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ABSTRACT

The Design of Training Systems (DOTS) project was initiated by the Department of Defense to develop tools for the effective management of military training organizations. Phase 2 of the project, from which this report emanates, involved the design and development of three computer-based mathematical models and their validation. Volume 1 presents an overview of the activities that comprised the design and development effort for the three DOTS models, a description of the validation process, and the long-range implications of the development of an operational system of DOTS models. Included in the volume are descriptions of the three models developed, their hardware and software requirements, and some of the organizational implications flowing from their implementation. (DGC)

TAEG

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GROUP

TAEG REPORT NO. 12-2

DESIGN OF TRAINING SYSTEMS
PHASE II REPORT, Volume I
PHASE II OVERVIEW

FOCUS ON THE TRAINED MAN

December 1974

TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO, FLORIDA 32813

Technical Report: TAEG REPORT NO. 12-2

DESIGN OF TRAINING SYSTEMS

PHASE II REPORT

ABSTRACT

This report consists of three volumes: Volume I presents an overview of the activities that comprised the design and development effort for the three Design of Training Systems computer-based models, a description of the validation process, and the long-range implications of the development of an operational system of DOTS models.

Volume II presents a detailed description of the System Capabilities/Requirements and Resources model, the Educational Technology Evaluation model, and the Training Process Flow model. Model logic design, input/output parameters, and data base communications are discussed at a level which allows an analytical evaluation of each model's design. In addition, Level I validation scenarios are presented in sufficient detail to allow their duplication if desired.

Volume III contains the model and data base program descriptions and operating procedures. Flow charts and program listings for the models, interface programs, and the data base applications programs are presented in appropriate sections.

The results of Phase II indicate that the selected modeling applications are feasible. The models' validation demonstrated response to realistic system variable parameters. It was concluded that the system of DOTS models is implementable and will indeed represent a significant training cost savings.

The DOTS Phase II design and development tasks were performed by IBM Corporation for the Training Analysis and Evaluation Group, Orlando, Florida (Contract No. N61339-73-C-0097).

FOREWORD

This report presents Phase II of a three-phase project called "Design of Training Systems," undertaken in consonance with the requirements of Advanced Development Objective 43-03X, "Education and Training." One of the major objectives of the project is to develop tools for the effective management of training organizations. The tools include computer-based mathematical models of subsystems of the training system. Phase I developed a functional descriptive model of the naval training system and idealized concepts oriented toward a 1980 time-frame. Phase II involved the design and development of three computer-based mathematical models and their validation. Phase III will involve the verfication of the models and the development of their potential applications.

Sincere thanks is expressed for the close cooperation of all elements of the Naval Education and Training Command. The response to requests for information was enthusiastic and in all cases helpful and to the point. The personnel of the data processing organization (DPSCLANT), the office of the Director of Training, and the individual school staffs at the Fleet Training Center, Norfolk, Virginia, were especially cooperative in their support of this task.

The System Capabilities/Requirements and Resources (SCRR) model, the Educational Technology Evaluation (ETE) model, and the Training Process Flow (TPF) model, were developed by Mr. R. Yanko, Mr. H. Bellamy, and Mr. K. Branch respectively. The statistical analysis for the TPF model was designed and carried out by Mr. L. Duffy. The long-range implications were developed by Mr. R. Hallman. Mr. C. Edison developed management applications and coordinated documentation for Phase II. Mrs. S. Goodell and Mrs. L. Girard provided editorial and secretarial services.

The Training Analysis and Evaluation Group project team members, Mr. H. Okraski, Dr. W. Rankin, Mr. T. McNaney, and Mr. W. Lindahl complemented the contracted effort by establishing organizational interfaces and by providing guidance.

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INTRODUCTION

DESIGN OF TRAINING SYSTEMS PROJECT DESCRIPTION

The Department of Defense (DOD) is faced with maintaining a strong national defense posture despite declining allocations and the impact of world inflation. The increasing cost of complex weapons systems and supporting manpower is significantly increasing the challenge of meeting national defense objectives.

Approximately 14%[1] of the DOD annual budget is allocated to some form of education or training. This represents about 25% of DOD's total manpower budget. Obviously, a major strategic thrust of the military services is to reduce education and training costs to a minimum, while maintaining the required level of effectiveness.

As one of its actions in support of DOD's strategic thrust, the Navy is reducing costs through application of advanced management techniques and tools at all levels of planning and control within its education and training system. One of the major objectives supporting this activity is included in the Design of Training Systems (DOTS) project.

A major DOTS thrust is directed toward providing training officials, under command of the Chief of Naval Education and Training (CNET), with an expanded decision-making capability for rapid and effective response to external factors such as the all-volunteer force and prospects of decreased military spending, and internal factors such as the consolidation of training activities and the application of new techniques and approaches to training. By application of advanced management systems techniques to the Navy training program, significant increases in both effectiveness and efficiency are anticipated.

The DOTS project is tasked with experimental validation of the application of advanced management systems techniques to the CNET organization, with the intent of providing training officials with expanded decision-making capability. The project stresses a step-wise progression from systems analysis, through development of computer-based models of selected subelements within CNET, to formal recommendations for making the fully verified models operational. The objective of the DOTS project is to employ the techniques of system analysis, educational technology, behavioral science, and operations research to provide a set of tools for gathering data on the quantitative performance of the training system as is, and for projecting the consequences of changes to the system.

Phase I of the DOTS project has been completed. It included: (1) a comprehensive study of the Naval Education and Training System, with special emphasis on those functions and organizations falling under the CNET; (2) development of a set of strategic assumptions describing the environmental elements expected to be affecting the Navy in the 1980's; (3) development of recommendations leading to an idealized training system in terms of the projected needs of the

[1] Defense Space Daily, Page 92, January 17, 1974.

1980's; and (4) creation of a list of candidate computer-based mathematical models to enhance the decision-making processes of CNET training officials. If further information is desired, consult the DOTS Phase I Final Report[2].

Phase II of the DOTS effort has also been completed and the purpose of this document is to present the results of that phase. Phase II primarily involved the design and development of three computer-based models selected from the Phase I list, and an appropriate data base for model execution and testing. Other significant tasks were included; however, they will be explained in later subsections of this report.

The thrust of Phase III will be towards the experimental validation of the models in an operational test site and the accomplishment of those tasks required to support their operational use.

PHASE II OBJECTIVES

The objectives of the second phase of the DOTS project were as follows:

To develop computer-based mathematical models of a subset of the functions performed by CNET, and to select an appropriate site for both evaluation and future testing of the models.

To identify or, where necessary, establish a data base for use in testing the models.

To identify those areas within the Naval Education and Training System which could not be modeled either because the existing system was not well enough defined, suitable modeling techniques did not exist, or where data for model input or testing could not be obtained. Areas of education and training requiring additional research were to be identified.

To derive estimates of hardware, software, and personnel required to produce an operational system.

To validate the models.

To design additional validation/verification studies to be carried out during Phase III.

The principal element of Phase II was the actual design and development of the models selected as being the most promising from the standpoint of scope, feasibility, and impact on training management decision-making and planning processes. The fact that these models were selected from a list of potential models which address all of the functional areas within the training system for which modeling is an appropriate management tool, facilitated the identification of areas needing additional study and the projection of the long-range implications of an operational system.

[2] Design of Training Systems, Phase I Final Report, TAEG Report No. 12-1, December 1973.

PHASE II TASKS

Analysis of the Phase II objectives resulted in the establishment of six specific tasks which are discussed below.

TASK 1 - MODEL SELECTION. The model selection process of Phase II was concurrent with the last portion of Phase I; therefore, the selection process was fully reported in the Phase I Final Report. The Phase II effort involved visits to the principal subcommands under CNET for identification of operational functions and subfunctions which could be described with a degree of completeness sufficient to permit modeling. At the same time, potential model users were surveyed to obtain direct inputs as to the most pressing, immediate, and long-term problems experienced by each command.

TASK 2 - MODEL DESIGN AND DEVELOPMENT. The design of each model started with the formulation of functional specifications; i.e., analysis of the purpose of the model and determination of the model outputs. The model design and the programming language were selected to effectively fulfill the functional specifications. A detailed discussion of each model is contained in Volume II of this report.

TASK 3 - DATA BASE REQUIREMENTS. The development of a data base for the models required that data sources be located and converted to a format acceptable to the data base design. Most of the data were in flat-paper form, therefore, the reformatting was primarily a manual task. Extraction programs were written, however, and used with BUPERS and DPSCLANT magnetic tapes for selecting and merging student data, class data, no-show rates, etc., for the purpose of statistical analysis and loading data into the data base. In addition to the development of appropriate extraction programs, it was necessary to develop file support programs which load and update the data base, and provide data access for the models. These programs are discussed in detail in later sections of the report.

TASK 4 - MODEL VALIDATION. The model validation task was divided in the original project design into two levels: Level 1 validation which took place during Phase II; and Level 2 Validation which was designated an objective of Phase III. The Level 1 validation task of Phase II consisted of:

a. A review of the model's intent and purposes by potential users at Fleet Training Center, Norfolk, Virginia, in which the assumptions, general design, etc., were examined for reasonableness.

b. Sensitivity testing during which the inputs were varied over a reasonable range to ascertain the degree of change they caused in the outputs.

c. Variability testing to ensure that stochastic processes, when employed, did not cause a high output variance[3].

d. Test scenarios which tested and demonstrated the performance of the models during hypothetical management problem situations. Test scenarios are presented in appropriate sections of Volume II of this report.

[3] Design and Use of Computer Simulation Models by James R. Emshoff and Roger L. Sisson (The Macmillan Company, New York, N.Y.) p. 204.

In addition to actual validation of the models, Task 4 required the selection of a test site location. Test site selection was important for two reasons. First, the DOTS project is intended to be a starting point for the development of a complete set of models for training management and planning. Second, the models developed during the DOTS project must be applied to other training sites if the models are to be of general, long-term value. Therefore, the site selected had to meet the following criteria:

a. Have an extensive mix of training activities to demonstrate the range of application of the models.

b. Be subjected to unpredictable requirements for new courses, quotas, etc., to allow comparison of response times for existing systems and the DOTS models.

c. Include all functions in the training development cycle from course design to implementation.

d. Be in the process of implementing or planning to implement new instructional techniques such as Individualized Learning Systems (ILS). The primary purpose of the DOTS model set is to assist in assessing the impact of proposed changes in both instructional techniques and training requirements. Therefore, both types of changes were desirable.

e. Have an active interest in the DOTS project at the command level.

f. Be general enough in level and type to be representative of a significant fraction of Navy training.

g. Have access to a computer system either directly or via remote terminals.

The Fleet Training Center at Norfolk, Virginia, has been selected as the test site.

TASK 5 - DETERMINATION OF LONG-RANGE IMPLICATIONS.

