's. Thus, generalization occurs because the content of a concept is an abstract of relevant features in the stimulus complex of job objects, events, and relationships.

When such generalization happens based on selective perceptions through symbolic habits, decision-making occurs: symbolic activity results in the selection of a Response not spontaneously elicited by Stimulus conditions.

Another important function of conceptual supports is to aid recall and performance of overt habits. Concepts add redundancy to a Stimulus-Response association and increase its probability of occurrence. Both the habit generalization and habit redundancy functions demand associations between explicit stimuli and the symbolic habit, and between the symbolic habit and overt response: these associations guarantee that the implicit habit or concept can be applied.

As a result, symbols should be chosen which already have the appropriate meaning to the trainee, which most concretely and completely cover the operational situations to which they will refer, and which are compatible with other symbols used. These four categories are also principles for organizing knowledges so that a maximum of implicit habit redundancy will increase the reliability of recall.

The conceptual difficulty of a job or task is related to the amount of implicit information the operator must handle at once when making decisions. That is, how much must be remembered, and the number of variables to be considered in making a decision or series of contingent decisions.

Summary

Briefly, this technique of "job knowledge analysis" starts with the task analyses, prepared in accordance with Miller (1956a), and has three outputs. The first is the operative conceptual content--the actual knowledge required to facilitate task performance. The second is the symbolic content, the actual words, pictures, or other media by which the operative content is presented for training. The third output is the selection of an organization for presenting this material which will provide further information and support to the learning and operational situations.

Scheduling or Phasing

Although this procedure appears to have been written with the thought of applying it to a job on equipment already operative, it may be revised slightly, as pointed out in the report, to be appropriate for use at any stage in development, as long as the task analysis has been prepared.

Summary of Method for Job Knowledge Analysis

Step 1.

Obtain or prepare a task analysis of the job, including human error and efficiency data, if possible. The possible operational contingencies or programs should be identified.

Step 2.

Set aside all behaviors and especially behavior sequences performed in a routine order to fixed stimulus objects and conditions. (These activities may be learned more rapidly when overt practice is preceded and supplemented with implicit, symbolic practice. On the other hand, determining when or where a routine is to be performed may involve decision-making. And there may be activities (such as tool-using) implied within a procedure which are not strictly routine, which may profit from conceptual supports.)

Step 3.

Identify job conditions and situations for which conceptual supports are desirable, i.e., those involving decision-making non-standardized job situations where only limited overt practice is practicable, and job situations likely to profit from the increased redundancy of implicit habit systems supporting overt habit systems.

These job conditions may be identified through analysis of actual or expected human errors in learning and peforming job behaviors. This procedure is apt to be lengthy and unreliable because of the difficulties in obtaining behavioral data, especially in early design stages.

A more practicable procedure is to use a checklist to determine the symbol-using and decision-making situations. The following list is suggested:

1. When nomenclature and locations must be known.

2. What to search for in nonstandard job environments.

3. When precautions are necessary.

4. When interpreting symbols or signal patterns is necessary.

5. When procedures must be learned for emergency situations not feasible to simulate.

6. When calculations have to be performed.

7. When problem solving, diagnosis, and troubleshooting are required.

8. When later conditions must be anticipated from earlier conditions.

9. When planning is required in job activities.

10. When strategies are required.

11. When action must be in accordance with briefing instructions.

12. When inventions and improvisations are required.

13. Identification and recognition of unusual and complex objects and signals.

14. When tools and test instruments are used.

15. When ideas and knowledges will simplify training and skills.

Step 3 is the reverse of and check on Step 2. There is no need for these categories to be mutually exclusive, since no discriminations are necessary between them.

Step 4.

Derive conceptual content to support the job behaviors identified in Step 3. The task analysis is the source of data. Identify the relationship between work stimuli or work responses, or between stimuli and responses, to be supported by a concept(s).

1. A format may be used with the following categories. See Van Cott, Berkun, and Purifoy (1955).

   Problem Stimuli (including statement of purpose of behavior, range of Stimulus conditions).

   Required Responses (responses which will fulfill goal requirements).

   Conceptual Supports (the concept which will facilitate performance of the required Responses).

2. List alternative goal approaches.

3. Cite program variables affecting each goal approach.

4. Determine the variable combinations likely to occur.

5. Identify the operating limitations of the system under given sets of program variable permutations.

6. Indicate the feasible goal approaches for each combination of variables.

7. For each set of program variable permutations, state the information the operator must have, to select the appropriate goal approach.

8. List the alternate ways of stating the minimal data needed by the operator.

9. Enter the statement of content derived above in the Job Knowledge Format.

Step 5.

Analyze in turn the conceptual supports for:

1. Job elements or activities within individual tasks.

2. Tasks and programs under which tasks are to be performed.

3. Position segments and the programs under which they are to be performed.

4. Characteristic mission or work cycles as a whole.

No recommendation is made for the order in which 1 through 4 should be performed.

Steps 4 and 5 require in many cases the equivalent of operations research for developing job knowledges. Where pre-existing "hypotheses" suggest what symbolic information may be appropriate conceptual supports, the hypothesis may be tested using the Job Knowledge Format. Insert the suggested support in the Support column, and enter the related Problem Stimuli and Required Responses. Then perform items 2 through 8 of Step 4 and see if item 9 matches the hypothesized support.

Step 6.

Select appropriate symbols and media for the operative conceptual support derived in Steps 4 and 5. In some cases the operative content and the symbol, which together comprise the conceptual support, may be equivalent. The total symbols, used in all conceptual supports for a job should be kept to a minimum. The following rules guide the selection of support symbols. See Peterson (1956) for further consideration of this area.

1. Select symbols denoting precisely the range of job conditions to which the operative content applies.

2. Select symbols having pre-existing meanings for the trainees. Give prefernece to action symbols.

3. Select symbols which are, or readily permit, diagrammatic representation.

4. Select symbols compatible with symbols used on the job.

5. Select symbols compatible with other symbols used in training.

6. Present the operative content in a variety of symbols and statements when the material is hard to learn and important to apply.

7. Give preference to symbols with concrete denotation.

8. Conceptual supports dealing with Stimulus references should be associated with those dealing with Response references.

Following this procedure, problems of deciding the "level of theory" for training become nonexistant. Step 6 tends to indicate the type of training aids most useful for presenting the conceptual supports.

Step 7.

Organize the conceptual content for training presentation. Conceptual supports may be grouped under:

Purposes to be fulfilled in the work environment.

Stimulus characteristics of objects and conditions in the work environment.

Response capabilities of objects in the work environment.

Activity sequences in the work environment.

Grouping a support under several of these categories increases the interassociations and implicit habit redundancy, increasing the chance of recalling the support when needed. Principles of organization thus become principles of association and are a major basis for learning and recall of job knowledges.

Step 8.

The difficulty of decision-making is proportional to the amount of information the operator must carry in his head and utilize simultaneously in choosing a Response. The simplest quantitative estimate can be based on the number of variables entering into the decision, the amount of information to be recalled, and the rapidity with which the decision must be made.

In estimating job complexity, determine the relative amount of time spent making decisions versus performing routines. A second and possibly more meaningful basis for selection procedures consists of estimating the range of decision-making problems in the over-all job. This is done by determining the numbers of situation groups distinguished from each other by (a) different stimulus variables entering the decisions, and (b) different recalled information required for the decision. Item (a) is simpler and more objective than (b).

Special Features

See Van Cott, Berkun, and Purifoy (1955) for an operational sample of the application of this method. Peterson, Folley, and Ostrich (1956) also discuss an application based on this method.

North American Aviation. (UNCLASSIFIED title) Task equipment analysis for (X). Report No. 58-93. Revised June 1958. (WADC Control No. 58 WCLD 1937-WCLDPTQ) (SECRET RESTRICTED document)

NOTE: Reference to classified equipment is omitted from this abstract, which is unclassified.

Purpose

This document reports a Task Equipment Analysis of a specific system as conducted at the blueprint stage of development. It covers the complete maintenance and operational requirements beginning with the delivery (not yet unloaded) of the system to the using organization.

Summary of Method

First of all, a logical functional sequence of events was conceived describing the entire mission cycle, from the time of system delivery on. Comparison of this system with similar existing systems facilitated the development of this "mission profile."

Task information was then obtained by dividing the system mission into segments. The point of separation between segments was determined by the following considerations:

1. Area of work performance.
2. Type of equipment used.
3. Type of work performed.
4. Ground or in-flight environment.

Each mission segment was divided into its own function cycles to establish meaningful procedural steps and task relationships.

Tasks thus established were ordered according to the type of functional requirement; i.e., assemble, service, inspect, monitor, etc. The structure of each task was defined by the determination of job elements (or subtasks). (The details of this determination were to be reported in a subsequent revision to this report.)

A mockup from blueprints was used to determine the general dimensions and physical locations of access doors, panels, etc. It provided data on numbers of fasteners and latches, etc., and was used to estimate access times, replacement times, etc.

System environment was checked to determine whether the tasks were performed indoors or out of doors, with or without temperature and lighting control, etc.

The knowledges and skills required for the performance of each task were determined by experienced operator and maintenance line personnel. The methods used in this separate study were not included in this report. Knowledge of safety precautions was included in the study.

All of the above data were collected on the Task Equipment Analysis Form, illustrated in Figure 1.

Mission Segment ______________________ Cycle ___________________

Tasks and Job Elements	Location	Equipment	Elapsed Time	Personnel	Worker Environment	Knowledges and Skills	Remarks

Figure 1. Task Equipment Analysis Format

The first column lists the <u>tasks</u> (the function to be accomplished) and the <u>job elements</u> (how the task is to be performed).

The <u>physical location</u> in which the task is performed is identified generally, such as "in the hangar," or specifically, such as the particular work station, where possible.

The <u>equipment</u> required for performance of the task is listed numerically. The numbers, however, are not related to the job elements; they refer to the task requirement in general.

The <u>elapsed time</u> required for the performance of each task is noted.

The number of <u>personnel</u> required for performance of the task is indicated in column five.

The <u>environment</u> of work is stated in physiological terms, supplemented by its psychological properties, where appropriate. This data is important in determining ways of improving productivity and efficiency.

The knowledge and skill requirements are determined by the operations and maintenance task definitions, system design, and the maintainability of the equipment.

A remarks column is provided for any additional comments.

Special Content

In addition to the task equipment analysis format, the report contains a glossary of definitions.

Comments

The report, unfortunately, does not include any discussion of the rationale for the determination of "job elements" (subtasks) or the identification of knowledge and skill requirements.

This presentation closely parallels that described by Stackfleth (1958).

Peterson, R. O. Two general approaches for deriving knowledge content from electronic maintenance tasks. Pittsburgh: American Institute for Research, November 1956. (AIR-199-56-IR-55)

Purpose

This report reviews two approaches to the application of the stimulus-response identity technique for identifying common knowledge content. Stimulus-response identity is identified primarily in terms of the job objects (test equipment, tools, powercarts) common to two or more of the F-86D electronic maintenance positions. The two approaches are the vertical hierarchy approach and the direct relevance approach.

Rationale and Summary of Method

The vertical hierarchy approach, developed first in the study for the development of core training for F-86D electronic maintenance positions, consisted of two steps: deriving or postulating a universe of possible relevant content, and then selecting by specific criteria the content most relevant to training.

The universe of common content was to be derived systematically and somewhat comprehensively by starting with the most operational concepts, skills and knowledges--such as those which were prescriptions applicable to one or more tasks in two or more positions. Example: "The selector switch on the multimeter must not be rotated beyond its first or last position." A step-by-step examination of the job instructions and of the related job objects--tools, test equipment, facilitating equipment, etc.--indicated a tremendous number of these concepts directly related to specific operations and tasks. Technical terms with their operational definitions constituted one large portion of this level of concepts.

Above this operational level of concepts may be considered any number of additional levels of superordinate concepts, where each additional level is more abstract than the one immediately below it. For example, the concept above may be abstracted and combined with other operational concepts in the following steps:

1. Selector switches on test equipment must not be rotated beyond their first or last settings.

2. Selector switches in general must not be rotated beyond their first or last positions.

3. Selector switches must not be rotated beyond their first or last positions since to do so would damage the equipment.

4. Switches on equipment should never be manipulated such that the equipment would be damaged.

5. Equipment should never be damaged.

While the original example is probably the most operational, the last may not be the most abstract, nor are the various levels of abstraction necessarily comparable to levels of abstraction for other concepts. However, such a hierarchy presumably can be organized to subsume all operational concepts. This hypothetical structure of concepts ranging from operational to abstract suggests the term "vertical hierarchy" of concepts, applied to this approach. In order to facilitate this development and make the hierarchy comprehensive, development can also take place from the abstract ("For a given alternating current, the flux linkage in a coil is approximately proportional to the square of the number of turns of wire in the coil"), to the operational concept ("There are two kinds of current, a-c and d-c").

The next step in this approach to training content is to define and apply specific criteria for selecting the most appropriate of these concepts. The content for training should include concepts which utilize only certain critical criteria of association, criteria based mainly on a combination of training value and operational utility. See the criteria for symbol selection in Miller and Van Cott (1955).

In applying some subjective criteria of relevance while developing this approach, it was seen that if specific criteria for desirable training concepts were established <u>before</u> derivation of the vertical hierarchy, one might use only those criteria in deriving the hierarchy, thereby avoiding the derivation of concepts which would later be eliminated.

Because of this latter consideration, the vertical hierarchy approach was considered uneconomical in several aspects and a modification, the <u>direct relevance approach</u>, was proposed.

In the direct relevance approach, the selection process is so combined with the derivation process that all concepts resulting from the derivation would be included in core training, instead of deriving a universe of concepts, only some of which would be selected for core training. The direct relevance approach is parallel to one part of the vertical hierarchy approach, in that the operational concepts are gradually abstracted and built up into the desirable superordinate concepts. However, these superordinate concepts are limited to those which meet certain specific criteria of relevance established ahead of time.

First, a series of analysis methods was designed to locate sources of job relevant concepts, using the same information as for the vertical hierarchy approach, i.e., prime equipment, tools, job instructions, etc. See Peterson, Folley, and Ostrich (1956).

A fifth method of analysis was designed to study somewhat more microscopically the actual operations and behaviors performed by technicians in the positions (Miller & Van Cott, 1955; Van Cott, Berkun, & Purifoy, 1955). This breakdown of tasks into behaviors often facilitated the determination of skills and knowledges necessary to carry out, first, the behaviors and ultimately, the entire task.

The results of these several analyses were essentially a summary of sources of concepts desirable in core training, rather than the concepts themselves. The appropriate levels of abstraction, association, or organization still had to be determined, and the corresponding superordinate concepts derived or proposed. The determination of the appropriate level for such concepts was a function of the following criteria. See Miller and Van Cott (1955) for an earlier study of this area.

A core training concept must be tied down to job operations in stimulus and/or response. Thus, the concept "Equipment should never be damaged" has no operational utility since it specifies no actual responses and specifies stimuli only in a general sense. "Selector switches must not be rotated beyond their first or last positions," however, clearly includes both stimuli (switches) and responses (rotating between first and last positions). Sometimes a concept having only a stimulus or response is useful, i.e., it might be useful to know there are three different kinds of selector switches. The rationale for this criterion of relevance is that the fewer the steps a technician has to take between learning a concept and applying it to his job, the more useful it will be.

A core training concept should not generalize to situations outside of those which he will encounter in the related positions. If the concept includes more situations than those specified, it may introduce irrelevant associations and interfere with desired associations. If it does not generalize to as many job situations as possible, an opportunity to apply the concept may be missed.

Core training concepts should be compatible both with other core training concepts and with concepts from previous experience in order to reduce or prohibit interference effects during learning and remembering, while promoting associative effects.

Some core training concepts will be included only because they will help the trainees to learn or to remember other content.

Below is a sample application of these criteria to the concept "After using a multimeter, the meter should be set to the highest voltage level," considered desirable for training by one of the two approaches above.

1. The concept is tied to both stimulus and response, and so meets the first criterion.

2. It does not generalize sufficiently to include similar results obtained with other test equipment. If all test equipment is included, the response cannot be so simply stated as "setting to the highest scale." A more general choice would be "A test equipment control should always be left so it is least susceptible to damage if it is used without first making the proper settings." This requires that the technician know what will damage the equipment and seems removed from the appropriate response requirements.

3. The general statement above is compatible with another concept of what actions will damage the test equipment.

4. The inclusion in the concept of the idea that poor practice results in damage may motivate learning good practice.

5. Therefore, the concept is tentatively included, as last stated.

It is obvious that one difficulty of this method of content derivation is that the development of the appropriate superordinate concept presupposes simultaneous knowledge of all future training course content. This broad knowledge can be partly systematized by a method defined earlier in this study (Miller & Van Cott, 1955; Van Cott, Berkun, & Purifoy, 1955). It is also taken care of by an iterative process described below.

An operational concept sometimes suggests a series of superordinate concepts, and it is not immediately possible to screen out all inappropriate ones by applying the criteria of relevance. Two alternatives are possible: (a) propose temporarily all content or concepts which seem appropriate and cannot immediately be screened out, or (b) propose temporarily only the lowest, most operational level of concepts. The latter is probably best, for greater job relevance and least undesirable abstraction.

After deriving what appears to be comprehensive training content in this fashion, a second examination of the proposed training content should be made, especially for the addition of superordinate concepts according to the fourth criterion above. This second go-around reduces somewhat the need to know all possible sources of content and to remember all concepts after they are proposed, since there is a second chance for re-examination. Thus, concepts proposed in the first stage, common except for range of situations covered, would be reconciled the second time. Review of the first stage results might indicate incompatible concepts, etc.

Recommendations

The final product of the direct relevance approach is a long list of concepts to be included in core training. During the study it appeared to be more economical to move from the lower operational concepts upward to the superordinate than vice versa, using the direct relevance approach. The results appeared equivalent, if not superior, to those of the more comprehensive vertical hierarchy method.

Special Features

Two appendices contain additional samples of concept derivation by both approaches.

Comments

A parallel technique to stimulus-response identity is symbol-mediated similarity, discussed but not investigated fully in the series of reports: Development of core training for F-86D electronic maintenance positions, Lowry Air Force Base, Colo: Air Force Personnel and Training Research Center, June 1956. (Maintenance Laboratory Technical Memoranda 56-1, 2, 3, 4)

See Peterson, Jones, and Ellis (1957) for a review of the entire project and the role of this technique in the total study.

Peterson, R. O., Jones, Edna M., & Ellis, D. S. Core training for electronic maintenance: Principles and techniques. Lowry Air Force Base, Colo: Air Force Personnel and Training Research Center, November, 1957. (Maintenance Laboratory Technical Memorandum 57-2) (Project No. 7729, Task No. 37300, Contract No. AF 18(600)-1351)

Purpose

The purpose of this project was to develop training which would facilitate later training within and between electronic maintenance positions on the F-86D and F-102A systems. The approach developed here was that of core training, although the training content derived might be equally applicable to inclusion in specialized courses for each position, designed to facilitate eventual cross-training. The initial training developed here differs radically in content and conception from fundamentals training in that it is derived from an analytic study of anticipated on-the-job maintenance activities.

This report, in addition to reviewing the entire project, describes the methods and techniques which emerged from this development work. They are a major product of the study and should have general applicability for training derivation. More detailed discussions of individual methodologies are presented in Peterson (1956) and Miller and Van Cott (1955). More general reviews of the project are given in Westen and Peterson (1958) and Peterson, Folley, and Ostrich (1956), which are not abstracted.

Scheduling or Phasing

This study was performed on one operational system (F-86D) and one which was not yet operational (F-102A). The methods used should be equally applicable to equipments in earlier development stages, although the recommendations would naturally be subject to review.

Rationale and Summary of Method

The initial step was to enumerate all maintenance tasks for each electronic maintenance position. Concurrently, information was obtained on the complete details of operations performed, the tools used and their purposes, the facilitating equipment used, test equipment used, and job objects, symbols, and processes to be identified.

This information was obtained from Technical Orders, field observations, and interviews for the operational F-86D. QPR information and observations of system suitability tests supplemented T.O.'s for the F-102A system. All of the task activity data was expanded and developed to the subtask level.

The subtasks were not further broken down to the behavioral level. (That is, such a breakdown was apparently tried and later abandoned. See Peterson, Folley, & Ostrich, 1956.) Ideally, the transition from systematized task information to final core training content would follow three steps: the description of maintenance tasks in behavioral terms having definite implications for the skills and knowledges required; comparison of these implied skills and knowledges to identify those common to the jobs being considered; and development and organization of training situations appropriate for learning these core skills and knowledges. While tasks such as "detecting a blown fuse" and "noting dangerously frayed insulation" could be classed as discriminations, it was felt that little could be inferred from this fact as to skills and knowledges common to the two tasks. Even more difficulty was anticipated in comparing behaviors of different classes, as discriminations and manipulations. Because of these difficulties of behavioral description, a less systematic but workable method was adopted.

Derivation of core knowledges and skills by-passed behavioral description by starting with a direct comparison of subtask descriptions, grouped according to the maintenance classes of checking, inspecting, troubleshooting, servicing, replacing, repairing, and the preparatory and closing phases of maintenance work, and compared within classes.

In comparing the tasks, common maintenance activities, with an emphasis on activities that were not dependent on equipment specifics, were sought. Tasks related to common tools and test equipments were also included. The common units of activity identified ranged in complexity over a broad scale.

Once the units of activity were identified, the skills and knowledges required were spelled out. To thoroughly develop the job-oriented skills and knowledges, the task descriptions obtained above were supplemented with information obtained by the following techniques:

1. Analysis of job objects. Tools, test equipment, auxiliary equipment and materials used were analysed to identify special skills and knowledges required in their use.

2. Analysis of job instructions. Terms, processes, etc., which were ambiguous or assumed particular knowledge on the part of the user were identified.

3. Analysis of precautions. Precautions for task performance were reviewed and implied knowledges identified as well as the precautions themselves.

4. Analysis of job tricks. Job instructions or observation revealed tips for facilitating work, anticipating job cues, etc., in unique ways, the knowledge of some of these being required for task performance.

The presentation of the derived skills and knowledges is illustrated in Figure 1, taken from a group of samples in the report. The first column lists the units of maintenance activity from which the skills and knowledges were derived. The second column, Training Situations, presents effective ways of training the required skills. This column might have been called Core Skills, except that it is difficult to identify skills meaningfully without reference to the training situation which can produce them. Note that verbal explanation alone is never recommended as the only training procedure, and that all situations call for practice of skills in a job-like situation. Special devices may be recommended. The Associated Knowledges of the third column are those necessary to support the skills in column 2. Many of these are rules, principles, or conditions of performance; others are straightforward knowledge descriptions. See Van Cott, Berkun, and Purifoy (1955) and Miller and Van Cott (1955) for a technique of skill and knowledge derivation used at this point for some of the tasks.

While the preceding methodology identified the "operational knowledges," general knowledges which would support a variety of activities or aid in learning and remembering the operational knowledges remained to be determined. As described in Peterson (1956) these "superordinate" concepts or knowledges were derived by the application of four criteria of relevance and the stimulus-identity technique. The four criteria are (a) the fewer steps intervening between a knowledge and its application, the better; (b) knowledges need generalize only to the situations encountered throughout the maintenance positions to be trained; (c) knowledges should be compatible with other core knowledges and those from previous experience; and (d) some knowledges can be admitted to training content because they facilitate learning and recall. In this instance the abstract knowledges were derived by working up from the operational job-oriented knowledges.

An alternative procedure is to start with general areas of knowledge suggested not by the maintenance activities but by the kind of equipment and physical principles involved. This is called here the equipment-oriented approach, and was attempted. However, this technique was not so successful in generating knowledges which met the four criteria.

Unit of Maintenance Activity	Training Situation	Operational Knowledges
Checking		
a. Reading dials and indicators.	Practice in reading values from various types of dials and indicators.	Read indicators directly from the front.
Servicing		
a. Removing rust or corrosion.	Practice in cleaning rusted or corroded parts.	Solvent may be tried first. If not effective, fine sandpaper may be used. Never use emery cloth or steel wool since these may cut through metal surfaces or otherwise mar equipment.

Figure 1. Examples of Knowledges and Skills Identified from Comparing Task Descriptions

The remainder of the report reviews the organization, content, and characteristics recommended for the core course. It is very interesting and certainly related sequence, but is omitted here, since it is less relevant to the present survey.

Recommendations

Two aspects of the core training development can be questioned:

1. Is initial maintenance training the most effective situation in which to teach core skills and knowledges? It was felt that this content could be taught just as effectively as part of specific position training.

2. Did the core training derivation miss critical knowledges and skills for electronic maintenance? By emphasizing common activity units, common behaviors in different-appearing activity units may have been missed. Further, the requirement that knowledges be closely linked to activities and specific stimuli and responses may have eliminated some critical knowledges by too strict interpretation. However, further study is required before exact areas of weakness in this methodology can be determined.

Ray, J. T., Passey, G. E., Adams, O. S., Smader, R. C., & Simon, G. B. Preparation of position-task-equipment analysis for weapon systems. Introduction. Marietta, Georgia: Lockheed Aircraft Corp., April 1957. (Air Force Personnel and Training Research Center Contract No. 41(657)-67)(a)

Purpose

This abstract covers Chapter IV, The Position-Task-Equipment Analysis, of the document above. (See Comments.) The purpose of this analysis is to apportion the total maintenance requirement to specific maintenance positions on a rational basis. The analysis proceeds from the assignment of skill levels to tasks to and through the development of manning requirements.

Rationale

This procedure takes as the starting point the nonposition-oriented task descriptions resulting from the preceding task analysis. It is assumed, according to that analysis, that the maintenance workload was defined for each echelon or maintenance level by AFR 66-1, and that the analysis data were therefore for a specific level (organization, field, depot). Two considerations basic to this procedure are that it will use system utilization potential as the general criterion for determining position, and "turn-around-time" available for organizational maintenance as a corollary criterion. There criteria inherently involve consideration of manning requirements.

Scheduling

The "position-task-equipment analysis" comes after the "task analysis" described in this and Ray, Passey, Adams, Smader, & Simon (1957b), since it depends on specific data resulting from the task analysis.

Summary of Method

The first step is a tentative assignment of position title by major equipment system simply by adding a title such as "mechanic" or "repairman" to the major equipment system, i.e., "Hydraulic Repairman Position."

Each task should be assigned a level of skill requirement, noted as I, II, or III levels (see Comments; Ghiselli & Brown, 1955). The task skill levels should then be collated by major equipment systems, indicating the number of skill levels required for each system or tentative position.

Next, each task listed under a major equipment system should be reviewed and related to the pertinent AFSC, where the required AFSC exists.

At this point, the task skill levels and related AFSC's should be reviewed with ARDC, Hq. USAF, the using command, and ATC for confirmation and a decision as to whether new tasks will be incorporated into current, expanded AFS's, or will be combined into new AFS's. (See Comments.) The resulting AFSC's should be collated by major equipment subsystem.

The data so far developed represents the organization of the total maintenance requirement and represents the essence of a "position-task-equipment analysis report."

Apportionment of the maintenance tasks to echelons (field, depot, etc.) must be done before apportionment of tasks within echelons. This procedure presumes the accomplishment of such apportionment to echelons in the task analysis procedure preceding it in this document. No alternative method of making this allocation is given, for an instance in which that procedure is not used. (The example given in this chapter is done for a single position in the organizational echelon.)

The organizational maintenance times of each of the equipment systems must then be apportioned between the skill levels which have been specified. Going back to the task analysis (Miller, 1956a), this procedure uses the estimated performance times for each task. As a first step in making manning estimates, it is necessary to establish the workload required for the over-all line level maintenance operation during a single "turn-around-time" period. This total man-hour workload consists of (1) constant maintenance time required to perform routine tasks performed each turn-around, and (2) utilization maintenance time, the man-hours required for nonroutine tasks performed at varying time periods depending on the number of flying hours, etc. In a given example, utilization maintenance time may be estimated as a ratio of maintenance hours to flight hours. (Note: The statistical processes and formulae are omitted in this abstract.) The mean and standard deviation of the variable utilization maintenance times are used to describe their distribution over several turn-around periods. (See Comments.)

