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ABSTRACT

The training requirements analysis model (TRAMOD) described in this report represents an important portion of the larger effort called the Digital Avionics Information System (DAIS) Life Cycle Cost (LCC) Study. TRAMOD is the second of three models that comprise an LCC impact modeling system for use in the early stages of system development. As part of the overall modeling system, the training model is an efficient tool for developing training programs on the basis of task, time, and resources criteria. This report explains the approach used in developing this model and its analytic value as a method for determining training requirements, as well as the methodology used to develop the task-related characteristic data necessary for its application to the DAIS. The model is described by explaining the techniques and algorithms used to accomplish its function, and the task dictionary, task characteristic parameters/values, and acronyms are provided in appendices. A bibliography is included. (Author/JD)

AFHRL-TR-78-58(I)

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DIGITAL AVIONICS INFORMATION SYSTEM (DAIS):
TRAINING REQUIREMENTS ANALYSIS MODEL (TRAMOD)

By

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

The training requirements analysis model (TRAMOD) described in this report represents an important portion of the larger effort called the Digital Avionics Information System (DAIS) Life Cycle Cost (LCC) Study. TRAMOD is the second of three models that comprise a LCC impact modeling system for use in the early stages of system development. As part of the overall modeling system, the training model is an efficient tool for developing training programs on the basis of task, time, and resource criteria. This report explains the approach used in developing this model and its analytic value as a method for determining training requirements. Also, the methodology used to develop the task-related characteristic data necessary for its application to the DAIS are addressed. The model is described by explaining the techniques and algorithms used to accomplish its function.

Item 20 Continued:

The interactive nature of TRAMOD affords the user great flexibility in structuring its operation while retaining the capability of addressing specific training problems in depth. This report explains the basis for available options. The Users Guide, Volume II, presents these options and illustrates the manner in which user/model interaction is accomplished.

PREFACE

This two volume report describes the Training Requirements Analysis Model (TRAMOD). Volume I describes its development and composition. Volume II is a user's guide to its operation and specification. The report is one of a series of technical reports, models, and data banks produced under contract no. F33615-75-C-5218, "DAIS Life Cycle Costing Study." This study, in combination with present Air Force capabilities, will provide the means to assess the life cycle cost impact of the operational implementation of the Digital Avionics Information System (DAIS).

The study was directed by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, and is documented under Work Unit 2051-00-01, "DAIS Life Cycle Costing Study." It was performed under Air Force Avionics Laboratory Program Element 63243F, "Digital Avionics Information System," Project 2051. Project 2051, "Impact of DAIS on Life Cycle Costs," is jointly sponsored by the Air Force Human Resources Laboratory and the Air Force Avionics Laboratory, both of the Air Force Systems Command, and by the Air Force Logistics Command. Contract funds were provided by the Air Force Avionics Laboratory. The DAIS Program Manager is Lt. Col. Robert A. Dessert. The Air Force Human Resources Laboratory Project Scientist is Mr. H. Anthony Baran. The Air Force Logistics Command Project Officer is Captain Ronald Hahn. The latter two are DAIS Deputy Directors. The Contractor Program Manager is Mr. John Goclowski.

SUMMARY

BACKGROUND

This two volume report is one of a series of technical reports which describe products of the Digital Avionics Information System (DAIS) Life Cycle Cost (LCC) Study. That study supports the DAIS advanced development program, which is developing and testing a concept of integrated avionics as an information management system. Implementation of that concept in Air Force weapon systems is expected to have significant impacts on their LCC and system support requirements. The DAIS LCC Study was undertaken to advance the current technology for identifying and quantifying such impacts. Volume One of this report describes one of the results: a model for analyzing the potential impact of weapon system design on personnel training requirements. Volume Two provides detailed guidance in its use.

A number of techniques have been successfully applied to the quantitative analysis of weapon system support personnel requirements. There is a need, however, for means to evaluate the qualitative aspect of these requirements, i.e., the training requirements which they generate. The analysis of training impacts within the design process is an absolute necessity if weapon systems are to be designed to provide essential capability at an affordable cost. Part of the DAIS LCC Study was addressed to the provision of a technique for meeting this need.

OBJECTIVES

The objectives of the effort described in this report were twofold: (1) to provide a means for analyzing the training requirements generated by new weapon systems which could be applied to estimate potential impacts of the DAIS, and (2) to provide the data necessary for application of the results to the DAIS.

APPROACH

A literature search was undertaken to determine the availability of an analytic tool which could be used to model the training requirements of a DAIS application. The results indicated that no such capability existed. Therefore it was necessary to develop a model to evaluate tasks associated with equipment maintenance in terms of the training options available for preparing personnel to perform those tasks. The principal guidelines for themodel construction were adopted from the Instructional System Development (ISD) process (Reference 7).

The tasks and behaviors required for equipment maintenance were identified as the basic inputs to the model. A maintenance analysis was performed and a Task Dictionary was developed to organize and define the tasks, subtasks, and task elements necessary for an avionics maintenance technician to perform his job. The tasks were then analyzed to find common task-related characteristics which might impact the conduct of a training program. Five task-related characteristics (parameters) were chosen as those best suited for evaluating the tasks to determine whether training was required for their proper performance. Procedures were developed then for assigning values to them. These task definitions and the criteria chosen for determining whether a task would generate a training requirement were the basis for model development and data bank design. Characteristics of the job of which a task is a part, e.g., technician-, equipment-, or maintenance concept-related, were also recorded in the Task Dictionary and used as additional ground rules/constraints when assigning values to the task characteristic parameters for each task within the Task Dictionary.

The final part of the training analysis process was the development of a training model design. It was implemented in such a way that sufficient flexibility exists to permit model operation under a wide variety of data availability circumstances. This ensures its applicability in the early stages of the systems acquisition process when little hard data is available; and beyond, when more exact data is available, to yield a wide-ranging capability to aid in resolving problem situations within the normal routine of training planning.

For this initial phase of system development, certain assumptions were made to simplify the operation of the training model with minimal loss of authenticity. Furthermore, its general applicability to a variety of systems and problems was ensured by (1) designing the data bank so that its content and structure are user-defined (optional) and (2) designing the training model with sufficient flexibility so that selecting and sequencing of the internal analyses are user-defined (optional). In this way, TRAMOD was developed to accept various options reflecting changes in system, policy, and resource factors, so as to relate these with the resultant training impacts.

RESULTS AND CONCLUSIONS

The training model, TRAMOD, developed to meet the objectives of the DAIS LCC Study, consists of four main components:

(1) Training block generator
(2) Training plan generator
(3) Training program generator
(4) Training analyst

The first component (training block generator) selects those tasks which require training. The second component (training plan generator) produces a training plan consisting of a list of the tasks to be trained, the type of training for each (i.e., school or on-the-job), and training methods and media recommendations. The third component (training program generator), using the training plan, constructs a training schedule which takes into consideration the class and media requirements cited as requirements in the training plan. It also allows for the careful scheduling of scarce training resources. The training analyst, or "man in the loop," is included as a component of the model since he provides the judgemental feedback necessary for the process to be self-correcting and self-adjusting.

TRAMOD can facilitate the rapid estimation of training requirements and the consequences of alternative approaches to fulfilling them, thus providing a means to aid weapon system designers and planners to more fully consider the training implications of design. It can also serve as a first step in establishing a standardized approach to training requirements analysis. Equally important is that TRAMOD can allow the training analyst to better understand and evaluate the impacts of new systems on training requirements and the options available to fulfill them, in terms of the effects of the design and maintenance characteristics of equipment. This information can be used to influence the design process itself. Iterative use of the model, with systematic manipulation of constraint parameters, can refine results and enable the user to examine various sensitivities. In this way, TRAMOD can be applied to problems such as the early identification of excessive requirements, investigation of alternative policy decisions, and training cost estimation. This capability, along with its capability to be operated using data available early in system development, should go a long way toward avoiding unnecessary training expenditures by allowing a user to approach the solution of training problems in terms of their causes as well as their substance.

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DIGITAL AVIONICS INFORMATION SYSTEM (DAIS): TRAINING REQUIREMENTS ANALYSIS MODEL (TRAMOD)

1. INTRODUCTION

The training model (TRAMOD) described in this report was developed to: (1) meet a need for a means to assess the impact of the Digital Avionics Information System (DAIS) concept of avionics integration on training requirements; and (2) serve as a general tool for examining the consequences of circumstances which bear on the establishment of training requirements. Using a technique for classifying learning requirements and requisite training options as a function of the tasks to be performed, the model relates design and training in a way which allows trade-offs between cost and operational constraints. It provides a capability to rapidly assess training requirements and to select a training program most appropriate within the limits established by a set of user-specifiable constraining conditions, such as training cost and training time.

Although primarily designed for independent operation, TRAMOD is a part of the Life Cycle Cost Impact Modeling system (LCCIM) being constructed within the DAIS Life Cycle Cost (LCC) study to assess the potential LCC impact of the DAIS. The LCCIM will also provide improved means for incorporating LCC and system support personnel considerations into design, operation, and support decisions made throughout the systems acquisition process, particularly in its early stages.

Although the training data bank currently provided with TRAMOD is specific to avionics, the model itself represents an extremely broad approach to training analysis. Its primary contribution to training technology is its generalizability and the increased degree of logic and mechanization it brings to an area which is often thought to be more of an art than a science. TRAMOD provides a framework for a training evaluation process which can be built upon and expanded to more adequately address specific needs. In particular, the model can be applied to the early identification of training demands, the timely investigation of alternatives, and the estimation of training cost. It can also provide an increased discipline in the development of training programs.

2. GENERAL DISCUSSION

The basic objectives in developing TRAMOD were (1) to provide outputs to aid in estimating the training costs for the manpower requirements of the DAIS architecture, and (2) to provide the capability of evaluating alternative training approaches and training programs for DAIS maintenance. These two objectives are related in that cost can be used as a criterion to evaluate candidate programs.

BACKGROUND

Training costs are an integral part of the human resource component of weapon system LCC. More often than not, these costs are system specific and must be estimated in terms of actual equipment maintenance requirements, i.e., tasks. The identification of the maintenance requirements of a newly emerging weapon system, particularly one in its conceptual stage such as the DAIS, requires: (1) the analysis of the reliability and maintainability (R&M) characteristics of similar equipment, and (2) the extrapolation of these results to the new equipment. These adapted values help form the elements of the emerging system's support requirements, which in turn form the data base necessary for a training requirements analysis.

Such a training requirements analysis was conducted on a conceptual design configuration representative of a possible DAIS application. It was preceded by a maintenance analysis depicted in Figure 2-1 and reported in References 2, 3, and 4. Results included values for the type, number, and skill level of the technicians needed to perform the principal maintenance tasks associated with each subsystem and line replaceable unit (LRU) of the representative DAIS configuration. Support equipment (SE) requirements were also established. In this way, all maintenance data requirements for the subsequent training analysis were met. What remained was to transform them into precise criteria for the selection of training procedures and the establishment of training programs.