Analysis of Rejected Candidates. During model selection, potentially useful candidates were rejected because the system was not sufficiently defined for modeling, or the data required to establish a relationship between key variables were not available, or the effectiveness of a strategy in a military environment was unknown. Analysis of those rejected candidates resulted in recommendations for further studies which should serve to identify where additional data can be obtained with the ultimate goal of improving system control.

Estimation of Hardware/Software and Personnel Requirements. This subtask was concerned with projecting the cost of an operational system. Program size and the need for additional support programs were determined as the model proceeded through the development stage. The assumptions about hardware and operating environment for the system are presented in Section IV of this volume.

TASK 6 - MODEL TUTORIAL SOUND/SLIDE PRESENTATION. The purpose of this task was to create a sound/slide presentation that would develop a basic understanding of the operations research term "model" within all levels of CNET management, as well as all operations personnel who would be involved in the implementation and use of the models developed during the DOTS project. The presentation discusses the concept of mathematical modeling on a general level and does not address any of the three Phase II models specifically.[4]

PHASE II PRODUCTS

The tasks accomplished during Phase II provided the following products:

a. The Phase II Final Report

b. The Training Process Flow Model

c. The System Capabilities/Requirements and Resources Model

d. The Educational Technology Evaluation Model

e. The Model Data Base

f. The Sound/Slide Model Tutorial.

This Phase II Final Report contains the design specifications, program listings, flowcharts, and brief operating instructions for the three models and the data bases. In addition, this report contains verification plans, hardware and software estimates, and recommendations for additional studies of subfunctions within the training organization. Items a. and f. are the physical deliverables of Phase II; the work product of all Phase II tasks are contained in them.

[4]The Sound/Slide Presentation is distributed by the Training Analysis and Evaluation Group, Orlando, Florida 32813.

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SECTION II

DESIGN OF TRAINING SYSTEMS MODELS

OVERVIEW OF THE DOTS MODELS AND SYSTEM DIAGRAM

During Phase II of the DOTS project, three computer-based models (the System Capabilities/Requirements and Resources model, the Training Process Flow model, and the Educational Technology Evaluation model) were designed, developed, and validated. In addition, a data base was designed and developed as a separate entity which functions, however, as an integral part of the three model system. The models and the data base are presented in general terms in this section, which is intended to provide a description of their characteristics and capabilities as management tools. A detailed description of each model is presented in Volume II, and a detailed description of the data base is presented in Volume III of this report. Figure II-1 presents the Phase II DOTS system.

BACKGROUND - MODELING TECHNIQUES. Computer-based mathematical models are used to simulate real or hypothetical systems, or to optimize the use of a system for some specified objective. The design of a simulation model is such that system performance under specific conditions is duplicated. The input variables and constraints are manipulated by the model user, and the model provides one solution for that particular set of inputs utilized over a predetermined interval of time. By an iterative process of performing manual feedback and making multiple model runs, the user can determine the best set of input conditions that solve the problem.

The design of an optimization model is such that the internal logic of the model manipulates the variables to optimize the use of resources to solve a problem. Linear programming or other optimization techniques are used to search for the combination of resources that will maximize output or minimize cost for the set of inputs and constraints specified.

THE SYSTEM CAPABILITIES/REQUIREMENTS AND RESOURCES MODEL. The SCRR model is a linear programming (LP) optimization model. The SCRR model formulates an LP objective function and constraint equations from information contained in the data base. The LP problem is then solved to optimize training complex student throughput and resource utilization. Basically, the model has two modes of operation. In the first mode, the resources; i.e., the classrooms, laboratories, instructors, and the appropriate constraints and limitations applicable to each, are specified, and the model determines the maximum student throughput and the optimal mix of course convenings which can be attained in a specified time period. In the second mode, the desired output profile is specified, and the model determines the minimum combination of resources required to produce it. The model solution, consisting of the linear programming solution and the sensitivity analysis, gives a total picture of the training complex output and the utilization of each resource. Factors are presented which indicate the effectiveness of, and the limits for, manipulating each input variable without impacting the optimal solution.

THE TRAINING PROCESS FLOW MODEL. The TPF model is a simulation model. It uses information contained in the data base to create an aggregated data matrix, upon which the execution module logic operates in order to calculate output quantities

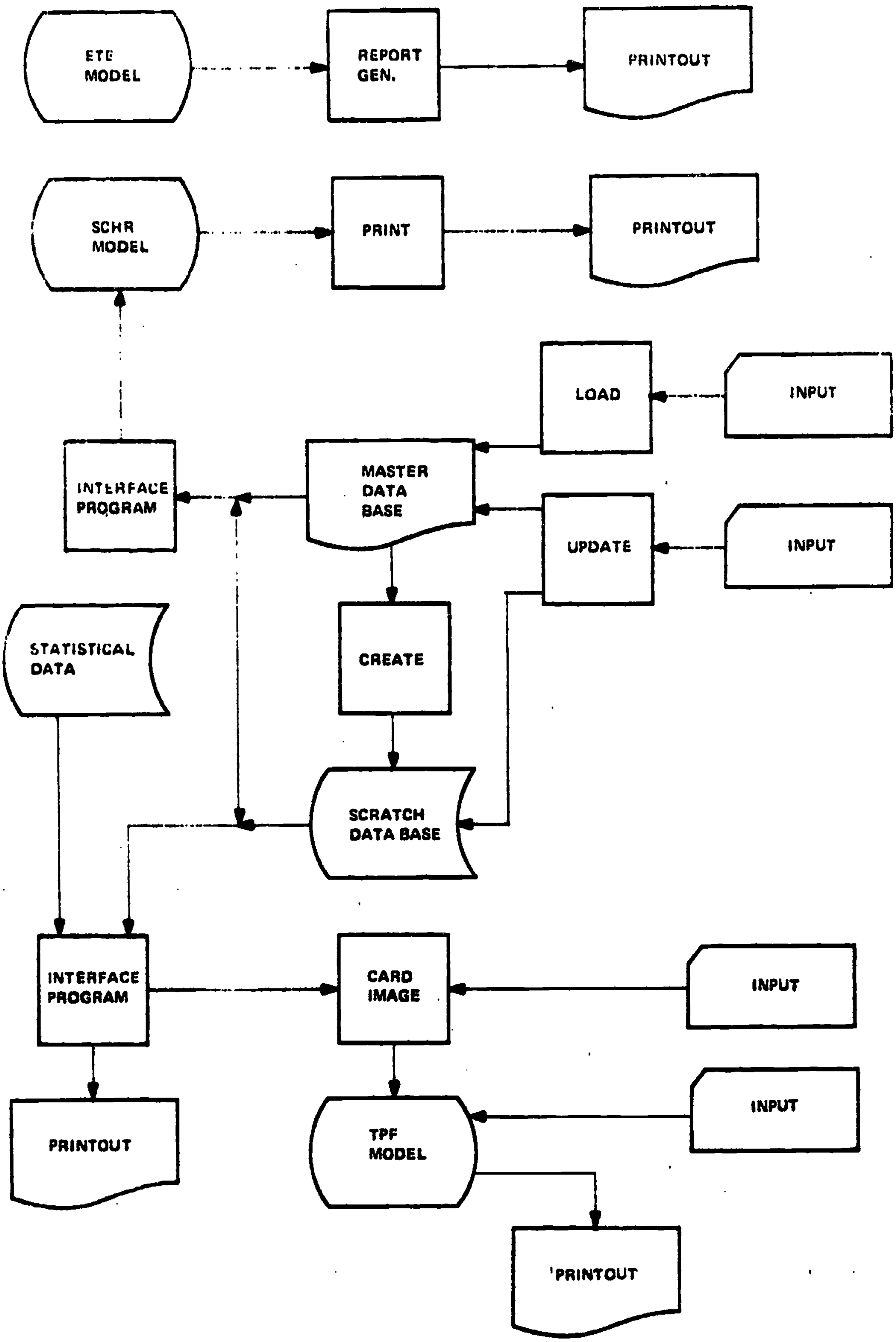

FIGURE II-1 DESIGN OF TRAINING SYSTEMS - PHASE II SYSTEM DIAGRAM which predict training system performance. The key elements of the TPF are the profiles of course characteristics and student characteristics by course. The profiles and the weighting factors associated with them were created by statistical analysis of historical data from BUPERS and the Fleet Training Center, Norfolk, Virginia. A substantial portion of the student performance data was not in an Automated Data Processing (ADP) form, and had to be gathered during instructor interviews. Further discussion of the statistical processes used to establish the profiles is presented in a later subsection of Volume I, Section II.

Basically, the TPF starts with a course convening schedule obtained from the data base, or an optimized convening frequency obtained from the SCRR model. The profile characteristics of the student groups are then compared with selected course factors; e.g., age, type, priority, etc., enrollment data; e.g., utilization, backlog, etc., and the throughput of the training complex is predicted. In addition to throughput, certain aspects of resource utilization are calculated from the predicted throughput versus maximum capacity figures.

THE EDUCATIONAL TECHNOLOGY EVALUATION MODEL. The ETE model is a simulation of an Individualized Learning System (ILS). It is an entity flow model which deals with the movement of individual students through a school as they are influenced by media characteristics, the number of course modules to be completed, and the contention for facilities and instructors. The term "evaluation" in the ETE name refers to its intended use in comparing the relative effectiveness of different ILS course designs. The ETE model uses the course curriculums, the student types by curriculum, and characteristics of the learning modules in the curriculum such as average completion time, instructors and other resources required, etc., to calculate the performance of the school in terms of throughput, elapsed time, and use of resources.

THEORETICAL BASIS FOR THE DESIGN AND DEVELOPMENT OF THE DOTS MODELS

The DOTS project is oriented toward filling a gap between theory as it presently relates to the management of large, complex systems, and practice as implemented at present in the management of training. The Navy is attempting to incorporate the latest system techniques, specifically modeling, into the design and operation of present and future training systems. The DOTS models were selected by a rigorous screening process to ensure that they represented modeling applications that were new and untried within the Navy, as well as feasible in terms of being amenable to known modeling techniques. All three models represented new projects completely within the domain of CNET.

MODELING - AN ESTABLISHED TECHNIQUE. It is correct to state that modeling is an established technique. Computer-based models have been tried and tested in both industry and the Navy. Systems analysts, operations research specialists, and managers have collectively had wide and varied experience in the development and application of computer-based models.

Computer-based modeling, both optimization and simulation, has been an outgrowth of relatively new analytic techniques and computational hardware development. The discipline of Operations Research (OR) had its beginnings in the multidisciplinary analysis of military problems during World War II. Although it has deviated from its original multidisciplinary emphasis, progress has been made in the use of a "scientific approach" to analyzing large systems and the problems associated with managing them.