The desired turn-around-time for the weapon system may be determined as a fixed quantity for the moment. Therefore, the length of time required for maintenance will affect the number of aircraft required to maintain operational strength.

The time required for a given position workload may be derived as a function of the level of confidence with which a specified time is expected to be adequate for performing all necessary position maintenance tasks during a turn-around period. Solving an algebraic relationship, a position maintenance workload is estimated for a given turn-around period for a given skill level specified for a given major equipment system, using as inputs the estimated performance times for tasks within the major equipment subsystem rated at the chosen skill level.

The potential utilization time of a system is a function of the daily pre- and post-flight check times, direct maintenance time, and loading, unloading, and refueling times. Algebraic relationships for solution of potential utilization time are given.

Before position maintenance workload can be related to manning requirements, it must be considered in relation to the time in which the workload must be accomplished. Dividing the position workload by turn-around-time, the number of people required for that position is given, assuming that all personnel work an equal amount of time.

The next problem is that of assigning personnel to maintenance positions by specialty skill levels.

All component systems do not require the same organizational maintenance times. Some system maintenance times may exceed the specified turn-around-time. Therefore, additional personnel may be assigned to the high-load maintenance position, or the workload may be redistributed to other system positions.

To develop a criterion for making this decision, a base for maintenance times must be established to keep all personnel about equally busy during the turn-around period. To obtain this base, each major equipment system must be associated with both the constant and utilization maintenance times, as determined for each skill level for each suggested AFSC of that system.

Having done this, the maintenance man-hours required per system may be reviewed and a base figure selected. In selecting the position skill level to be employed, each inspection and maintenance time must be reviewed to determine the limitations existing for further reduction of the maintenance time by the assignment of additional personnel to each skill level. Following this review, the limitations imposed at each skill level can be specified. The position skill level limitation requiring the greatest maintenance time should be selected as the base maintenance time figure. This value may then be inserted in the formula given to derive the potential utilization time.

Since manning should be done on a squadron basis, the base maintenance time plus a constant amount of time for the incidental nonmaintenance time required by each mechanic for each plane should be multiplied by the number of planes in the squadron. The product will be used as the operating term for determining the manning requirements.

Following the procedure outlined, the squadron will automatically be manned for maximum workload density, where all planes are to be serviced during one turn-around period.

After utilization potential has been determined for the limiting circumstance, manning requirements may be computed for the other position skill levels required by the weapon system.

Comments

This abstract covers only Chapter 4 of the total document, since the rest is essentially duplicated by Ray, Passey, Adams, Smader, and Simon (1957b), of which this document is the preproduction draft. Chapter 4, however, was omitted from the published report.

While this report presents an interesting approach to manning problems, some portions of the procedure seem to provide opportunity for error and are on a much less sytematic level than most of the analysis outlined. The first apparent gap is in the assignment and evaluation of skill levels. The levels are not defined, but the assumption is made that I, II, and III, as applied to tasks, are equivalent to the 7, 5, and 3 AFSC levels for positions. The awarding of these ratings appears to be entirely subjective. One of the potentially most serious problems is the basing of most of the procedures on the estimates of task duration. These data are often very difficult to obtain, thereby weakening the usefulness of a system predicated on them, especially to the extent that it depends on what is called "utilization maintenance time."

It is further felt that insufficient consideration is given to the loading and structure of the individual position, formed simply by grouping tasks identified as the same skill levels together.

Ray, J. T., Passey, G. E., Adams, O. S., Smader, R. C., & Simon, G. B. A technique of job activity description for new weapon systems: task equipment analysis. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1957. (AFPTRC Technical Report 57-13) (Project No. 7735, formerly 7709, Task No. 37306, Contract No. AF 41(657)-67) (b)

Purpose

This report describes a procedure and considerations for the production of "task equipment analyses." The initial phase involved a functional analysis of the weapon system as a whole, and was called equipment analysis (Miller & Folley, 1951a; Miller, Folley, & Smith, 1953a), concerned with equipment subsystems and components. The second phase was an analysis of the system in terms of required maintenance tasks, and was called a task analysis. The purpose of these procedures was to supply a greater detail in task information than frequently was available at the time the preliminary QPRI is required, (see Comments) as a basis for preparing handbooks and training courses.

Rationale

The method of data presentation described here is based on an equipment orientation, with the provision that this might be changed to a duty-type format on completing the analyses, pending identification of the use to which the data is to be put (Jones & Miller, 1956). For derivation of the basic principles, procedures, and techniques, see Comments .

Scheduling or Phasing

This method is intended for use during the design phase (Dice, 1955) and completion during the slow-production phase to permit its use in the preparation of the Final Operational and Training Plans. Also, it comes before the publication of Technical Orders--one of its virtues in providing training information.

Summary of Method

Equipment Analysis. Equipment analysis, as used in this report, is simply the gathering of the minimum equipment data necessary as a basis for the second phase, task analysis. It contains four steps.

1. The analyst must obtain a general orientation to the weapon system. This may be best accomplished by review of military and contractor documents. Military documents include QPRI reports, Development Planning Objectives, General Operational Requirements, Development Plans and Directions, and Preliminary Operational Concept and Plan (Dice, 1955). Contractor documents include prime and subcontractor plans and specifications and slow production hardware specifications (Miller, Meister, & Feroglia, 1955).

2. A functional outline of the weapon system, component systems, and subsystems is constructed. Its component system headings are of the type "Hydraulic Systems," "Instrument and Auto-pilot Systems," etc.

3. Narrative operating descriptions of each subsystem listed above are prepared, indicating the articulation of the principal components and items of equipment.

4. A checklist may then be prepared as a guide to obtaining data on the essential characteristics of equipment components, operation requirements, and maintenance requirements. Sample checklist items, more fully described in the report are:

   External Conditions and Equipment Deterioration; precautions, foreign materials, vibration effects, and exterior surfaces.

   Tools and Instruments; specialized tools, inspection instruments, functional test equipment, ground handling equipment, and jacking, hoisting, towing, and leveling instructions.

   Components--Location, Relations, Functions; interchangeability requirements, size, weight, and ease of maintenance, balancing of parts, magnetic effects, interaction of component functions, and quick-disconnect features.

   Accessibility; location and size of access openings, accessibility of electrical power and electronic panels, need for removal of intermediate parts.

Specifications Tolerances, Special Instructions and Requirements; lubricants, specifications, flight test requirements, technical data, training aid requirements, index for adjustment controls.

Safety Features; hazards, protective equipment, group handling procedures.

Task Analysis. Task analysis, as defined in this report, depends specifically on data from the QPRI report containing position descriptions and lists of tasks, and on AFR 66-1, defining the maintenance concept. Task analysis, as conceived here, includes steps 5 through 10 of the total procedure.

5. Starting with the tasks from the QPRI, the applicability of the seven principal maintenance duties (inspecting, checking, adjusting, replacing, servicing, repairing, and troubleshooting) (Miller, Folley, & Smith, 1953a) to each subsystem and component must be determined. Also, each duty must be judged for its applicability to the level of maintenance under consideration (Miller, 1956a) and stated by combining the duty and equipment item: "Replace the Starter." This step may be checked for completeness by using the checklist developed in step 4 and a matrix chart of subsystems versus the seven maintenance duties.

6. Distinguish between standard (SOP) and new tasks. See Miller (1956a) for an earlier definition of this area and comments on points made here. If the task involves an equipment unit identical to one in inventory, the task may be judged identical or similar to one performed on another weapon system and should be indicated SOP. If the task elements are common to those for an existing system but refer to new components where transition can be effected without additional training, the tasks may be called similar. The task should be labeled SOP and appropriately referenced.

   When new equipment is similar to, but not identical with current equipment, or when new procedures are developed for existing equipment in a new system, the analyst must either use a simple reference for the task in the existing system or supply additional information appropriate to the anticipated changes. A set criteria is recommended,reflecting the changes, to aid the decision. The criteria suggested are functional test procedures, damage precautions, safety regulations, mating operations, handling, interference problems, related equipment operations, alignment specifications, replacement or repair requirements, sequence of task elements (Miller, Folley, & Smith, 1954), inspection requirements, and personnel coordination requirements.

Another suggested set of criteria for "newness" of tasks includes:

a. Basic skills not found in the present service inventory.

b. A higher degree of specialization than is commonly found among present maintenance personnel.

c. Greater familiarization with related systems than normally found.

d. New interpretation of instrument indication.

e. Modification of old, or institution of new observation methods.

f. Development of alternate methods of repair and maintenance.

g. Transfer of maintenance responsibility to a new level (organization to field).

7. Outline the procedure for performing each "new" task. Every distinct action involved constitutes a task step or element (Miller, 1956a). Each element contains an action word (see sample list suggested in Miller, 1956a), a physical object, an indication, an indicator, and possibly, precautions, along with any special tools or test equipment used. Activity statements and precautions should be given in behavioral terms (Miller, Folley, & Smith, 1953a), and each must indicate what the man does to the system.

8. In order to use this task analysis for direct training and handbooks, the presentation of the data should be illustrated (Jones & Miller, 1956), and the illustrations should be task oriented, rather than equipment oriented. All non-SOP tasks should be illustrated. Equipment item size should be indicated. Further format and layout suggestions are included here.

9. Troubleshooting duties and tasks are described separately. Troubleshooting information is developed during the design stage by identifying all possible malfunctions for each

component. This information should be illustrated by data flow diagrams (Miller & Folley, 1951a). The troubleshooting approach should follow a systematic procedure using these diagrams, as the half-split technique (Miller, Folley, & Smith, 1953b; Miller, Folley, & Smith, 1953g), a probability approach, a probability-time approach, or a straight equipment sequence. Information should be arranged by functional systems and loops and activity should proceed by these systems. Symptom-cause information should be provided, primarily to supplement the systematic procedure (Miller, Folley, & Smith, 1953a).

10. The results of these procedures should be organized into documents for use in training (Jones & Miller, 1956; Peterson, Jones, & Ellis, 1957). Several systems of organization of the position information are suggested; by equipment system, or by duty headings, depending on the end purpose.

Comments

This document discusses the presentation of what is basically detailed QPRI data for use in preparing training course content and handbooks. However, very little, if any, rationale is described. It appears that the procedure described here is largely based on various earlier documents referenced in this abstract, and the procedure itself has relatively little new to offer beyond a rearrangement or restatement of earlier methods.

It should be noted that while this technique has in total, been termed task equipment analysis, it differs from what is generally understood by that term, principally in phasing. The method described, except for its basis on tasks as established by QPRI, is generally similar to what is presently known as TEA, on which QPRI is based. The phasing and application suggested in this document more closely resembles the aim of a "training functions analysis," although the rationale and procedure do not support this extension.

See Ray, Passey, Addams, Smader, & Simon (1957a), the prepublication draft of this report which includes a procedure for the determination of manning and skill level requirements, based on the procedures described above. This latter discussion was omitted from this final published report.

Stackfleth, D. Summary notes on status of QPRI program, prepared at closing of Air Force Personnel and Training Research Center Maintenance Laboratory. Lackland Air Force Base, Texas: Informal personal notes, 1958.

Purpose

This informal memo summarizes then-current procedures for preparing occupational information (QPRI) reports. It reviews four areas: format and editorial considerations; position description methodology; training equipment development; and definition of skill areas.

"As established in AFR 54-7, Occupational Information reports are development reports that provide preliminary estimates of the manning and organization of personnel needed for new weapon systems. This information is utilized by Headquarters USAF in determining the qualitative personnel requirements and guidance subsequently released in Personnel Planning Letters by that Headquarters. Although the Occupational Information Report is not directive in nature, it must provide personnel-oriented data that are as accurate as possible (at a specified point in time) so that personnel plans based thereon may provide for sufficient numbers of men with the requisite aptitude and training to operate and maintain the weapon system in the operational situation."

Conclusions

Report Format and Editorial Considerations. The Occupational Information Report follows the outline below. The report should only cover information relevant to the planned operational system, and include as little proprietary information as possible. The editorial style should follow APA order I, II, and III headings. Chapters should not be necessary. All detailed data should be reviewed in lettered appendices.

I. Introduction: Statement of report content, information sources, when and why the forecast was made, and the methodology used. The period in the development or operational "life" of the system to which the report data applies should be stated. The mission description should be brief, referring to more detailed documents.

II. Equipment Description (brief).

III. Assumptions; Operational (mission profiles), Maintenance (site and policies), and Logistics (level of maintenance and location). The description of anticipated ground support should cover by narrative, functional diagrams, charts, and photographs, the names and functions of the ground support equipment, the geographical locations and sequences of functions, and alternate ground support possibilities.

IV. Position Descriptions and Manpower Organization. Operation and maintenance requirements contingencies. Rationale for task groupings; manning estimates.

V. Discussion of New and Critical Tasks. Estimates should be made of the following types of qualifications required by the new positions or position components; knowledge of math, special psychomotor skills, special characteristics, and special courses. The resemblance between the new position and the older counterpart should be identified. Each standard task definition should include in tabular form, items a and j; descriptions of revised tasks should include items a, b, c, and f; descriptions of new tasks should include all items.

a. The specific human function, related to its goal, i.e., "adjusts gain to achieve maximum contrast."

b. Identification of equipment unit involved.

c. Features of the equipment.

d. Illustration of the subsystem at its current stage of development.

e. The skill area, and fixed or variable nature.

f. "Newness" of the task, rated (1) standard task, (2) revised task, (3) new task.

VI. Training Problems and Training Equipment Characteristics.

VII. Conclusions and Recommendations. Special problems, the rationale for their inclusion and suggested solutions.

VIII. References (APA style).

IX. Appendices. Position descriptions should all be in one appendix with positions in the same order as in the Manpower Organization Table in the report text.

X. Distribution List.

Position Description Methodology. The position description follows the format and content below.

I. General Features. Where the job is performed, what is done, and what equipment is used. See format in AFM 35-1.

II. Duties and Tasks. (The basic data from which occupational information is derived.) Tasks are rated for "difficulty," denoting training complexity: (a) common task related to common equipment, (b) revised tasks related to reconfigured equipment, and (c) new tasks related to new equipment. The tasks are identified to given positions and define the positions. The task is then defined--common tasks by word or phrase, revised tasks by a sentence or two, and new tasks in detail. Hypothetical manning estimates are given for each task.

III. General Comparison of Similarities to Existing Positions.

IV. Estimates of Personnel Qualification Requirements for Initial and Transition Training.

Training Equipment Development, discussed in Section VI of the report outline. In order to make recommendations in this area, first the critical (new) tasks are identified along with the critical skills and knowledges of those tasks. Then the student population (pipeline and transitioned) is assessed and defined. Recommendations are made for training equipment on the level of proficiency it should be used for, the kind of training to be supported, the phase of training in which it will be used, and available descriptions of anticipated training context, program or situation.

Definition of Skill Areas, covered in Section V of the report. Skills may be categorized as "fixed" or "variable procedure." They may be identified by systems or circuit analysis.

Special Features

This document contains definitions and examples of a Task Inventory, Hypothetical Manning List (from AFM 35-1), and a Training Devices Information Data Sheet.

Comments

The memo is intended to summarize then-current usage at AFPTRC, and does not present new ideas. The illustrations and examples are from other documents.

See the ARDC Reference Manual for QPRI (1958) for later development of this area.

Thorndike, R. L., Hagen, Elizabeth P., Orr, D. B., & Rosner, B. An empirical approach to the determination of Air Force job families. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, August 1957. (AFPTRC Technical Report 57-5)

Purpose

This study suggests a technique for assessing job requirements and grouping jobs into homogenous families. Such a technique would be applicable to the classification of airmen, and assignment to Air Force Specialties.

Summary of Method

The study consisted of three sections:

1. Identification of a set of basic dimensions by which a job can be defined.

2. Development of a procedure for determining a job's content in terms of these dimensions.

3. Application of this procedure to sample Air Force jobs, determination of job profiles, and examination of these profiles for job family clusters.

A Job Activities Blank was developed by "applying general logic of achievement test construction to the problem of appraising job requirements. This logic involves three steps":

1. Selection of sample items representing a domain of achievement, such as chemistry.

2. Performance of an item analysis to eliminate unsatisfactory items of inappropriate difficulty or low correlation with other items.

3. Evaluation of achievement by counting the items on the test answered correctly (possibly including an adjustment for presumed "guessing").

As applied to an appraisal of job requirements, these steps were modified. The following job activity analysis procedures resulted:

1. In selecting sample activity items to represent each achievement domain or dimensions, an attempt was made to fairly represent both the content and difficulty of each dimension.

2. Lists of sample items of several dimensions were checked by airmen of various specialties for the following:

   a. Never do it.

   b. Seldom do it: not more than once a week on the average.

   c. Occasionally do it: four or five times a week on the average.

   d. Do it often: four or five times a day on the average.

   e. Do it very often: more than five times a day on the average.

   In the statistical analysis, "b" and "c" and "d" and "e" were combined.

3. An item analysis was performed, correlating each item with the total score for its own dimension scale, and with the total score of each of the other dimension scales.

4. Each item was retained in its particular dimension scale only if there were substantial correlation with that scale, and an appreciably lower correlation with the other scales.

5. The scales were then revised and analysed again. The complete statistical procedures are included in the report.

The item analysis resulted in a total of 219 activity items and 14 dimension scales. These dimensions are listed briefly below.

1. Social-verbal. Verbal fluency and temperamental qualities useful in dealing with people. Most of the items were verbal, as making an oral report, writing a memo, etc.

2. Managerial ability. Skills of handling people, such as in assigning jobs, checking, deciding, evaluating, etc.

3. Clerical accuracy. Clerical detail, as in maintaining supply records.

4. Reasoning. Mainly inductive problem-solving, as deciding to "go by the book," or modify procedures.

5. Concentration amidst distractions. Working in a noisy environment.

6. Arithmetic computation. Use of a slide rule.

7. Mechanical ability. Oil, adjust, etc.

8. Interpreting spatial relations. Estimating speed of a moving object.

9. Strength. Principally strength, but also endurance, as in running 100 yards, or prolonged manual work with arms extended over head.

10. Speed. Working against a deadline.

11. Foot-hand coordination. Driving a heavy truck.

12. Work under hazardous conditions. Also, working in an unpleasant environment, as working out of doors in all kinds of weather.

13. Manual dexterity. Adjusting equipment to close tolerances.

14. Equipment accuracy. A general accuracy scale for tasks like setting a signal up so it is exactly horizontal or vertical.

Results

A dimensions matrix of 13 dimensions was factored. (The equipment accuracy dimension had a .98 correlation with manual dexterity when corrected for attenuation, and was discarded.) Scoring of the job requirements was based on a summation of item responses. Each job was represented by a point (its score) on a matrix based on factor scores of the AFSC's used in the study. Each job family was defined by the most compact cluster of job points on the matrix.

Special Feature

The report draws a comparison between this study and its predecessor, reported by Norris (1956). The Norris study attempted to identify job requirements from a factor analysis of ratings of aspects of the job requirements. The following differences exist between the two approaches:

1. In the earlier study, the basic data were ratings. Here they were activities performed.

2. Norris emphasized rating job elements on their importance. This study rated job elements on frequency of performance, a measure intended to be an approximation of "importance," and easier to measure.

3. The earlier study used specially trained psychologists as its raters. This study used enlisted job incumbents. (The high correlation among attributes may relfect a halo effect in responses by the untrained personnel.)

4. Norris used standard job descriptions as the basic data source for his ratings. This study used the specific, actual jobs as practiced.

5. The dimensions used in the two studies differed.

Conclusions

The method was not satisfactory. Some of the reasons were:

1. The rationale for the rating was that a sample should be selected representing an area of job demand, and the demand made should be appraised by a rating score based on the number of items rated as done, and their frequency. In a suitable sample, the items should not be too specialized. However, in this study, the scales were based on too small sample, and the items ranged from general to specific.

2. Much of the incisiveness of the analysis was lost, as several of the dimensions were found to be highly correlated.

3. The dimensions, such as reasoning, do overlap, in spite of the fact that they were selected on the basis of a factor analysis.

Van Cott, H. P., Berkun, M. M., & Purifoy, G. R., Jr. How to determine job knowledge content. The application of a procedure to several Air Force jobs. Pittsburgh: American Institute for Research, December 1955. (Project No. 7714, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205)

Purpose

The purpose of this document is to provide examples of the application of the technique described in Miller and Van Cott (1955) for the determination of job knowledge content.

Summary of Method

The rationale for the method is developed in Miller and Van Cott (1955), including a more complete description of the entries for the format in Figure 1. That document should be referred to in conjunction with this abstract. One of the nine sample applications is given here, to illustrate the method. This procedure takes as its input, task analyses prepared as described in Miller (1956a). Each task or subtask is reviewed with the checklist in Miller and Van Cott (1955), and those meeting one of the criteria of the checklist are entered on the format of Figure 1. The sample below begins at that point.

Problem Stimulus	Identifying Condition for Conceptual Support	Conceptual Support(s)	Required Response(s)
Need to land	Decision making is needed	(Product of derivation)	Make landing without cutting helicopter tires or causing undue vibration to helicopter from taxiing on rough field.

Figure 1. Sample Job Knowledge Format

Example 1: Conceptual Content for Decision Making

A helicopter pilot approaches an unfamiliar landing field, He must decide whether or not he can land and, if he can, whether to make a vertical descent or a near horizontal approach or flare. In either case his goal is to bring the helicopter to a landing.

If conditions permit a landing, two alternative approaches to the goal can be made (e.g., the vertical or horizontal approaches). The selection of the appropriate alternative will depend on the environmental conditions which exist at the time the landing is to be made and the accuracy with which the pilot is able to estimate them. They will also depend on any qualitative or quantitative critera which must be met in achieving the goal.

For the purpose of this example, it is assumed that the two goal approaches and the program conditions are exhaustive of all of the ways in which the pilot can land a helicopter and of all of the conditions which may affect a landing. Additional factors required to make this example technically complete would not alter the way in which the method is used.

JOB KNOWLEDGE ANALYSIS

STEPS	INFORMATION	NOTES
1	(See Figure 1)	The analyst prepares a format similar to Figure 1.
2	Alternative strategies or approaches to the goal of landing the helicopter: a. A vertical descent may be made. This consists of a slow, near or completely vertical settling of the helicopter, either under power or in autorotation. b. Near horizontal flare may be made. This type of landing consists of a forward horizontal movement of the helicopter parallel to the landing surface during the drop.	The analyst, with the help of an expert, lists the number of different alternative courses of action which may be adopted in effecting a landing. For practical purposes the listing of the two basic approach patterns suffices, we can assume some arbitrary point separates the vertical from the horizontal attack.

STEPS	INFORMATION	NOTES
3	Program conditions affecting helicopter landing. a. Length of landing path 1) Longer than 150 feet (L) 2) Shorter than 150 feet (S) b. Roughness of landing surface 1) Rough field containing ice croppings, stones, cinders, or other jagged edges. (R) 2) Flat field with smooth runway surface (F) c. Tilt of field 1) Tilted more than 20° (T) 2) Titled less than 20° (N)	All of the conditions which would affect the landing of a helicopter are listed. If, for example, one of the criteria of goal achievement is that a precaution be taken against cutting the tires or jarring injured passengers or delicate cargo, then the roughness of the surface of the field must be included as a relevant program condition.
4	Determine the combinations of program variables likely to occur. The eight combinations of programs are presented in a row near the top of Fig. 2. All will occur with significant frequency.	In Step 3, each value of a program variable is assigned a code letter. Each combination listed in Step 4 is then identified by the appropriate group of letters.
5	Determine the operating limitations of the system. a. In a horizontal flare landing the helicopter cannot be stopped in less than 150 feet of taxiing. b. Taxiing over rough surface will cut the tires and jar the cargo. c. A tilt of more than 20° will permit the rotor blades to strike the ground.	The physical conditions that limit the landing of a helicopter are listed here. These limitations, when considered together with the coded combinations in Step 4, will determine the goal approach to be followed.
6	For each combination of program variables, indicate the goal approach or approaches which can be taken. a. Any path less than 150 feet requires a vertical descent. b. Roughness of the surface requires a vertical descent.	The combinations of these are presented in Fig. 2, where the permitted response for each of the eight possible conditions is given.

STEPS	INFORMATION	NOTES
6 (cont.)	c. A tilt of greater than 20° prevents any descent, and requires further search.	
7	For each set of program variables, state the information which the operator must have to select or perform the appropriate goal response.	This information is given in Step 6 above.
8	List the alternative ways of stating the minimal information needed to make the appropriate decision. These sentences summarize the essential information. a. If tilt is greater than 20° pilot must continue search for landing site. b. If field is less than 150 feet long he must descend vertically. c. If tilt of field and length permit horizontal flared landing, then ground must present a smooth surface.	Fig. 2 presents the development of the conditions under which each of the three permitted responses is appropriate.

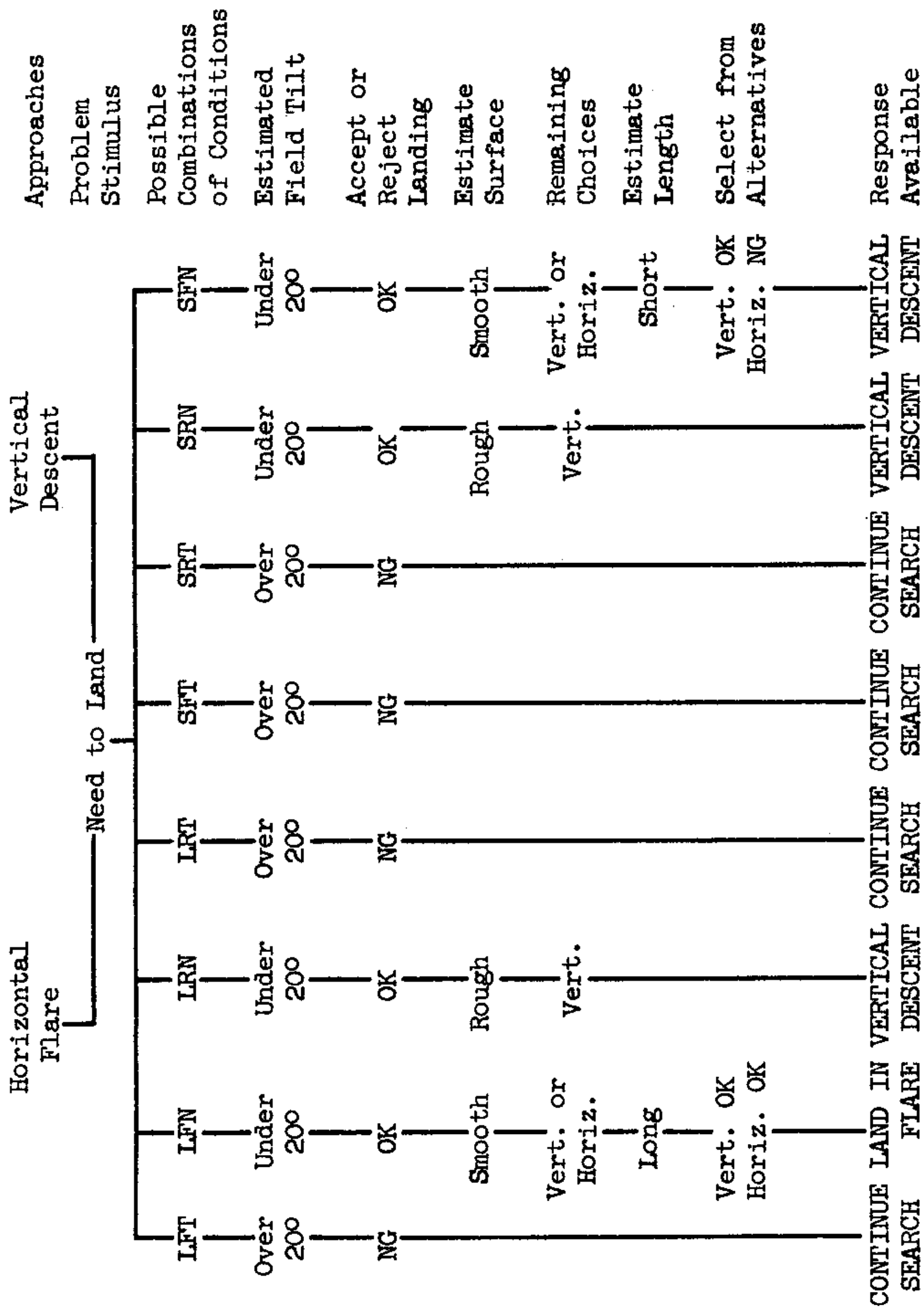

Figure 2. The Eight Combinations of Program Conditions to Be Considered by a Helicopter Pilot About to Land

Warren, N. D., Wolbers, H. L., Atkins, D. W., Darrow, J. L., Goedinghaus, C. H., Mahoney, H. G., & Piatt, D. M. (UNCLASSIFIED title) Research on aircraft observer training procedures: Part II. An analysis of the activities in the task of the K-system observer. Lackland Air Force Base, Texas: Human Resources Research Center, December 1953. (HRRC Technical Report 53-37) (Project No. 506-005-0001, Contract No. AF 18(600)-399)(CONFIDENTIAL report)

Note: This abstract omits reference to classified system information, and is not classified.