A literature search was conducted to identify existing techniques and/or models which could relate tasks to be performed to the particulars of training program establishment. A methodology and associated model were desired which could assist a training analyst in conducting the trade-off studies required to develop the most cost-effective training program. Although considerable research has been conducted in this area (see bibliography), indicating a need

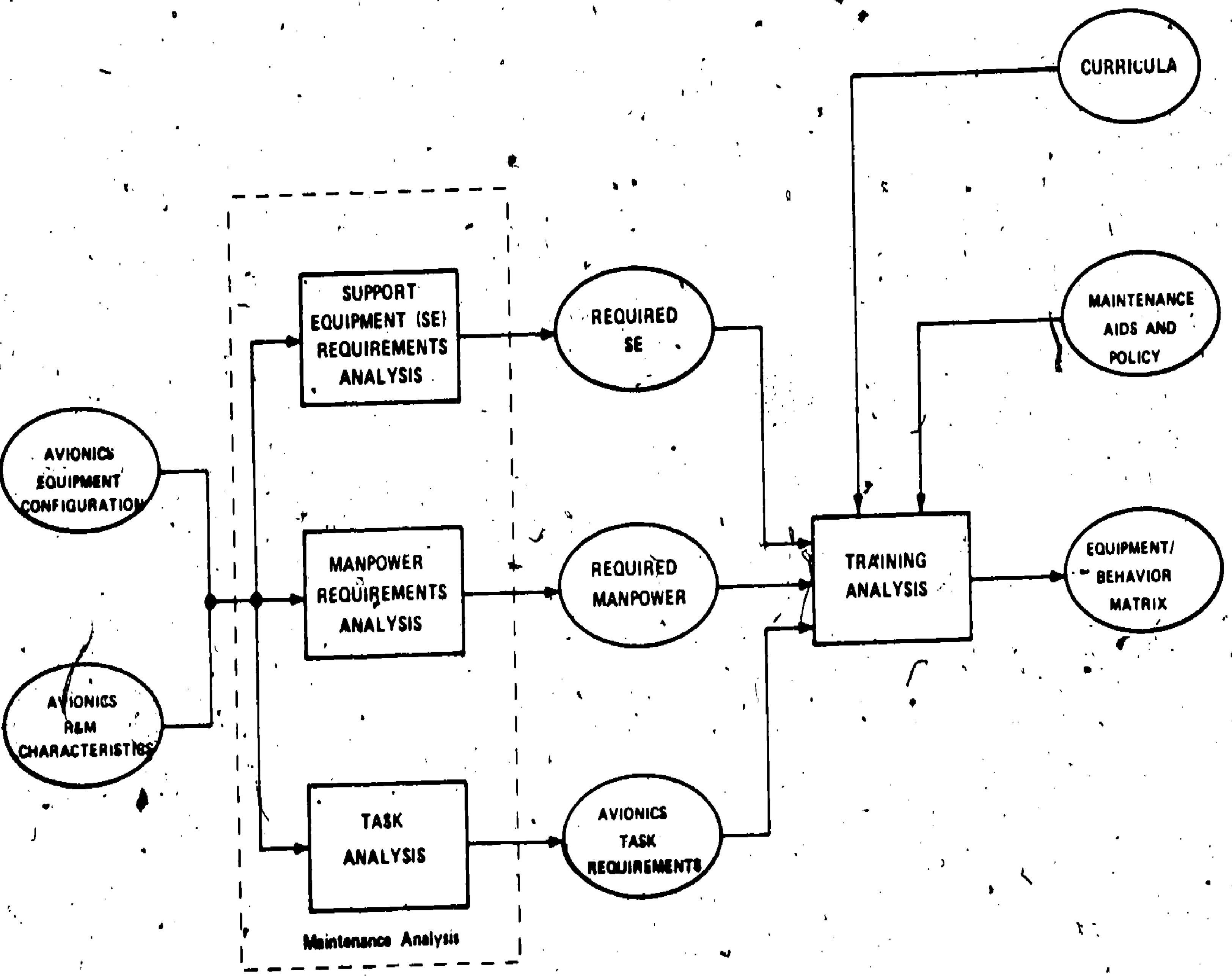


Figure 2-1 Inputs to training analysis

for a methodology with this capability, no computerized analytical model could be found that was capable of satisfying the needs at hand. The lack of a historical precedent necessitated the design of an analytic approach to develop the desired training model and data bank. Basic guidelines were adopted from the Instructional System Development (ISD) process, defined in Air Force Manual 50-2 (Reference 7); which is the process generally associated with the generation and application of actual training programs within the Air Force. TRAMOD represents an adaption of that process for use (1) in assessing training requirements during the conceptual phase of a weapon system acquisition program and (2) as a research tool in advanced development studies. The five phases that constitute the ISD process are shown in Table 2-1, along with the corresponding elements of the training model.

Table 2-1
ISD/Training Model Comparison

ISD Phases	Training Model Elements
1. Analysis	Task Analysis Data Bank Preparation
2. Design	Selection of Task Blocks Alternative Criteria School/OJT Mix
3. Development	Training Plan Methods and Media
4. Implementation	Training Program Schedule
5. Evaluation	Feedback

TRAINING ANALYSIS

An overview of the approach used to develop TRAMOD and its associated data bank is given in Figure 2-2. The principal steps are numbered in the block diagram and will be referred to in the general description that follows.

The basic data input requirements for the model are the specific tasks and associated behaviors necessary to accomplish equipment maintenance. This statement follows from the assumption that attainment of the skills and knowledges necessary to

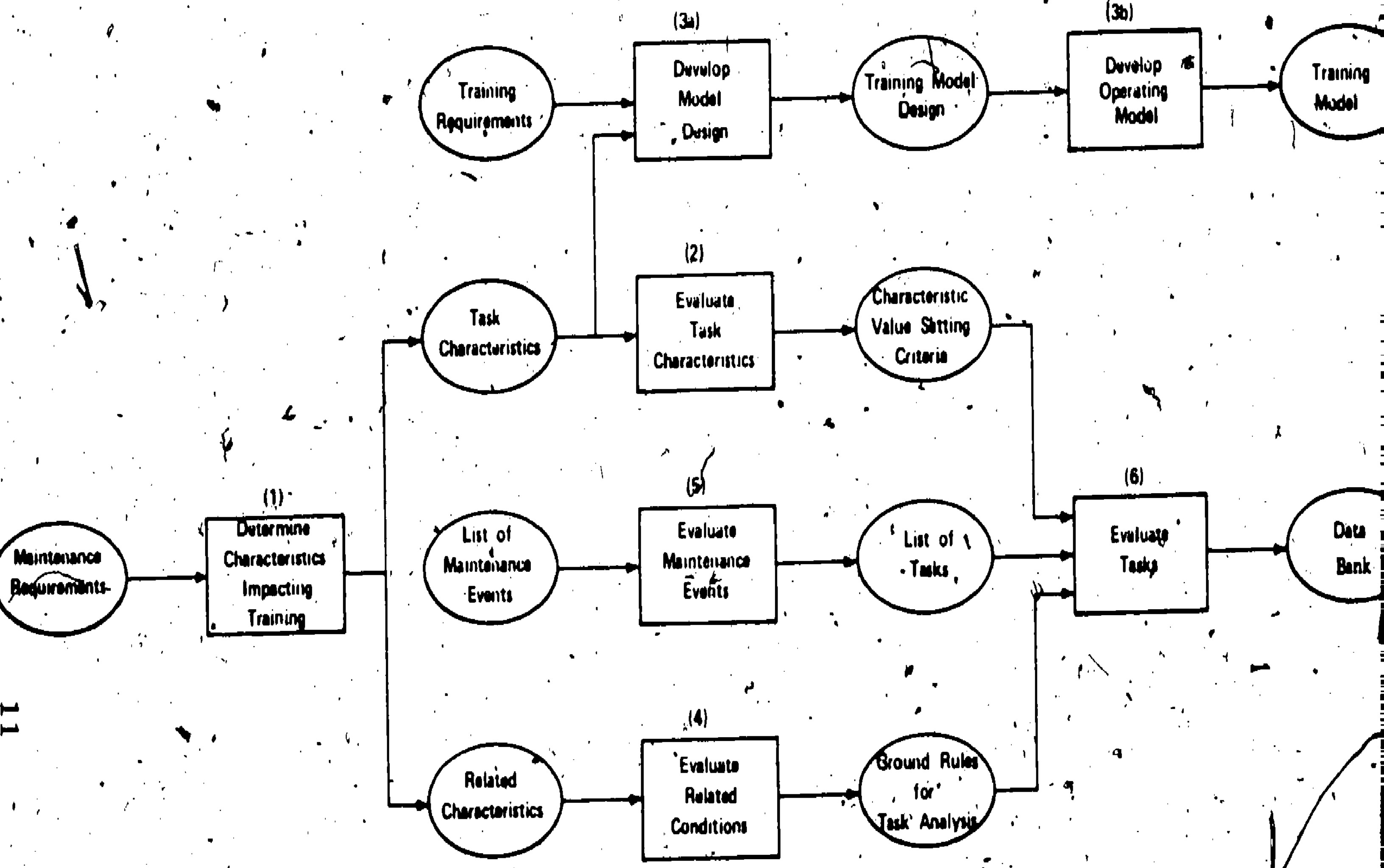


Figure 2-2 Development of training model and data bank

accomplish the designated task events is the principal objective of any training program. Therefore, the maintenance requirements were evaluated (Block 1) in terms of those job characteristics which might impact that objective and thus influence the training program.

This evaluation consisted of identifying the most significant job characteristics and then categorizing them into the four groups shown in Table 2-2. These descriptors were chosen after researching such sources as Air Force Occupational Survey Reports, Job Inventories, Specialty Training Standards, Air Training Command Course Outlines, and the Instructional System Development Manual. Subsequent to this, the five task-related characteristics were identified as having the greatest impact on the designing of a training program and were selected (Block 3a) as the parameters to be used by the model for evaluating tasks. Algorithms and procedures were then developed (Block 2) that could systematically be applied to assign values to these five task-related characteristics. Application of these procedures to assign values for the task-related characteristics rely upon the judgement of analysts or technicians familiar with the equipment and the associated tasks necessary for its maintenance. Appendix B contains the definitions and criteria selected for evaluating the five task-related characteristics. The remaining three groups of technician-, equipment-, and maintenance concept-related job characteristics were then used to establish ground rules (Block 4) for the task analysis. These ground rules provide the "a priori" and the baseline information concerning the system under study and the environment in which the tasks are to be performed. They also provide a common reference frame for all subsequent analyses of tasks.

Other considerations used in the development of the training model design included its input and output requirements. Inputs to TRAMOD are quantifiable elements such as: student entry rate, time to train per subject matter or task, and the average cost per student. The required outputs of the training model, subject to the provision of additional inputs concerning the characteristics of specific tasks, were defined to include: course length, required media, and type of training (on-the-job (OJT) training or technical training school (TTS)).

The on- and off-equipment maintenance events were analyzed and used to develop a list of tasks (Block 5) which spanned the tasks, subtasks, and behaviors necessary for an avionics maintenance technician to perform his job. Any commonality of tasks among maintenance events was identified and used to group the tasks into duty areas. This list became the composite avionics task dictionary

Table 2-2

Job Characteristics Impacting Training

Task

- Criticality to job performance
- Difficulty to learn
- Frequency of performance
- Skill (psychomotor requirement)
- Knowledge (cognitive requirement)

Technician

- Prior training/experience
- Skill level
- Training-to-application interval

Equipment

- Support equipment
- Tools
- Safety
- Newness

Maintenance Concept

- Technical orders/job guide material
- Crew size
- Criticality to operational mission

which is included in Appendix A. The previously described criteria and ground rules for quantifying the task characteristics were then used to evaluate the elements of the task dictionary (Block 6). Two data banks were developed: (1) a baseline historical training data bank which is based on a non-DAIS avionics suite and (2) a theoretical training data bank which is predicated on a DAIS avionics architecture. The design and development of the data banks will be discussed in detail in Section 3.