In parallel with the development of OR techniques, the digital computer has developed from rudimentary experimental designs into the familiar high speed, high density, large storage capacity computers of today. The mathematical modeling techniques of OR and other mathematical techniques for simulating a system, whether it was a hardware system or a functional analysis of an organization, were found to be adaptable to being programmed into computers. This combination of mathematical and programming techniques has developed into a discipline generally referred to as computer-based modeling.

The theoretical basis for the design and development of the DOTS models was embodied in the method used for approaching and accomplishing the task. The project team approached the design of the models from two aspects. One aspect was the technical process of designing and developing a model, the second aspect was the practical considerations of producing models that management would use. The technical process followed the generally accepted approach to an OR project.[5] Three parts to the approach: selection and definition of the area to be modeled; design and development of the models; and validation of each model, were carried out during Phase II. Two additional parts; establishing control over the solution, and preparations for implementation, will be accomplished in Phase III. The key activity of the design task was the selection of an appropriate modeling technique for each problem area.

Technical Considerations. The Naval Education and Training System, more particularly CNET, and the subelements within it could be described in terms of personnel, resources, and their interrelations and operations over time. The selection of particular modeling techniques representing the fundamental design or type of model for each selected subelement depended upon a multiplicity of factors derived from the nature of the system itself, from the objectives to be met by the model, and the limitations imposed by complexity and hardware considerations.

The DOTS project team implicitly defined the system as the Fleet Training Center, Norfolk, Virginia, the test site. The system factors are: (1) the process involved; (2) the resources being used; (3) management processes, and (4) internal versus external environmental elements.

The product at the Fleet Training Center, Norfolk, Virginia, is competent people. The process is the conducting of approximately 125 courses consisting of "A" Schools, "C" Schools, and Fleet Training Courses - of these, approximately 25 issue an NEC. The resources used consist of classrooms, laboratories, training devices and equipment, elements of ILS equipment, publications and materials, and instructors. The management processes involve, among other things, meeting personnel requirements, meeting Fleet training demands, planning for growth and contraction, planning for the use of new training technologies, budgeting, etc. The environmental factors include those that are internal to the Navy, but external to CNET; for example, naval personnel rotation policies and career path designations, as well as Fleet demand and new equipment acquisition demands. Environmental factors also include those that are external to the Navy; for example, the academic background of available recruits, military spending, and physical environmental factors that affect trainee arrivals, etc.

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[5] Introduction to Operations Research by Churchman, Ackoff, and Arnoff (John Wiley & Son, Inc., London 1957) p. 13.

The objectives of the models, and the constraints imposed by the limitations of the modeling techniques and potential hardware, had to be considered simultaneously because the designer had to formulate reasonable and prudent objectives, and this can only be done when constraints are taken into account. The objective of the model was, of course, dependent upon the intended use of the model. Perhaps the major discriminating factor in describing model use is whether or not it is desirable to optimize some aspect of the system, or to simulate all or part of the system to observe system response. In making this discrimination, certain prerequisites had to be considered. First, if an optimization model was to be chosen, then a particular objective function to be maximized or minimized had to be identified. Second, if linear programming was used, then linear relationships between variables had to be demonstrated in order for the model to be valid. Third, if mathematical programming of linear or other types was to be used, then there were complexity limits to observe in order to keep the project feasible. Fourth, if it was desirable to simulate the system or its elements in order to observe system response to varying inputs, then: (1) data about past system performance had to be available, and the historical data would have to be subjected to various statistical analysis techniques to determine the relationships and patterns of influence and reaction that described system performance; or (2) interrelationships would have to be estimated or manipulated by stochastic or probabalistic methods.

With the considerations about system characteristics, model objectives, and complexity limitations in mind, the project team selected the major design features of each of the three candidate models. The Training System Capabilities/Requirements and the Training Resource Allocation modeling applications both pertained to resource management. It was determined that they would have the greatest benefit if combined into a System Capabilities/Requirements and Resources model with an overall objective of optimizing student throughput with the resources available. The SCRR is a typical allocation model[6] in which the resource requirements and availabilities are specified, and the task of the model is to determine the combination of efforts which will yield the maximum return on the use of resources. Given the instructor to student ratios, class size, course length, etc., it was intuitively obvious that the resource usages per convening were linear. Therefore, linear programming was selected to achieve the desired optimization.

The Training Process Flow model was seen as a tool for studying the flow of trainees through the naval training process rather than as an optimization of any one aspect of the process. The TPF model was designed as a simulation of a training complex. Extensive statistical analysis of historical data was undertaken to establish the relationships between a multitude of variables which were thought to represent student capabilities, course characteristics, delivery system performance, etc. During the course of the data analysis, parameters that proved to have no relevance to system performance were screened out. The relationships established by analysis were incorporated into the model logic design to obtain a chronological profile of the training complex output by student type. It was decided that any optimization desired by a model user would best be accomplished externally through repeated operation of the model with different input values specified. At the same time, the simulation capability of the model would allow the evaluation of proposed training system designs.

[6] Ibid, p. 275

Simulation was selected for the Educational Technology Evaluation model primarily because the model was intended as a tool for comparing different ILS configurations, a task for which simulation is well suited. Only a small percentage of the courses taught in the training system had been converted to ILS; therefore, it was not clear which aspects of the configuration would prove most taxing on resources. The ETE model provided the opportunity to observe the behavior of the system under different test conditions which could not be observed in reality. In contrast to the advantages of simulation for the ETE model, there were two reasons for rejecting an optimization model for this modeling area. First, due to lack of ILS experience, it was not clear as to which aspect of the system should be optimized, if any. Second, the students in an ILS contend for facilities, consequently, queues or waiting lines develop which are non-linear and, therefore, less adaptable to an optimization process.

Managerial Considerations. Computer-based modeling has been expanding in industry and government as the management sciences have grown in influence. The thrust has been toward the creation of tools for reliable operation and planning in the management of large organizations; the thrust has been away from "seat-of-the-pants" management, with its inherent non-reproducibility and lack of long-term efficiency. There has been resistance to the acceptance of new techniques, however, and modeling has been no exception. Often, managers will agree to the efficacy of new modeling tools, but when the experts leave, the model is shelved because proper groundwork was not undertaken to ensure that the model was needed and understood by potential users. Greater management acceptance can be cultivated if the project is executed properly.

Hammond[7] has summarized some of the salient points of a modeling project and enumerated precautions to be taken by management scientists attempting to produce useful models. They may be summarized briefly as follows:

a. An analysis of the organization's functions must be made in order to determine potential modeling areas. Then, the areas of greatest potential are identified and a decision is made whether or not to model each one. In considering potential modeling areas, the organizational climate should be evaluated for the degree of management support behind the project.

b. The purpose of the model is defined and the specifications are generated with clearly defined goals in mind.

c. The model is designed with user involvement. Input and output information should be in a format that is familiar to the user.

d. The model is coded and debugged.

e. The model is validated, then verified by the user.

f. Education is provided to the user in order to gain acceptance for the model.

[7] Do's and Don't's of Computer Models for Planning by John S. Hammond III, (Harvard Business Review, March-April 1974).

g. The model is implemented in the management process.

h. The overall concept of simplicity of scope and design is a guide throughout model development.

Although the guidelines listed pertain to a planning model development project, they are applicable to the DOTS model design and development process. The DOTS project team followed virtually the same process during Phase I and II, and will continue the process into Phase III.

In order to gain acceptance for the project models, potential user orientation and user perspective on problem areas were used as benchmarks during the model selection process. The test site selection process was specifically designed to find an organizational element that had the proper management support as well as the technical intricacy needed to properly validate the models. During model design, modeling techniques were evaluated with respect to potential usefulness of the model, and data flow into and out of the model was formatted in readily accessible, familiar form.

During Phase IIA, training courses for potential model users will be written and conducted. These courses will bridge the gap between personnel who participated in the development and validation of the models and those whose first exposure will be to the finished product. Phase III will lay the groundwork for implementation, and will further enhance management acceptance by implementing recommended refinements to model/user communications and input/output processing.

One can conclude from the preceding paragraphs that the DOTS project models have a theoretical basis in both the technical aspects of model design and the practical aspects of winning user acceptance of the operational models. In addition to technical and practical aspects, the model designs have been influenced by concepts of decision theory and statistical analysis. These points are discussed in the following paragraphs.

THE USE OF MODELS IN DECISION MAKING. The process of decision making has been conceptualized as the activities that result when a potential decision maker receives an external stimulus.[8] The initial response is to consider the alternatives and make a mental construct of the decision problem. If the alternatives are inadequate to allow a clear basis for choice, additional alternatives will be sought. At this point, the decision maker may or may not seek data which will aid the prediction of the likelihood that the assumptions involved in each alternative will come true. When, in the decision maker's judgment, the evidence is sufficient, he selects one alternative course of action. Depending upon the strength of the likelihood or probability which can be assigned to alternatives, the decision can be considered as falling under one of three categories: assumed certainty, risk, or uncertainty.[9]

It is obvious that making a decision under assumed certainty does not present a particularly stressful situation; the decision maker is quite confident in his

[8] The Analysis of Management Decisions by William T. Morris (Richard D. Erwin, Inc., Homewood, Illinois, 1964) p. 88.

[9] Ibid, p. 10.

choice. It is under conditions of risk or uncertainty that methods of analyzing the decision situation and selecting the best alternative are needed.

A relatively new discipline called Decision Analysis has been developed around this problem of making a decision under uncertain outcomes. The decision process has been described by one decision analysis researcher as consisting of: (1) a deterministic phase in which variables are defined and values assigned to possible outcomes; (2) a probabilistic phase which assigns probabilities to decision inputs in order to derive probabilities for the outcomes; (3) an informational phase in which estimates of value are derived for additional information; and (4) the allocation of resources.[10]

The important point to express about the decision process is that a decision requires information whether it is perceived as a search for alternatives in response to a stimulus, or perceived as the process of assigning values and probabilities to outcomes. The DOTS models can generate the required information. A training official can derive alternatives quickly and imaginatively. He can assign probabilities to outcomes because the models, having been validated, are reliable predictors of training system element's response to changing input variables. Thus, from the analytic viewpoint of gathering, evaluating, and using data to reduce uncertainty in decision making, the DOTS models are a useful management tool. There is, however, another important aspect to decision making. It is the interaction between managers and the models, and managers with each other in a problem solving situation.

In order to study the effectiveness of computer-based support of management decision making, Morton[11] conducted a field experiment at one division of a large multiproduct corporation. The experiment consisted of observing the management decision process prior to and after the installation of computer-based models and a display system. The goals of the project were to determine: (1) if the system could be used; (2) at what management level it could be used; and (3) what impact the computer-based models and display could have on the decision making process.