Purpose

For selection, classification, and evaluation of training procedures, a job description of the K-system operator was desired. An earlier report analysed the job from the standpoint of the equipment involved. This report considers the activities in which the operator is engaged, an analysis of the time spent in these activities, and a discussion of their importance. See Christensen (1949) for early work in this area and for the original development and application of this general type of "activity analysis."

Procedure

Two types of procedures are of special interest here. The first is the data collection procedure, a derivation of Christensen's "activity analysis" technique. The second is a data analysis and presentation technique--"link analysis." The orientation, in this combination of procedures, is toward the links established between the man and the equipment during the completion of the several job tasks. The method is such that measurements are in terms of the frequency with which a given link becomes established. In addition, consideration is given to the amount of time spent in completing various subtasks in the job.

Data gathering was accomplished by means of a tape recorder. The person making the recording started the machine at the beginning of each 45-minute run and as the operator was observed to begin performing a new action, this was entered on the tape. The length of time the tape ran without further comments indicated the length of the activity. When the activity ceased, "Stop" and the name of the next activity were entered on the tape. When more than one activity was performed at once, both activites were named, followed by "Both." The activities observed were categorized into 55 types. On the basis of several trial flights and the opinions of instructors and system operators, this list was reduced to 44 and then to 21. The following reporting activity categories resulted:

1. Rest - includes such sedentary behavior as yawning, stretching, "staring into space," eye-rubbing, slumping in seat, and similar observable behavior in which the apparent purpose is rest or relaxation.

3. Receiver Gain - receiver gain being adjusted.

4. Degree Tilt - degrees tilt being adjusted.

5. Range - range selector being adjusted.

19. Video Gain - video gain being adjusted.

20. Brill Mark - brilliance mark being adjusted.

22. Other-Tuning - includes the adjustment of one or more of the following seldom-used controls located on the radar control unit or the indicator unit: contrast, tuning, manual tuning, power switch, horizontal centering, vertical centering, bias, focus, scale illumination, backlash, sweep delay, sweep amplitude, sector position, sector amplitude, illumination, motor switch, and ring lites. The use of all these controls together accounts for only one to three per cent of the operator's time.

23. Tool Work - one or more of the following tools is being used: dividers, compass, plotter, computers, pencils, erasers.

28. Map Work - maps or charts are being used.

29. Log Work - Air Force navigator's log is being used.

30. Nav - operator adjusts one or more controls and/or is viewing one of the displays provided by the navigation control unit.

31. PPI - operator is watching the PPI presentation.

34. Attitude - attitude correction knob is being used and/or the operator is viewing the altitude display window.

35. Ballistics - one or more control is being adjusted and/or the operator is viewing a display provided by this unit.

40. Tracking - tracking control is being utilized.

44. Instructor - operator-instructor communication occurring.

45. Pilot - operator-pilot communication occurring.

47. Other-Communication - communication between operator and persons other than pilot or instructor occurring.

53. Other - includes behavior not fitting any other category. The operator is active but his behavior may not be primarily job oriented: smoking, oxygen check, eating, etc.

54. Reference - use is being made of reference materials such as TPO's, handbooks, route sheets, turn tables, maintenance manuals, scope or aerial photographs, etc.

60. Tank - operator is viewing trainer presentation indicating accuracy of "bomb release."

One of the original categories, "Operator engaging in in-flight maintenance," was dropped because no such activity was observed.

The limitations of this procedure are that the observer must be very familiar with the operational controls and procedures of the equipment and be well acquainted with the significance of the observable behavior patterns. Also, activities which take less than one second were omitted, because the rate of speech of the observer limits the recording speed at that point.

The determination of the time value attached to each recorded interval was accomplished by playing back the tape at the recording rate and timing the intervals with a stop watch.

The data obtained was analysed and presented both in terms of activities occurring singly and those occurring in combinations of two or more. The link-analysis presentation summarizes the more important aspects of the data contained in several tabular presentations. The 21 reporting activities are represented by circles. Within each is indicated the percentage of time during which this activity occurred as a single activity. The connecting lines between activity circles represent multiple activity bonds. These lines are heavy or light according to the amount of total mission time involving the multiple pair indicated. The percentage of total mission time for each pair is shown adjacent to the connecting line. Percentages less than one per cent of total mission time are omitted for clarity. The relative positions of the various activity circles have no significance.

In addition to this cross-sectional analysis, a further indication of behavior patterns of the operator can be seen in a longitudinal analysis. The advantage of this type of analysis is that it provides an indication of the patterns and sequences of behavior in which the operator engages. Such a logitudinal presentation is illustrated in the report.

Conclusions

A method is presented which facilitates the collection of job information during the operation of highly complex man-equipment systems. The method provides:

1. An inherent time base in the recording system which

    a. yields detailed information concerning the amount of time devoted to observable job elements, and

    b. yields detailed information concerning the amount of time devoted to observable combinations of job elements.

2. A technique for recording the nature of rapidly changing sequences of observable job behavior and the time devoted to these sequences.

3. Limited flexibility in recording the nature of unanticipated observable job behavior and the time devoted to it.

4. Constant observation of job behavior. Behavior is not missed as a result of referring to guide sheets or checklists. Clarifying notes may be made without interrupting observations.

5. Observable job behavior may be simultaneously described and timed over relatively long periods of complex man-equipment operations.

Recommendations were made for the training program based on the following criteria:

1. The amount of total mission time consumed by each activity.

2. The importance of the activity to the successful completion of the system's mission. (This is not necessarily the same as the first criterion.)

3. The difficulty involved in learning the activity.

Comments

While the data gathering approach has limited use during system development, it could be valuable in the observation of other similar operational systems and during prototype evaluation. The link analysis and presentation suggested would certainly be applicable to mock-up studies during development, as well as during prototype evaluation. See Miller (1956b).

It should be noted that the behavior categories used in this analysis are constructed specifically for the system and position involved, and are not of general applicability.

Weislogel, R. L., & Jacobs, T. O. A technique for displaying task analysis information. Kirtland Air Force Base, New Mexico: Air Force Special Weapons Center, March 1956. (AFSWC Technical Note 56-11) (Project No. 7800, Contract No. AF 29(601)-175)

Purpose

The purpose of this study was to develop a method for presenting, in a concise easy to comprehend format, the task analysis data needed to determine:

1. Basic job requirements for piloting a high-speed single-place interceptor aircraft.

2. Additional requirements imposed upon the operator when delivery of a weapon is part of his mission.

The purpose was also to identify segments of the mission which might be "overloaded" with psychological requirements; specifically, visual scanning and discrimination, control manipulation, and decision-making, as a basis for recommendations in equipment design, training course content, and operator error-prone situations.

Rationale

Whether the analysis is called task analysis (Miller, 1953b), equipment analysis (Miller, Folley, & Smith, 1953a), activity analysis, or some parallel term, it consists of a systematic method of listing "demands" made by the machine on the operator, and by the operator on the machine. These demands are enumerated in a hierarchial arrangement, from gross job "segments" to subtask "steps." The resulting volume of data, while necessary, is difficult to handle, hard to recall from page to page, and so bulky that the chain of thought and significance is often lost. This gives rise to the need for a method of displaying the information so it may be easily assimilated and used, without a knowledge of the psychological vernacular.

Summary of the Method

Essentially, the method consists of placing analytical material on top of descriptive material, by means of overlays. The "base-page" of the display consists of columns headed by each of the job segments, each column containing sequential abbreviated statements of the tasks, subtasks, and steps within that segment. A time line at the bottom of the base page indicates the amount of time available for each segment.

It is now possible to superimpose on the job activities the psychological and special manipulative demands made on the operator in accomplishing the sequences of job requirements. Statements of these demands are so placed on the overlays that they will appear in proper alignment with their associated job operations on the base page (preceding or following).

The psychological variables may be color-coded on the overlays. In the sample presented, the base page of standard activities was printed in black. Activities required in operating the fire control system and other activities associated with weapon delivery are shown on two overlay pages; perceptual requirements are listed on one overlay page in red, and control manipulations and decisions (enclosed in boxes) are presented on the other overlay, in green.

This procedure vividly displays the additional load imposed on the pilot as the scope of his job is increased to include weapon delivery.

Testimony to the effectiveness in meeting the needs expressed for such a display is given by the fact that, in one case, 70 pages of task analysis data were presented on a single 16" x 20" display.

Recommendations

The authors were, at the time of publication, attempting to improve the technique as a tool for predicting job segments likely to produce human error, the type of error, and the probable consequence of the error. Others may find the overlay technique useful for quite different purposes.

APPENDIX II

ABSTRACTS

Air Force Personnel and Training Research Center. (UNCLASSIFIED title) MA-2 bombing navigational system QPRI. Lackland Air Force Base, Texas: Author, November 1955. (Technical Memorandum 55-1) (CONFIDENTIAL report)

Purpose. This memorandum presents an early QPRI for the MA-2 bomb-navigation system. In addition to the identification of the positions required, the rationale for the total structure is discussed. The factors considered include the physical and functional characteristics of the hardware, the maintenance concepts, using command practices, economy of training time, skill and knowledge clusters likely to be available and trainable in any one man, and the principles of parsimonious manpower utilization.

Comments. This report was not abstracted for, although it recognizes areas of consideration important to the structuring of positions, it does not present a systematic method for their application.

NOTE: The above abstract omits reference to classified equipment, etc., and is unclassified.

Abstracted by: E. M. Jones

Location of Document: Engineering Psychology Branch
Aerospace Medical Laboratory, WADD
AIR Technical Library

Air Force Personnel and Training Research Center. The qualitative personnel requirements information program: A briefing. Lackland Air Force Base, Texas: Author, August 1956.

Purpose. This document is the publication of a briefing held at the Air Force Personnel and Training Research Center, Air Research and Development Command, Lackland Air Force Base, on August 25, 1956, to present to the System Management Directorate the Qualitative Personnel Requirements Information Program as it relates to Weapon System Project Office responsibilities. It reviews the developing need for QPRI, the assignment of the program to AFPTRC as the responsible agency, the operation of the program, and the status of qualitative personnel requirements information for current systems, under AFPTRC jurisdiction.

Conclusions. The QPRI method of operation in use during 1956 was divided into two phases, premock-up and postmock-up. Within these phases, the use of four types of analyses is described: the task inventory, hypothetical manning list, position description, and training devices information formats illustrate the presentation of the results of these analyses.

Premock-up studies and reports are time phased according to the system mock-up schedule. Two types of premock-up reports are furnished: manpower and organization, and special training device information.

Comments. This document, including the analytical formats presented, is abstracted in full, except for those sections concerning the then existing development systems and Air Force organization.

Location of Document: Training Psychology Branch
Aerospace Medical Division, WADD

Abstracted by: E. M. Jones

Air Research and Development Command. Proposed revision B to AFBM exhibit 58-18. Final coordination copy. Wright-Patterson Air Force Base, Ohio: Author, June 1959.

Purpose: The major revisions suggested were in the area of skill identification. Several formats were included for the presentation of personnel information data.

Conclusions. In using the first format below, skills were to be identified by three subjective ratings:

Newness of the task; 1-2-3 levels
Type of skill required; Pp Jj Mm (--low demand)
Task criticality; 1(high), 2(medium), -(low)

Duties and Task Format

Subsystem Operation Involved	Duties and Tasks	Special Tools and GSE	Skill Identification: Newness	Skill Identification: Type of Skill & Level of Demand	Skill Identification: Criticality	Time Frequency
Guidance countdown			1	PJm	2	
				M	2	

Position Comparison Format

Title of Previously Reported Position	AFSC	Title of New Position	AFSC	Reasons for Change

Manning Estimates Format

Sub-System	Position Number	Position Types by Work Area or Section	Recomended AFSC	AFS Title	Number Required and Recommended Grade Structure: Shift 1	Shift 2	Shift 3

Comments. This memorandum was not considered sufficiently relevant for abstracting, as no rationales were given. See AFPTRC (1956) and ARDC Hq. (1958) for similar earlier presentations of the same type.

Location of Document: Training Psychology Branch Aerospace Medical Division, WADD

Abstracted by: E. M. Jones

Air Research and Development Command, Headquarters. Reference manual for QPRI. Wright-Patterson Air Force Base, Ohio, October 1958.

Purpose. QPRI defines the equipment-associated military positions required for a standard working shift for a weapon/support system. It includes information on duty positions for all operator and maintenance type people associated directly with the system. QPRI does not include descriptions for logistics or base support positions, nor statements of training requirements or training.

This document reviews the procedures for preparing qualitative personnel requirements information and the status of the QPRI program at the time of its publishing.

Conclusion. The format presented is based on a Headquarters, USAF, 17 July 1958 letter to the Commander, ARDC, on "Production of QPRI," directing ARDC to assume responsibility for QPRI research and development. The following report format was established:

I. System Description.
   1. Military purpose and operational characteristics.
   2. Maintenance and operational concepts, plans, and assumptions.
   3. Statement of development stage or phase.

II. Description of New Equipment.

III. Maintenance Operations Sequence Summary. Organizational and work flow diagrams.

IV. Manning Estimates.

V. Position Descriptions.

VI. Special Information or Problems.

Comments. Except for sections of the document on Responsibilities, Management Policies and Procedures, Project Status, and Regulations and Letters, the document is abstracted in full.

Location of Document: Training Psychology Branch
Aerospace Medical Division, WADD

Abstracted by: E. M. Jones

Altman, J. W. Preliminary training analysis. Unpublished memorandum. Pittsburgh: American Institute for Research, January 1959.

Purpose. This memorandum duplicates the methodology section of Altman and Purifoy (1959) as a prepublication document and work guide. Since that document is abstracted, this memorandum is not.

The purpose of this report is to provide a technique for the derivation of preliminary training requirements early in a system development sequence before detailed equipment data are available. It is necessarily a less specific approach than is possible later on, but it does provide preliminary data on which early planning for training, selection, and procurement can be based.

Summary of Method. Essentially, the method analyzes those skills and knowledges identified for each personnel function early in system development, which are required for system operation and maintenance. Review of training research and development reports and rational analysis of the specific system training problems suggested ten dimensions of principal importance for training. These dimensions are: equipment subsystem, technical field of knowledges, skills and knowledges required, background and experience of trainee, types of performance aids recommended, training location suggested, proficiency required at each stage of training, training methods suggested, types of training aids suggested, and types of training equipment recommended. Each dimension is categorized and coded, and the appropriate code for each dimension is applied to each personnel function identified.

The training requirements for each functional position are then summarized, and special training problems which appear are analyzed.

Comments. This approach was found to give good results for the purpose for which it was designed and the phase of system development in which it was intended to be used.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Altman, J. W., & Purifoy, G. R., Jr. AN/AMQ-15 weather reconnaissance system: preliminary training report. Pittsburgh: American Institute for Research, January 1959. (Subcontract BSD P. O. A2736, Prime Contract No. AF 33(600)-37984)

Purpose. The purpose of this report was to outline an approach to the development of comprehensive and economical training recommendations for a complex weapon system, identify sources of information available for this analysis during the design development stage, and illustrate the application of this technique to the AN/AMQ-15 Weather Reconnaissance System.

Summary of Method. Personnel functions were the basic data to which a group of skill and training dimensions were applied for analysis of training requirements. Each personnel function was reviewed by an analyst and coded on the skill and training dimensions.

The coded training dimensions of each function were then sorted so that a cross section was obtained for each position. Training requirements summaries for each unique position were then prepared, based on the coded functions. These summaries, of which the report contains samples, present:

1. A functional description of each position.
2. An outline of training requirements for each position.
3. Recommendations for the location of each training segment.
4. Recommendations for types of training and job aids for each training segment.
5. Recommendations of the types and characteristics of training equipment.

Comments. Altman (1959) presents the Method of Analysis (that portion of this report which is abstracted) in an earlier memorandum.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

American Institute for Research. A study of methods of anticipating requirements for maintenance of complex electronic equipment. Final Report. Pittsburgh: Author, February 1955. (Air Force Personnel and Training Research Center Project No. 7709, Task No. 77151, Contract No. AF 18(600)-600)

Purpose. This report summarizes the whole study briefly. It was an attempt to demonstrate that a detailed training program based on a task analysis of a line maintenance job (for the A-3A in this study) could be developed prior to production of an electronic equipment. The study also considered what maintenance activities were common to three electronic systems. (Folley & Miller, 1955) The characteristics of a training program and the format and content of a line maintenance handbook were also to result.

Procedure. The task analysis of A-3A line maintenance was begun first, along with the development of hypotheses regarding training, the handbook, and the comparison of job requirements. The maintenance tasks were recorded on Job Behavior Forms developed earlier (Miller, Folley,& Smith, 1953a). An Activity Analysis (Miller & Folley, 1951a) was also attempted of maintenance activities as practiced on the prototypes.

The characteristics for training course content were based on the job-task description, which provided the details of what was to be demonstrated and practiced; training devices were viewed as supports for demonstration and practice of the required job behaviors.

An earlier comparison of common job requirements for the Q-24 and K-1 (Miller, Folley, & Smith, 1954) was extended to include the A-3A (Folley & Miller, 1955). While there was a fair amount of common behavioral content, there was not much basis for abstracting a separate "basic" course.

Comments. Except for a section of administrative material, this document was abstracted in full.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

American Institute for Research. A systems approach to the determination of functional training equipment requirements. Project Memorandum No. 2. Pittsburgh: Author, November 1959. (Naval Training Device Center Project 9-1034A, Contract N61339-669).

Purpose. This memorandum supplements an earlier study plan by identifying in detail the methodologies to be employed in determining functional training equipment requirements for the project.

Summary. A general discussion of the problem of identifying functional training requirements is provided in the body of the report. The appendices outline step-by-step procedures and formats for the required data derivations. Functions analysis and allocation, skill and knowledge analysis and training allocation, task equipment analysis, and error analysis are reviewed in detail, as applied to the derivation of training equipment requirements.

Comments. This memorandum would have been abstracted fully, had it been included in the bibliography earlier. Although there are some obvious gaps in the procedure, as in the determination of skill level, it presents a very well integrated and easy to follow overview of the rationale and resulting procedures used in the solution of the problem. The outline of functions analysis, its nature, extent, and place in the whole sequence, is especially interesting.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Bamford, H. E. Task and conceptual analysis of the changing of a tire. Pittsburgh: American Institute for Research, October 1954. (Appendix to: Miller, R. B. Preliminary statement of some working definitions and hypotheses on the conceptual process as it relates to training and job operations: Memorandum Report No. 1. Pittsburgh: American Institute for Research, October 1954. (Air Force Personnel and Training Research Center Contract No. AF 18(600) -1205)

Purpose. This document presents the sample formats for a task analysis and resulting conceptual analysis, to illustrate the abstraction of conceptual content from a description of job behaviors. No judgment is implied as to the relative influence on job performance of these examples of conceptual content. Neither are the examples indicative of the form in which the conceptual content of a job would appear in training. It is merely an indication of an approach to the problem of conceptual analysis of job behaviors.

Rationale. The task analysis consists of a detailed description of the discriminations and other responses which are required by the job. The conceptual analysis sets forth the conceptualizations which might or should mediate those discriminations, decisions, and motor responses. Conceptual content is thought of throughout as stored information (mediating particular job behaviors), in any one of the following modes:

1. Object-imagery on map-like conceptualization
2. Abstraction and classification of objective stimuli
3. Process sequence and cause-effect conceptualization
4. Symbol or image transformation
5. Conceptualization of procedures

Comments. This document and the conceptual analysis formats are abstracted.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Beach, C. K., Paolucci, D. J., & Milano, J. E. The development of a multi-purpose analysis technique for Navy ratings. Part I. Ithaca, New York: School of Industrial and Labor Relations, Cornell University, October 1953. (Technical Bulletin No. 53-1) (Bureau of Naval Personnel Contract Nonr 401(10))

Purpose. The purpose of this study was to develop a method of analysis and procedure for data collection for a specified Naval rating, for use on "new-type" weapons.

Procedure. The guided questionnaire technique was used, in combination with a comparative examination of relevant Operating Procedures, to obtain task data for the Gunner's Mate billet on the 3"/50 Rapid Fire Twin Mount weapon. Emphasis was placed on casualty or malfunction data as a source of job information.

Results. The methods of data collection and analysis were designed for use with a system which had been in operation for some time, and on which a large number of men had been trained. The questionnaire used was similar to but less exhaustive than the Standard Maintenance Form developed for the Air Force (Miller, Folley & Flanagan, 1951). In addition to outlining the maintenance-troubleshooting tasks, the study pointed up shortcomings in the Operating Procedures manuals.

Comments. Because the study is concerned with systems already in operation it is not abstracted.

The approach does not really get to the basic elements of skills and knowledges to be trained, but depends on Gunner's Mates' judgments of tasks and knowledges, stated in nonbehavioral terms (see Wiley, 1959; Kershner, 1955). In attempts to identify "criticalness" by "frequency of occurrence," and by "amount and rate of supervision."

Location of Document: ASTIA AD 21710
AIR Technical Library

Abstracted by: J. B. Fairman

Besnard, G. G. Shredouts of tasks performed by senior B-29 mechanics (AFSC 43151-B). Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, April 20, 1954. (Technical Report 54-4) (Project No. 507-015-0001)

Purpose. This study attempted to determine whether a job is divisable into "shredouts" according to the number and average difficulty of the tasks in the total job that each shredout performs.

Procedure. The job of Senior Aircraft Mechanic on the B-29 (AFSC 43151-B) was divided into component tasks and the technical difficulty of each task established by averaged evaluations by equipment experts, assigning ratings of "relatively difficult," "average difficulty," or "relatively simple."

To identify clusters of related tasks, an inverse factor analysis was performed, which resulted in six factors of men performing similar tasks.

To determine whether the shredout factors differed on the basis of technical difficulty, each factor was scored by summing 3-2-1 weights attached to the difficulty ratings above.

Results. It was found that the job of Senior Aircraft Mechanic could be shredded-out operationally into six different part jobs. These six could be combined into four "jobs" on the basis of technical difficulty, each of the four being significantly different from the others on the dimensions of difficulty.

Conclusions. The implications of these results in the field of training is that broad formal training for all incumbents of an AFS is often not utilized on the job, and that a basic course of practical information would be more economical.

Comments. This document is abstracted in full.

Location of Document: ASTIA AD 32406
AIR Technical Library

Abstracted by: J. B. Fairman

Buckner, D. N. Construction of proficiency examination for maintenance personnel of a new weapon system. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1956. (AFPTRC Technical Note 56-105)

Purpose. This technical note suggests that the development of proficiency tests should not be delayed until a system becomes operational, if they are to be ready in time. When tests are developed as part of system development on the basis of early manufacturer's manuals and Technical Orders, they are regularly modified as system development, testing, and operation progresses.

Comments. Although the determination of performance tolerances is important in anticipating training requirements, this report was not abstracted since it did not suggest specific techniques for determining tolerance requirements or developing proficiency examinations.

Location of Document: ASTIA AD 98 880 Abstracted by: E. M. Jones

Christensen, J. M. Arctic aerial navigation: a method of analysis of complex activities and its application to the job of the arctic aerial navigator. Mechanical Engng., 1949, 71, 11-16, 22.

Purpose. This study was conducted to gather data relevant to the design of crew workspace.

The basic problem is that of reducing the number of required crew members, because as new aircraft are developed, the problem of weight and room becomes more critical.

Summary of Method. The method, a sampling technique, was called "Activity Analysis." It uses sampling theory to obtain the times devoted to different elements of a complex activity, and their general sequence.

An observer's prompting buzzer sounded every five seconds, requiring the analyst to record at each sounding the behavior observed in the subject. Later analysis showed that thirty second intervals would have been just as effective, permitting the observation of three men alternately, one every ten seconds.

The chief merits of the method are simplicity and flexibility. They include the factors that the observer can keep pace with the subject for long periods of time, that the equipment involved is negligible and requires no special installation in the aircraft (a special head set connected to the battery operated buzzer signal at one ear and the intercom at the other), and that the large number of samplings assures that the less time-consuming activities are adequately sampled. It also tells exactly what the operator is doing, what equipment he is using, how long he uses it, and how frequently he uses it. The one prerequisite is that the analyst be as familiar with the position or type of position being studied as possible.

Results. By employing activity analysis, it was possible to determine how often the operator used each control and the sequence in which he used them.

Comments. Specific recommendations are given for changes in the equipment, work space layout, and task allocation. This article is abstracted.

Abstracted by: J. B. Fairman

Location of Document: Carnegie Inst. of Technology Library.

Christian, G. L. Report on QPRI: Part I. USAF program welds man, hardware; Part II: USAF probes systems maintenance. Aviation Week, 1957; (July 22), 79-88; (July 29), 66-70.

Purpose. These articles describe the two-year old QPRI program and its applications. Because it does not discuss methods, rationales, or specifics, it is not abstracted.

Conclusions. Part I describes the scheduling of the QPRI program in relation to weapon system development, and specifies the agencies which were then responsible for the various aspects of the program. See Dice (1955). The QPRI program must determine what new skills will be required by a new weapon system, what skills can be salvaged from previous systems, and what major training devices will be necessary.

In doing this, AFPTRC scientists divide mental ability into four related factors:

1. Mechanical aptitude, or the ability to perform manual, mechanical tasks with more or less dexterity.

2. Academic or clerical, aptitude.

3. Psychomotor reaction, pertaining to muscular action ensuring directly from a mental process.

4. Reasoning, a problem-solving ability--an originality or creativity dimension.

Inputs to the QPRI program include personnel procurement and assignment, career management, USAF job structure, training and training devices, handbooks and other job aids, proficiency evaluation, personnel and training knowledge and theory, hardware characteristics, and the weapon system operations concept. Part II discusses the role of AFPTRC's Maintenance Laboratory in the QPRI program. It was concerned with the conditions of efficient learning, characteristics of maintenance training equipment, measurement of individual proficiency, aids to job performance, and forecasting maintenance job requirements.

Five elements which should be included in a subject matter or procedural training device are guidance to the correct answer, feedback of performance results, opportunity for practice, pacing training to the capability of the trainee evaluation of trainee's performance.