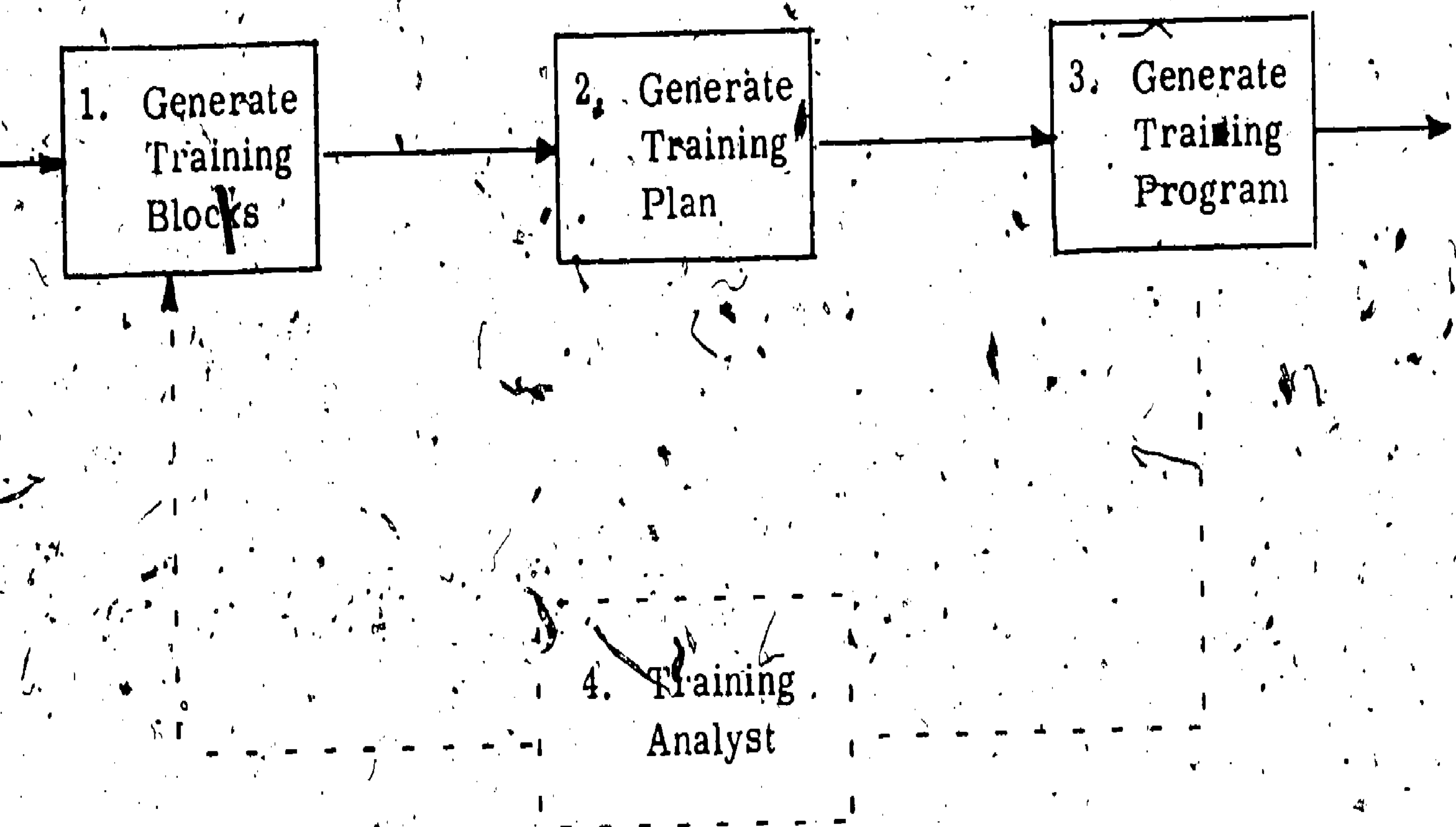
MODEL DESIGN

The training model represents a methodology developed to optimize both the approach to training and the training program itself. The technical approach used in designing such a training model included the following considerations:

(1) Identification of main components in the development of a training program
(2) Compatibility with associated data bank
(3) Introduction of simplifying assumptions
(4) Selection of available analytic techniques
(5) Development of necessary algorithms to perform analyses
(6) Construction of model to provide required compatibility with needs of training analyst.

These items are discussed in general terms in this subsection and described in greater detail in Sections 3 and 4.

Figure 2-3 illustrates the four main components selected to ensure that the training model concept followed the ISD procedure. The training model analysis begins by using pre-established criteria to select those task blocks that require training. The second component in the model generates the training plan, consisting of the following: task blocks to be trained, type of training each will receive (i.e., school or OJT), and recommended methods and media for training each task block. The third model component uses the training plan to construct the training program. This indicates the schedule used for training and the resulting resource requirements. The fourth, and perhaps most important, component required for successful development of a training program is the training analyst. This "man in the loop" feature provides the feedback that enables the process to become self-correcting, and the user is able to examine the intermediate outputs of the training model and react to unanticipated variations or repeated irregularities in the procedure.



Main components in development of a training program

Figure 2-3

In addition to these four components, the training model also required appropriate input data. It was recognized that the model design would be influenced by the current availability of data. All of the considerations in the technical approach to the model were made in conjunction with the simultaneous development of the data bank. The model was designed with enough flexibility and adaptability, however, to allow its use with more complete data in later phases of weapon system development.

The training model presented in this technical report should be thought of as a prototype, to be modified and refined in the future stages of development. Certain assumptions were made in developing the model design which simplify the operation of the resulting model with minimal loss of accuracy and authenticity. There is no consideration of possible variations in the aptitude of the students who will follow the training program being generated. All students are assumed to reach the desired proficiency level in the given amount of time. It is further assumed that school and OJT give equally effective training results; there is no evaluation of the quality of a particular type of training or the competency of the trained person in performing a task.

Once the components of the model, the available data, and the basic assumptions had been identified, appropriate techniques were needed to perform the required analyses. The training mode assignment can be made according to two different policy requirements. When it is necessary for a student to receive all the required training through one type of instruction, the resulting problem is best suited to a linear programming analysis (Reference 5). However, when the policy choice results in the problem of selecting the combination of TTS and OJT instruction for each student that minimizes cost subject to a time constraint, the solution is best obtained through a dynamic programming application (Reference 5). Methods and media are assigned according to relationships between tasks, training objectives, and training type. In this component of the training model, the most appropriate technique is a two-step mapping: the first from task to training objective; the second from training objective to method and medium.

Certain aspects of the training model analysis necessitated the development of appropriate algorithms. For example, the selection of task blocks for training is accomplished with one of five possible decision algorithms which screen the input task data in tests of varying degrees of restrictiveness. The training program generator presented a similar situation. Since the special nature and requirements of the training program analysis (e.g., special equipment of high cost or scarce resources) prohibited the use of established scheduling routines, a special algorithm had to be developed for the construction of training schedules.

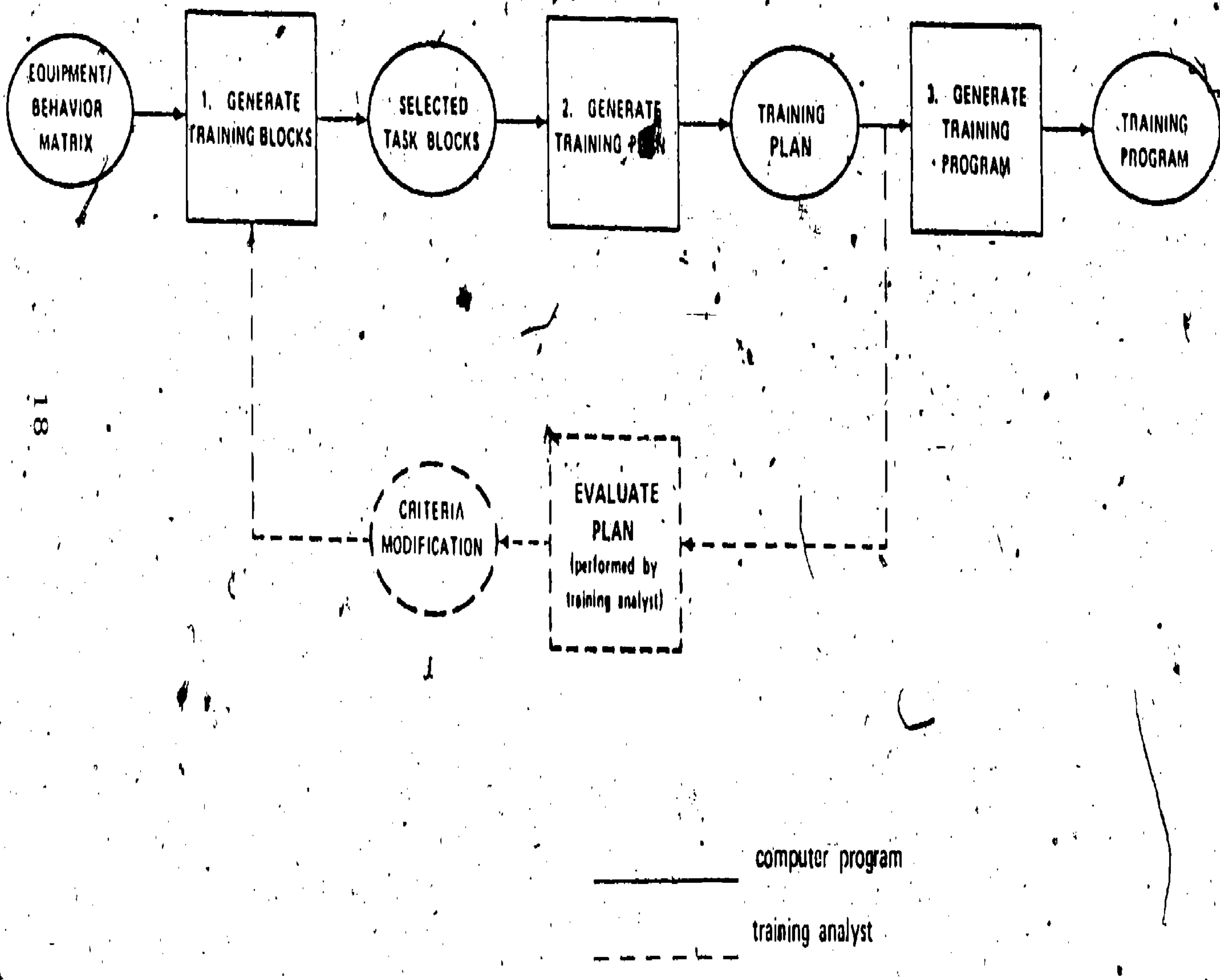
The final consideration in designing the training model was that it be compatible with the needs of the training analyst. Towards this goal, many options were added to the model design to accommodate different system and policy requirements, as well as resource and operational constraints. The mappings used to assign methods and media can be altered by the user to reflect his needs and preferences. The policy choice in reference to the training mode assignment is another example of this adaptability. The means of relating system/policy/resource factors to the resultant training impacts are also contained in the model, thus allowing the training analyst to obtain relative impact estimates of great value early in the weapon system development process.