The results of the experiment contain direct implications about the expected usefulness of the DOTS models. Morton found that the computer-based management decision system, in the opinion of the managers using it, did indeed aid the decision making process. By observing problem-solving situations, he concluded that the system made problem identification easier, provided more alternatives, reduced the time required to make decisions, and improved communications between managers. The improved communications between managers was considered the important factor for producing more creative and beneficial solutions to managerial problems. Thus, part of the theoretical basis for the DOTS models was derived from the relationship between rapid information processing and efficient decision making.

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[10] Decision Analysis: Toward Better Naval Management Decisions by Lt. N. Clark Williams, U. S. Navy (Naval War College Review).

[11] Management Decision Systems by Michael S. Scott Morton (Division of Research, Graduate School of Business Administration, Harvard University, Boston, 1971).

STATISTICAL PROCESSES IN THE DOTS MODELS DESIGN. This subsection applies exclusively to the Training Process Flow model. The TPF model logic design process incorporated statistical analysis as a fundamental determinant of the mathematical and logical interrelationships linking the input variables to the model outputs. The SCRR model, as mentioned previously, used a standard linear programming technique which did not require a statistical analysis of input variables. Once the inherent linearity of resource usage was accepted, the problem was amenable to a deterministic mathematical solution. The ETE model used a statistical queuing model to determine waiting time at facilities and the length of queue or number of students waiting, but other parametric factors were determined by the user at the time of model execution.

The determination of interrelationships among variables of the Training Process Flow model comprised a collection phase and an analysis phase. The collection effort was shaped by two factors: (1) it was necessary to obtain a large sample of records in order to confidently project sample characteristics into the role of population parameter predictors; and (2) some records were available in ADP form, making bulk collection feasible; others were in flat-paper form making collection by hand necessary.

To obtain the records that were stored in ADP form, programs were written to extract data from DPSCLANT tapes and merge them with other DPSCLANT data or BUPERS data as appropriate. The process proceeded as follows:

a. The social security numbers and pass/fail data for the majority of students attending school at the Fleet Training Center, Norfolk, between 1 January and 30 June 1974, were extracted from the DPSCLANT student file - some 27,000 records in all.

b. All courses were examined for size, frequency, and pass/fail history in order to select courses that might show causal relationships between student and course characteristics and pass/fail behavior. Team training, orientation, and non-graded courses were eliminated. After evaluation, approximately 5,000 social security numbers of students who had attended 42 of the courses were sent to BUPERS to obtain student characteristics; e.g., rate, years of education, GCT score, ARI score, etc., from the Enlisted Master tape. BUPERS returned approximately 4,000 student records, representing all those among the 5,000 who were still on active, enlisted duty.

c. Student characteristics, pass/fail data, and manual inputs such as grades obtained from instructor records, were merged into a data base and retained for statistical analysis.

d. A second statistical data base was created from selected student data, the DPSCLANT no-show file, and course characteristics; e.g., course age, revision activity, priority, etc., for 110 courses. Course information was supplied by school training staff members.

The statistical analysis of the student and course data base files was accomplished using SPSS Version G.[12] First, the data were processed and presented in descriptive

[12] Statistical Package for the Social Sciences, National Opinion Research Center, University of Chicago.

formats; i.e., tabulated, displayed in histograms, and summarized by key statistics in order to screen the variables for overall characteristics indicating potential relevance to the problem. The student file variables were then subjected to a correlation analysis to determine the degree of covariation between the 31 student/course characteristics for the 42 selected courses. In addition, correlations were run on 15 characteristics for all remaining courses taught at the Fleet Training Center.

After the correlations were complete, multiple regression analyses were run on the variables. The regression analysis was used to determine the degree of dependence and hence, the predictive capabilities of variables. The results of the statistical analysis were evaluated for reasonableness in order to eliminate spurious associations. The attribution of a cause-and-effect relationship was a judgmental function of the analyst. The relationships emerging from the evaluation were incorporated, where appropriate, into the model logic and/or the data base for use by the TPF model during execution.

MANAGEMENT APPLICATIONS OF THE DOTS MODELS

The decision to develop computer-based models was greatly influenced by the size and complexity of the Navy training organization. The system is complex enough that it is difficult for a manager to keep all the relevant factors of a problem situation in order, and apply them at all appropriate areas of impact. Properly designed computer-based models, such as the DOTS models, have no difficulty tracking and manipulating a multitude of variables, constraints, and operational relationships.

Effective training management requires that managers understand training goals and objectives, establish priorities, select performance standards, and establish a feedback and control system for training operations. Within that management framework, the DOTS models can be applied in the following general areas:

a. Planning - to assess long-range demand estimates, to provide for inclusion of new training technology, to allow for changes in student's educational background, to provide for alternative staffing policies, and to design new training systems. The DOTS models give managers the opportunity to test system reactions in areas where they have not had previous experience, without running the risk of disrupting the training system. Thus, the probability of high quality planning is increased and the cost of correcting mistakes is reduced proportionately.

b. Evaluation to assess the present use of resources and measure the effectiveness or efficiency of resource usage, to measure training complex sensitivity to various resource changes, to evaluate the cost of different training technologies, and to evaluate school performance in terms of failure rates, etc.

c. Problem solving - to anticipate problems by asking "what if" type questions and exercising the models to get answers, and to project the impact of short-range changes in demand, resources, student characteristics, etc.

d. Information retrieval - to gain perspective on system functions and performance by observing simulated system operations. In addition, use of the models gives the manager rapid access to information in the data base. If properly updated and maintained, the data base is a valuable inventory of all the training resources of the complex and the constraints upon their use.

SYSTEM CAPABILITIES/REQUIREMENTS AND RESOURCES MODEL APPLICATIONS. The SCRR model can be applied in the following specific types of situations:

a. Assessment of long-term training demand. The SCRR model in its first mode of operation will optimize the number of course convenings or student throughput within stated resource constraints. It can be used, therefore, to determine whether annual training requirements are feasible. If demand is projected beyond the coming year, the SCRR model can signal the need for additional facilities before present facilities are exhausted. The optimized convening rate can serve as a guideline for course scheduling.

b. Assessment of the impact of short-term demand that might arise from unscheduled events, such as a ship repair operation, an activation of reserves, or unusual seasonal recruitment levels. In these instances, the SCRR model maximized throughput by course would serve as an immediate indication of training complex capability. If necessary, a training manager can alter the present course convening schedule, deleting low priority courses to gain classroom space, and possibly instructors, for additional sessions of high priority courses.

c. Assessment of the use of training resources. In its second mode of operation, the SCRR model will take the current throughput rates and determine the optimum combination of resources required to produce them. In this mode of operation, the model output can be compared with real resource utilization to obtain estimates of the efficiency of training complex resource use.

d. Comparison of alternative training implementation strategies. Either mode of operation may be used to evaluate different combinations of training technologies (when average-time-to-complete, etc., are supplied). In addition, the sensitivity analysis gives an indication of the sensitivity of the training complex throughput to each resource. As explained in Volume II, page II-7, sensitivity factors indicate the range over which the resource may be manipulated without affecting the optimum convening/throughput rate. The training manager can easily determine the limiting resource for any particular set of conditions, and apply his energy effectively by dealing with the most crucial problem. If, for example, instructor availability proved to be the limiting factor on one course, cross-training of present staff might prove to be the most cost-effective way to increase school throughput.

In summary, the SCRR model has two basic modes of operation. In the first mode, training complex throughput is maximized within specified constraints and available resources; in the second mode, the throughput by course is specified by the user, and the model outputs the optimum (minimum) mix of resources required to produce that throughput. By using one or the other of these modes of operation as appropriate, the training official or training staff member may plan for meeting projected demand, solve resource use problems, or assess different training implementation strategies.

TRAINING PROCESS FLOW MODEL APPLICATIONS. Although the TPF model is intended as a resource utilization control tool similar to the SCRR, because its design incorporates student characteristics and additional course information, its applications are significantly different. The TPF model can be applied in the following specific types of situations:

a. Simulation of the training complex to determine the accumulated effects of demand. In this type of application, the TPF will assess the average-on-board, the training complex throughput, and the student backlog that builds if demand exceeds the enrollment capability.

b. Assessment of overutilization or underutilization of resources at the course level. In this application, the model is used to evaluate the effects of increasing the demand for a particular course. Evaluation of the capacity, utilization, and no-show data will determine the need for scheduling additional sessions of the course or tightening the input requirements and the methods of reserving space in class.

c. Analysis of the effects of student characteristics on performance. The TPF can be used to determine the effect that changes in student academic background have on course failure rates and academic set-backs. In this type of application, the model will simulate throughput with the GCT scores, ARI scores, time in rate, etc., specified. Training managers can determine which type of student, among those available, optimizes utilization of the course, and reduces failure rate and academic set-backs to the lowest practical levels. In this mode of operation, the training official can evaluate the performance versus resource consumption statistics for each course, and calculate the efficiency of each school within the training complex.

In summary, the Training Process Flow model can be used in the analysis of resource utilization at the training complex level, or at the individual course level. The TPF can assess the effects of changing the student quantity and/or academic background. As a simulation tool, the TPF allows the training manager to evaluate different training resource utilization strategies in terms of overall training implementation efficiency. While the SCRR can determine the maximal throughput based on total class capacity and convening frequency, the TPF can predict actual throughput based on the maximal throughput, student attrition, and no-show data.

EDUCATIONAL TECHNOLOGY EVALUATION MODEL APPLICATION. The ETE model is applicable to problems that arise in the design and management of Individualized Learning Systems (ILS). As a simulation of the flow of students through an ILS, the ETE can be used in the following specific types of situations:

a. Projecting resource requirements for an ILS course design. The ETE model can be used to simulate the operation of a new ILS course for the purpose of determining the number of instructors, instructional equipment, classroom space, carrels, etc., that are needed to support the estimated student load for the course.

b. Projecting throughput for an ILS course. The ETE will project the number of students completing the course and the average-time-to-complete for all students. In this application, the training manager specifies the facilities and training resources that are available, and the model determines the student completion rate, waiting lines, etc.

c. Evaluating the effect of changes in staff and equipment. The training manager can evaluate the effect of instructor cross-training on student flow and compare the benefit versus cost of staff upgrading. The ETE will also indicate the effect that additional resources have on waiting lines, time-to-complete, throughput, and facilities utilization.

d. Assessment of the cost-effectiveness of different ILS configurations. The training staff can use the ETE to run comparisons of student flow with different equipment being used to support the learning modules within a curriculum. Measures of effectiveness of the configurations can be projected from cost per student calculations based on throughput versus the cost of resources consumed.

In summary, the Educational Technology Evaluation model can be used during the design stage of an ILS curriculum, or during operational implementation of an existing ILS school. The ETE can be used at the school level for evaluating resource utilization, or at the training complex level for assessing the cost-effectiveness and feasibility of converting from conventional lockstep instruction to some form of individualized instruction.