One problem of the Laboratory is to define tasks reliably. To be reliable, the description must use action words, indicate the objective of the task, state what the specific equipment is, and state what test equipment is necessary. It is still necessary to infer job resemblances, and some kind of job categorization is essential. Standard behavioral definitions would be a start in this direction.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Columbia University Teachers College. Evaluation of a technique for characterizing the job requirements of selected Air Force jobs. Quarterly Reports 1, 3, 9. New York: Author, September 1954, June 1955, December 1956. (Contract No. AF 18(600)-1208)

Purpose. These administrative reports describe project personnel changes and record the data trips which were made.

Comments. These reports have no bearing on the present survey, and are not abstracted.

Location of Document: ASTIA AD 135 640 Abstracted by: E. M. Jones

Cotterman, T. E. Task classification: An approach to partially ordering information on human learning. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, January 1959. (WADC Technical Note 58-374)

Purpose. This report presents ideas related to establishing a unified knowledge of human learning as it applies to training issues. It proposes (a) needed research and an approach to each area, and (b) an illustrative set of generalized definitions of familiar learning situations and associated traditional labels.

Summary. A set of twelve abstract task definitions in terms of generalized descriptions of stimuli, responses, and their relationships useful as a basis for establishing task categories, is presented. An example is:

	Traditional Task Label	Generalized Definition
1.	Classical conditioning S-R association Simple association	For each succeeding occurrence of essentially the same discrete input, essentially the same specified discrete output occurs.

The criterion for a category of tasks is that for all tasks subsumed under it, the effects of certain basic variables or principles remain reasonably invariant. To be useful the number of categories should be less than a dozen.

Comments. This document, and the complete list of task categories, is abstracted.

Location of Document: ASTIA AD 210 716
AIR Technical Library

Abstracted by: E. M.Jones

Crossman, E. R. F. W. Perception study: a complement to motion study. Great Britian: Medical Research Council, January 7, 1955.

Conclusions.

1. Gilbreth's original motion study work included perceptual content. This was lost in the development of methodology.

2. The time division of control processes is:

   A plan is formulated by the man. (Information → decision → action.)
   The plan is initiated.
   There is current control or simple control.

   Purpose → Information ↗ Decision ↘ Action → Achievement
   (Action ↙ Result ↖ Information)

   End of work unit.
   Check (sensory data).

3. The control or decision may be symbolic or nonsymbolic, e.g., if the aim of a task is hit a point visually locatable, the error signal is constantly present and symbolic control is in action; if aim is inserting screw driver in a slot, it is more symbolic.

4. A three-fold classification of work processes is then possible:

Time Sequence	Type of Work	Channel
Plan Initiate	Sensory (information)	Vision, Hearing, touch, etc.
Control End	Mental	Symbolic, nonsymbolic
Check	Physical (action)	Right hand, lift, etc.

Location of Document: ASTIA AD 783 18

Abstracted by: E. M. Jones

Darby, D. C., Brown, W. F., Smith, D. C., & Fightmaster, W. J. The development of job descriptions for Nike/Ajax battery officers. Washington, D. C.: Human Relations Research Office, April 1959. (Technical Report 54)

Purpose. The purpose of the over-all study was to determine the level of skill and knowledge required by Nike/Ajax battery officers, so that Air Defense School could optimize training courses for them. The six parts of the study were: Determine job duties, delineate training requirements, develop proficiency criteria, analyze training procedures, revise the training program, and evaluate training program revisions.

This report covers the first stage and part of the second.

Procedure. The study attempted to analyze and describe the job requirements of assigned battery officers, and information about the relative importance of selected duties of each position in terms of "need for training."

The preliminary job descriptions were composites of notes from observation and interview of officers at permanent installations and those on Annual Training, plus familiarization from a briefing course and review of technical literature. These descriptions were confirmed by field personnel review.

The final descriptions were returned to the officers, with selected activities numbered. To determine the training needs of those activities, (presumably critical) the officer was asked to make a three-point judgment (high, moderate, low) on each of three questions:

1. What degree of importance would you assign to the activity in contributing to effective battery operation?
2. What degree of proficiency do you feel is required for satisfactory performance of the activity?
3. What degree of priority would you assign to the activity in planning subject matter content for the appropriate course at Air Defense School?

It was concluded that the scores for each of the questions were additive because of high intercorrelations, so for each "critical" activity a summary or "training need" score was computed.

Comments. No criteria for the identification of "critical" activities is given. One wonders, assuming that the job requirements chosen were critical, whether their relative importance or criticality, and therefore training priority is the important question or whether, assuming that they are all necessary for the job, the real question should be how much and what type of training emphasis would be required to train the behaviors involved. It has been suggested elsewhere (Kershner, 1955; Wiley, 1959) that job requirements judgments by field analysts are not very useful.

Because this study is concerned with job analysis of existing positions, it is not abstracted.

Location of Document: ASTIA AD 216 118
AIR Technical Library

Abstracted by: J. B. Fairman

Department of the Air Force. Military personnel occupational analysis. Washington, D. C.: Author, August 1954. (Air Force Manual 35-2)

Purpose. This manual establishes policies and procedures for maintaining the Air Force military occupational structures which support the manning, personnel classification, and personnel reporting systems. It is included in this bibliography primarily because of Appendix A of Section III, Air Force Position Evaluation Scale.

Summary. Ten 6-level rating scales are presented. They are knowledge, physical skills, adaptability and resourcefulness, responsibility for money and materials, responsibility for safety of others, responsibility for directing others, physical effort, attention, job conditions, and military and combat. In addition to the definitions of each level of each factor, operational examples are provided.

These rating scales are of interest to this survey because, in addition to their use in evaluating existing Air Force positions, several of them, the first and second especially, have been borrowed for application to the rating of the qualification requirements of tasks derived for new weapon systems. See Wiley, Harber, and Giorgia (1959).

Comments. This appendix is not abstracted because of its length.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Dice, R. F. Weapon system development procedures as related to qualitative personnel requirements. Memorandum. Wright-Patterson Air Force Base, Ohio: Air Research and Development Command, June 1954, revised June 1955.

Purpose. This memorandum describes how weapon systems are developed, to facilitate the establishment of a research and development program aimed at producing the personnel systems required to complement the hardware systems. It was prepared at the time that the QPRI program was being established, and identifies the agencies, documents, phasing, and responsibilities established by regulation to implement the "weapon system concept."

Comments. The document presents a comprehensive and explicit description of the organization, operation, responsibilities, and products of the weapon system development concept, as related to the then newly-established requirements for qualitative personnel requirements information. It stresses the structures and procedures established by regulation and references the source documents and binding Air Force regulations. However, it is not concerned with the logic or rationale of the QPRI products, and so was not considered sufficiently relevant to the survey to be abstracted.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Ellson, D. G., & Gilbarg, D. The application of operational analysis to human motor behavior. Wright-Patterson Air Force Base, Ohio: Air Materiel Command, May 3, 1948. (WPAFB Memorandum Serial No. MCREXD-694-2J)(Contract No. W33-038-AC-13968)

Purpose. During the forties, developments in military and industrial equipment design produced a need for specific information on motor behavior characteristics of the human operator. Considerable research had been performed on the form of motor responses as a function of those characteristics of the task determined by machine design, but no conceptual scheme had been presented to integrate the results of these experiments. This paper suggests that operational analysis, a mathematical technique for analysis of input-output relationships of electrical and mechanical transmission systems, be applied to aspects of human motor behavior, to predict responses to complex inputs.

Conclusions. The method parallels the stimulus-response approach, which is concenred with relationships between stimuli and responses rather than with intervening physiological mechanisms. To apply the method, it is necessary to identify the separate components of a complex input, the separate components of the output produced by each input component, and to establish that the separate output components are additive to form the complex output; that is, it must be a linear system. This approach is particularly applicable to analysis and prediction of servo-systems in which the human is an integral system link.

Comments. The possibility that this approach may be useful in human engineering analyses does not qualify it as relevant to this QPRI survey. It is therefore not abstracted.

Location of Document: ASTIA ATI 27519
AIR Technical Library

Abstracted by: J. B. Fairman

Erickson, D. J., & Rabideau, G. F. Functions and task analysis as a weapon system development tool. Hawthorne, California: Northrop Aircraft, Inc., October 1957. (NAI Report No. 57-1148)

Purpose. This report considers function and task analysis procedures in the light of the following variables; required levels of analytical detail, function and task analysis data sources and their use in terms of level of analysis, and function and task analysis methodology.

The value of this form of activity analysis, as it assists in the determination of the following items, is discussed:

1. Crew Size - The determination of sequential and simultaneous tasks, their relative difficulties, and time limitations, will help determine this manning factor.

2. Crew Duties - Function and task analysis data will assist in man-machine inter-crew and inter-crew function allocations.

3. Equipment Design - Recommendations for controls and displays depend in part on these analyses.

4. Personnel Skills and Training Requirements - Task analyses identify task complexity, probable skill-level requirements, and effective types of training.

Comments. This report, including its sample activity time-line chart, is abstracted fully. While drawing extensively from Van Cott and Altman (1956), it offers an interesting and clear review of the function and task analysis techniques.

Location of Document: AIR Technical Library
Adams' Personal Files
Stackfleth's Personal Files

Abstracted by: J. B. Fairman

Flanagan, J. C. Job requirements. in Current trends in industrial psychology. Pittsburgh: University of Pittsburgh Press, February 1949. Pp. 32-54.

Purpose. This discussion traces briefly the historical development of the field of job requirements identification, outlines some advances that had been made, notably the Critical Incident Technique, and indicates possible lines of future development. Emphasis is on basic principles and the broad outlines of procedure application.

The historical review included work done in 1913 at Harvard and in 1926 at Carnegie Institute of Technology, on the problem of identifying those significant aspects of a job and its performance by which the job may be defined and evaluated. Later studies by Charters in the earlier twenties, Viteles in 1932 (32 job component traits, and Ghiselli and Brown in 1948, are also reviewed.

The Critical Incident Technique is suggested as a new approach to this historic problem. It emphasizes observation of incumbents by supervisors or trained analysts, and the recording of actual behavioral incidents which stand out as being especially good or bad examples of job performance. The analysis and categorization of these incidents provides a job description structure and rating scale useful in proficiency measurement, training evaluation, etc.

Recommendations. It was suggested that whole classes of jobs may be defined within common areas or subareas by common job elements. These elements provide a basis for directly relating training and aptitude requirements to specific job behaviors. Observational checklists based on these elements would permit the improvement of equipment and job designs in fundamental ways without waiting for field tryouts.

Comments. Regarding the Critical Incident Technique, other reports present the methodology involved. However, it is generally more applicable to the evaluation of existing jobs than new ones, with the possible exception of the point mentioned above. For this reason, it is not abstracted.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Folley, J. D., Jr., & Miller, R. B. Summary comparison of job requirements for line maintenance of three complex electronic systems. Lowry Air Force Base, Colorado: Armament Systems Personnel Research Laboratory, Air Force Personnel and Training Research Center, September 1955. (ASPRL Technical Memorandum 55-17) (Contract No. AF 18(600)-600)

Purpose. This study, an extension of the study reported in Miller, Folley, and Smith (1954), was directed at finding some common denominators among line maintenance jobs, using the Q-24, K-1, and A-3A electronic systems as samples.

Results. Tasks previously identified were compared by behavior categories (Miller, Folley, & Smith, 1953a) for the three equipment.

A high degree of similarity of the specific job behaviors, as "reading dials," was found among the three equipment. Major differences existed in the organization and sequences of the behaviors into procedures. The "information content" of the jobs differed substantially, including the nomenclature and location of components, and this material appeared to have very low transferability. Transfer of inferring and interpreting behaviors, as well as the use of block diagrams or job instructions, depend on the type of training received and the format organization of the materials. If training emphasized the method of tracing signals from one diagram to another, transfer to other equipment should be quite high.

Comments. This report is abstracted.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Forrester, J. W. Industrial dynamics. A major breakthrough for decision makers. Harvard Bus. Rev. XXXVI, 1958, 4, (July, August), 37-66.

Purpose. This report describes work done in the area of electronic data processing as an aid to the development of a professional approach to management, including the areas of inventory control, production scheduling, advertising, sales, and other problems. Although eleaborate techniques are involved in this approach, the concern of the report is not with techniques and prescriptions.

Comments. While this statistical approach to the problem of management decision making is very interesting, it has no relation to the present survey, and is not abstracted.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

French, R. S. Functional characteristics, utilization, and procurement of a MAC trainer: K-system TEA form for MAC trainer. Appendix: Description of K-system task characteristics analysis form. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, February 1957.

Purpose. The purpose of this report was to set down the procedure used for translating technical information on the K-1 Bombing-Navigational system into the most useable form for incorporation into training devices or techniques. Task Equipment Analysis (TEA) was used. The Task Equipment Analysis format is illustrated and described in detail. Each element of each task is rated on ten dimensions pertinent to training device design. The ten dimensions are memorization, training, difficulty, uniqueness, criteria, special ability, sequence, manipulation, supplementary equipment, and simulation.

The system of analysis used provides information regarding:

1. Physical make-up of the planned devices.
2. Where in the design of the device the critical discriminations should be provided for.
3. Procedures and tasks which might introduce scoring and reliability problems.
4. Factor content of the task. (Many complex procedures are actually combinations of simpler procedures which can be trained for separately.)

Comments. This report and the analytical format are abstracted.

Location of Document: AFPTRC Inventory Files   Abstracted by: E. M. Jones

Gagne, R. M. Training devices and simulators: Some research issues. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, 1954. (Technical Report 54-16) (Project No. 509-020-0009)

Purpose. This paper attempted to describe and clarify some research issues which occur in connection with the development, use, and evaluation of training devices.

Conclusions. It was maintained that the kinds of utilization of training devices are two: Performance measurement and performance improvement, distinguished particularly in the characteristics of the device essential to each purpose. When the device is used for performance measurement, the important characteristics are reliability and validity. When it is used for improving performance, the important characteristic is the amount of transfer of learning to an operational task. In either case, the degree of simulation becomes a secondary consideration.

Among the problems identified which require further research and which are related to the present survey are the following:

1. The differentiation of critical job activities from those which are routine and easy is one of the central problems faced in designing training devices.
2. It is impossible to design a trainer unless one knows what behaviors are included in the job, and which are the critical behaviors to be trained.

Discussions of research problems included proficiency measurement, criterion development, the determinants of human variability, relationship of set and motivation to learning, and the mechanisms of transfer of learning.

Comments. The portions of this paper related to the QPRI problem are abstracted briefly.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Gagne, R. M. Methods of forecasting maintenance job requirements. Symposium on Electronics Maintenance (Asst. Secretary of Defense, Research and Development) Washington, D. C.: August 3-5, 1955.

Purpose. This document reports a symposium presentation of current QPRI methodology and thinking.

Conclusions. QPRI is needed for selection, classification, training and assignment programs for new systems.

Some of the major problems to be resolved are:

1. How do we get from equipment descriptions to job descriptions?
2. Can job requirements be derived from equipment in development stages, and if so, will they be reliable?
3. How can jobs be described in a way that is both reliable and meaningful?

The author, Gagne, suggests the following categories of behavior:

1. Discrimination (e.g., reading dials, aligning dials)
2. Recall (e.g., remembering procedures)
3. The use of symbols (e.g., interpreting charts)
4. Decision making (making complex judgments of different courses of action)
5. Motor skill (tool using, etc.)

We also need to develop an adequate set of operational definitions of behavior categories. Points of correspondence between predicted and actual job behavior need to be explored. (See Miller, Folley, and Smith, 1954)

Comments. This report is abstracted briefly.

Location of Document: ASTIA AD 78340 Abstracted by: E. M. Jones

General Electric, Cornell Advanced Electronics Center. (UNCLASSIFIED title) Automation and personnel requirements for guided missile ground support functions. Fourth Quarterly Report. Ithaca, New York: Author, no date. (Aero Med. Project No. 7185, Task No. 71584, Contract No. AF 41(675)-170) (CONFIDENTIAL report)

Purpose. This study was conducted to investigate the relationship between automated systems and personnel requirements for guided missile support systems, especially as required for the preparation of QPRI material.

Comments. This quarterly report discusses some of the techniques used, but because the material in this document is classified and because the same methods are reviewed in an unclassified form in Knowles (1959), this document is not abstracted.

NOTE: **The above abstract omits reference to classified equipment, etc., and is unclassified.**

Location of Document: Technical Specialties Branch
Offensive Systems, WADD

Abstracted by: E. M. Jones

Ghiselli, E. E., & Brown, C. W. Personnel and industrial psychology. New York: McGraw Hill, 1955. Chapter 2.

Purpose. This chapter, Job and Worker Analyses, presents various approaches to the operational description of existing jobs (job analysis) and personnel requirements (worker analysis).

Conclusions. Job analysis as described here is essentially oriented to the consideration of existing, more or less standard jobs. However, the early thinking described does indicate the origins of later techniques related to the task analysis, qualitative personnel requirement areas.

Early worker analysis techniques considered the skills, knowledges, and abilities of job incumbents, as anticipated for a new job.

Early listings of job "traits" were too general and subjective. A subsequent refinement was the recognition that the relative importance of some traits (criticality) was important in describing a job and that the amount of each trait required (skill level) was also significant. Traits were later rated on a three-point scale, indicating the degree of the trait required in the job. Sample traits: keeness of vision, initiative, oral expression.

Comments. Those portions of the chapter related to the present survey are abstracted, including a sample activity time-line chart.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Glaser, R., Hahn, J., & Phillips, J. C. (UNCLASSIFIED title) Collecting and compiling task information for newly developed guided missiles. Guided Missile Personnel Research Report No. 2, Part 1. Pittsburgh: American Institute for Research, August 1953. (BUPers. Bulletin 53-2) (Bureau of Navy Personnel Contract No. N7onr-37008, NR-152-079) (CONFIDENTIAL report) (a)

Purpose. Part 1 of this report presents recommendations and considerations for the collection and processing of task data by a method applicable to newly developed weapons in general. The processing and organization of task data is discussed in the following steps:

1. An over-all categorization and description of the activities involved in the operation and maintenance of the new weapon.

2. Specification of the overlap between the activities of existing Navy ratings and activities required by the new weapon.

3. Identification of the nonoverlapping activities of the new weapon that require detailed personnel research and analysis.

4. Organization and presentation of task analyses and task information for the nonoverlapping activities.

Sources of the various kinds of information are identified in detail.

Comments. This document provides a very useful reference for the collection of task analysis data, and is abstracted in full.

NOTE: The above abstract omits reference to classified equipment, etc., and is unclassified.

Location of Document: ASTIA AD 24 492
AIR Technical Library

Abstracted by: J. B. Fairman

Glaser, R., Hahn, J., & Phillips, J. C. (UNCLASSIFIED title) A compilation of task information for Terrier missile activities. Guided Missile Personnel Research Report No. 2, Part II, Volume 1. Pittsburgh: American Institute for Research, August 1953. (Bureau of Naval Personnel Contract N7onr-37008, NR-152-079) (CONFIDENTIAL report) (b)

NOTE: This abstract omits reference to classified equipment, etc., and is not classified.

Purpose. The purpose of this report was to present a compilation of task information for Terrier missile activities which would facilitate the work of Navy agencies concerned with personnel and training.

Procedure and Results. The methods and formats used are described in Glaser, Hahn, and Phillips (1953a), Part I of this report. The results of the application of the methods are split and presented in Volumes 1 and 2 because of the bulk involved. Volume 1 contains the following:

1. Detailed analyses of the tasks involved in the following activities:

   a. Handling, storage and assembly.

   b. Missile servicing.

   c. Missile testing and checkout.

   d. Adjustment, replacement, and repair for the missile and associated equipment.

   e. Troubleshooting and casualty analysis for the missile and its associated equipment. Maintenance Data Forms and Equipment Casualty Reports.

2. An index of the technical documents concerning the Terrier Missile and associated equipment which were collected during the test and evaluation stage of the weapon.

Comments. Because this document presents only the resulting data from the method but not the method itself, it is not abstracted.

Location of Document: ASTIA AD 24 493
AIR Technical Library

Abstracted by: J. B. Fairman

Glaser, R., Hahn. J., & Phillips, J. C. (UNCLASSIFIED title) A compilation of task information for Terrier missile activities. Guided Missile Personnel Research Report No. 2, Part II, Volume 2. Pittsburgh: American Institute for Research, August 1953. (Bureau of Naval Personnel Contract N7onr-37008, NR-152-079) (CONFIDENTIAL report) (c)

NOTE: This abstract omits reference to classified equipment, etc., and is unclassified.

Purpose. The purpose of this report was to present a compilation of task information for Terrier missile activities which would facilitate the work of Navy agencies concerned with personnel and training.

Procedure and Results. The methods and formats used are described in Glaser, Hahn, and Phillips (1953a), Part I of this report.

The results of the application of the methods are split and presented in Volumes 1 and 2 because of the bulk involved. Volume 2 contains the following:

1. A technical summary of the Terrier missile. The first part describes the technical features in terms requiring a minimum of technhical background. The second part presents a technical engineering analysis of each of the system functional units. These notes presume some technical knowledge.

2. A comparison of Terrier subject matter with standard curriculum material similar to Navy common core electronics curriculum. Each functional unit is rated "basic" or "special" according to its uniqueness to the Navy inventory.

Comments. Because this document presents only the resulting data from the method but not the method itself, it is not abstracted.

Location of Document: ASTIA AD 24 494
AIR Technical Library

Abstracted by: J. B. Fairman

Gunn, R. L. An empirical study of the job components checklist. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, October 1956. (AFPTRC Technical Note 56-123)

Purpose. This technical note describes a factor analysis which evaluated three job component checklists as administered to Air Force mechanics. The first checklist was task assignment, for which the mechanic rates his own ability in the position assigned. The second was task difficulty and the third, task frequency. The mechanics completed each of the three checklists, using a five-point scale.

The checklists were found to be valid.

Comments. These rating scales might be useful in identifying homogeneous tasks by clusters of task elements, e.g., inspection by difficulty level and frequency. The document was not considered sufficiently relevant to the survey to be abstracted.

See Wiley (1959) for a discussion of rater tendencies.

Location of Document: ASTIA AD 098 897 Abstracted by: E. M. Jones

Hahn, C. P. A survey of personnel and training research in government, business, and industry. Lackland Air Force Base, Texas: Human Resources Research Center, July 1953. (Technical Report 53-22) (Project No. 507-011-0001, Contract No. AF 33(038)-24682)

Purpose. The survey reported here reviewed personnel and training research and practices in government, business, and industry to determine if procedures could be isolated which were applicable to the Air Force but relatively unknown to the military because of lack of technical dissemination. Professional and trade journals, house organs, and other publications of the sixty organizations studied, plus interviews with personnel officials from each organization, provided the data for the survey. Information was collected on the following six topics: personnel, selection and classification, training programs, evaluation of employee performance, job evaluation, safety programs, and morale.

Conclusions. The survey revealed few applicable techniques which had not been applied in Air Force sponsored research. Perhaps the most important conclusion was that the volume and quality of personnel research work in the military exceeds that in industry. The advantage of the military is partially a result of the availability of relatively large groups, homogeneous with respect to the variables being studied, and of the control which can be exercised over these groups for experimentation.

Comments. Considerable attention is given to recommendations for research in each of the six data-collection areas, as a result of the study. However, the report presents few specific techniques of interest to military psychologists, and none of the areas bear directly on the QPRI problem. This report is therefore not abstracted.

Location of Document: AFPTRC Files
AIR Technical Library

Abstracted by: J. B. Fairman

Hahn, C. P. The identification and description of some critical aircrew job requirements. Randolph Air Force Base, Texas: USAF School of Aviation Medicine, February 1954. (Project No. 21-29-014, Report No. 2)

Purpose. This study was the second step in a long-range research program to facilitate the analysis of aircrew specialties and classification of aircrew personnel. The aim of this step was to refine by statistical means the aircrew job elements and their component behaviors previously developed for various aircrew positions. It describes an approach to the categorization of behaviors into comprehensive and homogeneous groups. The initial step developed a job analysis procedure based on the critical incident technique.

Procedure. Eighteen job elements had been identified in the first study and reported in the "Job Element Record Form," (JERF). The procedure for analyzing these for homogeneity and independence consisted of three steps:

1. Construction of short tests to measure specific behaviors in the JERF.

2. Administration of the tests to a representative sample of male high school seniors. (Five hundred and sixty-two students were used.)

3. Correlational analysis of the performances on the tests.

Conclusions. Eleven job elements involving ability factors and four job elements involving nonability factors (dealing with motives, temperament, and leadership) were identifiable. Sample elements: understanding verbal materials, working effectively with others. All of these may be satisfactorily tested by paper-and-pencil tests.

Comments. This report is abstracted, including the "job element" categories derived.

Location of Document: ASTIA AD 28 357
AIR Technical Library

Abstracted by: E. M. Jones

Harding, F. D., & Brokaw, L. D. Implications of Air Force personnel information for job requirements. Lackland Air Force Base, Texas: Air Research and Development Command, February 1958. (Technical Memorandum PL-TM-58-3)

Purpose. This technical manual is an aid for the interpretation of the aptitude information used in the Air Force classification program.

Comments. Because the Air Force classification program is concerned with existing rather than new jobs, this document is not abstracted.

Location of Document: Training Psychology Branch
Aerospace Medical Division, WADD

Abstracted by: E. M. Jones

Highland, R. W. (UNCLASSIFIED title) Initial QPRI for weapon system 200A (IM-99 Bomarc). Development Report. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, September 1956. (AFPTRC Technical Note 56-116) (ARDC Project No. 8738, Task No. 87343) (CONFIDENTIAL report)

NOTE: This abstract omits reference to classified equipments, etc., and is unclassified.

Purpose. This report estimates the personnel requirements associated with maintaining and servicing WS 200A(IM-99 Bomarc), including manning, organization, and special training device requirements.

Procedure. This report is based on position descriptions listing duties and tasks, previously prepared by Boeing, and on personnel operations generated by system hardware development, planned system utilization, and the Air Force career field structure, including the latest proposed changes to that structure. The method of "analysis" is an early attempt to utilize the developing concepts of the qualitative personnel requirements program. (See AFPTRC, 1956) The analysis considered the functions of assembling, testing, servicing, and maintaining at each of the "shop" and "line" locations.

In deriving manning, positions were considered new if the skills and knowledges required by the tasks differed appreciably from those required in existing AF positions, regardless of superficial title similarities or differences.

Results. Tentative manning for "new" squadron positions was presented using the format headings: Function, Descriptive Job Title, Standard Position Title, Work Station, Related AFS, and Number of Incumbents Suggested.

Training device requirements for new positions were presented using as format headings: Position No., Descriptive Position Title, Description of Device, and Functional Characteristics.

Recommendations. Training should be "position-oriented" (what people do and need to know) instead of "equipment-oriented" (What the equipment does). Simple procedural tasks should be trained by repeated task practice. Simulators need not resemble operational equipment completely. See Gagne (1954)

Comments. Since the methods for determining skills and knowledges, job "newness," and an adequate derivation of training equipment functional requirements are not discussed, this report is of limited value to the survey, and is not abstracted.

Location of Document: ASTIA AD 098 891 Abstracted by: J. B. Fairman

Highland, R. W., Newman, S. E., & Waller, H. S. A descriptive study of electronic troubleshooting. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, January 1956. (AFPTRC Technical Note 56-26) (Project No. 7709)

Purpose. This study sought to gain further information on the knowledges and skills involved in electronic troubleshooting, to describe the methods used in locating a malfunction, and to get informatiom helpful in formulating hypotheses of the nature of important variables associated with successful troubleshooting. It was hoped the results would lead to better ways of proficiency measurement and training of electronic mechanics.

Procedure. Three hundred and sixty experienced radar mechanics took written tests of electronic fundamentals, knowledge of oscilloscope functioning, and reasoning ability. Each man also tried to locate six malfunctions in an oscilloscope kit.