MODEL OPERATION

Figure 2-4 gives an overview of the training model which resulted from the technical approach described in the previous sections. Operation of the model is predicated upon the establishment of a data bank containing the list of tasks to be performed. Their level of specificity is a user-defined variable allowing for flexibility of task definition. Each task should be assigned a scalar value for each of five task characteristics denoting: frequency, criticality, learning difficulty, and psychomotor and cognitive levels. Scalar ranges and quantification criteria are provided in Appendix B.

The data bank is input to the training block generator which screens the total set of tasks in a series of go/no-go decisions to determine those tasks which require training. The selected set of task blocks becomes the input data set for the training plan generator. The user maintains control of the screening process by his choice of selection criteria, i.e., screening algorithm and task characteristic thresholds.

At this point, it is assumed that all output tasks are to be trained. The user now designates values for three constraining conditions: personnel required (number), maximum training cost (dollars), and maximum training time (months). The training plan generator then performs an analysis to determine the training mode



Training model operation

Figure 2-4

assignment for the outputted task blocks, based upon policy considerations assigned by the training analyst. (For example, one policy option assumes each student receives all his training in either school or OJT. The alternate method assigns each student to a mix of TTS and OJT training.) The training plan generator then recommends methods and media for each task block based upon task classification and the assigned policy for training mode selection.

After reviewing the initial training plan, the training analyst may opt to re-execute the task selector and training plan generator using a different set of training criteria. This procedure may be iterated to generate alternative training plans until an acceptable one is obtained. This final training plan now becomes the input data set for the training program generator. The user specifies class size restrictions, a task descriptor to govern the training sequence, and a (optional) high cost training medium whose use is to be optimized. The final output of the model is a representative training program consisting of the schedule, number of classes, and required items of selected media needed for the postulated trainee group.

COMPUTER IMPLEMENTATION

TRAMOD has been programmed for operation on the CDC-6600 computer. A listing of the program is included in Volume II of this report. TRAMOD was designed as an interactive program in order to give the user the greatest amount of control over its execution. In addition to data bank inputs, its operation calls for several interactive inputs. These are listed in Table 2-3. TRAMOD prints a request for them, as they are needed, and reads input from the terminal in a free format. This prevents the possibility of an aborted computer run due to bad data and appreciably lessens the amount of preparatory work required of the user. It also helps the user to develop a more complete understanding of the effects of individual data items on the training model results.

The interactive nature of TRAMOD also allows for increased flexibility in its operation by allowing for a variety of options to meet the needs of different training policies and designs. Whenever the program reaches a point where a decision is required in order to continue execution, a message is printed to the user. The program identifies the possible options and waits for the user's input, as in the screening algorithm choice required to establish the user's task selection criteria. There are also occasions where the user is offered the option of changing data default values, i.e., specific data values incorporated as part of the program, such as the methods and media mappings.

Table 2-3

Interactive Inputs

1. Threshold cutoff levels for the input characteristics*
   (a) Criticality
   (b) Learning difficulty
   (c) Frequency
   (d) Psychomotor level
   (e) Cognitive level
2. Task selection algorithm choice*
3. Number of trainees to be trained in each AFSC*
4. Regression coefficients for derivation of cost and time data for each task block+
5. Training time constraint*
6. Training cost constraint+
7. TTS/OJT split+
8. Alternative training objective mapping+
9. Alternative methods and media for training+
10. Scarce TTS resource to be optimally scheduled+
11. Minimum class size*
12. Maximum class size*

*required input

+default values available

All the results generated by the training model are output interactively as they are obtained, unless suppressed by the user. This feature assists the user in directing the program flow, since he can examine and use the effects of previous decisions to help him make his next selection. Interactive output also aids the user in quickly identifying inappropriate choices made during runs in which the resulting training program is not satisfactory.

Each analytic component of the training model presents the user with several alternative options for performing the required analyses. By exercising the model using different decision criteria, the user not only refines his results but also determines those combinations of algorithms and data inputs best suited for particular applications. In some instances the user may decide that additional options are needed to match the needs and constraints of a particular design specification. The modular nature of TRAMOD makes modifications possible and allows for adaptability and refinement to meet future needs.

Iterative use of TRAMOD lets the user direct the program to repeat analyses, both within and among the major components of the model. This control gives the user the added capability of identifying the sensitivities of the various options and parameter values. Through examining the relative effects of input data changes, the user can identify those elements of design and policy which could give rise to problems in the planning of training. This feature makes the model an excellent research tool for the training analyst interested in identifying the potential training consequences of design options for a new weapon system.

3. DATA BANK DEVELOPMENT

One of the first considerations in analyzing the training impact of a new system is the creation of a data bank containing information for use in translating the equipment and/or maintenance characteristics and requirements into the data necessary to generate training programs. Basically, this consists of a systems maintenance/operations requirements analysis in terms of task objectives for the system. It is assumed that each exercise of the model is to be accomplished using tasks within a single technical specialty area. Therefore, the tasks are grouped primarily by career field designation and sub-grouped by subsystem for the purpose of data base organization. A dictionary comprised of these task objectives is subsequently developed in terms of the behaviors subsumed by the identified tasks to achieve a more refined description of the tasks in terms of their behavioral characteristics. The classification and grading of tasks on the basis of behavioral variables are used in the training model as criteria for the decisions concerning the choice of tasks to be trained and for training plan and training program definition.

Three principal aspects relating to the development of a data bank for input to TRAMOD have been identified as requiring in-depth explanation:

(1) Establishing the task dictionary
(2) Establishing characteristic parameters for the tasks and assigning their values
(3) Assigning training times and costs to each task

TRAMOD was designed as a tool for analyzing the training requirements of any new weapon system. The two data banks referred to in this section, however, have been developed specifically for use in the DAIS LCC application. The above aspects of data bank development are, therefore, discussed in two reference frames in the following subsections. They are first presented with application to the historical or baseline data base, and then with consideration of the effect of DAIS implementation upon the baseline data due to changes in avionics, support equipment, and maintenance concepts.

TASK DICTIONARY

The initial step in the development of the data base task dictionary was to perform an analysis of the maintenance/operations requirements for the avionics suite conceptual design developed within the DAIS LCC study (Reference 10). The requirements were examined in terms of the task performance required of a maintenance technician at the completion of his specialty training program. This analysis was necessary to establish a link between the equipment and a task oriented training program necessary to teach the skills and knowledge required to maintain that equipment. A hierarchy of tasks was established so that training requirements could be identified for each maintenance event associated with specific avionics equipment. This analysis was accomplished with the aid of the previously developed (Reference 3) DAIS reliability and maintainability (R&M) model classification of maintenance events which include: "set-up support equipment," "troubleshoot," "remove and replace," "on-equipment maintenance," "verify the subsystem repair," and "bench check and repair." Related tasks within each event were identified for a generic avionics suite by listing the various maintenance actions that would occur during each event. Several iterations of this last process were exercised to ensure that the avionics equipment maintenance tasks identified were comprehensive, though not necessarily exhaustive.

This in-depth analysis revealed the existence of redundant tasks across maintenance events. In addition, the combined tasks could not, in themselves, be construed as a complete training program for a maintenance technician since there were additional background knowledge requirements necessary to guarantee successful performance. To correct the first problem noted, the R&M maintenance events were grouped into four independent duty areas: flight line duties, shop duties, flight line support equipment duties, and avionics support equipment repair duties. Redundant tasks within a duty area were then combined leaving a single list of tasks for each of the four duties. For the second problem, current Air Force avionics maintenance personnel training course curricula were consulted. This resulted in the addition of two new duty areas: General Technical and General Non-Technical. A list of job related tasks derived from the training courses was appended to the appropriate duty area.

Finally, the tasks within the six duty areas were reviewed again for omissions or redundancies, and the resultant list became the task dictionary as presented in Appendix A. It should be noted that some of the listed task designates are amended by either subtasks or modifiers. The purpose of the modifiers (unnumbered task elements) is to aid the training analyst in evaluating the scope of the task. Where subtasks are listed (identified in the least significant digit of the task identifier), the analyst may use these subtasks both to identify the scope of the task and also to exercise a greater level of detail in the model if desired. If this capability is used, the training model treats the task identifier as a nesting parameter indicating associated subtasks. This parameter serves to designate tasks which logically fall together, either on the basis of their performance interaction or requirements generated by the actual provision of training.

CHARACTERISTIC PARAMETERS

Having completed the task dictionary, the next step in constructing a historical data base required that a set of parameters be identified to serve as a means for evaluating individual tasks. Those selected had to be common to all tasks in the dictionary and measurable with some degree of reliability or repeatability. This ensures that different personnel involved in training analyses may arrive at similar evaluations of the same task.

A review of the task dictionary was conducted to identify common parameters which would most impact a training program. Candidates were extracted from the ISD manual or suggested by engineering personnel experienced in electronics maintenance. A list was then compiled under several headings such as task-related, technician-related, equipment-related, or maintenance concept-related. The task-related category of parameters was chosen as that best suited for evaluating tasks in terms of training requirements, and was thus selected for use in the data bank. The five task characteristic parameters identified are (1) criticality to job performance, (2) difficulty in learning, (3) frequency of performance, (4) cognitive activity, and (5) psychomotor activity. The first three are self-explanatory in concept and are defined in Appendix B. The last two are used in lieu of "knowledge" and "skills." No suitable specific taxonomy exists for defining or measuring the skill and knowledge levels required for performing maintenance tasks. Therefore, the means of defining the last two task characteristic parameters were derived from a behavioral taxonomy developed by Bloom (Reference 1). Appendix B, Task Characteristic Parameters/ Values, defines the above five parameters with respect to their use in the data bank.

Five distinct levels were assigned to each of the parameters, with the exception of criticality which was assigned three levels. This number of levels appears to be consistent with the accuracy of data available during the conceptual phase of the design process and also with the sensitivity requirements of the model. Appendix B defines the relative values assigned to each parameter and also provides examples of skills which might be required for successful performance of a task. Appendix B was used by the engineers performing the task evaluation of the historical non-DAIS and the DAIS equipment configurations. For the historical data bank, each engineer evaluated all tasks in the dictionary while considering a generic avionics subsystem. The results of these evaluations demonstrated a high degree of uniformity. Where a difference of two or more levels existed for any parameter, the evaluations were discussed before a consensus value was assigned. Concurrent analysis indicated that the major reason for the differences resulted from variations in interpretation or concept of the tasks on the part of the evaluator, rather than his misconstruction of the level definitions.

Following the task evaluation of a generic avionics subsystem, it was noted that the value assignments of some of the task characteristic parameters for certain tasks, such as "isolate malfunction," were driven by properties of the equipment. These tasks were identified, and engineers familiar with the subsystems modified the level assignments for the parameters accordingly. For the remaining tasks, which are independent of equipment properties, the previously determined parameter values were used for all subsystems.