GENERAL OPERATIONAL REQUIREMENTS AND LIMITATIONS OF MODEL APPLICATION. Use of the education management models being developed for the DOTS project is subject to the same limitations and requirements as the use of any computer-based model:

a. Proper use of the model requires trained personnel who are familiar with the training system, the model design, and the proposed use of the outputs.

b. The model does not give an absolute "right" answer. It gives an answer based on the variables and constraints specified by the user. The user must understand the degree of reasonableness of the variables specified.

c. The model data base must be updated by parts of the system outside the model. The model output can only be useful when data base information is timely and accurate. For this reason, it is imperative to provide for an information flow into the data base.

d. Models are simplifications of reality and they must be treated as such. Their use requires good judgment. They do not relieve the manager of the ultimate responsibility for decision making. It must be emphasized that the model is only a tool. The manager/user must evaluate many aspects of the alternatives that are not included in the model. Environmental factors, such as intangible preferences, and guidelines must be taken into consideration. The judgment and intelligence of the manager will determine the operational effectiveness of the models and is the key to their eventual integration into the management system.

MODEL OBJECTIVES AND GENERAL FUNCTIONAL SPECIFICATIONS

The model objectives and general functional specifications were an outgrowth of the development of a list of candidate modeling applications during DOTS Phase I. The candidate list was constructed by a two-fold process involving interviews with potential users and an analysis of the functional model of the Naval Education and Training Command. The objectives and the general functional specifications for each modeling application were determined by putting each candidate into perspective against a framework of all potential and existing models within CNET. The framework formed a composite model of the total training system which, if developed, would be capable of predicting the behavior of the system under a variety of conditions.

The DOTS project was constrained, however, to develop only a small subset of all the possible candidate modeling applications. The objectives and general functional specifications for each of the three candidates selected for further design and development evolved during the Phase I conceptualization, and were clarified during the early, definitive design stages of Phase II. They are described in the following paragraphs.

SYSTEM CAPABILITIES/REQUIREMENTS AND RESOURCES MODEL OBJECTIVES AND GENERAL FUNCTIONAL SPECIFICATIONS. The objectives of the SCRR model are:

a. To assess the feasibility of meeting annual training requirements at the training complex level in terms of desired school throughput.

b. To evaluate alternative training implementation plans and their effect on the training organization.

c. To address instructor billet utilization at the school level as a function of training requirements.

d. To assess the utilization of existing resources in the daily operation of the training complex.

From the model objectives, overall functions were specified for the SCRR model:

- Maximize the student throughput based on the optimal mix of course convenings which the training complex can achieve in a specified period of time within the resources available. As a subfunction of this optimization process, the model should evaluate resource utilization, and analyze the sensitivity of the throughput to each resource involved.

- Minimize the resources used to achieve a particular, stated output-mix objective. As a subfunction of this process, resource utilization should be evaluated also.

EDUCATIONAL TECHNOLOGY EVALUATION MODEL OBJECTIVES AND GENERAL FUNCTIONAL SPECIFICATIONS. The objectives of the ETE model are:

a. To provide information for educational technology trade-off analyses based on variables which determine the costs of training associated with utilization of various educational strategies.

b. To provide information which will allow design of the training process that will produce the desired annual output while minimizing required equipment.

From the model objectives, overall functions were specified for the ETE model:

- Simulate the flow of students through a self-paced, individualized learning environment.

- Given curricula and media descriptions, an estimate of the input rate for different student types, an inventory of instructors, learning modules, and facilities, project system output, average time-to-complete, and instructor and facility utilization.

TRAINING PROCESS FLOW MODEL OBJECTIVES AND GENERAL FUNCTIONAL SPECIFICATIONS. The objectives of the TPF model are:

a. To provide for analysis of the relationship between school throughput rate and student arrival rate, course scheduling, capacity utilization, etc.

b. To provide information which will allow design of the training process that will produce the desired annual output while maximizing utilization.

From the model objectives, overall functions were specified for the TPF model:

- Simulate the flow of students through a collection of schools.

- Wherever possible, project course output based on the student input characteristics and expected performance.

- Produce a time-oriented profile of the training complex output mix.

DATA BASE GENERAL DESCRIPTION

Data bases are common data storage banks designed for applications where more than one program must have access to the same data elements. Prior to the emergence of the data base concept, new programs were generated independently of any already in existence. The data used by each program were specified and entered into storage by the programmer, and such data could only be accessed by one program.

Development and use of a data base for a program system, whether it is a management information system or a group of related models, results in higher efficiency of data operations. Data base operations have less redundancy of data storage, greater speed in updating data, and allow the updating of all data in one update program operation. Consequently, the overhead involved in data maintenance is reduced, and the models can be applied to a problem sequentially without the need for multiple data crosschecking.

The data base developed for the DOTS project has two overall functions. The primary function is to interface with the models to supply the variables and constants used in the execution of mathematical and logical operations (see Figure II-1, System Diagram). Only two of the models developed during Phase II, the SCRR and the TPF models, interface with the data base; the ETE model does not require a data base, primarily because of a lack of historical data about Individualized Learning Systems within the Navy. The secondary function of the data base is to serve as a stand-alone, automated inventory of training resources which will provide timely resource information for the training staff. A detailed description of the data base structure and contents is contained in Volume III, Section V, of this report.

The functional requirements for the data base system were established by the data needs of each model. These requirements fall into three categories: data base content, data base structure, and data base maintenance.

DATA BASE STRUCTURE. The data base system consists of application programs, a file management/data base interface system, data files, and associated procedures. These elements comprise a total system which operates in a batch processing environment to satisfy the data base functional requirements.

The system contains the model-required and narrative data, in either numeric or character form, in two data files for ease of maintenance and design simplicity.

The two data files are called the "course file" and the "instructor file." Student data is stored in the course file under appropriate course numbers. The complexity of the data elements composing each file influenced the structure of the file itself. The instructor file has a simple structure consisting of only single segments, which contain no dependent segments or additional information. The course file, however, has a complex, hierarchical structure based on parent segments and subordinate segments for each data element in the file.

The files' structures can be described briefly as follows. The instructor file is a simple sequential file containing instructor name, rate, department, reporting date, rotation date, and availability. The course file is a complex file containing: (1) a parent segment with the course number, course name, department, length, number of convenings, etc.; and (2) subordinate segments for related courses, student/instructor ratios, qualified instructors, classrooms available, student group characteristics, and the statistical regression coefficients. The two files, collectively, hold all the information required by the SCRR and TPF models. As mentioned previously, the ETE model does not access the data base at this time.

DATA BASE MAINTENANCE. Five basic application programs; load, update, print, dump, and restore, perform the data maintenance function for each data file. As the name implies, the load programs load each file either initially or upon file reorganization. The load programs read data from punched cards, reformat the data, and perform limited error checking. The update programs serve a similar purpose, but will provide the capability to add, change, replace, or delete data from the data base.

The file print programs retrieve all data from the data base and print a formatted file report. This report can be used to examine and update the files. The dump program and the restore program are used in the creation of the scratch data base or the reorganization of the data bases. The scratch data base supplies problem oriented data to the model interface programs.

MODEL/DATA BASE INTERFACE

The interface programs between the models and the data files comprise the communication link between the model logic, per se, and the data base. The interface programs perform three functions. First, the data elements required by the model are extracted from the total data contained in the data base. Second, simple calculations are performed on the selected data. Third, the data and/or the results of the calculations are reformatted and passed to the model logic. In the case of the SCRR model, for example, the resource requirements algorithm extracts instructor group, the hours instructors are available, classroom numbers, etc., and builds the resource requirements matrix which is used to formulate the inputs for the linear programming module.

The interface program for the TPF model performs the same general functions of extraction, calculation, and reformatting of three types of data. One routine accesses course data for scheduling purposes, a second routine accesses student data and calculates performance factors, a third routine extracts nomenclature and other information for the output routines.

Data transfer and communication is a undirectional process from the data base to the models; model results are not automatically loaded into the data base, they are printed and stored in memory for further use. This design preserves the integrity and accuracy of the data base. If it is desirable to alter the data base contents, the update application program is used.

MODEL INTERACTION AND SEQUENTIAL APPLICATION

The terms interaction and sequential operation are used because the models interact through indirect transfer of the output information of one model to the input information for another model. This implies that the model user is involved in the interaction of the models, and that is indeed true. An intermediate, user performed analysis and interpretation of the results of a model application using the first model is required. The interpreted output is used in posing questions and formulating a problem for the second model. The problem is formatted in terms of the input variables of the second model, and the results of the second model's operation are in turn analyzed and interpreted by the user. At this point, it may be desirable to run another iteration with the same two models, or possibly, use the third model for additional information.

The sequence of model operation is determined by the conceptualization and definition of the problem. The number of iterations and the precision of the results are a function of experience with problem formulation and model application.

In general terms, the function of each model, as an element of the set of models, may be thought of as providing inputs, or constraints, upon input data for another model. For example:

a. The SCRR model projects throughput based on the number of convenings for each course in the time specified. This is based on the assumption that all students complete the course. The TPF will constrain or refine this throughput value with student performance factors in order to predict "actual" throughput.

b. The TPF operations are dependent upon a convening schedule produced within the model. The SCRR can determine if the desired number of convenings is feasible with the training resources available and thus, the output is realistic and useful.

c. The ETE model interacts with the SCRR model through the exchange of data on resources available, results pertaining to average-time-to-complete, instructors used, etc.

The number of combinations of sequential applications is highly dependent upon the acceptance and use of the DOTS models by training officials. It is obvious that model interaction hinges on the complexity of the problems or plans that are being evaluated. The maximum benefit will be obtained when problems of a complexity that precludes solution by other means are used with the models.

SECTION III

VALIDATION PLAN

GENERAL VALIDATION APPROACH

The general validation approach was to validate the models during three stages of the design and development process. First, during the initial stages of design and development, the modelers discussed their general design concepts and alternatives with potential users of the models. It was necessary to ensure that the model being developed was appropriate to the user environment. Areas that were examined included: (1) the appropriateness of the input variables in terms of representing the significant parameters in the user's problem solving situation; (2) input data availability; (3) significant relationships to be simulated; and (4) definition of the objective function to be optimized. The essential element of this phase of model validation was the determination of how the training complex actually operated. How were priorities established? Which operations were defined in terms that allowed mechanization in model form? Which operations were too subtle, too unpredictable, or so infrequently used that modeling them was inappropriate, etc.? Each modeler used these discussions to guide the development of his model.