Results. Analysis of the experimental data gave the following results on the hypotheses being tested:

1. Technical knowledge of oscilloscope and electronic fundamentals seemed to account for more of the variance associated with troubleshooting success than did reasoning ability as measured by a pencil and paper test.
2. Relatively successful troubleshooters required no less time to locate malfunctions than less successful ones.
3. Relatively successful troubleshooters used as many checks to isolate malfunctions as the less successful men.
4. Relatively successful troubleshooters make fewer repeat responses in varying controls, but they repeated other checks more often than unsuccessful men.
5. While all mechanics referred to schematics equally often on correct solutions, good mechanics used the schematics much more often than poor ones on incorrect solutions.
6. Relatively successful troubleshooters tended to vary their checking attack more than unsuccessful ones.

Five hypotheses suggested by the study are presented for further research.

Comments. This report does not investigate the specific skills and knowledges involved in troubleshooting behaviors, and so is not abstracted.

Location of Document: ASTIA AD 124 451
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Indiana University Institute for Educational Research. Task-oriented analysis of the K-system and its relationship to the development of the K-system fundamentals proficiency tests. Annual report. Air Force Personnel and Training Research Center, July 1953. (Contract No. AF 18(600)-306)

Purpose. This report describes a detailed analysis of the K-system equipment and discusses the relationship between such a detailed equipment analysis and the logical development of proficiency tests.

Procedure. The equipment analysis was done first, then a task analysis. The tasks were then ordered on a concrete-to-abstract (routine to complex) continuum.

From this continuum, the tasks were classified into four categories or levels of complexity. These were:

Identity. Mechanic brings together objects on the basis of exact sensory attributes.

Partial Identity. Similar in some ways or in terms of one sensory attribute.

Cojunctionality. Objects which seem to belong together in a given situation on the basis of being used together.

Categorical Similarity. Objects belong in the same general category.

If one accepts the categories defined, the task oriented analysis is reducible to four basic classes of tasks:

1. Tasks of reading dials and indications.
2. Knowledge of what happens when certain controls are manipulated.
3. Knowledge of the rudiments of data flow.
4. Knowledge of the bombing problem.

Comments. This report is abstracted briefly, including the Task Oriented Analysis Form.

Location of Document: AFPTRC Inventory Files

Abstracted by: E. M. Jones

Irwin, I. A., & Dice, R. F. QPRI for C-130 combat air transport system (400L). Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, February 1956. (AFPTRC Technical Note 56-45)

Purpose. This report describes seventeen jobs most critical to the operation, maintenance, and ground support of the C-130 system.

Conclusions. The description of each job begins with a general summary of the major duties involved, followed by a summary of the skills and knowledges required, a list of courses planned or recommended, and a list of new or unique duties.

Newness was determined by comparison with the C97A, C119B, and C124A systems. Activities involving equipment not in these systems were judged new, as were activities not normally performed by the AFS basic to the job. The listing of new tasks was by title, e.g., "testing booster power system" under the maintenance categories of testing, adjusting, replacing, repairing, servicing, ground handling, and troubleshooting, and the operator categories of inspecting, testing, starting, checking, monitoring, flying, and handling emergencies.

Comments. Skills and knowledges were not clearly identified, nor was the method of derivation specified. Because methodology discussion is omitted, this report is not abstracted.

Location of Document: ASTIA AD 99 482
AFPTRC Inventory Files

Abstracted by: E. M. Jones

Jackson, J. The assignment problem. Summary of talk given by J. Von Neumann at Lynch Auditorium, Rand Corporation, Los Angeles: Numerical Research Analysis, University of California, August 1952. (Report on Logistics Research Project, Discussion Paper No. 10, Contract Nonr 23302)

Purpose. These informal notes, preceding a formal journal article, present mathematical models for determining the assignment of men to jobs and the relative efficiency of splitting jobs among different workers.

Comments. While this approach may have real applicability to the problems of position structure and manning, this report was not considered sufficiently relevant to the survey to merit abstracting.

Location of Document: ASTIA AD 147 542

Abstracted by: E. M. Jones

Jones, Edna M., & Miller, R. B. The use of pictures and diagrams in job descriptions. Pittsburgh: American Institute for Research, September 1956. (Project No. 7709, Task No. 77150, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1203)

Purpose. This report suggests principles and technique applications for the preparation of pictorial and diagrammatic materials to support job descriptions in the Air Force Qualitative Personnel Requirements Information program.

The report reviews the theoretical considerations in the use of illustrations to support written text, available illustration techniques, and the types of illustrations appropriate to specific areas of job descriptions. The latter area of consideration is emphasized in the abstract of this report.

Conclusion. Eleven principles and ten tentative hypotheses were evolved from the theoretical considerations which guided and supplemented the specific recommendations. They parallel the steps for determining position-task requirements, as outlined in Miller (1956a).

Comments. This report is abstracted, as noted above. The reader may refer to the document for a more thorough review of the theoretical considerations and greater detail of the illustration techniques.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Jones, Margaret H., Hulbert, S. F., & Haase, R. H. A survey of the literature on job analysis of technical positions. Personnel Psychol., 1953, 6, 173-194. (Technical Report No. 1, Office of Naval Research Contract Nonr 233(08))

Purpose. This paper presents a survey of the literature of job analysis of technical positions, defined as those not of professional level, but requiring considerable background knowledge in a rather narrow area, and some knowledge of general principles. Prior to a job analysis of technical positions in the participating Naval Research Laboratories, a bibliographic survey was undertaken in an attempt to clarify any special problems which might exist in the analysis or evaluation of technical jobs.

Conclusions. All available bibliographic sources were searched for pertinent references, and every available article which appeared, from title or abstract, to be relevant was read. Some 300 references were read altogether, but the great majority of these contained no mention of technical personnel. In only nine articles were technical jobs explicitly recognized as problems or studied in their own right. Most of these were quite general. It was concluded that rather thorough study of technical positions was in order and that considerable emphasis should be placed on skills and knowledge rather than on supervisory factors.

Special Features. A three hundred and seven item bibliography of articles which appeared to be related to the job analysis of technical positions comprises the principal content of this document.

Comments. While this document certainly offers a significant reference source in its bibliography, the topic of its concern is not related to the present survey, but with the evaluation and classification of existing jobs. It was therefore not abstracted.

Location of Document: ASTIA AD 41 255
AIR Technical Library

Abstracted by: J. B. Fairman

Kappauf, W. E., & Payne, M. C. A selected, annotated bibliography on procedures used in activity analysis. Lackland Air Force Base, Texas: Human Resources Research Center, July 1952. (Technical Research Note 52-8) (Project No. 507-011-0001, Contract No. AF 33(038)-25726)

Purpose. The 22-item annotated bibliography presented covers a selected list of references in which various adaptations of four general techniques of studying behavior (activity analysis) are described. These four techniques are:

1. Continuous behavior observation (motion pictures, tape recording, movement recording, or a running log).

2. Time-sampling observation. See Christensen (1949).

3. Use of a checklist or behavior inventory for the experimenter or worker himself.

4. Questioning people who should know about the job - "indirect" observation.

The references are classified according to research objectives--analyzing the nature of the job, or discovering the most important or critical parts of a job--and each of the above techniques.

The principal authors cited are: Arrington, R. E.; Barnes, R. M.; Brogden, H. E.; Channell, R. C.; Champanis, A.; Christensen, J. M.; Flanagan, J. C.; Ghiselli, E. E.; Lindahl, L. G.; Moore, H.; Sandberg, K. O. W.; Thomas, D. S.; Thorndike, R. L.; Viteles, M. S.; and Warren, N. P.

Comments. This note provides a general review of documents, many of which are themselves general texts in the area of job analysis. Although variations of some of the techniques may have some application to activity analysis in verifying earlier task analysis, the material covered is not closely related to the survey. This note is therefore not abstracted fully.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Kershner, A. M. A report on job analysis. Washington, D. C.: Office of Naval Research, 1955. (ONR Report ACR-5)

Purpose. This report provides a critical review, with the assistance of an extensive bibliography, of (1) purposes or uses for which job analysis is performed, (2) terminology and definitions of job analysis, (3) methods of job analysis, (4) research on methods, (5) some recent studies concerned with job analysis procedures, job evaluation, and factor analysis, and (6) discussions and conclusions.

Conclusions. This report is not systematically abstracted because in job analysis, the focus of attention is usually "the job as it now is," an orientation unsuited to the purpose of this survey. However, some of the criticisms, conclusions, and comments have some bearing on the problem of anticipating, describing, and structuring new positions. These are indicated here.

Job analysis methods are varied, but generally they consist of one or more of the following: observation, interview, questionnaire, work participation, and literature (including training manuals) review.

Of all the studies reviewed, the author felt that only one completed a serious attempt to attack the problem of job analysis methods: "Research into Basic Methods and Techniques of Air Force Job Analysis" (Rupe, 1951; 1952; 1954; Rupe and Westen, 1954). One of the conclusions of the study was that the ability of the type of analyst used on this project or, in fact, any operational job analyst, (not a psychologist) to make dependable, useful, and psychologically meaningful estimates of skill and knowledge requirements of existing jobs was held in question.

Comments. Those portions of this report related to the QPRI survey are abstracted.

Location of Document: ASTIA AD 91 519
AIR Technical Library

Abstracted by: J. B. Fairman

Knowles, W. B. Automation and personnel requirements for guided missile ground support functions. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, May 1959. (WADC Technical Report 59-240) (Aero Med. Project No. 7185, Task No. 71584, Contract No. AF 41(675)-170)

Purpose. The study was conducted to investigate the relationship between automated systems and personnel requirements for guided missiles/support systems, especially as required for the preparation of QPRI material. The QPRI approach was developed only as an idea, and tried out on the Mace system.

Summary of Method. The problem was how to go from a task analysis, stated in terms of "turn knob X," "read waveform Y," to the identification of the required electronics aptitude index, and knowledge and skill requirements.

The approach suggested here is a direct outgrowth of the equipment under consideration; it was proposed that tasks be categorized in one of five general types, these types coded, and the coded tasks diagrammed much the same way as computer functions are diagrammed for programming.

Procedure. Sample diagrams of tasks coded this way are:

1. Checks crystal currents: 2-S-2-S
2. Adjusts antenna yaw gain: 3-M-M-C<1 1

Conclusions. This procedure readily indicates to the designer the structure of tasks he has created, and any blind alleys, closed loops, or other incomplete procedures.

For the purpose of task simplification, an a priori ranking of the categories from difficult to simple, C-R-S-M-1, would indicate at least one basis for a sequence of elimination. In the application of this diagram system to the Mace, the designers found that this technique did suggest simplifications.

Comments. This document is abstracted briefly.

Location of Document: AIR Technical Library

Abstracted by: E. M. Jones

Krumm, R. L. Critical requirements of pilot instructors. Lackland Air Force Base, Texas: Human Resources Research Center, September 1952. (Technical Report 52-1) (Project No. 508-016-0003, Contract No. AF 33(038)-23183)

Purpose. The ultimate objectives of this study were to develop a flight instructor proficiency assessment device to validate a flight instructor selection battery. It was necessary to define tentative criteria of instructor effectiveness as a basis of developing this device. This report describes the procedures involved in defining the flight instructor's task.

Procedure. In arriving at a description of the job in terms of critical instructor behaviors, using the "critical incident" technique, individual and group interviews were conducted with students, instructors, officers, etc., to obtain reports of effective and ineffective behaviors. Similar behaviors were then grouped together until thirteen independent "components" of behaviors were identified, falling into three general "areas." These components were reviewed for relative importance by administering the classification as a rating scale to experienced pilot instructors.

Results. A review of the classification by experienced pilots and educators and the importance ratings indicated that the classification was a useable and useful description of the pilot instructor's job and, since it dealt completely with observable behaviors which were considered "critical," it would serve as a suitable basis for the development of an instructor proficiency evaluation device.

Comments. Because this study is concerned with jobs related to existing general equipment rather than specific development systems, and because the job description derived is concerned with the general characteristics of how he does his job rather than the details of what he does, this report is not abstracted.

Location of Document: ASTIA AD 188 250
AIR Technical Library

Abstracted by: J. B. Fairman

Larkins, J. T. (UNCLASSIFIED title) A report of QPRI for weapon system No. 103A (SM 62 Snark). Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, March 1957. (AFPTRC Technical Note 57-38) (ARDC Project No. 8734, Task No. 87317) (CONFIDENTIAL report)

Purpose. The purpose of this report prepared from task information supplied by Northrup, was to estimate qualitative personnel requirements for the new positions and skill requirements for standard Air Force positions. It is not abstracted, since no method is given.

Procedure. The determination of requirements took the operational, maintenance, logistics and installation plans as basic assumptions. Duties were related to existing AFSC's; when these did not cover new duties, new positions were defined.

Results. The QPR were set forth in the following format:

I. System Description. Outline of subsystems, test equipment, handling equipment.

II. Position Summaries. A three paragraph narrative description of position responsibilities, position operational and knowledge area requirements, and interpersonal working relationships.

III. Training Equipment Requirements. A three column table (Position Title, Individual Training, and Team Training) in which is noted the equipment on which training should be given.

IV. Position Definitions.
   A. General Features. Describes the types of activities in various work areas or job assignments.
   B. Duties and Tasks. Charts with the following columns were used:
      1. Type of Duty. Entries used were: operation, supervision, co-ordination, check, adjustment, inspection, troub shooting, removal, servicing, installation, or replacement.
      2. Duties and Tasks. Task elements were not included.
      3. Equipment Involved.
      4. Test Equipment Used. No tolerances or signal values were included.
      5. Frequency and Time. Daily or Infrequently was checked, and time required was shown in tenths of an hour under Hours.
      6. Skill Identification. Entries used were: complex procedure, simple procedure, system analysis, circuit analysis, and motor skill.
   C. Specialty Qualifications. Education in years, experience for entry into and award of AFS, and training in required service courses.
   D. Specialty Data. Military test score requirements.
   E. Illustrations of operating areas, test equipment, access points, etc. See Jones and Miller (1956).

Location of Document: ASTIA AD 126 368
AFPTRC Inventory Files

Abstracted by: J. B. Fairman

Lenard, Dorothy E., & North, W. E. Special equipment operator (refueling): A job description. Lackland Air Force Base, Texas: Human Resources Research Center, December 1952. (Research Report 52-9) (Project No. 507-015-0002) (a)

Purpose. This report presents a job description of an experienced Special Equipment Operator (Refueling), AFSC 60350, and a list of the tools, equipment, and materials worked with in this job. This job description was developed as a by-product of an extensive research project of evaluating the effectiveness of five methods of job analysis (Rupe, 1951; Rupe,1952). At the time, this job description was considered the most comprehensive one available for any Equipment Operator.

Procedure. Based on the information gathered by all five methods, a master outline of the duties and tasks performed was prepared. Each separate, specific activity reported by job incumbents was listed individually and classifed by this master list. The appended job description giving duties, tasks, and elements of work performed is the final criterion list used in scoring the job schedules used in the basic research. Similar data is given for tools, equipment and materials used.

Information on skills, knowledges, and physical demands was gathered during the original job analysis, but it was not included in this checklist. Many statements appearing in the schedules as skills and knowledges required were considered after careful study to be items actually belonging in the Work Performed Section, or statements with very limited usefulness. Listing of the physical demands was also eliminated, since it was felt job analysts cannot state measurable physical requirements adequately, and general statements added little information of real value.

Comments. While the above points are related to the present problem, the over-all concern with established existing jobs suggests that this report not be abstracted more fully. Lenard and North (1952b) is similar to this report.

Location of Document: ASTIA AD 3252
AIR Technical Library

Abstracted by: J. B. Fairman

Lenard, Dorothy E., & North, W. E. Senior firefighter: A job description. Lackland Air Force Base, Texas: Human Resources Research Center, December 1952. (Technical Report 52-12) (Project No. 507-015-0002) (b)

Purpose. This report presents a job description of an experienced Senior Firefighter, AFSC 95150, and a list of the tools, equipment, and materials worked with in this job. This job description was developed as a by-product of an extensive research project of evaluating the effectiveness of five methods of job analysis (Rupe, 1951; Rupe, 1952). At the time, this job description was considered the most comprehensive one available for any Firefighter.

Procedure. Based on the information gathered by all five methods, a master outline of the duties and tasks performed was prepared. Each separate, specific activity reported by job incumbents was listed individually and classified by this master list. The appended job description giving duties, tasks, and elements of work performed is the final criterion list used in scoring the job schedules used in the basic research. Similar data is given for tools, equipment, and materials used.

Information on skills, knowledges, and physical demands was gathered during the original job analysis, but it was not included in this checklist. Many statements appearing in the schedules as skills and knowledges required were considered after careful study to be items actually belonging in the Work Performed Section, or statements with very limited usefulness. Listing of the physical demands was also eliminated, since it was felt job analysts cannot state measurable physical requirements adequately, and general statements added little information of real value.

Comments. While the above points are related to the present problem, the over-all concern with established existing jobs suggests that this report not be abstracted more fully. Lenard and North (1952a) is similar to this report.

Location of Document: ASTIA AD 3676
AIR Technical Library

Abstracted by: J. B. Fairman

Lockheed Aircraft Corp. Development of prototype task equipment analysis. Final Report. Marietta, Georgia: Author, Human Engineering Department, Military Operations Research, Engineering Division, October 1956. (Contract No. AF 41(657)-67)

Purpose. This report presents the development of three prototype task equipment analyses for organization maintenance of the C-130A airplane, preparation of a rationale for the analysis, and a set of model specifications.

Summary of Method. The method of conducting the analysis is described in Ray, Passey, Adams, Smader, and Simon (1957a, b).

Format for organizing the task analysis should be based on the use intended. For planners of training programs, equipment-system type of organization should be used for all duties with the exception of troubleshooting. Troubleshooting should be organized by duty.

If the task analysis is for a position incumbent, inspections should be organized by duty and in terms of the type of inspection being performed, i.e., preflight, postflight, periodic, and special.

Special Content. The program reported here included two informal studies:

1. An objective evaluation of format arrangements for task analysis to determine organization and readability of several sample formats. The formats were used with a sample of Lockheed technician personnel. The relative value of several illustrations (showing equipment components in relation to their background) and specific illustrations (show only the equipment components concerned) was tested. This study found that general illustrations and the labeling of part names on equipment components were preferred.
2. Subject evaluation of the task analysis. Criticisms of the approach were summarized.

Comments. This report is an administrative Final Report, and presents very little information of methodology or rationale. The supplementary studies reported have little bearing on this survey. It is, therefore, not abstracted.

Location of Document: AFPTRC Inventory Files

Abstracted by: E. M. Jones

Mason, H. A further study of experience-centered and requirements-centered tests of job knowledge. J. Appl. Psychol., 1956, 40, 14-16.

Purpose. This article reports a study to determine whether experience-centered tests or requirement-centered tests when administered to mechanics, resulted in a higher relationship to the criterion of AFSC levels 3, 5, and 7.

Procedure and Results. Two standard Training Research Laboratory experience-centered tests (covering maintenance facts and aviation information), and three TRL requirement-centered tests (covering technical knowledge, basic principles, and mechanical comprehension), were given to 3, 5, and 7 level Air Force airplane and engine mechanics. Analysis of the scores demonstrated, as had a similar previous study, that experience-centered tests of aviation information and maintenance facts showed the higher correlation with the 3, 5, and 7 classification levels.

Recommendations. Further studies might consider whether subject matter relating to duties of this job is superior to subject matter related more closely to principles of mechanical functioning. If so, there would be evidence that "duties" and "job theory" are differentially valid as subject-matter areas. If this distinction did not appear, the superiority of the experience-centered tests would be in the method through which expert mechanics' insights were brought to bear upon development of test content.

Comments. Because the concern here is one of test construction and evaluation of incumbents in existing systems, it does not appear applicable to the anticipation of skill level requirements for new systems, and is not abstracted.

Location of Document: ASTIA AD 104 318
AIR Technical Library

Abstracted by: J. B. Fairman

May, R. V., Jr. The use of job analysis schedules in preparing job requirements checklists. Lackland Air Force Base, Texas: Human Resources Research Center, June 1951. (Technical Research Note 51-2) (Project No. 21-07-015)

Purpose. This report presents a review of difficulties encountered in utilizing existing job analysis schedules to develop a standard job requirements checklist. The purpose of the project was to develop a checklist of skills, knowledges, and abilities which could be used by a job analyst to report the requirements of Air Force jobs. A five per cent sample of 2170 job schedules compiled between 1946-48 was examined. The analysis produced 70,000 statements of skill, knowledge, and abilities required.

Conclusions.

1. It was found that inadequate emphasis was placed on skill and knowledge requirements in the original job description.
2. The majority of the statements were too specific to the job being analyzed, to be classified into useful psychological categories and placed in a job requirements checklist.
3. Many of the statements not specific to a given job were too broad in concept to be of much value.
4. There were many areas of skills and knowledges which were not identified by this system.
5. The data available was so inadequate that even a tentative systematic arrangement of knowledge, aptitude, skill, and ability classifications did not seem feasible.

Recommendations. A different approach is therefore required for development of the proposed job requirement checklist. Further research, or review of research, needs to be done on the isolation and classification of human knowledge, aptitude, skill, and ability.

Comments. This report is abstracted.

Location of Document: ASTIA ATI 168864
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: E. M. Jones

McReynolds, Jane. Aptitude levels in the enlisted manpower pool of the Air Force. Part II: Appendix. Lackland Air Force Base, Texas: Air Research and Development Command, September 1958. (WADC Technical Note 58-63(11). Project 7719, Task 17106)

Purpose. This appendix presents aptitude score distributions for each major career field for which data were obtained in the May 1957 Sample Survey. The frequencies in the tables represent the number of cases in the total Air Force for whom scores existed, based on the 4.5 per cent sample used. The indices (mechanical, administrative, general, and electronics) are composites of scores from the Airman Classification Battery AC-1A, AC-1B, or AC-2A and from Forms A, B, C, and D of the Airman Qualifying Examination. (The Airman Qualifying Exam is the source of aptitude scores for a majority of those in later enlistments, and the earlier forms of the AQE did not provide an Electronics Aptitude Index.)

The Air Force enlisted classification system groups all Air Force enlisted jobs into 43 main career fields. This sample includes all but the Rocket Propulsion career field. Following the procedure in "The U. S. Air Force Personnel Report,"[1] the 42 career fields were then grouped into three classifications of highly technical, technical, and semitechnical. For comparison, the distributions of scores have also been divided into aptitude levels, given in stanines and percentiles, for airmen in a first term of enlistment and for those in a second or subsequent enlistment.

Comments. This determination of aptitude levels is more related to existing jobs than to the problem of predicting skills and knowledges required for a new job. This document is therefore not abstracted fully.

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[1] The U. S. Air Force Personnel Report, Characteristics and attitudes from sample surveys. SS-PS-1G, Compendium, October 1, 1957, Vol. II, No. 3.

Location of Document: ASTIA AD 151 048
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Systems functions analysis. A method for anticipating maintenance requirements from early stages in the development of a new system. A summary to accompany Progress Report No. 2. Pittsburgh: American Institute for Research, December 1950. (Project No. 21-07-016, Human Resources Research Center Contract No. AF 33(038)-12921)

Purpose. A system is defined as a man-machine complete with identifiable purposes, objectives, outputs, or products. Other things being equal, an efficient system was the smallest number of people, the lowest level of general aptitude, and the shortest and cheapest training which will achieve the objectives.

Rationale. The first step is to specify the primary objectives of the system, including tolerance limits, as a basis for system performance evaluation.

The next step consists of obtaining by analysis the principle determining variables in the system. The primary objective is a direct function of these determining variables. It is important to stress that any system or subsystem can be identified by its function or purpose, as well as by its mechanics and circuits.

Function analysis proceeds from the objective or output of the system back to the various inputs of the system. Functional analysis provides a list of over-all job requirements for the system. The over-all job requirements are grouped into patterns of individual jobs, each of which requires psychological abilities known or believed to be relatively homogeneous. To the extent that jobs have homogeneous requirements, picking the right man for the job can be done more precisely and the "right man" by definition will learn his job more rapidly. Secondly, training may be developed from the concept of systems functions as the curriculum core, rather than the mechanical, electronic, or other highly abstract sets of principles.

Recommendations. The Standard Maintenance Form is suggested for collecting critical incidents of maintenance success and failure during prototype testing. After a generation of mechanics have worked on the system for some time, a modification of the critical incident method could be used to determine which job requirements are critical and need most training emphasis.

Comments. This document contains the preliminary descriptive statement of the systems function analysis technique detailed in Miller and Folley (1951a). This original statement emphasized the general orientation and rationale of the technique, rather than its specific application. Therefore, this document was not abstracted.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Use of system analysis methods for predicting job requirements from prototype equipment. Draft of paper submitted to Amer. Psychol. Assn., September 1951.

Purpose. The problem specific to the present research was the determination of a method of actually anticipating job and training requirements from prototype data. However, because Miller and Folley (1951b) discuss the details of the problem, this paper considers the broader issues of systems planning and monitoring.

Conclusions. To summarize the procedure proposed here for developing and maintaining development of a complex man-machine aggregate:

1. Determine the system requirements and define them by criteria of adequate performance and tolerance limits.
2. Define the secondary system criteria (estimate the man-hour and material system requirements for operation and maintenance).
3. Identify the independent functions which together contribute to system effectiveness.
4. Identify by functional analysis the system operation and maintenance behavior requirements.
5. Combine the system behavior requirements into job specialities.
6. Test and operate the prototype system.
7. Activate a procedure to obtain continuous operational and maintenance information on the system.

Comments. This document anticipates Miller and Folley (1951b), avoiding a specific discussion of the method proposed. It is therefore not abstracted.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Anticipating tomorrow's maintenance job. Lackland Air Force Base, Texas: Human Resources Research Center, March 1953. (HRRC Research Review 53-1) (Project No. 507-008-0001, Contract No. AF 33(038)-12921) (a)

Purpose. This document was published as a general review of the project to date, and especially covers Miller, Folley, and Smith (1953a), Miller and Folley (1951a), and Miller and Folley (1952). Because it is such a general review of basic material abstracted, the body of this document is not reviewed. Revision 4 of the Standard Maintenance Form, published in the Appendix, has been included in the abstract of Miller and Folley (1951a), where development of the form is detailed.

Only the remaining part of the Appendix, "An Outline of the Logic in Functional Analysis," is abstracted.

An Outline of the Logic in Functional Analysis. The following steps trace the relationships between the over-all purpose or objective of the equipment and the job actions which must be performed on the equipment. The "job" of the machine is shown as interlocking with the job of the man. This analysis may be carried down to extremely specific man-machine tasks.

A detailed extension of this scheme provides a basis for integrating equipment design and job design during their formative stages. It also provides for a systematic job analysis.

1. What is the operational function of the equipment?
2. What are the variables in the operational function which are controlled by the equipment?
3. What are the interaction requirements of the parts of the equipment to each other within subsystems?
4. What are the indicator requirements of the equipment?
5. What are the mechanic's information requirements?
6. What are the mechanic's action requirements?
7. What are the mechanic's feedback information requirements?

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. A method for man-machine task analysis. Pittsburgh: American Institute for Research, June 1953. (Preliminary draft of WADC Technical Report 53-137) (Aero Medical Laboratory Contract No. AF 33(038)-22638) (b)

Purpose. The procedure described here was designed to specify training requirements for equipment operators in detailed and unambiguous psychological terms. This formal task analysis procedure identifies the sufficient and necessary tasks in the man-machine functional system.

Rationale. Task analysis can be used without empirical data about job performance because the behavioral requirements of a man-machine task may be given by the equipment displays, available response alternatives, and controls. An assumption of this presentation is that the design of the operational equipment is taken as a given, although such an assumption is not necessary to the application of the technique.