TIMES AND COSTS

The final step in developing the historical data base for TRAMOD was the assignment of task training times and costs for each subsystem. Attempts were made to insure that both times and costs were as realistic as possible through the use of existing data and extensive engineering analysis. Data needed for establishing training times was taken from sources such as the DAIS historical R&M data (Reference 3), Air Training Command (ATC) information, and course curricula for the Air Force Specialty Codes (AFSCs) of interest (References 11 and 12). Training cost data were extracted from Air Force sources and Rand studies (References 13 and 14). Both times and costs were isolated by training type: OJT or TTS.

One of the features of the training model is that the user may substitute up to four sets of regression coefficients (one set each for TTS time, TTS cost, OJT time, and OJT cost data) in lieu of the individual task segment training time and cost data contained in a data base. This feature is included because it is anticipated that the training model will be used in applications for which task segment times and/or costs may not be known. If so, the user may judge that the application under study has strong similarity to some prior use for which the needed values were available. In that case, a regression or similar analysis on this prior data could provide viable input coefficients to determine the needed data. The coefficients are used in conjunction with the task characteristic parameter values to determine the time and/or cost data either across-the-board to reflect a general change, or for those specific tasks for which no time or cost data is available. However, when an analyst wishes to change time or cost data for a selected subset of tasks within the larger set of tasks assigned to a given AFSC, this must be accomplished through modification of the data bank itself rather than through use of regression coefficients. Each set of coefficients comprises one constant value and five multipliers, one for each of the task characteristic parameter values. These coefficients are entered manually by the analyst as an interactive step.

For the case where neither current nor user-generated coefficients are available, sets of default coefficients that are incorporated within program TRAMOD may be used on demand. The default coefficients supplied were determined through linear regression analysis on a data bank prepared for tasks peculiar to the DAIS training application. It is important that the analyst realize that these default coefficients should be used only when no reliable data exist and, even then, the output products should be screened with care.

DAIS CONCEPT

Once the methodology and terminology were established for developing the historical training model data bank, construction of the DAIS theoretical data bank depended primarily upon defining the training requirements in terms of the DAIS concept. The development of the DAIS theoretical training model data bank was a logical extension of the maintenance analysis that preceded the development of the mid-1980s DAIS R&M model theoretical data bank (Reference 2). The determination of the effects of DAIS upon equipment R&M characteristics was followed by an analysis to determine the corresponding effects upon maintenance personnel training requirements. The major considerations were (1) equipment design, i.e., the hardware and its associated software, and (2) the general maintenance policies affected by DAIS, such as manpower allocation. The following paragraphs initially deal with the above two aspects, and then proceed to describe the necessary changes to the historical training model data bank as a result of DAIS.

Focusing attention first on DAIS hardware/software-related aspects, the major effects of DAIS were studied after first establishing conditions or guidelines; the principal ones include:

1) All sensors remain as is, i.e., there is no change of equipment configuration, with the exception that certain control, display, and interface units are relocated in the core. The core elements of the DAIS architecture consist of the multiplex bus and interface units, processors, integrated controls and displays, and special software. Whereas most primary functions are centralized under the DAIS concept of avionics utilization, certain computational devices such as the navigation, mission, and bombing computers or processors were reconfigured as a core function. The appropriate R&M model characteristics were adjusted for this transfer of functions (References 2, 3, and 4). Specifically, these adjustments consisted of transferring the task requirements (e.g., time to accomplish, number of technicians, their Air Force Specialty Code, and Support Equipment) to the new core subsystem maintenance networks. Appropriate reliability values were also assigned for these new subsystems.

2) In accordance with the DAIS system architectural guidelines, the controls, displays, and processors are integrated as much as is feasible. Additional software is assumed to exist to aid in integration and to reduce the common hardware items in the core.

3) As a result of the above two considerations, minor A/D (analog to digital) and D/A redesigns have been postulated to permit sensor/core interface. This interface is a function of the remote terminal units (RTUs) in any DAIS configuration, and does not affect the sensors (Reference 2).

4) DAIS design lends itself to the inclusion of a Central Integrated Test System (CITS) for isolating malfunctionging LRUs on the flight line. The capability of a CITS to provide an improved built-in test (BIT) capability, thus reducing the cannot duplicate malfunction (CND) rates both on the flight line and in the shop, must be considered. (The R&M model data, which was obtained from the DAIS maintenance analysis (References 2 and 3), reflected these CITS impacts.)

5) Although DAIS avionics support equipment is different from non-DAIS, its major impact on training requirements derives from the number of tests it will perform and the accuracy of these tests rather than its speed of accomplishment (References 2 and 9).

The above conditions and effects have subtle impacts on the data bank, both directly and indirectly. The indirect impact is reflected in the general maintenance policy considerations, defined below, which were identified as appropriate to a DAIS avionics configuration.

1) Consideration is given to the possibility that maintenance technicians may be assigned solely to the flight line or shop e.g., consider the policy of training only one to three AFSCs to perform all flight line tasks and similarly training six different AFSCs to perform the shop tasks (one for each of the six test stations). This solution is dependent to some degree upon the BIT/CITS capabilities at the flight line and the test station capabilities in the shop. However, it may reduce the teaching of extraneous information and thereby reduce overall training times.

2) Training for DAIS personnel will probably be limited to "need to know" subjects. For example, assume that the test stations are capable of isolating malfunctions at the functional or modular level. If the LRUs for a subsystem are repaired mainly by removing and replacing the shop replaceable units (SRU), then it is quite likely that the technician need not receive the in-depth training in "knowledge of electronic principles," which constitutes a major portion of the current course curricula.

3) The mean time to repair (MTTR) times per task at the LRU level remain the same for both DAIS and non-DAIS airmen. However, maintenance man hour (MMH) times change as a function of the number of personnel assigned per task and there will probably be differences between the non-DAIS and DAIS configurations. This was determined in the R&M model maintenance analysis (References 2 and 4).

CONSTRUCTION

Construction of the DAIS data banks consisted primarily of defining the previously reviewed DAIS impacts in terms of the data bank variables: the tasks; their characteristic parameter values; and associated training times, and costs.

Task assignments: The tasks listed in the historical data bank dictionary, with the exception of a few additional subtasks and modifiers added to account for the increased software, were comprehensive enough to cover DAIS avionics.

Task characteristic parameter level assignments: The following was concluded from a task oriented training analysis which took into account the previously reviewed DAIS impacts:

- No need to change any of the criticality assignments between the two data banks.
- No need to change any of the psychomotor assignments between the two data banks.
- Frequency values formerly scaled relative to historical subsystems maintenance index data should now be scaled relative to the maintenance index data for DAIS subsystems. The algorithm for level determination need not be changed.
- Cognitive and difficulty levels should be modified slightly to account for DAIS vs. non-DAIS differences in the equipment-related tasks mentioned previously.

Training time and cost assignments: No change is needed in either the TTS or OJT hourly costs between the two data banks because the dominant cost factors (wages, benefits, and facilities) are not impacted. OJT times by task change only as a function of the DAIS architecture partitioning. TTS times by task change mostly as a function of the architecture partitioning. However, a few of the general duty task times such as "knowledge of electronic principles" are reduced.

A comparison of the DAIS data bank with the historical data bank, by duty area, reveals little difference between the two. This results from using similar equipment in the two avionics suites. The major differences occur only where the equipment has changed sufficiently to generate new support personnel requirements. The required tasks and their assigned characteristic parameter values, times, and costs for the flight line support equipment and the avionics support equipment repair duty areas are identical between the data banks. Only time allocations are slightly changed because the flight line and shop duty area tasks remain the same for both the non-DAIS and DAIS configurations. The equipment related tasks do, however, reflect changes in the difficulty and cognitive level evaluations as a result of DAIS; as do some of the OJT times. The General Technical and General Non-Technical duty area tasks maintain the same task characteristic parameter values and costs, but their associated TTS and OJT times are slightly changed. Finally, the "knowledge of specific subsystems" or "knowledge of specific test stations" tasks required modification to reflect the differences between the DAIS and non-DAIS avionics.

4. TRAINING MODEL DESCRIPTION

This section provides a detailed explanation of the techniques used in TRAMOD and its operational capabilities. The discussion is segmented in terms of the model's four primary functions: task selection, training mode assignment, methods and media assignment, and training program scheduling.

TASK SELECTION

The first component of TRAMOD functions, under user defined constraining conditions, to select the tasks which require training from those in the initial input task list. Output is in the form of task sets or "blocks" of tasks to be trained as a unit. This function is performed on the basis of a set of decision algorithms which screen the input data against test criteria established by the user. These criteria are limiting values for each of the task characteristic parameters described in Section 3 which establish cutoff levels for each screening decision. Five algorithms allow these thresholds (N_i) to be compared with the actual task characteristic parameter values (C_i) in tests which vary in their degree of restrictiveness.

The selection of an algorithm for model operation is dependent upon the user's interpretation of the relationship between the tasks and their individual task characteristics. The most restrictive of the screening tests, the "All" decision tree algorithm, considers all parameters to be equally important and requires each to meet a specified level for training to be warranted. However, this algorithm can be used to test on the basis of single or groups of parameters within the total set. This would be appropriate when the user perceives unusual differences in task characteristic parameter relevancy or wishes to explore outcome possibilities based on their postulated existence. Selective parameter exclusion from the train/no-train decision process is achieved by entering a "O" cutoff level for those to be excluded. This causes them to be ignored by the "All" decision tree algorithm, resulting in a training requirement decision based solely on the remaining parameters.

The least restrictive test algorithm is the "Any" decision tree. This requires that only one of the task characteristic parameters meet a user-selected threshold value. In general, for a given set of N_i values, this algorithm will yield the largest subset of test blocks to be trained, permitting any one of the five parameters to dominate the establishment of a training requirement. This test is most appropriate when the user feels that a specific parameter should be the sole factor in the screening decision. Choosing values of "6" for four of the five possible cutoff levels will result in an affirmative task block training decision only if the value of the remaining task characteristic parameter meets its threshold.

The remaining three algorithms test functions of the task characteristic parameter values rather than the individual values themselves. A given set of N_i values used with one of these tests results in a group of tasks designated for training having more varied task parameter values than those designated by the two decision tree algorithms. Two of the tests compute the root-mean-square (RMS) value and the pure average of the parameter values and compare them to a selected threshold value. The last of the screening algorithm choices computes a weighted average of the parameter values on the assumption that the user's choice of individual parameter value cutoff levels indicates the relative importance of the five parameters. Table 4-1 illustrates the results of applying the various decision algorithms to a set of tasks, using a fixed set of threshold values (N_i) and task characteristic parameter values (C_i).

The RMS and pure average decision algorithms allow task characteristic parameters with high values to compensate for others with low values. An RMS test passes tasks that may fail the pure average test, since the squaring of the parameter values gives parameters with high values even more weight than they would be accorded in an averaging process. This property makes the RMS algorithm most appropriate for screening tasks whose sets of characteristic parameter values deviate significantly from the mean of those values. The most appropriate choice between these two options is dependent upon the thresholds selected as well as on the task characteristic parameter value profile desired to characterize a task to be trained. Consider the following two sets of threshold values: 3, 2, 3, 3, 2 and 1, 5, 4, 1, 2. Both sets have the same mean value, but the second set has a much higher standard deviation. If this set of thresholds is used, then the RMS algorithm will generally select more tasks for training.