The second stage of validation consisted of the evaluation of the internal operation of each model. The tasks involved were model dependent rather than part of a uniform testing procedure. The Educational Technology Evaluation (ETE) model is written in General Purpose System Simulator (GPSS) programming language. GPSS, by its transactional nature, tends to produce a monolithic or one system model, as opposed to a model composed of a number of subsystems with data flow between. This language characteristic, combined with the general purpose entity flow design, resulted in a situation that required evaluation of the internal operation either from the total model operation aspect, or from a detailed entity flow aspect. Both were accomplished. The ETE was evaluated with a trace program to ensure that every student who entered the school followed the correct flow path for his curriculum and used the proper resources for each selected learning module. All possible paths were examined. Next, the ETE model was evaluated on a macro level to ensure that model results were reasonable for each test problem. The ETE model, being a generalized simulation intended to aid the design of future Individualized Learning Systems (ILS), presented a difficult validation problem. When the system being modeled does not exist at the time of validation, the modeler must rely on judgment for evaluation of what is and what is not reasonable. Therefore, the model solutions had to be reasonable in terms of all the information that could be gathered about the expected operation of an ILS school.

Fortunately, there was an opportunity to run the ETE model with input data which were being used in the design of a new individualized Electronics Warfare (EW) school. A specialized EW model[13] had been developed to aid that specific task. Running both models with the same input data resulted in very similar output values; this comparison of two different approaches (generalized vs. specialized) to the same problem strengthened confidence in the validity of both models.

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[13]The EW model was developed by the Training Analysis and Evaluation Group, Orlando, Florida.

The SCRR model used an established mathematical programming product. Therefore, the validation did not require testing of the internal operation of the model, beyond checking of the data manipulation routines which prepared input data obtained from the data base and formatted model outputs. This task was accomplished by manually cross-checking model input data with the data base contents, and comparing model outputs with solutions that were hand calculated. After the data handling routines were validated, the emphasis was placed on testing the entire model with test problems.

The Training Process Flow (TPF) model has a well defined subsystem structure. Therefore, internal validation was centered at a subsystem level, and was focused on the functional performance of the subsystems and the screening techniques used to trap input data which exceeded values that were acceptable to the model (see Volume II, Section IV). Examples of some of the functions tested included:

a. Releasing students for courses by properly controlling backlog, no-shows, BUPERS seats, and substitute quotas.

b. Establishing an on-going situation by prerunning the quarter prior to problem start.

c. Determining pass/fail, setbacks, non-academic disenrollments, AOB, and student days of training.

d. Establishing conditions at the end of the quarter.

e. Establishing year-end totals and outputting a report.

After the subsystems were tested and integrated, the data flow between subsections was tested by running test problems using the entire model.

The third stage of validation was to evaluate the overall performance of each model by running hypothetical problem situations with realistic or, when possible, historical Fleet Training Center (FLTRACEN, NORVA) data. The test scenarios that comprised those model tests are discussed in Sections II, III, and IV of Volume II of this report.

EXPECTED PERFORMANCE CHARACTERISTICS

The goal of model validation was to ensure that the SCRR, ETE, and TPF models met their respective objectives, and performed realistically and suitably in a problem solving situation. There were no specific numerical criteria or specifications to use in judging performance; consequently, each modeler had to subjectively determine the level of performance that indicated the model response to input changes was adequate, but not too large. This type of determination requires an analysis of the system being modeled, as well as an analysis of the model's output. Problems arise within that area concerned with system sensitivity because real systems, especially organizations, often do not perform at the margins of their capability. This means that historical data on system performance may indicate only an insignificant change in system output for fairly large changes in input. The slack or excess capacity within the system absorbs input change unless it is large enough to exhaust one or more of the system resources. The modeler has to determine the happy medium between modeling an imperfect system exactingly, or modeling the system as if it were perfect. In summary, the expected performance characteristics of the DOTS models were comprised of model objectives as presented on page II-14, performed within a reasonable degree of real system performance.

SECTION IV

LONG-RANGE IMPLICATIONS

RESOURCE ESTIMATES FOR AN OPERATIONAL DOTS SYSTEM

This section presents the results of DOTS Phase II, Task 5, Determination of Long-Range Implications. The objective of Task 5 was to define the anticipated resources required to support projected implementation of the SCRR, ETE, and TPF models in an operational environment. A strategic plan for developing a multi-level system of models was also developed as a subtask of Task 5. Necessarily, both the near-term plan for model implementation and the strategic plan for multi-level development are predicated on positive predictive validation results during DOTS Phase III.

Phase II emphasized the basic design, development, and experimental validation of the SCRR, ETE, and TPF models. Due to the substantial interaction with the training officials and staff at the Norfolk Fleet Training Center during Phase II, and the use of actual historical data for experimental validation, it is anticipated the major portion of the Phase III effort will be devoted to activities leading to operational implementation, with predictive validation representing a minority effort. Therefore, the hardware, software, and personnel resource plans presented here assume full implementation of the three Phase II models at the end of Phase III.

The strategic plan for developing a multi-level system of models was based on the long-range thrust of the current Technical Development Plan P43-03 (P01A) and the DOTS Phase I report's[14] functional recommendations, strategic assumptions, and candidate model survey. These considerations were merged with the Phase II validation results as a basis for developing the strategic plan presented in this section.

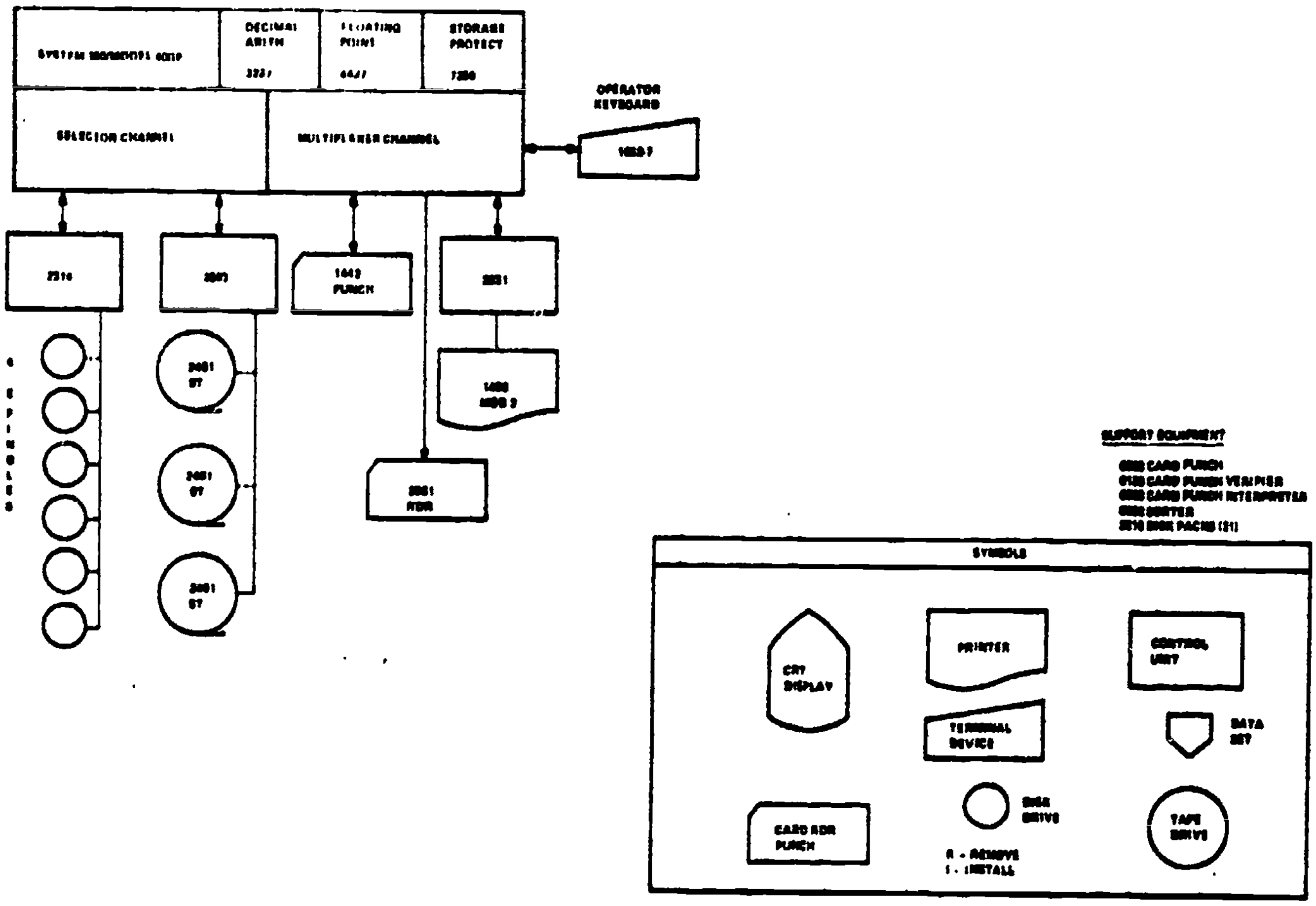
SYSTEM DEVELOPMENT AND IMPLEMENTATION. The resource estimate for an operational DOTS system is divided into two major categories. The first addresses a system comprised of the three Phase II models and their associated data base. This category is based on near-term planning. The second category deals with suggested plans for long-range programs leading to a complex of multi-level models supporting a decision analysis based training management system.

Based on various cost factors developed for categories 1 and 2, a forward pricing exercise was performed that projected an estimated cost for implementing the three models and data base at appropriate locations. The cost exercise is documented under <u>Cost Estimate - Integrated DOTS System</u>, page IV-9.

<u>Category 1 - SCRR, ETE, and TPF Resource Requirements</u>. The Phase II models were developed and validated on an IBM System/360 Model 40 GF. Figure IV-1, page IV-2, presents an overview of that system, including programming support. Most of the hardware and software components were utilized in either the development of the models, or are required for their operational use. To enable

14 <u>Design of Training Systems, Phase I Final Report</u>, TAEG Report No. 12-1, December 1973

HARDWARE



SOFTWARE

OS/MFT – OPERATING SYSTEM/MULTIPROGRAMMING FIXED TASKS

- **BAL – BASIC ASSEMBLER LANGUAGE**
- **PL/1 – PROGRAMMING LANGUAGE/1**
- **COBOL – COMMON BUSINESS ORIENTED LANGUAGE**
- **FORTRAN IV – FORMULA TRANSLATION LANGUAGE**

MPSX – MATHEMATICAL PROGRAMMING SYSTEM – EXTENDED

GPSS V – GENERAL PURPOSE SIMULATION SYSTEM

SPSS – STATISTICAL PACKAGE FOR SOCIAL SCIENCES

DL/1 – DATA LANGUAGE/1

AUTOFLOW – FLOWCHARTING SYSTEM

FIGURE IV-1

IBM SYSTEM/360, MODEL 40 GF

discrimination between development and operational requirements, the two areas have been separated for purposes of estimating resources.

Figure IV-2, page IV-4, and Figure IV-3, page IV-5, present the system requirements based on the assumption that the three models and data base will become operational without the supporting programs projected for development under DOTS Phases IIA and III. Resources are designated on the two figures as, "D" - required in the Phase II development, "O" - required for operational use, and "M" - required for operational maintenance.