Task analysis consists of the enumeration of discriminations, decisions, and action behaviors which are necessary and sufficient to operate the system within the tolerances allowed. These behaviors are grouped both by system purpose and by temporal relationship. Some task requirements overlap in time, and these must be identified to indicate the psychological load required of the operator in the performance of his job. Task analysis should therefore provide both a longitudinal and cross-sectional analysis of job behaviors with respect to time. It is recommended that this behavioral analysis be supplemented by observations of "critical incidents" of operator error, such as those arising from built-in human characteristics, individual experience, previous training, and methods of approach to the task, which cannot readily be forecast from a systematic analysis.

Because "procedures" and "continuous feedback skills" show different transfer of training characteristics and pose different training problems, different methods and formats for task analysis have been developed for each.

Comments. This key document is reviewed in full, within the limits of a brief abstract. The reader is urged to consult the original document for further detail.

Location of Document: ASTIA AD 15 921
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Some working concepts of systems analysis. Pittsburgh: American Institute for Research, February 1954. (a)

Purpose. This report presents a very brief six-page review of the system analysis concept, and defines the system and psychological terms and their interrelationships. Sources of psychological behavioral data are discussed, means of analysis are identified, and special considerations to be included are noted. Advantages of the systems approach are outlined. However, no specific techniques are discussed.

Conclusions. This document is not abstracted because the material dealing with the development of qualitative personnel requirements information is covered in greater detail in other abstracted reports. See Miller (1953b) for a discussion of program analysis and Miller and Folley (1951a) and Miller, Folley, and Smith (1953a) for further discussions of task analysis procedures. This document also covers the content of Miller (1955a), which is not relevant to this survey.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Seigel, A. I. The checklist as a criterion of proficiency. J. of App. Psych., 1954, (May 26), 38:93-95.

Purpose. This article briefly summarizes work done by the Institute for Research in Human Relations on Contract Nonr-872(00) for the Office of Naval Research. The study attempted to assign scores to task performance elements, safety precautions to be followed, and elements of adherence of final maintenance activity products to prescribed standards. All of these elements, in checklist fashion, were evaluated for a group of seamen maintenance technicians in performing each of four maintenance tasks. The checklist scores obtained were then correlated with objective judgments by instructor maintenance officers of the rank, from best to worst, of the end products produced by each seaman on each maintenance task.

Comments. The article reports the statistical results of the study, but does not discuss the rationale for the derivation of the task elements used or for the assigning of element scores, all of which are totaled for a master score of the performance proficiency of each seaman for each of the given maintenance tasks. There is no indication that the technique would be applicable to predicting task or proficiency elements. The study does not appear to be relevant to this survey, and is not abstracted.

Location of Document: ASTIA AD 88 754
AIR Technical Library

Abstracted by: J. B. Fairman

Snyder, M. B. Methods of recording and reporting task analysis information. State College, Pennsylvania: H. R. B. Singer, Inc., October 1959. (Special Publication No. 16) (Paper presented at "Conference on the Uses of Task Analysis in the Derivation of Training and Training Equipment Requirements for Complex Electronic Reconnaissance Systems" sponsored by Wright Air Development Center)

Purpose. This symposium paper describes a technique used by H.R.B.Singer, Inc. for presenting task analysis data: IDA graphic presentation offers an alternative to the standard tabular format.

Summary. The IDA (information-decision-action) presentation resembles a flow chart, prepared for each task sequence or position. Separate symbols for information, decision, action, and feedback are keyed with task element numbers. The keyed elements are written out to the right of the flow chart. Time markings are placed to the left of the flow diagram, exchange of data between personnel is shown by horizontal dashed lines, and "loops" as in continuous tracking tasks are easily shown.

Results. While this type of presentation is somewhat more bulky than the standard tabular form of present task analysis data, it is felt that it's graphical characteristics go a long way to showing interrelationships, and that it avoids the omission of significant steps such as multiple decisions (discrimminative decisions and decisions to act).

Comments. This approach not only omits equipment information from the presentation as being of less importance to the purpose of training, but it also seems to omit a careful qualitative analysis or presentation of the psychological factors involved, other than stating that decisions may depend on many variables, actions may be difficult, or that an appreciable amount of recall is required. Skills and knowledges as such do not appear in the present presentation procedure.

This report is not abstracted fully, due to its late inclusion in the bibliography.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

Spector, P., Gaylord, R. H., & Krumm, R. L. (UNCLASSIFIED title) Tentative forecast of personnel requirements for operation of the SUBROC MK-113 fire control system. Washington, D. C.: American Institute for Research, July 1959. (Bureau of Naval Research Contract Nonr-2871(00)) (CONFIDENTIAL report)

Purpose. This project was undertaken to:

1. Collect and analyze data on the SUBROC fire control system, to predict personnel and requirements for operating and maintaining the system.
2. Identify and describe billet and duty assignments required for system operation and maintenance.
3. Determine the "best fit" between system job requirements and personnel qualifications identified in NEC, Qualifications for Advancement and Rating, and NOBC job descriptions; and recommend specific rank or rating, pay grade within rating, and NOBC or NEC code for each billet or duty assignment.
4. Determine special training requirements for proficiency development, and recommend training for each new billet or duty assignment.

Procedures. Most of the data was obtained during early development from interviews with manufacturers' representatives and Navy personnel.

The recommended duty assignments were structured on the basis of three criteria--temporal task grouping, spatial task grouping, and task difficulty. Because the system is utilized in a particular way in each of three temporal phases, operations were grouped by phases, each phase requiring a different set of tasks. Also the system is used in one of four ways during one phase: "subphases" or cycles are described for each mode in that major segment.

Result. A job task analysis presented as a detailed operational duty sequence, plus billet and duty descriptions, resulted. Billet descriptions included rank and rating, pay grade, and NOBC-NEC standard codes, found to be satisfactory. Training recommendations included knowledge areas requiring familiarization, tasks needing individual simulator practice, and procedures requiring crew shipboard practice.

Manning levels were identified and presented in a matrix, combining tactical-operational circumstances anticipated with each of the operational phases.

Comments. This report does not identify the exact methods of analysis used, and is not abstracted.

NOTE: The above abstract omits reference to classified equipment, etc., and is unclassified.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Spector, P., Swain, A. D., & Meister, D. Human factors in the design of electronics test equipment. Pittsburgh: American Institute for Research, April 1955. (Rome Air Development Center Technical Report 55-83)

Purpose. The purpose of this report was to determine what difficulties are found in the use of test equipment, suggest means of eliminating these difficulties by using human engineering principles in test equipment design, and to outline a method of applying these human engineering principles in actual design of test equipment.

Procedure. Eleven test equipment job segments were identified; selecting test equipment, locating it, transporting it, attaching it to prime equipment, setting it up, determining test equipment accuracy, identifying test points, reading test equipment information, interpreting the information, securing test equipment, and hazardous conditions.

An activity analysis was made of the work of various types of maintenance personnel, including 3, 5, and 7 ratings, varying amounts of experience, varying complexity of assignments, with work status from apprentice to supervisor, involving the maintenance of radio, radar, and teletype equipment. Mechanics were observed in scheduled preventive and corrective maintenance and troubleshooting from the time the need was indicated to the time the equipment was functioning properly. Each relevant behavior was recorded and categorized under the appropriate segment. Discriminations, decisions, manipulations, indications of response adequacy, and error situations were noted.

Structured interviews then requested the men to identify, for each category, the difficult tasks or incorrect behaviors; the type of task in which the difficulty was noted, as calibration check; the amount of training and practice the mechanic had with maintenance tasks when the difficulty arose; and the parts of the test equipment he liked or disliked.

Comments. This study deals strictly with human engineering and equipment design. It is not related to the QPRI problem, and so is not abstracted. Its one value in this bibliography is its emphasis on the importance of considering job behaviors and thereby, training requirements, associated with test equipment.

Location of Document: AIR Technical Library — Abstracted by: J. B. Fairman

Stackfleth, Lt. D. Summary notes on status of QPRI program, prepared at closing of Air Force Personnel and Training Research Center Maintenance Laboratory. Lackland Air Force Base, Texas: Informal personal notes, 1958.

Purpose. This informal memo summarizes then-current procedures for preparing occupational information (QPRI) reports. It reviews four areas: format and editorial considerations; position description methodology; training equipment development; and definition of skill areas.

"As established in AFR-54-7, Occupational Information reports are development reports that provide preliminary estimates of the manning and organization of personnel needed for new weapon systems. This information is utilized by Headquarters USAF in determining the qualitative personnel requirements and guidance subsequently released in Personnel Planning Letters by that Headquarters. Although the Occupational Information Report is not directive in nature, it must provide personnel-oriented data that are as accurate as possible (at a specified point in time) so that personnel plans based thereon may provide for sufficient numbers of men with the requisite aptitude and training to operate and maintain the weapon system in the operational situation."

Comments. This memo is abstracted, including an outline of current QPRI format definitions and examples of a Task Inventory, Hypothetical Manning List (from AFM 35-1), and a Training Devices Information Data Sheet. It is intended to summarize then-current usage at AFPTRC, and does not present new ideas. The illustrations and examples are from other documents.

Location of Document: Training Psychology Branch Aerospace Medical Division, WADD

Abstracted by: E. M. Jones

Miller, R. B. Suggestions for shortcuts in task analysis procedures. Pittsburgh: American Institute for Research, December 1954. (Aero Medical Laboratory Contract No. AF 33(616)-2080) (b)

Purpose. This report is the result of a study of methods for reducing the time and effort spent on task analysis prior to making training device design recommendations. Normally, a task analysis is expected to make inputs to many areas, such as the effective use of training equipment, selection and proficiency determination, human engineering, operations analysis, job design and job procedures, and job instructions. This study attempts to identify the shortcuts possible if all the purposes for a task analysis were eliminated except that of designing training equipment.

Summary. The essential feature of the shortcut is that only those aspects of tasks are recorded that the analyst judges may present some special training problems and therefore possibly require special training device characteristics. The task analysis procedure taken as a point of departure is described in full in Miller (1953b).

Comments. This report is abstracted in full.

Location of Document: ASTIA AD 78 439
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Some general characteristics of a man-machine system. Chapter II of draft, Manual for man-machine job-task description. Pittsburgh: American Institute for Research, June 1955. (a)

Purpose. This chapter presents a brief general discussion of a man-machine system and the advantages of considering the entire system in planning any aspect of the system, especially as in performing a "job-task analysis." Inputs, outputs, system variables, and the role of training are considered.

Comments. This document is not abstracted since it does not contribute directly or uniquely to the problem of the survey. The material it contains was published earlier (Miller, 1954a) in a more comprehensive document.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. General processes and terms in behavioral description. Chapter III of draft, Manual for man-machine job-task description. Pittsburgh: American Institute for Research, June 1955. (b)

Purpose. This chapter consists mainly of definitions of terms used in describing man-machine task analysis methods, with special emphasis on the area of decision-making and knowledge derivation.

Conclusions. The abstract of this report lists sample definitions and related considerations. In the text, each definition and its implications are generally discussed in more detail with examples, and greater continuity. Three areas of behavior are defined: perceiving, decision-making, and manipulation.

Perception in man-machine systems, is essentially the discrimination of an out-of-tolerance condition from an in-tolerance condition. Reference standards, natural stimuli versus symbolic stimuli, and channels of information are considered.

Decision Making is a response consisting of three segments: (1) responding to a group of stimuli, (2) recalling pertinent information, and (3) interpreting. Recalling, job-task inferring, and interpreting are defined.

With regard to manipulation in man-machine tasks, the term "control" may refer to any object which in the course of job performance must be adjusted, pressed, twisted, shifted, lifted, or otherwise requires some change of position. Efficiency in using controls, accessibility to controls, reaction time, rate and accuracy of control movement, and shifting from one control to another, are discussed.

Comments. This chapter is scanned in the abstract. The reader is referred to the original document for greater detail.

Location of Document: AIR Technical Library — Abstracted by: J. B. Fairman

Miller, R. B. Determining the man-machine performance criteria. Chapter V of draft, Manual for man-machine job-task descriptions. Pittsburgh: American Institute for Research, June 1955. (c)

Purpose. This chapter discusses the performance criteria required of man-machine systems as they affect the definition of operator and mechanic jobs. It is not abstracted since the material is covered more completely elsewhere.

Conclusions. A program or program variable is an input; a system function is an output directed to a specific purpose. A functional analysis of system outputs leads directly to job functions and job requirements. It is an orderly way of covering completely the human control requirements. In revealing system functions, the need becomes apparent for performance tolerances for the man-machine team. These tolerances are reflected in job performance tolerance requirements.

Maintenance operations usually do not have rigorous time limits, but do have quality standards or equipment operating tolerances which must be maintained. Operators must fulfill time as well as quality or accuracy criteria. Because error always exists in a system, tolerances should be stated as acceptable probabilities of meeting the required tolerances. Acceptability, of course, depends on the purpose to be achieved. Tighter operating tolerances demand higher skill and often, qualitative differences in operator skill. A point of diminishing returns from increased training is determined by the limits of human capability and the constant and random errors in the machine linkages between input and output.

In tasks with inflexible time demands, task priorities must be part of the habit structure of the operator. Such relative priorities normally are established in the Air Force by the Operational Plan.

In summary, to determine the human requirements in a man-machine system, reference must be made to the qualitiative and quantitative standards demanded of the machine output with respect to given input programs to the system.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

Miller, R. B. A theory of concept-mediation in learning and performance. Pittsburgh: American Institute for Research, December 1955. (Project No. 7714, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205) (d)

Purpose. This report is intended to provide the theoretical background for techniques whereby essential job knowledges can be systematically determined from a set of job requirements. It is a companion report to Miller and Van Cott (1955).

Rationale. The theory develops the paradigm of conceptual behavior symbolized by S--(s--)--R in which S is a discriminable, environmental Stimulus characteristic, deviating from some objective goal state of affairs, (s) is an implicit surrogate of the discriminated S; (r) is an implicit surrogate of the overt Response or Response family; and R is the overt Response made on some control in the work environment. An effective conceptualization requires associative units between S and (s), (s) and (r), and (r and R. Associations also may be trained among (s-r)'s on the basis of generalization of the (s), the (r), or both. The (s) may be symbolic of an environmental goal state, in which case it is treated as "purpose." In this form it may also mediate both implicit and explicit generalization.

The assumptions and behavioral inferences derviced lead to hypotheses not only for deriving operative knowledge content, but for sympolizing that content, and also for the design and utilization of training and training aids, job instructions, and the organization of symbolic content in training.

Comments. This rather complex theoretical treatise is not abstracted. Much the same materials is reviewed by Miller and Van Cott (1955), which is abstracted.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

Miller, R. B. A suggested guide to position-task description. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, April 1956. (ASPRL Technical Memorandum 56-6) (Project No. 7709, Task No. 77150, Contract No. AF 18(600)-1203) (a)

Purpose. This guide details methods for describing job requirements for operation and maintenance of new Air Force weapon systems, as part of a Qualitative Personnel Requirements program. Position-task analysis provides data, not answers to problems: it shows what has to be trained, but not the best way to do the training; it may suggest, but not direct, changes in procedures or equipment design. Position description is not an end in itself; it is information permitting old and new positions to be compared with a view to selection requirements, and to determine training and other personnel requirements. The critical information is usually contained in the description of position elements within tasks, rather than in task names and duty titles.

The more specific the description of human requirements, the more precisely can habits, skills, and abilities be modified or built-in to meet the requirements. The purpose of a description determines the level of specificity needed.

Special Features. This document contains an especially good glossary of terms drawn from four companion guides, this and Miller (1956b) being among them.

Comments. This report reviews and draws together many of the techniques of analysis and presentation developed at earlier times, and weaves them into a logical, comprehensive, and smooth-flowing whole for the presentation of qualitative personnel requirements information. This is certainly one of the key items in the survey.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. A suggested guide to position structure. Lowry Air Force Base. Colorado: Air Force Personnel and Training Research Center, May 1956. (Maintenance Laboratory Technical Memorandum 56-13) (Contract No. AF 18(600)-1203) (b)

Purpose and Phasing. The purpose of this guide is to provide guiding principles for the development of position structures and Position Organization Tables at about the time a newly developed weapon system reaches the stage of the Operational Concept and Plan.

Position structure is the assigning of all tasks and groups of tasks within an organizational unit to individual positions on the basis of requirements of the organizational unit to accomplish a goal, and the psychological factors going into individual training and performance. The product of this structuring is a Position Organization Table which will provide the data for Tables of Organization and Manning Tables.

Summary. Three techniques for testing position structure are suggested: a "Blackboard Test," use of a simulator, and utilization of the Operational Suitability Test situation.

To perform the "Blackboard Test," a Proponent, Opponent, and Umpire are chosen. The Opponent poses specific program conditions and the Proponent tries to accomplish the mission objective. The Umpire rules out unrealistic programs and keeps data on the results. The results are limited principally because the procedure deals with symbolic rather than actual events, and depends largely on the astuteness of the players.

The simulator test may be used to check the position structures developed in earlier phases. It presumes that all positions and their functional interrelationships in a crew are represented in the simulator.

The Operational Suitability Test provides still greater realism, in some respects than the simulator. It is less useful than the simulator only in that it is less flexible in presenting stimulus inputs and in representing emergency conditions. In both simulator and Operational Suitability Tests, the same categories of data are required as for the Blackboard Test. Data from system simulations are likely to be far more valid as bases for inference and recommendations than from the Blackboard Test.

Comments. This key report is reviewed fully, within the confines of a brief abstract. Included are guidelines and specific procedures, in addition to the discussion of the three test techniques.

Location of Document: AFPTRC Inventory Files
AIR Technical Laboratory

Abstracted by: J. B. Fairman

Miller, R. B. Suggested approaches to programmatic research on position and occupational structures in the Air Force. Working paper. Pittsburgh: American Institute for Research, November 1956. (c)

Purpose. Three general proposals are outlined in this working paper. The first is principally ameliorative, presupposing the then current Air Force structure of human factors management. The study of current policies and needs, as they reflect in communication requirements about human factors between agencies is suggested.

The second proposal suggests that a systems analysis and synethesis approach be taken in generating an idealized model of personnel decisions and actions, together with principles for making personnel decisions and a format for supplying specific behavioral and policy data required to make each class of decision.

The third proposal suggests that a transfer of training taxonomy might be developed that would provide "basic units" of behavioral description amenable to the various personnel decisions and actions that need to be taken, including occupational and position structures, selection, training, proficiency evaluation, and task assignment.

Comments. This paper, largely a general discussion of the topics above, is not abstracted, since it does not present any unique approach or procedure related to the present survey.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Miller, R. B. A study of developmental history of certain complex electronics systems. Final Report. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1956. (AFPTRC Technical Report 56-1) (Project No. 7709, Task No. 77150, Contract No. AF 18(600)-1203) (d)

Purpose. This document is the final administrative report of the project, and so is not abstracted. Other products of the project which were included in the survey are Miller (1956a; 1956b), Jones and Miller (1956), and Miller, Meister, and Feroglia (1955).

There were two general purposes for the project. The first objective was to determine what maintenance information should be collected, and from what sources; at what stage in the developmental sequence it is feasible to collect this information for job forecast purposes; and how this maintenance information can be assembled for the anticipation of maintenance job requirements.

The second major objective of the study consisted in the preparation of a series of guides describing procedures for anticipating operator and maintenance job information, and for converting this information into training and training device requirements, position structures, and handbooks of job instructions. These guides were prepared for the use of the Air Force Personnel and Training Research Center in conjunction with the development of the Qualitative Personnel Requirements Information program.

A brief review of the over-all project is given.

Special Features. This report lists all nine of the documents prepared during the project, other than this administrative report.

Location of Document: ASTIA 098904
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B. Derivation of skills and knowledges in electronic maintenance. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, January 1957. (Project No. 7709, Task No. 37300, Contract No. AF 18(600)-1351) (AFPTRC Technical Note 57-5).

Purpose. The purpose of this study was to derive a behaviorally oriented method of developing generalizable training content. The scientific problem was to systematize the abstraction of generalizable course content based on actual job behaviors, rather than on the conventional theory of design and operation of equipment. The practical purpose was to develop training which would permit cross-trainability among six electronics maintenance positions for the F-86D aircraft.

Procedure. The procedure, adapted from a previous research development (Miller & Van Cott, 1955) consisted of four principal steps:

1. Making explicit the assumptions and conditions on which the training was to be based.
2. Identifying and describing the position requirements in sufficient detail that inferences could be made about common skills and knowledges.
3. Inferring the skills and knowledges common to two or more positions.

Deriving common knowledges was the key problem in the study. Knowledges were thought of as "symbol-mediated" similarities, because the mechanic may be able to form and generalize a capability by means of ideas, concepts, and symbols. In identifying common knowledges the approach was to induce conceptual content and knowledges from detailed behavioral data.

4. Translating the common skills and knowledges into characteristics for core training.

Comments. This paper is abstracted fully. The conclusion not reached was whether the generalizable skills and knowledges derived could best be taught in a "core" course or as part of specialized training.

Location of Document: ASTIA 113 045
AIR Techncial Library

Abstracted by: J. B. Fairman

Miller, R. B., & Folley, J. D., Jr. A study of methods for determining skill, knowledge, and ability requirements for maintenance of newly developed equipment. Technical Appendices I-VII. Pittsburgh: American Institute for Research, June 1951. (Project No. 21-07-016) (Human Resources Research Center Contract No. AF 33(038)-12921) (a)

Purpose. This document, the second report of the study of methods for determining skill, knowledge, and ability requirements for maintenance of newly developed equipment, sets forth the formats and rationales of the two analytical methods developed to obtain, record, and organize the behavioral data needed to anticipate the personnel requirements of the equipment under development.

One section of the report, dealing with the influence which equipment design exerts on the subsequent job requirements, and offering some elementary guide lines whereby training for maintenance and maintainability may be aided, is not reviewed in the abstract.

The Standard Maintenance Form (SMF) is used to record maintenance incidents and behaviors not anticipated from equipment design, and to indicate special maintenance difficulties. It also provides frequency data with respect to given kinds of maladjustments and malfunctions, emphasizing the importance of certain maintenance behaviors by a simple tally.

Summary. The list of Job Behaviors as made from the equipment itself and supplemented and amended by empirical Standard Maintenance Form data will be an exhaustive list of over-all maintenance at a given level. This list identifies the essential tasks, which constitute the minimum training requirements for job effectiveness: if the trainee is taught these things he can be effective in his job; if he is not taught them, no matter how much else he is taught, he will not be effective until he learns them.

Comments. This basic document is abstracted briefly. The detailed rationale of individual SMF items is omitted because of its length.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., & Folley, J. D., Jr. Recommendations on designing electronics equipment for the job of maintenance. Lackland Air Force Base, Texas: Human Resources Research Center, December 1951. (Research Bulletin 51-33) (Project No. 507-008-0001, Contract No. AF 33(038)-12921) (b)

Purpose. This report is basically a reprint of pages 1-47 of Miller and Folley (1951a). This portion of the original document is less applicable to the survey at hand than the remaining portion of the original document, and so is not abstracted.

Summary of Method. Maintenance job requirements can be anticipated in three ways, and it is recommended that all three be used when practicable. First, maintenance tasks should be simplified by the way the equipment is designed. Most of the report is concerned with this area. The second approach was the use of Job Behavior Forms to compile job behavior data indicated by the design of the equipment, according to the categories of checking, adjusting, troubleshooting, replacing, and repairing.

The third approach consists of keeping appropriate maintenance records using the Standard Maintenance Form, on the prototype and production equipment. The second and third methods were being tested when the report was prepared (Miller & Folley, 1952; Miller, Folley, & Smith, 1953a).

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., & Folley, J. D., Jr. The validity of maintenance job analysis from the prototype of an electronic equipment. Part I: AN/APQ-24 radar set. Technical Appendices I-V. Pittsburgh: American Institute for Research, June 1952. (Project No. 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921)

Purpose. This report precedes Miller, Folley, and Smith (1953a) as the first application of a method for anticipating line maintenance job requirements from prototype development data. The job analysis of the AN/APQ-24 was secondary in this project to the testing of the job anticipation procedures. These procedures, covered in this document, are reported in full in Miller, Folley, and Smith (1953a) Miller and Folley (1951a), and Miller and Folley (1951b). The text of this document is therefore not abstracted.

Special Features. This report, stressing the equipment analysis of the AN/APQ-24, provides substantial coverage of the technical aspects of the line maintenance job, especially for the troubleshooting techniques and behaviors involved. Sample comparative formats of line and shop troubleshooting procedures using the logical elimination technique are presented, and include sample inferences of the troubleshooting skill and knowledge requirements. The first part of this troubleshooting behavior analysis format is presented in the abstract.

Location of Document: ASTIA AD 5864
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., & Folley, J. D., Jr. Development of core training for F-86D electronic maintenance positions: IV. Principles and techniques. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, June 1956. (Maintenance Laboratory Technical Memorandum 56-4) (Project No. 7709, Task No. 37300, Contract No. AF 18(600)-1351)

Purpose. This report describes the psychological problem and general principles and techniques for deriving core or generalizable training used in this study.

Summary. The principles and techniques, along with the general problems identified, are outlined in this report. The development of a core training course in this study consisted of:

1. Making explicit the assumptions and conditions on which the training was to be based.
2. Identifying and describing the position requirements in sufficient detail that inferences could be made about common skills and knowledges.
3. Inferring the skills and knowledges common to two or more positions.
4. Translating the common skills and knowledges into characteristics for core training.

To aid in its basic problem of skill and knowledge identification, a "Checklist of Questions for Identifying Job Situations Where Knowledge Support Maybe Useful" is provided. However, this is the only specific technique or procedure spelled out in this report.

Comments. This document was added to the bibliograpy late, and was not abstracted. The methods it discusses are presented more fully by Miller and Van Cott (1955), Miller (1955d), and Peterson (1956).

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Flanagan, J. C. The standard maintenance form. Its purpose, development, and use. Pittsburgh: American Institute for Research, February 1951. (Project No. 21-07-016, Human Resources Research Center Contract No. AF 33(038)-12921)

Purpose. This interim report presents a description of the first revision of the Standard Maintenance Form (SMF). A description of the third revision and an illustration of the fourth revision are presented in Miller and Folley (1951a). Because the material in this report is identical to one section of the Miller and Folley document, except for changes required by the revision, this interim report is not abstracted.

The original purpose of designing the SMF was to provide a simple, reliable way of getting data from prototype testing of newly developed equipment. Each item on the SMF is justified by some purpose to be served by the data obtained from it. These justifications and detailed instructions for its use are presented in this report.

Its development and use were aimed at assisting in the functions of:

1. Predicting over-all maintenance job requirements for a given equipment to determine training requirements (what the mechanic must learn to do) and training criteria (tests of fitness for the job).
2. Guiding modification of equipment, test devices, and procedures.
3. Designing maintenance jobs.
4. Organizing maintenance operations for maximum efficiency.
5. Standardizing and simplifying recording, classifying, and filing of maintenance information.
6. Aiding line maintenance personnel in their duties.
7. Providing criterion data for evaluating maintenance at the levels of individuals, organizations, fields, and equipment systems.
8. Helping find maintenance operations bottlenecks.

Comments. The SMF, in revised form, was found to be very helpful in obtaining equipment information in conjunction with "activity analysis," during prototype testing and operation of new equipment.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. The validity of maintenance job analysis from the prototype of an electronic system. Part II: K-1 bombing-navigational system. Pittsburgh: American Institute for Research, February 1953. (Project No. 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921) (a)

Purpose. This report reviews the second application of a procedure developed earlier in this project (Miller & Folley, 1951a; Miller & Folley, 1952), for the anticipation of maintenance job requirements of an electronics equipment for data available at the prototype stage of equipment development. The purpose of this second application was to provide a second check on the adequacy (validity) of the procedure.