The model uses the screening criteria to select individual tasks requiring training, and then collates them into associated task blocks. It does this by examining the task-associated nesting parameters described in Section 3. If one task in a nested group is selected for training, then the entire group will be trained as a task block. Therefore, the task characteristic parameter values assigned to each task block are the maximum values of those within the nested task group. These outputted task blocks become the input data set for the second component of the model which constructs an initial training plan.

Table 4-1 Task Selection Algorithms

	Criticality	Difficulty	Frequency	Psychomotor	Cognitive
Task 1.	5	2	3	1	2
Task 2.	3	3	3	3	2
Task 3.	4	3	2	2	2
Task 4.	3	2	5	1	2
Task 5.	2	3	4	3	3
Thresholds N_i:	2	3	4	2	3

Algorithm	Test	Passing Tasks
"All" Decision Tree	$C_i \geq N_i$, all i	5
"Any" Decision Tree	$C_i \geq N_i$, any i	1, 2, 3, 4, 5
Pure Average	$\sum_{i=1}^{5} C_i \geq \sum_{i=1}^{5} N_i$	2, 5
RMS	$\sum_{i=1}^{5} (C_i)^2 \geq \sum_{i=1}^{5} (N_i)^2$	1, 4, 5
Weighted Average	$\sum_{i=1}^{5} C_i \cdot w_i \geq \frac{1}{5} \sum_{i=1}^{5} N_i$ where $w_i = \frac{6 - N_i}{\sum_{j=1}^{5} (6-N_j)}$	2, 5

TRAINING MODE ASSIGNMENT

The first half of the training plan generator identifies the type of training to be assigned to each task block. The training mode decision, TTS or OJT, is determined by the training analyst's choice of policy, cost and time constraints, and number of personnel required. In order to perform this analysis, OJT and TTS training time and cost requirements must be assigned to each task block. There are three methods available for obtaining these data:

(1) Direct input of training times and costs for each task block in the input data set

(2) Calculation of training times and costs with user-selected regression coefficients; times and costs are linear combinations of the task characteristics, e.g.,

$$\text{Cost (i, OJT)} = K_o + \sum_{j=1}^{5} K_j \bullet C_{ij}$$

for each task block i where:

K_j is the regression coefficient for OJT training costs for the j^{th} characteristic, $j=1, \ldots, 5$.

C_{ij} is the value of the j^{th} characteristics of the i^{th} task block.

(3) Derivation of times and costs using the fixed default regression coefficients presently available in TRAMOD in consort with the above equation.

Selection of the first option indicates that the data have already been read in as part of the input data bank. As task blocks are selected for training, the appropriate time and cost data are accumulated and stored with the rest of the task block data. The second option requests the user-selected regression coefficients be entered interactively during execution of the model. The third option requires no data input, as the default coefficients are stored in TRAMOD and are available upon demand. During sessions with multiple runs, regression coefficients entered under the second option become default coefficients for all successive runs. All three options result in the times and costs data arrays needed for the training mode selection process. The training model makes the TTS/OJT decision in one of two ways depending on the policy requirements of the training program.

A "non-mix" option assumes each student is trained solely through school or OJT, but not both. The model calculates the student split between TTS and OJT based on a "quality" assessment of the training requirement. The concept of quality used in this section is a measure of deviation from the optimum candidate criteria for both TTS and OJT, as explained herein.

First, the model computes the time and cost values to train a student through school and OJT using the initial screening options available to the training analyst. Then, these values T_S, T_O, C_S, and C_O, respectively, are tested against the user-defined constraints for training program time and cost T_{max}, C_{max}). Next, the model checks for the feasibility of each of the training modes within the time constraint. A subsequent test compares C_{max} with the costs for those values meeting the time constraint. The model calculates the student split only when both TTS and OJT training modes are feasible. Let OC_i and SC_i, $i = 1, \ldots, 5$ represent those values of the five task characteristics which are most appropriate for OJT and TTS training. Define two "distance" functions, d_o and d_s, applied to each task block selected for training, as follows:

$$d_s(j) = \sum_{i=1}^{5} [(C(j,i) - SC_i)^2]^{1/2}$$

$$d_o(j) = \sum_{i=1}^{5} [(C(j,i) - OC_i)^2]^{1/2}$$

where $C(j,i)$ denotes the value of the i^{th} characteristic of the j^{th} task block. Then $d_S(j)$ is a measure of the deviation of task block j from the optimum candidate for TTS training, and similarly, $d_O(j)$ with OJT training. Both functions can be averaged over the selected task blocks and the overall population deviation from the optimum training criteria can be defined as

$$J = N_s \bullet [\frac{1}{n} \sum_{j=1}^{n} d_S(j)] + N_o \bullet [\frac{1}{n} \sum_{j=1}^{n} d_o(j)]$$

where N_S and N_O are the number of students in TTS and OJT. The "quality" of the resulting training requirements, as previously defined, is maximized as J is minimized. This problem can be solved by a linear programming application (Reference 5) and reduces to the equations:

$$N_s = \frac{C_{max} - C_o \bullet N}{(C_s - C_o)}; \qquad N_o = N - N_s = \frac{C_{max} - C_s \bullet N}{(C_o - C_s)}$$

These two equations then give the split of the trainees to be trained in TTS and OJT.

The alternate method of determining the training mode assumes each student can be trained through a combined program of school and OJT. The model uses the time constraint for the training program and assigns a training mode to each task block through a sequence of interrelated decisions. The analysis is performed through a dynamic programming algorithm which provides a systematic procedure for determining the combination of decisions that minimizes the overall cost. The basic features which characterize this as a dynamic programming problem are discussed below.

The model examines the task blocks and keeps track of the time and resources expended by each under the two training modes. Each task block is then assigned to OJT or TTS in order to minimize overall resource consumption for the training program. In dynamic programming terms, each task block represents a "stage" requiring a decision. The "state" for each stage/task block is the amount of unconsumed time left for training the unassigned task blocks. For example, if the decision is made to train task block n at TTS when there are 30 weeks left for training, and task block n takes 16 weeks to train, then the decision for block n+1 is made with 14 weeks remaining in the training program.

A recursive relationship identifies the optimal policy for each state at task block n, given the optimal policy for each state at task block n+1. The minimum cost for training task block n with s_n time remaining in the training program is

$$f_n(s_n) = \min_{t_n \leq s_n} \left\{ f_{n+1}(s_n - t_n) + c_n(t_n) \right\}$$

where

s_n = time left to allocate to task block n

t_n = time required for either OJT or TTS training

$c_n(t_n)$ = cost associated with either OJT or TTS training.

Therefore, finding the optimum policy when starting in states s_n at task block n requires finding the minimizing value of t_n. When there are N task blocks to be trained, the optimum training plan is found by iterating the above equation N times. Further discussion of the algorithm can be found in Reference 5.

At this point in the execution of the model, each task block has an assignment of TTS or OJT training. If the combination TTS/OJT instruction has been chosen by the model user, all students will follow the same training plan. Otherwise the model will generate two training plans; one appropriate to the OJT and the other appropriate to the TTS course of study.

METHODS AND MEDIA ASSIGNMENT

The second half of the training plan generator assigns an appropriate training method and medium to each selected task block. In order to do this effectively, it is necessary to correspond method and media characteristics with human performance requirements. This in turn requires a meaningful classification of human performance with respect to the significance of learning principles and the importance of specific task influences. The classification system used in the training model is defined in Parker and Downs (Reference 6) and consists of the following six classes of training objectives. It is recognized, however, that this system is only one of many which might have been used.

1. Learning Identifications. This means pointing to or locating objects and locations, naming them, or identifying what goes with what -- either physically or in words or symbols. The latter includes much of what is commonly denoted by the word "facts".

2. Learning Perceptual Discriminations. This involves the use of visual, auditory, and similar cues in a manner which allows the identification of a particular stimulus. The integration of these cues, some of which may be just above the threshold of perception, occurs primarily in the course of direct practice.

3. Understanding Principles and Relationships. This usually means understanding a statement of relationship -- as shown by being able to state, illustrate, and recognize its implications. Often this is a statement which tells how a cause produces an effect, or how a result can be predicted from several component factors. It may involve knowing arbitrary rules of contingent procedures, e.g., "if such is observed, do thus and so".

4. Learning Procedural Sequence. This means knowing how to carry out a set of operations that must be carried out in a fixed sequence.

5. Making Decisions (Choosing Courses of Action). This usually involves the application of conceptual rules of principles as the basis for making the kinds of decisions that are involved in diagnosing or interpreting complex situations.

6. Performing Skilled Perceptual-Motor Acts. These may be quite simple (using basic hand tools) or quite difficult (manipulating the controls of an airplane or performing a sensitive adjustment that requires precise timing). Often, like the learning of identifications, the performance of uncomplicated activity requiring only rudimentary skill provides for the accomplishment of necessary steps in more complex tasks that require the following of lengthy procedures.

The human performance data used in the training model are in the form of the five task characteristic parameters described in Section 3. The training plan generator incorporates a mapping of each of the taxonomic levels which can be assigned to a task block with a particular training objective. It uses the higher of the two cognitive and psychomotor values associated with each task block to determine the most appropriate training objective for that block. This mapping is illustrated in Table 4.2.

The six training objectives are each assigned a method and medium most appropriate for conveying the learning principles they represent, and also most appropriate for the mode of training assigned to each task block (Table 4-3). The following definitions, found in Reference 8, identify the training methods which comprise the present TRAMOD selection repertoire.

Informal Lecture:	a discourse given before an audience for instructional purposes
Demonstration:	an accurate portrayal of the precise actions necessary to perform skills or processes
Performance:	a student practices, performs, and applies, under controlled conditions and close supervision, the skills or knowledges which have been previously explained and demonstrated
Discussion:	an interaction between students and/or an instructor in order to analyze, explore, and/or debate an issue, topic, or problem

Table 4-2

Mapping for Task Classification

Taxonomic Description →	Training Objective
Psychomotor 1 (Imitation) Cognitive 1 (Comprehension)	1. Learning Identifications
Psychomotor 2 (Manipulation) Psychomotor 3 (Precision)	2. Learning Perceptual Discriminations
Psychomotor 4 (Articulation) Cognitive 2 (Application)	3. Understanding Principles and Relationships
Cognitive 3 (Analysis) Cognitive 4 (Synthesis)	4. Learning Procedural Sequences
Cognitive 5 (Evaluation)	5. Making Decisions
Psychomotor 5 (Naturalization)	6. Performing Skilled Perceptual Motor Arts

Table 4-3

Mapping for Methods and Media

Training Objective →	Method/Media
1. Learning Identifications	TTS: Discussion/Transparencies OJT: Informal Lecture/ Transparencies
2. Learning Perceptual Discriminations	TTS: Simulation/Training Film OJT: Demonstration/Training
3. Understanding Principles & Relationships	TTS: Simulation/Simulator OJT: Performance/Mock-Ups
4. Learning Procedural Sequences	TTS: Performance/Simulator OJT: Performance/Training Film
5. Making Decisions	TTS: Simulation/Simulator OJT: Performance/Training Film
6. Performing Skilled Perceptual Motor Arts	TTS: Performance/Simulator OJT: Performance/On-Equipment

Simulation: a representation of some aspects of reality (either a process, event, or hardware) by symbols or devices that can be manipulated more readily than their actual counterparts.