The planned Command and Control Center Task of DOTS Phase IIA is intended to embed the three models and data base in a time-sharing system, with access being accomplished through a teleprocessing terminal. The estimated resource requirements of the terminal and time-sharing service will be covered as a separate exercise in this section. The estimate to follow will ignore the Command and Control project. It will also assume that no significant systems resource requirement impacts will result from the impending Phase III effort.

Based on the system's requirements outlined in Figures IV-2 and 3, an estimated monthly and annual cost for various patterns of data base and model operation was developed. From a systems perspective, the models can be exercised independently or independent of the data base. Although actual software and hardware current monthly rental rates were applied to the development of these resource costs, they should be treated as approximations only. The following were points considered in developing the costs in Figure IV-4, page IV-6.

a. Costs reflect only monthly hardware and software costs. No occupancy, personnel, expendables, power, etc., are included.

b. It was assumed the entire system cost would be charged to the data base and/or models as opposed to being distributed over a number of other user applications.

c. The costs are based on a minimum system capability to exercise the models within practical time limits.

It is unlikely that any training activity, agency, or complex will require or could justify a dedicated system for the sole purpose of exercising the SCRR, ETE, and TPF models. For this reason, an effort was initiated on 30 August 1974, to investigate the application of the time-sharing concept to model utilization. Use of a teleprocessing terminal in a Command and Control Center environment would permit greater flexibility in incorporating the current and future models into a decision analysis system. This project is designated DOTS, Phase IIA.

Whereas the previous resource estimate, Figure IV-4, was based on the assumption of a totally dedicated system, with no part of the cost being shared by other applications, the time-sharing or "Command and Control Center" pricing to follow assumes shared costs with other applications and, from that standpoint, represents a more valid projection of true cost to an individual using location.

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UNIT/FEATURE DESCRIPTION	DATA BASE		SCRR		ETE		TPF	
IBM SYSTEM/360 MODEL 40GF	DEV	OP	DEV	OP	DEV	OP	DEV	OP
2040 PROCESSING UNIT	D	0	D	0	D	0	D	0
196K CORE (140K AVAILABLE)	D	0	D	0	D	0*	D	0
DECIMAL ARITHMETIC	D	0	D	0	D	0	D	0
FLOATING POINT	-	-	D	0	D	0	D	0
STORAGE PROTECT	D	0	D	0	D	0	D	0
1052 KEYBOARD	D	0	D	0	D	0	D	0
2821 CONTROL UNIT	D	0	D	0	D	0	D	0
1403 M-2 PRINTER	D	0	D	0	D	0	D	0
2314 DIRECT ACCESS CONTROL	D	0	D	0	D	0	D	0
2319 ATTACHMENT (2 UNITS)	D	0	D	0	D	0	D	0
2316 DISK PACKS	D	0	D	0	D	0	D	0
2803 TAPE CONTROL UNIT	D	0	-	-	-	-	D	0
2401 NINE TRACK DRIVE (2 UNITS)	D	0	-	-	-	-	D	0
2401 SEVEN TRACK DRIVE (1 UNIT)	-	-	-	-	-	-	-	-
1442 CARD PUNCH	-	-	-	-	-	-	D	0
2501 CARD READER	D	0	D	0	D	0	D	0

*ETE development and validation was accomplished within the available core. However, 262K (200K available) is recommended for optimum operational use. This was considered in estimating future requirements.

D - Required during development

0 - Required for operational use

FIGURE IV-2

HARDWARE UNIT AND FEATURE REQUIREMENTS

PHASE II MODELS AND DATA BASE

UNIT/FEATURE DESCRIPTION	DATA BASE		SCRR		ETE		TPF	
IBM SYSTEM/360 MODEL 40GF	DEV	OP	DEV	OP	DEV	OP	DEV	OP
OPERATING SYSTEM/360	D	O	D	O	D	O	D	O
MFT - MULTIPROGRAMMING FIXED TASK	D	O	D	O	D	O	D	O
BAL - BASIC ASSEMBLER LANGUAGE	D	M[3]	D	M	-	-	D	M
PL/1 - PROGRAMMING LANGUAGE/1	D	M	D	M	-	-	D	M
COBOL - COMMON BUSINESS ORIENTED LANGUAGE	-	-	-	-	-	-	-	-
FORTRAN IV - FORMULA TRANSLATION LANGUAGE	-	-	-	-	-	-	D	M
MPSX - MATHEMATICAL PROGRAMMING LANGUAGE - EXTENDED	-	-	D	O	-	-	-	-
MIP - MIXED INTEGER PROG'MG	-	-	-	-	-	-	-	-
GPSS V - GENERAL PURPOSE SIMULATION SYSTEM	-	-	-	-	D	O	-	-
SPSS[1] - STATISTICAL PACKAGE FOR SOCIAL SCIENCES	-	O	-	-	-	-	D	M
DL/1 - DATA LANGUAGE/1	D	O	-	O	-	O	-	O
AUTOFLOW[2] - FLOWCHARTING SYSTEM	D	M	D	M	-	-	D	M

[1]SPSS - National Opinion Research Center, 6030 Ellis Ave., Chicago, Ill. 60637

[2]Autoflow - Applied Data Research, 2425 Wilson Blvd., Arlington, Va. 22201

[3]"M" - Designates programming revision and maintenance as opposed to day-to-day operations.

FIGURE IV-3

SOFTWARE - REQUIREMENTS

PHASE II MODELS AND DATA BASE

	SOFTWARE		HARDWARE		COMBINED	
	MONTHLY	ANNUAL	MONTHLY	ANNUAL	MONTHLY	ANNUAL
DATA BASE ALONE	654	7,848	16,670	200,040	17,324	207,888
SCRR ALONE	736	8,832	15,337	184,044	16,073	192,876
ETE ALONE	56	672	17,137	205,644	17,193	206,316
TPF ALONE	720	8,640	17,177	206,124	17,897	214,764
DATA BASE AND SCRR	786	9,432	16,776	201,312	17,562	210,744
DATA BASE, SCRR AND ETE	842	10,104	18,576	222,912	19,418	233,016
DATA BASE, SCRR, ETE AND TPF	908	10,896	18,977	227,724	19,885	238,620

NOTE: SPSS represented a one time charge of $600 as opposed to a monthly rental. This was pro-rated at $50.00 a month over one year. Therefore, the Data Base and TPF monthly software charges will drop $50.00 after the first year.

FIGURE IV-4

ESTIMATED HARDWARE AND SOFTWARE RENTAL COSTS

The Phase IIA Command and Control Center task is scheduled for completion on 28 February 1975. The Phase IIA final report will contain an accurate price projection based on actual experimentation with an installed terminal and time-sharing service. However, a tentative forward pricing estimate has been developed and is presented here for information purposes.

Based on a typical large training activity using the models and data base in its decision process, it is estimated that terminal, line, and time-sharing CPU total cost will run about twenty-thousand dollars per year.

The above estimate presupposes that most actual model runs will take place during the time-sharing services low load shifts. The terminal will be used to initiate model run requests, to selectively display stored run results, to input or update data, and to extract data. In those cases where the entire model run is required, a mail run will be requested as opposed to printing the entire run through the terminal printer. The time-shared system is included as one of the alternatives in the subsection entitled, Cost Estimate-Integrated DOTS System, page IV-9.

Category 2 - Strategic Plan Multi-Level Model Development. The long-range thrust of Technical Development Plan P43-03 (P01A) is towards the integration of computerized mathematical models into all appropriate areas of the CNET's decision analysis process. This thrust implies change in the way decisions are currently being made if the total decision process is to derive maximum benefit from the models. Therefore, an orderly and logical implementation of both the models and changes to the decision process itself are essential if the ultimate results are to be accepted and effectively used.

The resources defined under Category 2 apply primarily to the programs required to achieve this orderly and logical transition, rather than to those resources required to provide operational software and hardware coverage for the completed total DOTS modeling system. To attempt such a speculative exercise would produce costs of such limited accuracy as to be valueless. However, on a unit cost basis, it can be assumed that the operational systems cost of more sophisticated models will not greatly exceed that of the SCRR, ETE, or TPF models.

For purposes of estimating the resources required for the design, development, validation, and implementation of a total CNET's decision analysis system, models were arbitrarily divided into three levels. The hierarchy was based more on the functional use of the models than on the level of training command using the results of the models, although the two do tend to equate. Figure IV-5, page IV-8, provides an overview of the three levels.

The SCRR, ETE, and TPF models are examples of the first level. They are primarily concerned with the projection of training resources and student flow. The development of a multi-level DOTS modeling system was initiated at the first level, since the horizontal implementation of these models across the Naval Education and Training System will require standardization of a basic data base and associated procedures. Such a standard will be essential to the support of higher level models. This same advantage will apply to the evolution from the second to the third level.