The project was concerned with two principal objectives. One of these was to determine the extent to which job behaviors of maintenance personnel can be predicted from preproduction data of newly developed equipment. The other was to devise relatively simple, practical methods for getting this job information during preproduction phases of equipment development, since the earlier the job requirements can be anticipated, the sooner a training program can be prepared and support provided for the equipment in the field.

Procedure. The general approach used in this project was the comparison of maintenance job requirements data available at the prototype stage of development with similar data obtained from the early operational equipment. A set of behavior categories and maintenance functions are used in the comparison. The result confirmed the earlier finding that job requirements, described at the level of these categories, are predictable from the prototype.

Comments. This key report is abstracted fully.

Location of Document: ASTIA AD 10 316
AFPTRC Inventory Files
AIR Techncial Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. Troubleshooting in electronic equipment. A proposed method. Pittsburgh: American Institute for Research, March 1953. (Special report on Project No. 507-008-0001, Human Resources Research Center Contract 33(038-12921) (b)

Purpose. This report provides step-by-step procedures, including statements of the inferred skill and knowledge requirements, as presented for both line troubleshooting to assemblies and shop troubleshooting to parts.

Rationale. Several troubleshooting techniques are investigated; troubleshooting from malfunction probability data, troubleshooting by "logical elimination," and troubleshooting by the "half-split" technique. The probability approach was shown to be unsatisfactory because of its "historical" data requirements and from the standpoints of operational effectiveness and its impracticability for advance or cross-training.

The logical elimination approach, using a functional block or circuit diagram, was considered more desirable on all these counts and was the basis for the derivation of the behaviors and inferred skills and knowledges.

The half-split technique is designed for the isolation of a malfunction within a given chain and is closely related to Information Theory. The mathematical proof of this technique further demonstrates the relative inadequacies of the probability approach.

Recommendations. In addition to endorsing the logical elimination technique, it is suggested that the half-split technique be extended to the entire troubleshooting problem, with positive implications for new principles of maintenance check design, equipment design, and preproduction test data requirements.

Comments. Part I of this report was lifted bodily from Miller and Folley (1952) which is abstracted, and Part II is duplicated in Miller, Folley and Smith (1953g), which is considered separately. Because of this and its indirect applicability to the present survey, it is not abstracted.

Location of Document: ASTIA AD 11 046
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. A preliminary report on the comparison of line maintenance job requirements of electronics equipment. A special report based on AN/APQ-24 and K-1 line maintenance job data. Pittsburgh: American Institute for Research, June 1953. (Project No. 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921) (c)

Purpose. This report is a preliminary study for the determination of those job requirements of line electronics mechanics common to various equipment at the line level of maintenance, as a basis for a "fundamentals" course incorporating the common job requirements.

Procedure. On the basis of detailed task analyses of the AN/APQ-24 and K-1 line maintenance jobs the following comparisons were made:

1. Comparison of specific behavior content between the AN/APQ-24 and K-1.
2. Comparison of categorized checking, adjusting, and replacing job behaviors: prototype versus production models for the Q-24 and K-1.
3. Comparison of subtask procedures for the checking function.
4. Comparison of adjustment subtasks.
5. Computer replacement procedures.
6. Comparison of skill and knowledge requirements for the repair function.
7. Comparison of production model test equipment.

Results. Although many individual behaviors in the two jobs studied were more or less equivalent, the organizations of these behaviors into procedures were so different as not to be transferable unless the same components of hardware were common to both equipment. It was felt that if the logical method of troubleshooting were taught as a general technique, it would transfer from one equipment to another. Procedures on similar test equipment and precautions should also transfer. Training time might be reduced if symbols used by the Q-24 and the K-1 manufacturers to represent the variables in the bombing and navigational problems were identical, where the variables were the same.

Comments. Although this report contains information relevant to the survey it was not abstracted since Miller, Folley, and Smith (1954), a reprint of this report, is reviewed.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. A study of methods for determining skill, knowledge, and ability requirements for maintenance of newly developed equipment. Final Report. Pittsburgh: American Institute for Research, June 1953. (Project No. 507-008-0001, Human Resources Research Center Contract No. AF 33(038)-12921) (d)

Purpose. This document is the complete administrative final report on the project. Miller, Folley, and Smith (1953e) abstracts from this the administrative material and annotated bibliography of project products. This report was not abstracted because the methods and rationales involved are more thoroughly reviewed in other documents.

Conclusions. The phasing problem which gave rise to the study--the need to obtain maintenance job data during the design and development stages of system development--is reviewed historically.

The preliminary investigation and concept orientation is next outlined, i.e., a system function analysis approach. Implementation of this man-machine concept is described as being accomplished by the development of the Standard Maintenance Form (Miller, Folley, and Flanagan, 1951) and "activity analysis," and by the Job Behavior Form (Miller & Folley, 1951a) and "equipment analysis." This latter technique attempted to consider the psychological aspects of the job, and was found to be more satisfactory in obtaining predictive data early in system development.

The combined procedures were then tested by application to two weapon systems, one of which was the predecessor of the other. These were the AN/APQ-24 and the K-1 bombing-navigation systems. The report describes these applications briefly. The results correlated well and indicated that this method should be useful in predicting the job requirements of new systems.

A troubleshooting technique was also developed during the study (Miller, Folley, & Smith, 1953b), based on the "logical elimination" approach.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. Summary and review of research on job anticipation procedures applied to electronics maintenance. Pittsburgh: American Institute for Research, June 1953. (Human Resources Research Center Contract AF 33(038)-12921, Project No. 507-008-0001) (e)

Purpose. This document contains administrative material (pages 1-2 and 29-46) abstracted directly from Miller, Folley, and Smith (1953d) and is therefore not abstracted. The report presents a chronological overview, in summary form of the background, research activities, and outcomes of the project, including an annotated bibliography of the products of the project.

Conclusions. The project was initiated to develop a method for anticipating maintenance job requirements prior to production, by obtaining data during the prototype and early system development stages. The method is based on the concept of maintenance as a man-machine system with identifiable purposes. Once these purposes are stated, the activities required to achieve them can also be specified.

The two techniques developed and used for obtaining the required data were the Standard Maintenance Form, in conjunction with "activity analysis," and the Job Behavior Form, in conjunction with "equipment analysis," which taken together constituted "task analysis." "Equipment analysis" was later found to be the more fruitful for purposes of predicting personnel requirements during the early development stages.

The procedure developed was applied to the AN/APQ-24 and K-1 bombing-navigational systems to test its effectiveness and usability. The results of this comparative application were highly correlated.

A troubleshooting technique of general applicability--the logical elimination technique--was also developed during the project. This was done primarily as a basis for treating the tasks and procedures of troubleshooting systematically in the study, since no explicit troubleshooting technique was available at that time. The technique has appreciably increased the effectiveness of field troubleshooting as it and its later variations have been applied.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. Job anticipation procedures applied to the K-1 system. Lackland Air Force Base, Texas: Human Resources Research Center, July 1953. (Technical Report 53-20) (Project No. 507-008-0001, Contract No. AF 33(038)-12921) (f)

Purpose. This document is an abridgement of the earlier, more detailed report on the K-1 phase of the study (Miller, Folley, & Smith, 1953a). Because the original document is abstracted, and because this abridgement omits some of the pertinent methodology involved, it is not abstracted.

Procedure. The program of which this study is the second phase was predicated on the question "Can maintenance job requirements for an electronic equipment be predicted accurately from information available at the prototype and preprototype stages of development?". A method for anticipating maintenance job requirements prior to the introduction of new equipment was developed and initially validated on the AN/APQ-24 (Miller & Folley, 1952). This report reviews a second application of the method to the K-1 system to check the adequacy and validity of the method.

To analyze a complex man-machine system, both the demands of the machine on the man and the behaviors carried out in maintaining (or operating) the machine must be studied. The first was considered by "equipment analysis," and the second by "activity analysis."

Results. Experience indicated that while the data obtained from equipment analysis appear both necessary and sufficient for anticipating maintenance job requirements, the data collected by activity analysis may leave parts of the maintenance job unaccounted for.

Location of Document: ASTIA AD 190 45
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. Systematic troubleshooting and the half-split technique. Lackland Air Force Base, Texas: Human Resources Research Center, July 1953. (Technical Report 53-21) (Project No. 507-008-0001, Contract No. AF 33(038)-12921) (g)

Purpose. This report describes in detail a mathematical technique developed in conjunction with the above contract and recommended as permitting reliable anticipation of troubleshooting tasks and troubleshooting training prior to field operation. It requires a moderate amount of logic on the part of the mechanic, in addition to the necessary checking and adjusting skills. It utilizes function diagrams for line maintenance and circuit diagrams for shop maintenance. It is an outgrowth of and adjunct to the logical elimination troubleshooting technique recommended by Miller and Folley (1952) and Miller, Folley, and Smith (1953a). The mathematical proof of the technique is given in the appendix.

Comments. This report summarizes material from Miller and Folley (1952) and reprints Part II of Miller, Folley, and Smith (1953b). While part of the same project, this largely mathematical and information theory technique of maintenance troubleshooting does not have a direct bearing on the present survey and is not abstracted.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Folley, J. D., Jr., & Smith, P. R. A comparison of job requirements for line maintenance of two sets of electronics equipment. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1954. (Technical Report 54-83) (Project No. 7709, Task No. 77150, Contract No. AF 33(038)-12921)

Purpose. The purpose of this offshoot from the study of methods of analyzing maintenance jobs was to provide an example of a systematic approach and set of procedures for comparing job activities involved in the maintenance of two or more systems. Such a comparison could provide preliminary suggestions for the kinds of transition training appropriate from one equipment to another and the common features of line maintenance jobs in several equipment which would provide the content of a course "basic" to them all.

Conclusions. The individual behaviors required in the perceptual and motor aspects of the job functions of checking, adjusting, replacing, and repairing appeared to have a high degree of pscyhological similarity. The two sets had had little in common in the knowledge of nomenclature and location requirements for the identical components. The knowledge and practice of precautions was found to be about the same for both sets, and the activities of transcribing and recording data and making arithmetic computations were almost identical. A high degree of carry-over was present when block diagrams and logical elimination troubleshooting are taught as a generalizable skill. However, if troubleshooting training were stimulus-bound as in the use of a malfunction probability technique, very little transfer would occur. A number of recommendations are given for a "maintenance fundamentals" course.

Comments. This report is abstracted fully.

Location of Document: ASTIA AD 53 727
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., Meister, D., & Feroglia, W. E. Sources of maintenance job information: I.V. Development of information for anticipating maintenance job requirements of new electronic systems. Lowry Air Force Base, Colorado: Armament Systems Personnel Research Laboratory, Air Force Personnel and Training Research Center, August 1955. (ASPRL Technical Memorandum 55-16) (Project No. 7709, Task No. 77150, Contract No. AF 18(600)-1203)

Purpose. This report presents the implications of a study of the kinds and sources of information required for anticipating the job and training requirements for maintenance of electronic equipment during early stages of development.

The maintenance duties to be anticipated are categorized as checking and inspecting, adjusting, troubleshooting, replacing, repairing, and servicing.

Recommendations. It is estimated that a reliable forecast of both line and shop maintenance job requirements can normally be made 18 months at the latest after beginning the development model of the system. This data should coincide with the mock-up inspection which usually precedes initiation of the "slow production " model. Assuming no major revisions, minor design changes can easily be incorporated in the on-going maintenance training program. By the time the slow production model is contracted for, most of the developmental products should be available, and the planning for maintenance training should be started.

Comments. This report is abstracted fully, including the very useful outline provided of the sources and kinds of information available which may be used in estimating job and training requirements.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Miller, R. B., & Van Cott, H. P. The determination of knowledge content for complex man-machine jobs. Pittsburgh: American Institute for Research, December 1955. (Project No. 7714, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205)

Purpose. The purpose of this report is to present the logical development of and procedure for a method of determining the necessary knowledge content for performing, and hence, learning a complex man-machine job, and for translating the results into content suitable for training. Brief consideration (Appendix B) is also given to a tentative approach to the determination of the level of task or job complexity.

Rationale. The rationale for the method is developed at length, logically and step-by-step in the body of the report, in psychological terms.

Knowledges are not equivalent to job behaviors; they are not operational work outputs. Consequently, although a knowledge may support the selection and making of a required Response, it is not itself a job requirement. Knowledges are therefore called "conceptual supports" rather than "conceptual requirements," and "learning by rote" is distinguished from "learning by concept."

Summary. This technique of "job knowledge analysis" starts with task analyses, prepared in accordance with Miller (1956a), and has three outputs. The first is the operative conceptual content--the actual knowledges required to facilitate task performance. The second is the symbolic content, the actual words, pictures, or other media by which the operative content is presented for training. The third output is the selection of an organization for presenting this material which will provide further information and support to the learning and operational situations.

Comments. Appendix A, which summarizes the rationale in operational terms, is the portion of the report which is abstracted. Van Cott, Berkun, and Purifoy (1955) provide examples of the application of this approach.

Location of Document: ASTIA AD 125 407
AIR Technical Library

Abstracted by: J. B. Fairman

Murphy, G. L., Fairman, Jean B., Lindner, H. G., Smith, R. W., & Purifoy, G. R., Jr
AN/AMQ-15 Weather reconnaissance system. Personnel operations analysis. Pittsburgh: American Institute for Research, April 1959. (Subcontract BSD P. O. A2736, Prime Contract No. AF 33(600)-37984)

Purpose. This report was the fourth in the development series of the human factors program. It is intended to define and organize the required Q-15 operations and maintenance activities as they exist within the 460L squadron, so their man-man and man-machine relationships can be specified and described in the greatest detail allowed by available equipment information.

Summary. The report contains operational and maintenance assumptions, tentative squadron organization, revised manning, work load analyses, position descriptions, and detailed task descriptions.

The data itself is of little importance to the survey. However, some of the methods of work load analysis and presentation, especially the work analysis time-line chart for operator positions, are of interest. This chart illustrates by different figures the following task behaviors:

Manipulation of a control or mechanical feature
Manual recording of data; writing, plotting
Visual checking, observing of discrete indications
Decision making, advising.

The presentation technique differentiates between task behaviors (Clements) which are fixed in their position in the time sequence and those which may be shifted for better loading distribution.

Comments. This document was not abstracted due to its late addition to the bibliography.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Murphy, G. L., Jones, Edna M., & Folley, J. D., Jr. Suggested procedures for integrating training decisions and actions into missile system development. Pittsburgh: American Institute for Research, February 1959.

Purpose. This report consists of 14 suggested support documents to aid in the planning, development, and integration of the necessary training decisions and actions into a total missile system development program. The report is included in this survey bibliography because of Exhibit 1 in Section 8: Support Document for Preparation of Course Training Standards.

Summary. Exhibit 1, Training Standards Code Key, presents a seven-level coding system for rating the level of proficiency required on the job in the tactical or operational situation.

Performance is described in terms of four major dimensions. These are:

1. Time. How long does it take the person to perform the task?
2. Accuracy. How many and what kinds of errors are made?
3. Amount and kind of supervision and coaching required.
4. Amount of reference to job aids other than those normally available and used in the operational performance of the task.

Each of the seven levels is defined in operational training situation terms. For example, level 1 is defined:

Time: no limit

Accuracy: can describe the general goals of the task and name the major items of equipment used in its performance. Cannot perform the task.
Supervision: no limit
Job Aids: none permitted

Comments. This Exhibit would have been fully abstracted, had it been included in the bibliography earlier. Its significance is in the hypothesis that dimensions one through three (time, accuracy, and amount of supervision) can completely define skill level. Dimension four, of course, is related to knowledge requirements.

Location of Document: AIR Technical Library

Abstractec by: J. B. Fairman

Naurath, D. A., & Kelly, R. P. Prototype task equipment analysis: Hydraulic mechanic. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, 1956. (Maintenance Laboratory Technical Manual 56-12)

Purpose. This report illustrates one attempt to present maintenance (trouble-shooting) "task equipment analysis" data.

Summary of Method. The system for which the hydraulic tasks were reported had two independent hydraulic systems. Each system was divided into five functional loops to which a malfunction could be isolated by systematic functional checks.

The task analysis was illustrated by system diagrams and a diagram for each functional loop. The following format contained the task data. Information in the last column was coded to the diagrams.

Functional Loops	Symptom Types	Troubleshooting Procedure
1.		
1.1 Identified by function	Available symptoms	When ________ Do ________ If ________ If ________

Comments. This report is not abstracted, since it does not discuss the method by which the data presented was derived.

Location of Document: AFPTRC Inventory Files

Abstracted by: E. M. Jones

Norbury, C. J. The application of memo-motion to industrial operation. Great Britain: College of Aeronautics, December 1954. (Report No. 86)

Purpose. This report describes the application of memo-motion study to the analysis of efficiency in aircraft assembly. Its application to other man-machine studies is suggested.

Comments. The memo-motion technique, developed by Mundel at Purdue, is described briefly by Ghiselli and Brown (1955).

This report was not abstracted since the technique discussed has limited applicability to systems still in the development and prototype stages.

Location of Document: ASTIA AD 55 326

Abstracted by: E. M. Jones

Norris, R. C. Development of an efficient set of dimensions for description of Air Force ground crew jobs: Part I. Rating dimensions; Part II. Technical applications. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, June 1956. (AFPTRC Technical Note 56-63)

Purpose. This technical note describes a factor analysis study of the traits possessed by ground crew incumbents of 150 jobs. Eleven general characteristics were factored out.

Comments. This report was not abstracted, since it dealt only with existing jobs. Thorndike, Hagen, Orr, and Rosner (1957) report the sequel to this study, including a comparison between the two studies.

Location of Document: ASTIA AD 125 134

Abstracted by: E. M. Jones

North American Aviation. (UNCLASSIFIED title) Task equipment analysis for (X). Report No. 58-93. Revised June 1958. (WADC Control No. 58 WCLD 1937 - WCLDPTQ) (SECRET RESTRICTED document)

NOTE: Reference to classified equipment is omitted from this abstract, which is unclassified.

Purpose. This document reports a Task Equipment Analysis of a specific system as conducted at the blueprint stage of development. It covers the complete maintenance and operational requirements beginning with the delivery (not yet unloaded) of the system to the using organization.

Summary of Method. First of all, a logical functional sequence of events was conceived describing the entire mmssion cycle. Task information was then obtained by dividing the system mission into segments. The point of separation between segments was determined by the following considerations:

1. Area of work performance
2. Type of equipment used
3. Type of work performed
4. Ground or in-flight environment

Each mission segment was divided into its own function cycles to establish meaningful procedural steps and task relationships.

Tasks thus established were ordered according to the type of functional requirements; i.e., assemble, service, inspect, monitor, etc. The structure of each task was defined by the determination of job elements (or subtasks).

Special Content. In addition to the task equipment analysis format, the report contains a glossary of definitions.

Comments. This report is abstracted, including a tabular format for presenting the task data. The report, unfortunately, does not include any discussion of the rationale for the determination of "job elements" (subtasks) or the identification of skill and knowledge requirements.

Location of Document: Training Psychology Branch, Aerospace Medical Division, WADD — Abstracted by: E. M. Jones

Peterson, R. O. Two general approaches for deriving knowledge content from electronic maintenance tasks. Pittsburgh: American Institute for Research, November 1956. (AIR-199-56-IR-55)

Purpose. This report reviews two approaches to the application of the stimulus-response identity technique for identifying common knowledge content. Stimulus-response identity in this study is identified primarily in terms of the job objects (test equipment, tools, power carts) common to two or more F-86D electronic maintenance positions. The two approaches are the vertical hierarchy approach and the direct relevance approach.

Recommendations. The final product of the direct relevance approach is a long list of concepts to be included in core training. During the study it appeared to be more economical to move from the lower operational concepts upward to the superordinate than vice versa, using the direct relevance approach. The results appeared equivalent if not superior to those of the more comprehensive vertical hierachy method.

Special Features. Two appendices contain additional samples of concept derivation by both approaches.

Comments. This report is abstracted in full. A parallel technique to stimulus-response identity is symbol-mediated similarity, discussed but not investigated fully in the series of reports on Development of core training for F-86D electronic maintenance positions, Lowry Air Force Base, Colorado: Maintenance Laboratory, Air Force Personnel and Training Research Center, June 1956. (Technical Memorandum ML-TM-56-1, 2, 3, 4).

See Peterson, Jones, and Ellis (1957) for a review of the entire project and the role of this technique in the total study.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Peterson, R. O., Folley, J. D., Jr., & Ostrich, R. Development and application of methods for deriving generalizable course content from electronic equipment. Phase 7. Derivation of common skills and knowledges. Pittsburgh: American Institute for Research, September 1956. (Project No. 7709, Task No. 37300, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1351)

Purpose. This report covers the phase of the study in which tasks and equipments identified for electronic maintenance positions for the F-102A are compared to identify commonalities, and the skill and knowledge requirements of these commonalities determined, as a basis for core training content.

Procedure. Five independent approaches were used. The comparisons for commonalities were done by a straight equipment (job object) comparison and the "symbol-mediated similarity" technique, described in Folley and Miller (1956). Some complex skills and knowledges were derived by a method based on the behavior analysis technique outlined in Miller and Van Cott (1955) and Van Cott, Berkun and Purifoy (1955).

The job behaviors inferred from the identified tasks were compared and the commonalities classified by discrimination, manipulation, recall (short and long term), and decision-making. Job instructions were compared for common information required for understanding and applying the instructions. These information requirements were grouped under nomenclature, criteria for decisions, and explanations of processes or procedures. Skills and knowledges were not derived in this area.

Comparisons for common job precautions and job tricks and "gimmicks" were also made. The latter was not fruitful.

Results and Recommendations. The actual data results of this phase are given in the appendix. The derivation of knowledges or superordinate concepts desirable for training purposes remains to be accomplished.

Comments. See Peterson, Jones and Ellis (1957) for a comparable review of this section of the project, as well as of the other sections. Westen and Peterson (1958) is the final report on the project.

Other than specific methods or data referred to in other documents, no significant new method or approach is discussed here; in fact, even the approach used is not really clearly explained.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Peterson, R. O., Jones, Edna M., & Ellis, D. S. Core training for electronic maintenance: Principles and techniques. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, November 1957. (Maintenance Laboratory Technical Memorandum 57-2) (Project No. 7729, Task No. 37300, Contract No. AF 18(600)-1351)

Purpose. The purpose of this project was to develop training which would facilitate later training within and between electronic maintenance positions on the F-86D and F-102A systems. The approach developed here was that of core training, although the training content derived might be equally applicable to inclusion in specialized causes for each position, designed to facilitate eventual cross-training. The initial training developed here differs in content and conception from conventional "fundamentals" training in that it is derived from an analytic study of anticipated on-the-job maintenance activities.

This report, in addition to reviewing the entire project, describes the methods and techniques which emerged from this development work. They are a major product of the study and should have general applicability for training derivation.

Recommendations. Two questions are raised regarding core training:

1. Is initial maintenance training the most effective situation in which to teach core skills and knowledges? It was felt that this content could be taught just as effectively as part of specific position training.

2. Did the core training derivation miss critical knowledges and skills for electronic maintenance? By emphasizing common activity units, common behaviors in different-appearing activity units may have been missed. Further, the requirement that knowledges be closely linked to activities and specific stimuli and responses may have eliminated some critical knowledges by too strict interpretation. However, further study is required before exact areas of weakness in this methodology can be determined.

Comments. This report is abstracted. More detailed discussions of individual methodologies are presented in Peterson (1956) and Miller and Van Cott (1955). More general reviews of the project are given in Westen and Peterson (1958) and Peterson, Folley, and Ostrich (1956), which are not abstracted.

Location of Document: AIR Technical Library Abstracted by: J. B. Fairman

Purifoy, G. R., Jr., & Fairman, Jean B. AN/AMQ-15 weather reconnaissance system. Training study planning report. Pittsburgh: American Institute for Research, July 1959. (Subcontract BSD P. O. A2736, Prime Contract No. AF 33(600)-37984)

Purpose. The purpose of this study plan was to outline a suggested approach to the derivation of training requirements for a new system in the prototype stage of development. The second half of the report, Q-15 Training Development, is of principal interest to this survey.

Summary. The steps discussed in this suggested approach to the generation of training requirements are updating system requirements, task equipment analysis, QPRI, training functions analysis, training courses, and training aids and equipment requirements. Data collection formats for line maintenance, shop maintenance, and operator data are suggested, plus a task-equipment analysis format, ground support task tabulation and time-line format, and a QPRI position description format.

Following a review of the procedures associated with each of these, the training functions analysis is presented in a step-by-step procedure plus appropriate formats for task description and the skills and knowledges to be trained. The training functions analysis technique, which is the unique contribution of this report, seeks to answer the following questions:

1. Which tasks, for which positions, require task practice for job competence?

   Which of these require a critical proficiency in terms of speed, accuracy, etc.? See Murphy, Jones, and Folley (1959).

2. Which tasks, for which positions, require crew or team training?
3. What skills are required to perform each task for each position?
4. What job aids, including tools and test equipment, are required to support performance on each task for each position?
5. What knowledges are required to perform each task for each position?

Comments. Had this report been added to the bibliography earlier, it would have been fully abstracted.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman

Rabideau, G. F. (UNCLASSIFIED title) Human engineering considerations in the design of training equipment for the F-102 fighter-interceptor simulator trainer. Pittsburgh: American Institute for Research, June 1954. (Aero Med Laboratory Contract No. AF 33(616)-2080) (CONFIDENTIAL report)

Purpose. This document reports the study of the F-102 trainer to validate "A Method for Determining Human Engineering Design Requirements for Trainer Equipment," TR-53-135, and to set forth the training equipment design recommendations made for that trainer in the course of the study, along with the assumptions on which these recommendations were based.

Procedures and Results. The F-102 flight simulator's design characteristics were arrived at following three steps. First a task analysis was made in accordance with TR-53-137 (Miller 1953b), providing data on the perceptual discriminations, decisions, and responses required of an F-102 pilot on a combat mission, including indications of relative pilot load stress during various parts of the mission.

The data were next analyzed by application of the "Human Engineering Design Schedule for Training Equipment," TR-53-138; the design recommendations were developed from that analysis plus consideration of specific principles of human learning found in TR-53-136, "Handbook on Training and Training Equipment Design." The presentation format for the recommendations consisted of arranging the recommendations on separate pages, and in considering separately the physical and functional properties of the recommended equipment, its use, and pertinent rationales.

Special Features. This document contains a detailed glossary and a series of good, illustrative sample mission Time Charts covering various "programs" or operational situations in which the combat-intercept job must be accomplished.

Comments. Since this report does not describe the actual methods or procedures used in developing the training requirement predictions, it is not abstracted.

NOTE: The above abstract omits reference to classified equipment, etc., and is unclassified.

Location of Document: ASTIA AD 78 541
AIR Technical Library

Abstracted by: J. B. Fairman

Ray, J. T., Passey, G. E., Adams, O. S., Smader, R. C., & Simon, G. B. Preparation of position-task-equipment analysis for weapon systems. Introduction. Marietta, Georgia: Lockheed Aircraft Corporation, April 1957. (Air Force Personnel and Training Research Center Contract No. AF 41(657)-67) (a)

Purpose. The purpose of Chapter IV, The Position-Task-Equipment Analysis, of the document above (see Comments) is to apportion the total maintenance requirement to specific maintenance positions on a rational basis. The analysis proceeds from the assignment of skill levels to tasks to and through the development of manning requirements.

Rationale. This procedure takes as the starting point the nonposition-oriented task descriptions resulting from the preceding task analysis. Two considerations basic to this procedure are that it will use system utilization potential as the general criterion for determining positions, and "turn-around-time" available for organizational maintenance as a corollary criterion. These criteria inherently involve consideration of manning requirements.

Scheduling. The "position-task-equipment analysis" comes after the "task analysis" described in this and Ray, Passey, Adams, Smader, and Simon (1957b), since it depends on specific data resulting from the task analysis.