Informal lecture, demonstration, and performance are used for OJT courses as the craftsman-apprentice nature of this training lends itself to these methods of instruction. Tasks trained through the more traditional instruction offered by TTS are assigned methods of either discussion, simulation, or performance.

The model assigns each task-block one of the following five specific media (Reference 6):

Simulator: any device which presents most of the parameters of the work situation

Training Film: a film produced as a means of imparting technical information generally to large groups of trainees

Transparencies: pictures or drawings projected onto a viewing screen during a training lecture.

Mock-ups: three dimensional equipment representations which may or may not use actual equipment components

On-Equipment: the actual system for which the training is being conducted.

Each of the first four media is considered to be representative of a larger class of media. The four classes of media and their members are listed in Table 4-4. Some of the factors to be considered in media selection include the number of students involved in the program, the costs of hardware acquisition and operation, and the costs associated with producing and maintaining courseware. The model user may choose to select an alternative medium within the appropriate class in accordance with specific training or design requirements and resource constraints. He can also alter either of the mappings themselves through appropriate options in the training model.

Table 4-4

Classes of Media

Environmental Media/Aids	Visual Aids: Still Images
*Simulator	Opaque Projections
Games	*Transparencies
Role Play	Slides
Procedures Trainer	Charts

Visual Aids: Exhibits	Transient Media: Audiovisual
*Mock-ups	Sound/Slide Projector
Cutaways	Television
Models	Motion Picture
Animated Panels	*Training Films (sound filmstrip)

*medium chosen to represent each class

TRAINING PROGRAM SCHEDULING

After reviewing the initial training plan, the TRAMOD user may select a different set of policy/decision criteria and exercise the model again to obtain another training plan. The task selector and training plan generator will generally be iterated several times as an investigation/optimization procedure prior to the selection of a final training plan. Of course, if the user accepts the initial results of the model as satisfactory, execution continues on to the training program generator. This final component of the training model then generates a representative training program based on a set of internalized rules of resource management. The training program consists of schedule, number and size of classes per program, number of media items, and course lengths. The user specifies the required number of trained personnel, minimum/maximum class sizes and a task characteristic parameter, such as difficulty, to order the training sequence of the task blocks.

TRAMOD also allows one of the assigned media to be identified as a high cost driver which is to be optimized. The algorithm in this section then generates all possible arrangements of the training schedule so as to minimize the required quantities of the specified medium. It combines the task blocks requiring the high cost medium into a consolidated group and then iteratively shifts the placement of this group in the training sequence. In this way, a single unit of a training medium can be used to train more than one class of students, which greatly increases its effective use. The relative training sequence among task blocks not using this medium remains fixed in accordance with the user's choice of an ordering task characteristic parameter. The result is a reasonable first cut at a training program with sufficient detail to obtain training cost estimates when the requirements are given as input to the life cycle cost impact modeling system of which the TRAMOD is a major component.

As in the training plan generator component of the TRAMOD, the results of the training program generator component may be iterated to determine various sensitivities. Doing so may reveal excesses in resource consumption which might be avoided by changes upstream close to the equipment design end of the training analysis procedure. The capability for iteration using different sets of criteria is clearly one of the strongest features of the TRAMOD.

5. CONCLUSIONS

A methodology has been developed which addresses the qualitative aspects of human resource requirements of new weapon systems. An extensive repertoire of training technology exists which supports the design of training systems. The training model presented in this report facilitates the application of this information.

Decisions concerning the establishment of training plans and programs are becoming more and more difficult due to the increasing number of variables which training analysts must consider. This situation is made worse by the narrowness of the time frame in which the results of training analyses may provide useful feedback to designers and planners. However, the problem assumes increased importance as planners become more attentive to the life cycle cost aspect of systems acquisition.

Training is expensive, and its expense reaches far beyond the cost of producing trained personnel. The real cost of training includes penalties paid in terms of lost opportunities. These are the costs associated with failure to capitalize on numerous potentials for cost avoidance due to an inability to extend the analysis of training requirements beyond its present role of reacting to given sets of conditions. Clearly, it would be advantageous for a training analysis to become an integral part of the weapon system design process rather than a post hoc activity. This requires the ongoing participation of the training analyst in all phases of those design and policy decisions which create training requirements. The modeling approach to training impact analysis can make this change possible. It can increase the speed and systematization of the procedures entailed in training planning and resource management. TRAMOD provides a means by which early analysis of training impacts may be standardized, thus offering potential cost avoidance.

Quite apart from its potential for aiding designers in the development of more maintainable and cost effective systems, its versatility makes the training model ideal for even the most mundane problems concerning the provision of training and resource management. The training analyst who has an understanding of the effects of the various training model parameters and options can generate a training program which reflects numerous policy, resource, and operational conditions. The sensitivities of changes in factors such as use of job guides, aptitude and experience of the trainees, and availability of support equipment can be examined by appropriate changes in the interactive inputs.

The training model described is a first step in defining a methodology for the practical application of the modeling approach. The model itself stands alone as a mechanism capable of performing many of the required data manipulations entailed in a training impact analysis. What remains is for the training community to continue its development in terms of data and criteria.

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3ABR32531, Avionics Instrument System Specialist, Chanute AFB
G3ALR32630A-000, Avionics AGE Specialist-Manual, Lowry AFB
G3ALR32630B-000, Avionics AGE Specialist-Automatic, Lowry AFB
G3ALR32631C-000, Integrated Avionics Components Specialist, Lowry AFB
3ABR326320, Integrated Avionics System Specialist, Chanute AFB
3ABR32830, Avionic Communication Specialist, Keesler AFB
3ABR32831, Avionic Navigation System Specialist, Keesler AFB
3ABR32833, Electronic Warfare Systems Specialist, Keesler AFB
E3ABR32834, Avionics Inertial & Radar Nav. Specialist, Keesler AFB
3ABR40431, Aerospace Photographic System Repairman, Lowry AFB
3ABR42335, Aerospace Ground Equipment Mechanic, Chanute AFB
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Appendix A

Task Dictionary

- General Technical Duties
- Flight Line Duties
- Shop Duties
- Avionics Support Equipment Repair Duties
- Flight Line Support Equipment Duties
- General Non-Technical Duties

Appendix A

TASK DICTIONARY

GENERAL TECHNICAL DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
06	60	0	Know and use general test equipment
			• Characteristics
			• Usage
			• Operation
	61	0	Know basic principles of electronics
		1	AC/DC theory
		2	RLC circuits
		3	Solid state principles and circuits
		4	Tube principles and circuits
		5	Microwave principles, devices, and circuits
		6	Analog techniques
		7	Digital techniques
		8	Servo systems
	62	0	Understand and use troubleshooting techniques
			• Visual checks
			• Electrical checks
			• Operational tests
			• Diagnostic tests
			• Analysis
			• Substitution
	63	0	Demonstrate repair techniques and procedures
			• Standards
			• Soldering
			• Wirewrap
			• Remove and replace
	64	0	Understand subsystem interfacing
			• Power Interface
			• Signal interface
			• Mechanical interface
	65	0	Know and use technical publications
	70	0	Demonstrate knowledge of specific subsystems, LRUs
	↓	1	Principles of operation
	↓	2	Performance standards
	↓	3	Signal flow
	↓	4	Failure modes
	79	5	Associated special test equipment
	80	0	Demonstrate knowledge of specific automatic test stations
	↓		
	89		
	90	0	Demonstrate knowledge of specific manual test stations
	↓		
	99		

Task Dictionary (continued)

FLIGHT-LINE DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
01	01	0	Identify necessary maintenance aids: All
		1	tools
		2	test equipment
		3	tech. orders, job guides, etc.
	02	0	Obtain and return maintenance aids • select • transport
	03	0	Gain/close access to equipment • open/close compartments • remove/replace access panels/cowling
	04	0	connect/disconnect test equipment
	05	0	Verify malfunction: all
		1	Use BITE
		2	Perform operational tests
		3	Perform visual checks
		4	Perform electrical/mechanical checks
		5	Perform special test equipment checks
		6	Perform diagnostic tests/CITS
	06	0	Evaluate discrepancy report/check previous history
	07	0	Isolate malfunction/locate fault
		1	Consult tech. orders/job guides
		2	Determine from symptoms
		3	Evaluate from BITE/CITS
		4	Evaluate from test results
		5	Interpret from analysis only (experience & knowledge)
		6	Switch and/or substitute
	08	0	Determine action to be taken • Not repairable (F/L→R&R, S→N) • Repairable (F/L→M A/C, S→W) • Cannot duplicate (F/L→CND, A/C, S→K)
	09	0	Perform repair maintenance
		1	Repair malfunction (wiring, connectors, etc.)
		2	Perform minor maintenance
	10	0	Service (lubricate, clean, pressurize, etc.)
	11	0	Calibrate/align
	12	0	Adjust
	13	0	Obtain/return replacement unit (LRU, SRU, etc.)
	14	0	Remove/replace safety wires/bonding straps
	15	0	Disconnect/remove/install/connect
		1	LRU
		2	SRU
		3	Component
	16	0	Record maintenance actions/results • MDC forms (scheduled/unscheduled) • Maintenance logs • Equipment logs • Supply forms

SHOP DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
02	01	0	Identify necessary maintenance aids
		1	tools
		2	test equipment/test station
		3	tech. orders, job guides, etc.
	02	0	Obtain and return maintenance aids
			• Select
			• Transport
	03	1	Gain/close access into equipment, unit, etc.
	17	0	Test operation of bench check equipment /test stations
	04	0	Connect/Disconnect test equipment/stations
	05	0	Verify malfunction; all
		1	Use BITE
		2	Perform operational tests
		3	Perform visual checks
		4	Perform electrical/mechanical checks
		5	Perform special test equipment checks
		6	Perform diagnostic tests/CITS
	06	0	Evaluate discrepancy report/check previous history
	07	0	Isolate malfunction/locate fault
		1	Consult tech. orders/job guides
		2	Determine from symptoms
		3	Evaluate from BITE/CITS
		4	Evaluate from test results
		5	Interpret by analysis only (experience/knowledge)
		6	Switch and/or substitute units
	08	0	Determine action to be taken
			• Not repairable (S, NRTS, N)
			• Repairable (S, W)
			• Cannot duplicate (S, K)
	13	0	Obtain/return replacement unit (LRU, SRU, etc.)
	09	0	Perform repair maintenance
		1	Repair malfunction (soldering, wiring, etc.)
		2	Perform minor maintenance
	15	0	Disconnect/remove/install/connect
		1	LRU
		2	SRU
		3	Component
	10	0	Service (lubricate, clean, pressurize, etc.)
	11	0	Calibrate/Align
	12	0	Adjust
	18	0	Verify repair of malfunction/maintenance procedure
	16	0	Record maintenance actions/results
			• MDC forms (scheduled/unscheduled)
			• Maintenance logs
			• Equipment logs
			• Supply forms
	19	0	Initiate disposition of equipment
			• Send to supply as ready for issue
			• Send to supply for depot repair

Task Dictionary (continued)

AVIONICS SUPPORT EQUIPMENT REPAIR DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
03	08	0	Determine action to be taken
			• Not repairable (send to calibration facility, etc.)
			• Repairable
			• Cannot duplicate
	01	0	Identify necessary maintenance aids
		1	Tools
		2	Test Equipment
		3	Tech orders, job guides, etc.
	02	0	Obtain and return maintenance aids
			• Select
			• Transport
	03	1	Gain/close access into equipment, unit, etc.
	04	0	Connect/disconnect test equipment
	05	0	Verify malfunction
		1	Use BITE
		2	Perform operational tests
		3	Perform visual checks
		4	Perform electrical/mechanical checks
		5	Perform special test equipment checks
		6	Perform diagnostic test/CITS
	06	0	Evaluate discrepancy report/check previous history
	07	0	Isolate malfunction
		1	Consult tech. orders/job guides
		2	Determine from symptoms
		3	Evaluate from BITE
		4	Evaluate from test results
		5	Interpret by analysis only (experience and knowledge)
		6	Switch and/or substitute units
	09	0	Perform repair maintenance
		1	Repair malfunction
		2	Perform minor maintenance
	10	0	Service (lubricate, clean, pressurize, etc.)
	11	0	Calibrate/align
	12	0	Adjust
	18	0	Verify maintenance procedure/repairs/malfunction
	16	0	Record maintenance actions/results
			• MDS forms
			• Maintenance logs
			• Equipment logs
			• Supply forms

Task Dictionary (continued)

FLIGHT LINE SUPPORT EQUIPMENT DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
04	01	0	Identify necessary maintenance aids
		4	Support equipment (SE)
	02	0	Obtain and return maintenance aids • Select • Transport • Position
	20	0	Operate support equipment (SE) • Inspect SE • Connect/disconnect SE • Turn on/turn off SE • Monitor
	16	0	Record maintenance actions/results • Maintain SE records/logs

Task Dictionary (continued)

GENERAL NON-TECHNICAL DUTIES

DUTY XX	TASK YY	SUBTASK Z	DESCRIPTOR
05	50	0	Observe safety precautions and requirements • General electrical safety • General aircraft safety • Equipment peculiar safety
	51	0	Observe security precautions and requirements • Document security • Equipment security • Base security • Nuclear security
	52	0	Use data documentation systems • Maintenance data collection system (MDCS) • Equipment/maintenance logs and reports • Aircraft logs and reports
	53	0	Understand/use supply system • Supply procedures • Supply documentation
	54	0	Demonstrate familiarity with maintenance organization policies, concepts, and procedures for: • Flight line • Shop
	55	0	Demonstrate familiarity with aircraft: • Purpose/mission • Equipment locations

Appendix B

Task Characteristic Parameters/Values

Appendix B

TASK CHARACTERISTICS

Task Criticality

It is necessary to evaluate each task/function within a maintenance event with respect to criticality. Inevitably, almost all tasks are of a high level of criticality in insuring the ultimate success of a mission. However, as the training of personnel to perform tasks is an end in itself, the tasks may be assigned individual levels of criticality within the context of each event. There are three levels of task criticality used for TRAMOD operation. They are defined as follows:

Level	Definition
1	Non-critical - tasks that, if not performed correctly and/or to standards, would not degrade the overall effectiveness of the event, but which might affect the efficiency of the performance (e.g., for the event ON-AIRCRAFT MAINTENANCE, the functions of the task "obtain tools and test equipment" might be incorrectly done in that insufficient or wrong tools, etc., are brought to the aircraft, so that another trip for tools is necessary).
3	Semi-critical - tasks that, if not performed correctly and/or to standards, would not substantially degrade the effectiveness of the maintenance event, but which, if performed correctly and to standards, would lead to an efficient and effective overall maintenance event performance (e.g., for the event ON-AIRCRAFT MAINTENANCE, the task "connect test equipment" might be performed incorrectly so that invalid measurements might be made, resulting in a need to repeat the event or a reduced equipment/system capability.
5	Critical - tasks that, if not performed correctly and to standards, would seriously affect the effectiveness and success of the maintenance event (e.g., for the event ON-AIRCRAFT MAINTENANCE, the incorrect performance of task "perform verification tests" may allow a serious degradation of equipment performance to go unnoticed).
0	Not-applicable - tasks that are not applicable to a given equipment or system. This designation may be used by the computer to allow it to bypass the other input characteristic parameters.

Learning Difficulty

The learning difficulty of a task/function may be expressed as a function of the time it takes to learn to perform the task relative to the population of learning times across all tasks associated with the same system. This relationship is convenient and sufficient for the purpose at hand. However, its limitation is realized as is the fact that the time involved in the learning process is a function of the interaction of many variables including effort, complexity, and practice. Although levels of task difficulty provided by recent USAF occupational surveys are based on a scale of one to nine, for the purposes of this data base, five levels were used. They are defined as follows:

Level	Definition
1	Extremely low - very much less than the mean value for learning times across all tasks associated with the subsystems studied.
2	Low - somewhat less than the mean value for learning times across all tasks associated with the subsystem studied.
3	Average - approximating the mean value for learning times across all tasks associated with the subsystems studied.
4	High - somewhat more than the mean value for learning times across all tasks associated with the subsystems studied.
5	Extremely High - very much more than the mean value for learning times across all tasks associated with the subsystems studied.

Task Frequency

Frequency of task/function occurrence is a measure of the exposure time of a trainee to each task he encounters when performing his duties. For the Shop, Flightline, and Support Equipment maintenance duties, the exposure time is obtained by exercising the following equation using reliability and maintainability data/estimates for the subsystem studied.

$$MI = \frac{\text{MTTR by Maintenance Event}}{\text{MFHBMA}}$$

where:

MI is the maintenance index of the time taken to perform a maintenance action on a given subsystem for each flight hour of operation.

MTTR is the mean time to repair (i.e., complete a specific event required as part of a maintenance action) given that a maintenance action is required. This value is calculated by multiplying the average time it takes to perform a task event by the probability of occurrence of that event.

MFHBMA is the mean flight hours between maintenance actions.

Five levels are used to record task frequency for TRAMOD operations. These values are obtained from the maintenance index values (MIs) of the subsystems for each maintenance event combination that requires the tasks of interest to be performed. Each of the MI levels are defined in relation to the MI rate of like tasks across all the subsystems studied. The scale used to obtain the levels represents the linearly partitioned relative weighting of the logarithmic values of the MIs. In other words, the logarithmic values of the MIs were divided into five discrete increments to obtain their relative level across subsystems as defined below:

Level	Definition
1	<u>Extremely Low</u> - Task is performed infrequently
2	<u>Low</u> - Task is performed at a rate less than the average
3	<u>Average</u> - Task is performed at the average rate
4	<u>High</u> - Task is performed at a rate above the average
5	<u>Extremely High</u> - Task is performed frequently

<u>Task Psychomotor Level</u>

Each task/function of a maintenance event entails some level of conscious, physical action in response to sensory inputs. The degree of visual acuity, reaction time, manual dexterity, multilimb coordination, finger dexterity, arm-hand steadiness, control precision or interactions of any of the above psychomotor factors, as measured by the amount of practice required to learn and apply each task, were chosen to serve as bases for evaluating task levels. As no suitable specific taxonomy exists for either defining or measuring the psychomotor levels of a maintenance task, a measurement criterion, presented below, was constructed to serve the needs of TRAMOD operation. An attempt is made to clarify the definitions by example.

Level	Definition
1	Imitation - Task demands little or no practice to perform. Only routine motor skills and perceptual discriminations are needed. Task performance may require instruction and illustration for a few simple parts [e.g., obtaining a piece of test equipment, using basic hand tools, noting whether or not a light is on, reading values on a simple dial, activating a button, knob, or switch].
2	Manipulation - Task requires some practice either to integrate routine motor skills and perceptions (e.g., turning a switch on when a dial indicates a particular value) or to perfect certain motor coordinations or perceptual discriminations (e.g., fastening or removing a spring clip, noting relative motions of a dial or scope presentation, performing minor maintenance or servicing procedures, operating test equipment). Task performance may be completed for the most part without assistance other than reference material. Speed is not critical.
3	Precision - Task requires moderate practice to perfect or integrate the perceptual motor skills. Task performance demands the ability to do all parts of the task (at minimum recommended level) unassisted with reasonable speed and accuracy. Inspection/verification of performance may be necessary (e.g., assembling electrical/mechanical fittings, soldering, performing electrical, operational, or diagnostic checks, performing routine repairs, LRU or SRU replacement).
4	Articulation - Task requires much practice to acquire the motor coordination and/or perceptual discriminations necessary for proficient performance in all activities of all parts of the task. High accuracy but not necessarily high speed is needed (e.g., performing major electronic/mechanical calibration and alignment procedures).
5	Naturalization - Task requires a great deal of practice to acquire the motor coordinations and perceptual discriminations necessary for proficient performance. Task requires highest speed and accuracy with maximum skill production without the use of reference materials (e.g., performing intricate soldering and wiring, precision machining, performing critical emergency repairs or shutdown procedures).

Task Cognitive Level

Each task/function within a maintenance event may be described in terms of the relative cognitive (knowledge) level needed by a person to learn or perform it. As no suitable specific taxonomy exists for measuring the cognitive levels required of a technician performing a maintenance task, a measurement criteria, presented below, was constructed to serve the needs of TRAMOD. These definitions are derived from a combination of the Specialty Training Standards (STS) proficiency code definitions and Bloom's (Reference 1) cognitive level definitions. An attempt is made to clarify the definitions by example. The five levels assigned are:

Level	Definition
1	Comprehension - task requires that basic facts and nomenclature be known for successful performance (e.g., names of basic tools and test equipment; how to read text materials and use visual maintenance aids; know special terminology and vocabulary associated with a job specialty).
2	Application - task requires that the principles and procedures involved be known and used for successful performance (e.g., using basic tools and test equipment; performing operational or diagnostic checks using good maintenance aids).
3	Analysis - task requires that operating principles be understood and an ability to draw rudimentary conclusions concerning the subject matter. Technicians should be able to evaluate the relevancy of data (e.g., performing fault isolation and troubleshooting, performing calibrations or alignments without step-by-step maintenance aids).
4	Synthesis - task requires that considerable theory be known and an ability to evaluate conditions (e.g., evaluating test results properly in terms of the theory of operation).
5	Evaluation - task requires all of the above abilities plus that of making predictions or decisions requiring a complete understanding of underlying theory (e.g., determining what caused a subtle problem and deciding the changes that must be made to insure successful event completion or non-recurrence of the problem).

Appendix C

Acronyms

Appendix C

ACRONYMS

A/D	analog to digital
AFSC	air force specialty code
ATC	air training command
BIT	built-in-test
CITS	central integrated test system
DAIS	digital avionics information system
CND	cannot duplicate discrepancy
ISD	instructional systems development
LCC	life cycle cost
LCCIM	life cycle cost impact model
LRU	line replaceable unit
MMH	maintenance man hours
MTTR	mean time to repair
OJT	on-the-job training
R&M	reliability and maintainability
RMS	root-mean-square
RTU	remote terminal unit
SE	support equipment
SRU	shop replaceable unit
TRAMOD	training requirements analysis model
TTS	technical training school

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