Summary of Method. The first step is a tentative assignment of position title by major equipment system simply by adding a title such a "mechanic" or "repairman" to the major equipment system, i.e., "Hydraulic Repairman Position." The method then proceeds by a series of judgments about skill level, similarity to existing positions, task performance times, apportionment of tasks to echelons and to positions, and finally to estimation of manpower requirements.

Comments. Only Chapter IV of this report draft is abstracted. The remainder of the report is abstracted from the final document (Ray, Passey, Adams, Smader, & Simon, 1957b).

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Ray, J. T., Passey, G. E., Adams, O. S., Smader, R. C., & Simon, G. B. A technique of job activity description for new weapon systems: Task equipment analysis. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1957. (AFPTRC Technical Report 57-13) (Project No. 7735, formerly 7709, Task No. 37306, Contract No. AF 41(657)-67) (b)

Purpose. This report describes a procedure and considerations for the production of "task equipment analyses." The initial phase involved a functional analysis of the weapon system as a whole, and was called equipment analysis (Miller & Folley, 1951a; Miller, Folley, & Smith, 1953a), concerned with equipment subsystems and components. The second phase was an analysis of the system in terms of required maintenance tasks, and was called a task analysis. The purpose of these procedures was to supply a greater detail in task information than frequently was available at the time the preliminary QPRI is required, as a basis for preparing handbooks and training courses.

Rationale. The method of data presentation described here is based on an equipment orientation, with the provision that this might be changed to a duty-type format on completing the analyses, pending identification of the use to which the data is to be put (Jones & Miller, 1956).

Comments. This report is abstracted. However, very little, if any, rationale is described. It appears that the procedure described here is largely based on various earlier documents referenced in the abstract, and the procedure itself has relatively little new to offer beyond a rearrangement or restatement of earlier methods.

Location of Document: ASTIA AD 146 419
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Rupe, J. C. Problems encountered in determining the scope of an Air Force job for research purposes. Lackland Air Force Base, Texas: Human Resources Research Center, March 1951. (Technical Research Note 51-1) (Project No. 21-07-014)

Purpose. The purpose of this study, "Research into the Basic Methods and Techniques of Air Force Job-Worker Analysis" was to measure the relative values of the five most commonly used methods of collecting job information by analyzing "identical" jobs using the five different methods of group interview, individual interview, observation interview, technical conference, and questionnaire-survey. Job was defined as the total work activity officially designated as required to be performed by one individual to accomplish specific results during a definite cycle of operation or a given period of time. This paper reviews the results of the project pilot study, and the implications for revising the structure of the experiment for the project.

Results. The pilot study, in setting out to perform the experiment by selecting airmen at different bases with the same SSN's (forerunner of AFS's) as representing "identical" jobs, found that jobs reported under one SSN often differed greatly in kinds of duties as well as degree of specialization. This paper, therefore, suggests a questionnaire format and procedure whereby truly "identical" jobs or those of similar scope could be preselected for inclusion in the study.

Comments. This largely administrative research note is not abstracted, since it does not contribute to the area of the survey, and deals with the problem of analyzing well established, existing jobs, rather than that of anticipating new ones. See Rupe (1952), Rupe and Westen (1955a), Rupe and Westen (1955b), and Rupe (1956) for the results of the study, using the preselected jobs. Lenard and North (1952a; 1952b) present sample job descriptions obtained during the first phase of the study.

Location of Document: AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Rupe, J. C. Research into basic methods and techniques of Air Force job analysis. I. Lackland Air Force Base, Texas: Human Relations Research Center, December 1952. (Technical Report 52-16) (Project No. 507-015-0002)

Purpose. The purpose of this study was to evaluate for the military situation the effectiveness of five common job analysis techniques. This report describes the application of these techniques to a block of four representative Air Force jobs. Rupe and Westen (1955a; 1955b) each report a similar application to four additional jobs, making a total of twelve jobs included in the study.

Procedures and Results. The five techniques used were:

Questionnaire - Survey. Incumbent describes job by completing questionnaire.

Group Interview. Analys obtains job data by group interviews.

Individual Interview. Job analyst interviews incumbents individually.

Observation Interview. Analyst observes incumbent on job and questions him regarding job activities.

Technical Conference - Analyst meets with group of job experts to obtain data.

Determination of the elements associated with a given job was based on judgments of a group of experts reviewing the elements yielded by each of the five methods.

The individual interview, observation interview, and technical conference appeared most fruitful; the individual interview seemed best with high-level personnel. See Rupe (1956) for the over-all results of the entire study.

Comments. This report is not abstracted because the techniques involved are concerned with existing jobs. See Kershner (1955) for comments on this study. Lenard and North (1952a; 1952b) present sample job descriptions derived during this phase of the project.

Location of Document: ASTIA AD 7468
AFPTRC Inventory Files
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Abstracted by: J. B. Fairman

Rupe, J. C. Research into basic methods and techniques of Air Force job analysis. Draft of paper presented at Amer. Psych. Assn. Job Analysis Symposium, September 1954.

Purpose. This paper reviews the study detailed in Rupe (1951 and 1952) to determine the relative value of five methods of job analysis for the military situation. See Kershner (1955). The five techniques were the questionnaire survey, group interview, individual interview, observation interview, and technical conference. One purpose of this study was the possible selection of one or more of the methods for an operational Air Force program of job analysis to provide the following information for classification and assignments, training, proficiency measurement, manpower allotment, and job evaluation:

1. Inventory of tasks performed in a given Air Force Specialty.
2. Manner and frequency of task performance.
3. Identification of common within-Specialty shredouts. See Besnard (1954).
4. Relative criticalness of tasks. A task is critical when it is important to the job, and supervisors have trouble getting satisfactory performance from presumably trained personnel. (Relative criticalness may be determined by paired-comparisons or ranking.)
5. Behavioral differences between satisfactory and unsatisfactory personnel in the performance of critical tasks. See Flanagan (1949).

Results. Checklist techniques appeared to be the best approach in the military situation, and the group interview least effective. See May (1951) and Beach, Paolucci, and Milano (1953). All of the conventional methods of job analysis tested, however, were considered unsatisfactory for the following reasons:

1. Job descriptions of conventional job schedules are not readily combined into inventories of tasks performed by given levels. (Rupe, 1951)
2. Task performance frequency is not obtained in a suitably structured manner or in sufficient numbers to assure reliability or validity of results when analyzed statistically.
3. There is no procedure in conventional job analysis for identifying "critical" tasks in the sense defined above, or for objectively determining the existence of stable specialized assignments within the Air Force. (Rupe, 1951)
4. The final results lack representativeness because time and expense generally prohibit obtaining adequate samples of the over-all job activities at representative locations.
5. Conventional job analysis does not appear to effectively identify objectively verifiable skill and knowledge requirements.

Comments. It may be that emphases on "task" analysis rather than "job" analysis has greater potential for manpower management. Because this paper is not directly related to the problem of anticipating requirements of new jobs, it is not abstracted fully.

Location of Document: AFPTRC Inventory Files
AIR Technical Liabrary

Abstracted by: J. B. Fairman

Rupe, J. C. Research into basic methods and techniques of Air Force job analysis. IV. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, April 1956. (AFPTRC Technical Note 56-61)

Purpose. This technical note incorporates the findings of reports I, II, and III of the same title, evaluating the relative effectiveness of five commonly used job analysis techniques. These are questionnaire survey, group interview, individual interview, observation interview, and technical conference. See Rupe (1951), Rupe (1952), and Rupe and Westen (1955a; 1955b).

Comments. Because this study was concerned with the analysis of existing jobs rather than new jobs, it was not abstracted.

See Rupe and Demaree (1953) for a study which grew out of this one, investigating a number of variable characteristics of a checklist technique for obtaining job information.

Location of Document: ASTIA AD 105 552
AFPTRC Inventory Files

Abstracted by: E. M. Jones

Rupe, J. C., & Demaree, R. G. Survey of research problems in the establishment of Air Force specialty requirements. A research proposal. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, April 1953.

Purpose. This research proposal, an outgrowth of the study made by Rupe (1951) suggests that in reviewing the conventional methods of job analysis, the factors of task criticality and skill and knowledge requirements are not adequately identified. It further proposes that the checklist method offers greater potential for determining Air Force specialty requirements.

Conclusions. Exploratory research (Rupe, 1951) suggests that the following checklist variables warrant empirical study:

Methods of administration.
Organization of tasks.
Length of checklists.
Specificity of tasks.
Period of time on job to be covered.
Responses required for each task.

Comments. Excerpts from this proposal are discussed by Kershner (1955). Because this paper does not discuss the rationales associated with each of the variables, it is not abstracted.

Location of Document: AFPTRC Inventory Files

Abstracted by: E. M. Jones

Rupe, J. C., & Westen, R. J. Research into basic methods and techniques of Air Force job analysis. III. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1955. (Technical Note 55-53) (Project No. 507-015-0002) (b)

Purpose. This study results from the need to obtain detailed information of operational jobs as they are actually performed in the field, as a basis for developing training courses, proficiency measures, and selection and classification procedures. Its purpose is to evaluate for the military situation the effectiveness of five common job analysis techniques. This report describes the application of these techniques to the third block of four representative Air Force jobs. Rupe (1952) and Rupe and Westen (1955a) each report similar previous applications to four additional jobs, making a total of twelve jobs included in the study

Procedures. The five techniques used were:

Questionnaire - Survey. Incumbent completes questionnaire to describe jobs.

Group Interview. Analyst obtains job data by group interview.

Individual Interview. Job analyst interviews incombents individually.

Observation Interview. Analyst observes incumbent on job and questions him regarding job activities.

Technical Conference. Analyst meets with group of job experts to obtain data.

Determination of the elements associated with a given job was based on judgments of a group of experts reviewing the elements yielded by each of the five methods.

Comments. This report is not abstracted since the techniques involved are concerned with existing jobs and are not directly related to the problems of this survey.

Location of Document: ASTIA 99035
AFPTRC Inventory Files

Abstracted by: E. M. Jones

Rupe, J. C., & Westen, R. J. Research into basic methods and techniques of Air Force job analysis. II. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, November 1955. (Technical Note 55-51) (Project No. 507-015-0002) (a)

Purpose. This study results from the need to obtain detailed information of operational jobs as they are actually performed in the field, as a basis for developing training courses, proficiency measures, and selection and classification procedures. Its purpose is to evaluate for the military situation the effectiveness of five common job analysis techniques. This report describes the application of these techniques to a second block of four representative Air Force jobs. Rupe (1952) and Rupe and Westen (1955b) each report a similar application to four additional jobs, making a total of twelve jobs included in the study.

Procedure. The five techniques used were:

Questionnaire - Survey. Incumbent completes questionnaire to describe job.

Group Interview. Analyst obtains job data by group interviews.

Individual Interview. Job analyst interviews incumbents individually.

Observation Interview. Analyst observes incumbent on job and questions him regarding job activities.

Technical Conference. Analyst meets with group of job experts to obtain data.

Determination of the elements associated with a given job was based on judgments of a group of experts reviewing the elements yielded by each of the five methods.

Comments. This report is not abstracted since the techniques involved are concerned with existing jobs and are not directly related to the problems of this survey.

Location of Document: ASTIA AD 99034
AFPTRC Ineventory Files

Abstracted by: E. M. Jones

Saupe, J. L. An analysis of troubleshooting behavior of radio mechanic trainees. Lowry Air Force Base, Colorado: Air Force Personnel and Training Research Center, November 1955. (AFPTRC Technical Note 55-47)

Purpose. This report describes an experimental study of the factors in effective troubleshooting. It tests nine hypothetical factors on the difference between "effective" and "noneffective" troubleshooters. These factors include the approach to the task, the quality of the performance of the task, and the background of each troubleshooter.

Comments. This study of troubleshooter proficiency and its results are not sufficiently related to the survey to be abstracted. See Highland, Newman and Waller (1956) for another study of the same area.

Location of Document: AFPTRC Inventory Files

Abstracted by: E. M. Jones

Taylor, F. V. Human engineering and psychology. Washington, D. C.: U. S. Naval Research Laboratory, March 1959. (a)

Purpose. The purpose of this paper is to define the relatively new field of human engineering, identifying its many ramifications and the work thas has been done in each; its similarities, differences, and past and future contributions to the parent fields of psychology and engineering; and to suggest an administrative and educational approach which the author feels will enhance the future contributions of the new "inter-discipline."

Conclusions and Recommendations. Human engineering, for the purpose of this paper, is defined as the study of the behavioral properties of man in interaction with machines and total man-machine systems, and the structuring of the latter with the aim of enhanced system performance. If any one thing epitomizes human engineering and sets it apart from psychology, it is the use of the concept of the man-machine system.

The field of human engineering is divided into two areas: the more classic, psychologically oriented "engineering psychology," and the more engineering-oriented "technology" of human engineering design. Within the first, man is discussed as a receiver, an emitter, and an information processor; the effects of stress on data processing and the evaluation of man-machine systems are also reviewed.

The second section meticulously discusses the interrelationships between psychology and human engineering; the goals, subject matter, methodology, experimental variables, and theoretical concepts of the two areas. Section three discusses the long-term contributions of human engineering to psychology in terms of methods, subject matter, and concepts. Section four recommends collaborative, administrative, and educational mechanisms for the facilitation of development by and contributions from the field of human engineering.

Special Features. The 163-item bibliography included in this paper and referenced widely throughout the report provides an excellent index to work done in the human engineering field as defined in this report.

Comments. While this document is a useful reference document for the field of human engineering, that field, as defined by the author, completely excludes consideration of the areas of investigation of the present survey. It therefore is not abstracted.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Taylor, F. V. The human as an engineering component. AMA Archives of Industrial Health, 1959, 19, 278-282. (b)

Purpose. This discussion describes the unique capabilities and limitations of man as a component of a man-machine system, and illustrates the possible benefits which can accrue to the system performance when these characteristics are considered in equipment design.

Conclusions. The useful properties of man which are identified are:

1. Flexibility - He can function in a fantastic variety of ways.
2. Self-Adjustment - He can learn and adjust behavior to circumstances at hand.
3. Response to Meta-Information - While performing in one functional loop, he can utilize information derived from other loops.
4. Model Redundancy and Homeostasis - Organically, he has enough redundant capabilities to function in spite of many "malfunctions."
5. Mechanical Independence - He can move about from one physical functional loop to another without requiring mechanical connections.
6. Energy Storage - He does not need an external power source; can remain effective for some time without food or power supplies.

The limitations listed are:

1. Lack of Standardization - Individual capabilities vary, requiring selection of individuals for specific jobs.
2. Limited Band-Width - A man can pass frequencies no higher than one or two cycles per second.
3. Transport Delay - His reaction time is long: from 1/10 second to several seconds.
4. Imprecision - He is less precise at any specific transformation than a machine designed for the purpose.
5. Variability - His performance is not consistent from moment to moment.
6. Noise - He generates a high level of interfering noise.

Quickening of displays and controls is cited as an example of the benefits to be derived from designing equipment with man's characteristics in mind.

Comments. The above considerations are valuable in a predevelopment systems analysis and function allocation, but are not sufficiently relevant to the QPRI for inclusion of this article among the abstracts.

Location of Document: AIR Technical Library   Abstracted by: J. B. Fairman

Thorndike, R. L., Hagen, E. P., Orr, D. B., & Rosner, B. An empirical approach to the determination of Air Force job families. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, August 1957. (AFPTRC Technical Report 57-5)

Purpose. This study suggests an item analysis technique for assessing job requirements and grouping jobs into homogeneous families, applicable to the classification of airmen, and assignment to Air Force Specialties.

Summary of Method. The study consisted of three sections:

1. Identification of a set of basic dimensions by which a job can be defined.
2. Development of a procedure for determining a job's content in terms of these dimensions.
3. Application of this procedure to sample Air Force jobs, determination of job profiles, and examination of these profiles for job family clusters.

The procedure used a test-development type of item analysis on job activity elements. The item analysis resulted in a total of 219 activity items and 14 dimensions scales. Sample dimensions: Social-verbal, reasoning, clerical accuracy.

Conclusions. The method was not satisfactory. Some of the reasons were: The scales were based on too small a sample, and the items ranged from general to specific; several of the dimensions were found to be highly correlated; the dimensions, such as reasoning, do overlap, in spite of the fact that they were selected on the basis of a factor analysis.

Location of Document: ASTIA 134 239
AIR Technical Library

Abstracted by: E. M. Jones

Thorndike, R. L., & Norris, R. C. Empirical evidence on Air Force career fields. Lackland Air Force Base, Texas: Human Resources Research Center, March 1952. (Research Bulletin 52-13) (Project No. 510-022-0001, Contract No. AF 33(038)-13474)

Purpose. Air Force jobs, for purposes of classification and career guidance, have been broken into "job families." A job family represents a cluster of specific jobs which seem to require the same set of abilities and aptitudes. These job families were established on the basis of job analysis, statistical research, and other logical considerations. This report is a continuation of the effort to examine the job family structure and isolate job families requiring relatively independent abilities and aptitudes.

Procedure and Results. An attempt was made to distinguish independent ability clusters by factor analysis. The only conclusion which seemed possible from this analysis is that there is little basis for differentiation of job clusters using the criterion of training school grades. For even the most sharply differentiated clusters, the estimated between-groups correlations averaged about eight-tenths as large as the correlations within groups.

Conclusions. The following possible reasons for the results were cited:

1. The method of analyses may have been faulty, leading to an incorrect picture of the situation.
2. The battery of predictor variables may have been inadequate in that it failed to tap the unique factors required for success in the various clusters.
3. The training school criterion may have been a poor measure of the distinctive aspects of success in the different jobs.
4. These may be, in truth, no more clustering of Air Force jobs than the results indicate.

Recommendations. These results reaffirm the vital need for validation of classification tests against measures of success on the job, rather than merely in training. This is the place where distinctiveness of job families must be sought. A less conclusive but more feasible approach to defining job families lies in statistical treatment of job analyses. Further development of predictor variables is also suggested.

Comments. This report is not abstracted, as it is concerned with how jobs or job families are structured after the fact, rather than before.

Location of Document: ASTI ATI No. 175 977
AIR Technical Library

Abstracted by: J. B. Fairman

Van Cott, H. P., & Altman, J. W. Procedures for including human engineering factors in the development of weapon systems. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, October 1956. (WADC Technical Report 56-488) (Project No. 5-(7-7192), Task No. 71533, Contract No. AF 33(616)-2986)

Purpose. The purpose of this report is to suggest procedures for identifying and methods for solving a number of human engineering problems. Through its use the system designer will be better able to articulate human engineering on a new system with other events occurring during the development.

Major emphasis is placed upon a human engineering design schedule to which procedures for functions analysis, man-machine and crew member allocation, work and component design, and human engineering evaluation may be tied.

Summary. Chapters 3, 4, and 5 (Functions Analysis, Functions Allocation, and Operator Performance Description) are of special importance to this survey. They present the first systematic statement of functions analysis as understood in this report. The rationale of this analytical approach is supplemented by sample data formats, time lines, mission profiles, flow charts and checklists, guide lines, and relevant principles of human behavior.

Comments. Unfortunately, this key document was not abstracted because of its late addition to the bibliography. It is, however, basic to much later work in this area. Erickson and Rabideau (1957) and Ray, Passey, Adams, Smader, and Simon (1957b), in particular, are largely based on this document.

Location of Document: ASTIA AD 97 305
AIR Technical Library

Abstracted by: J. B. Fairman

Van Cott, H. P., Berkun, M. M., & Purifoy, G. R., Jr. How to determine job knowledge content. The application of a procedure to several Air Force jobs. Pittsburgh: American Institute for Research, December 1955. (Project No. 7714, Air Force Personnel and Training Research Center Contract No. AF 18(600)-1205)

Purpose. The purpose of this document is to provide examples of the application of the technique described in Miller and Van Cott (1955) for the determination of job knowledge content. That document should be referred to in conjunction with this report.

Summary of Method. The rationale for the method is developed in Miller and Van Cott (1955). This procedure takes as its input, task analyses prepared as described in Miller (1956b).

Comments. One of the nine sample applications is reviewed in the abstract of this document.

Location of Document: ASTIA AD 129 069
AFPTRC Inventory Files
AIR Technical Library

Abstracted by: J. B. Fairman

Warren, N. D., Wolbers, H. L., Atkins, D. W., Darrow, J. L., Goedinghaus, C. H., Mahoney, H. G., & Piatt, D. M. (UNCLASSIFIED title) Research on aircraft observer training procedures: Part II. An analysis of the activities in the task of the K-system observer. Lackland Air Force Base, Texas: Human Resources Research Center, December 1953. (HRRC Technical Report 53-37) (Project No. 506-005-0001, Contract No. AF 18(600)-399) (CONFIDENTIAL report)

Purpose. This report is the second in a series concerned with the important components in the aircraft observer's job and with evaluation of training devices. It presents the assessment of similarities and differences in the manner in which K equipment operators utilize their time during training missions on the K supersonic trainer and the TB-50D, respectively.

Procedure. A "link analysis" technique of data presentation and analysis was employed, in conjunction with a variation of the activity analysis technique of Christensen (1949) to provide a record of systematic observation of the aircraft observer's behavior during K-system operation.

The report suggests some specific system-oriented activity categories.

Comments. Because of the possible applicability of the techniques of "activity analysis" and "link analysis" for data collection and analysis, and the two activity data presentation formats for the preparation and presentation of QPRI material, this report is abstracted.

NOTE: The above abstract omits reference to classified equipment, etc., and is unclassified.

Location of Document: ASTIA AD 27 406

Abstracted by: J. B. Fairman

Walston, C. E., & Warren, C. E. A mathematical analysis of the human operator in a closed loop control system. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1954. (AFPTRC Technical Report 54-96) (Project No. 7707, Task No. 77133, Contract No. AF 33(038)-10528)

Purpose. Research has attempted to learn more about human behavior in control systems, especially about the ability of the human operator as an information handling device. One phase of this research attempts to determine the human transfer function, particularly as relating to a visual-input, manual-output operation, i.e., tracking. The approach here is to use *a priori* reasoning to obtain an analytical expression or model for the human transfer function taking into account as many factors as possible, and then to check the validity of this expression by seeing how closely it matches experimental data for a human operator in a closed-loop control system.

Procedure. The tracking task required the subject to superimpose one oscilloscope light signal onto another signal by pivoting his arm and a lever to the right or left, radially. Both following and compensatory tracking tasks were presented, each requiring tracking of both a 30-cycle harmonic signal and a random motion pattern. In analyzing the system, the operator was the only unknown element.

Conclusions. Among the many interesting conclusions drawn from the comparison of the *a priori* model with the experimental results are that the model defines the tracking behavior in terms of the two hand motion vectors involved, the reaction time lag, and the human noise factor. These constants provide a means of classifying individual tracking differences, provide a performance criterion, and account for changes in operator behavior during learning to achieve satisfactory performance.

Comments. This study does not contribute appreciably to the area of this survey and is therefore not abstracted.

This study is also published in Human Resources Research Center Research Bulletin 53-32, under Project No. 509-020-0004, Contract No. AF 33(038)-10528.

Location of Document: ASTIA AD 62 105
AIR Technical Library

Abstracted by: J. B. Fairman

Weislogel, R. L., & Jacobs, T. O. A technique for displaying task analysis information. Kirtland Air Force Base, New Mexico: Air Force Special Weapons Center, March 1956. (AFSWC Technical Note 56-11) (Project No. 7800, Contract No. AF 29(601)-175)

Purpose. The purpose of this study was to develop a method for presenting, in a concise, easy to comprehend format, the task analysis data needed to determine:

1. Basic job requirements for piloting a high-speed single-place interceptor aircraft.

2. Additional requirements imposed upon the operator when delivery of a weapon is part of his mission.

The purpose was also to identify segments of the mission which might be "overloaded" with psychological requirements; specifically, visual scanning and discrimination, control manipulation, and decision making, as a basis for recommendations in equipment design, training course content, and operator error-prone situations.

Summary of the Method. Essentially, the method consists of placing analytical material on top of descriptive material, by means of overlays. The "base page" of the display consists of columns headed by each of the job segments, each column containing sequential abbreviated statements of the tasks, subtasks, and steps within that segment. A time line at the bottom of the base page indicates the amount of time available for each segment.

It is now possible to superimpose on the job activities the psychological and special manipulative demands made on the operator in accomplishing the sequences of job requirements. Statements of these demands are so placed on the overlays that they will appear in proper alignment with their associated job operations on the base page (preceding or following).

Comments. This report is abstracted fully.

Location of Document: ASTIA AD 96 920
AIR Technical Library

Abstracted by: J. B. Fairman

Westen, R. J., & Peterson, R. O. Development and application of methods for deriving generalizable course content from electronic equipment. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, February 1958. (Technical Report 58-8) (Project No. 7729, Task No. 37300, Contract No. AF 18(600)-1351)

Purpose. This report reviews the aims of providing an economical method for increasing cross-trainability of electronic maintenance technicians; specifically, on the F-86D and F-102A systems. The approach was to develop a core course conveying fundamentals common to jobs within and between the two systems, and directly related to the operational jobs.

Procedure. Task descriptions from Technical Orders, observation, and interview, supplemented by QPRI data, were sources for the identification of common job activities. The common activities were then analyzed for implied skill and knowledge requirements.

Task description data was supplemented by data from four additional analyses: job objects, to identify additional skills and knowledges; job instructions, to identify terms, procedures, etc., which required clarification or assumed knowledge on the part of the reader; precautions for critical knowledges implied; and job tricks and gimmicks, to identify useful operational knowledges.

All the resulting core skills and knowledges were developed to the proper level of abstractness for inclusion in core training, subject to four criteria of relevance to the operational job. (This is what is meant when job-oriented is suggested as preferrable to equipment-oriented in this study.)

The final portion deals with the development of training course characteristics and design, but is less related to the immediate survey.

Conclusions. While the core course designed appears to meet the original objectives satisfactorily, the authors question whether this same content might better be taught in a noncore course. The possibility of the omission of some skills and knowledges by this methodology is also posed.

Comments. This is an administrative final report. It provides a good, brief summary of the total project but does not really discuss the methodology used. Peterson, Jones, and Ellis (1957) is similar to this document but more detailed. This document is therefore not abstracted.

Location of Document: ASTIA AD 152 115
AIR Technical Library
AFPTRC Inventory Files

Abstracted by: J. B. Fairman

Wiley, L, Harber, H. B., & Giorgia, M. J. Rater tendencies in estimating qualifications required by Air Force jobs. Lackland Air Force Base, Texas: Wright Air Development Center, September 1959. (WADC Technical Note 59-195) (Project No. 7734, Task No. 17018)

Purpose. To forecast qualifications requirements of new Air Force jobs by using estimates of judges, the judgments must be accurate and consistent. The purpose of this study was to determine whether personal evaluation habits can influence interrater agreement.

Rationale. It was hypothesized that qualification requirements ratings may only be properly made for a new weapon system by people sufficiently familiar with the system to make such judgments. Because such people would be scarce, each person's judgment must be used to maximum effectiveness; individual rating habits, if they occur, must be measured and so compensated for.

Summary of Method. Tasks were drawn from fifteen Air Force career fields, and a group of ROTC pilot trainees rated these tasks and the specialties that include them. Judgments were made on 5-point scales to determine how much resourcefulness, general vocabulary, tool and instrument knowledge, number skill, physique and stamina, human contract skill, precision, formal training, and on-the-job training time is needed.

Results. Correlation of each rater's over-all mean rating in one session with that of the mean for the second session demonstrated consistent tendencies to give high, low, or medium ratings. Similar correlations between mean standard deviations gave evidence of individual tendencies to use or refrain from using the extremes of the rating scale. The data clearly showed the importance of building a rater yardstick where reliance must be placed on the pooled judgments of four or five individuals.

Comments. This report is not abstracted fully. Only one of the nine rating scales is included in the report.

Location of Document: AIR Technical Library

Abstracted by: J. B. Fairman