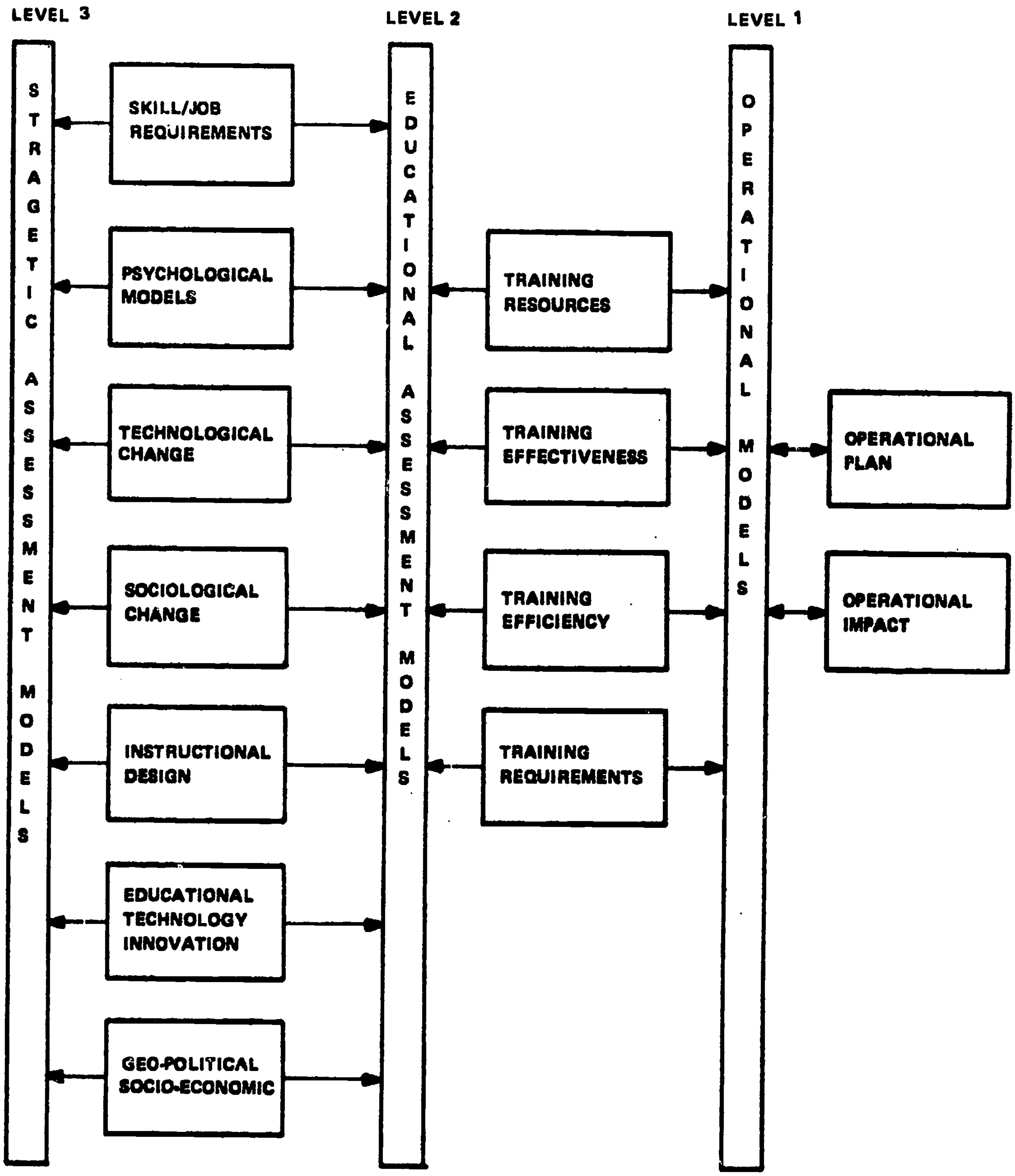

FIGURE IV-5

PROJECTED DOTS MULTI-LEVEL MODELING SYSTEM

The second level model is intended to serve as a mediating link between first and third levels. The third level is concerned with strategic concerns, extending over distant time horizons, having little to do with near-term operational CNET planning, but having an eventual indirect impact. The second level model will consider these impacts, as well as the projected impacts of anticipated training strategies and technologies, and convert them to a parametric form acceptable as inputs to the first level resource models.

Figure IV-6, page IV-10, provides an overview of the anticipated schedule of programs leading to an integrated DOTS multi-level modeling system. Developmental costs associated with each project are projected. Explanatory notes are provided. Pricing of an integrated operational system for the SCRR, ETE, and TPF models is covered in the next subsection.

Cost Estimate - Integrated DOTS System. Based on the pricing exercises under Categories 1 and 2, pages IV-1 and IV-7, a forward pricing analysis was performed in Phase II, projecting the costs of a horizontal extension of the SCRR, ETE, and TPF models to form an integrated CNET modeling system. Figures IV-9 and 10, pages IV-17 and IV-18, formed the basis for the estimated number of users as well as the personnel and supporting facilities required. Cost savings and avoidance resulting from implementation are covered in the Estimated Cost Savings and Avoidances, page IV-19.

Due to the number of variables and lack of operational experience, this pricing exercise must be considered highly speculative. DOTS Phase III will provide experience in an operational environment, enabling a more precise definition. However, the projected costs presented here should be sufficiently accurate to support tactical planning.

The results of the cost analysis are presented in Figure IV-7, page IV-11.

The following comments and definitions will assist in interpretation.

a. The hardware-software system supporting the DOTS system is projected as taking three possible forms categorized as Alternatives 1, 2, and 3.

   Alternative 1 assumes one large system supporting all users. It may or may not support other applications. Users would interface with the system through mail or phone requests. Response would normally be through the mailing of a printer run.

   Alternative 2 assumes each user will depend upon a system located in close geographic proximity. As with Alternative 1, interface would be through phone and mail service and, in addition, courier. Alternative 2 assumes these multiple systems are in existence and the DOTS application would be in addition to existing ones. Alternatives 1 and 2 assume utilization of a Navy or Government data system.

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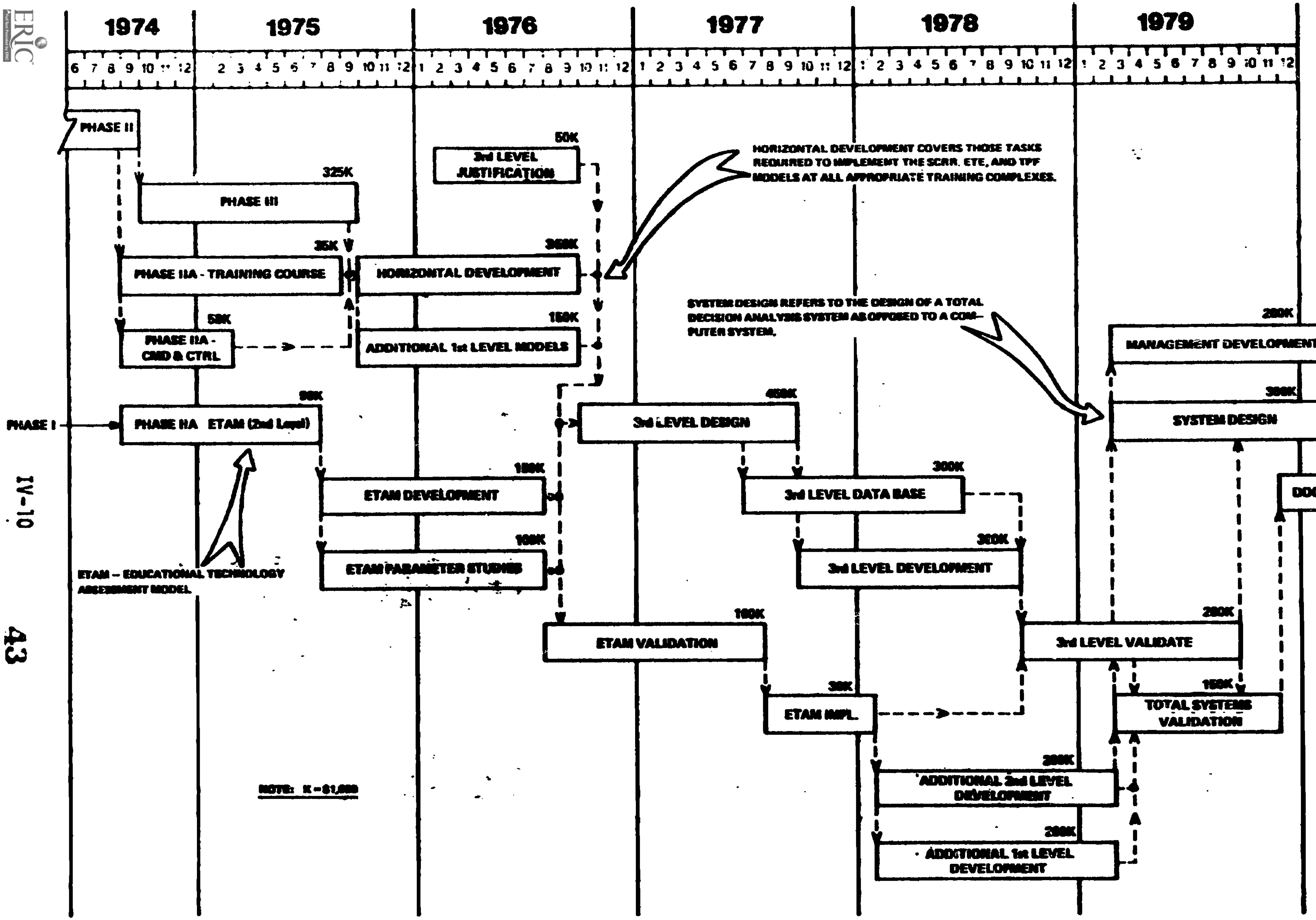

FIGURE IV-6
MULTI-LEVEL DOTS MODELING SYSTEM - ESTIMATED DEVELOPMENT COSTS

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• ASSUMES EIGHTEEN USER CENTERS • ASSUMES PHASED IMPLEMENTATION FY – 76	ALTERNATIVE – 1 ONE LARGE CENTRAL SYSTEM, NAVY OPERATED • BATCH PROCESSING • SHARED APPLICATION		ALTERNATIVE – 2 EIGHTEEN SMALL LOCAL SYSTEMS, NAVY OPERATED • BATCH PROCESSING • SHARED APPLICATION		ALTERNATIVE – 3 ONE TIME SHARING SYSTEM, COMMERCIAL • REAL TIME • BATCH PROCESSING • SHARED APPLICATION	
	1st YEAR FY – 76	2nd YEAR FY – 77	1st YEAR FY – 76	2nd YEAR FY – 77	1st YEAR FY – 76	2nd YEAR FY – 77
DATA BASE DEVELOPMENT ANALYSIS TEAM USER PERSONNEL	343,184	25,502	343,184	25,502	343,184	25,502
USER PERSONNEL – OPERATIONAL ADMINISTRATOR ANALYST MANAGEMENT	154,086	254,548	154,086	254,548	154,086	254,548
ADS PERSONNEL – OPERATIONAL CLERICAL OPERATOR SYSTEMS ANALYST MANAGEMENT	71,639	78,656	85,248	102,648	35,556	17,296
ADS SUPPORT – OPERATIONAL HARDWARE, SOFTWARE, CONSUMABLES LINE COST, TERMINAL ROOMS, TIME SHARE SERVICE	165,672	342,272	448,371	905,764	229,392	466,704
START-UP AND TRAINING COMMAND AND CONTROL CENTERS INSTALLATION COSTS DRAYAGE STAFF TRAINING	86,216	17,243	86,216	17,243	86,216	17,243
FINAL TOTALS	820,797	718,221	1,117,106	1,306,706	848,434	781,293

FIGURE IV-7 COST ESTIMATE - INTEGRATED DOTS SYSTEM

Alternative 3 assumes all users will interface with a common time-sharing service. In addition to phone and mail, their interface would include significant direct interaction through a teleprocessing display terminal. Alternative 3 cost projections assume a commercial time-sharing service.

b. To develop the data base for the Phase II and III validation tasks, a specific test site was used. The Data Base Development line, Figure IV-7, estimates the costs necessary to develop the data required for additional users.

c. User and systems personnel costs were based on the manpower billet costs for life cycle planning contained in the publication, Navy Military Manpower Billet Cost Data for Life Cycle Planning Purposes, Bureau of Naval Personnel, Personnel Research Division, Personnel Systems Research Branch, April 1972, NAVPERS 15163.

d. FY 76 is assumed as the year of implementation and FY 77 as first year of full operation. Costs were arbitrarily adjusted for inflation since 1972 and into future years.

DEVELOPMENT OF DATA SOURCES. Figure IV-8 illustrates the purpose of this subsection in the block entitled Lack of Data or Technique.

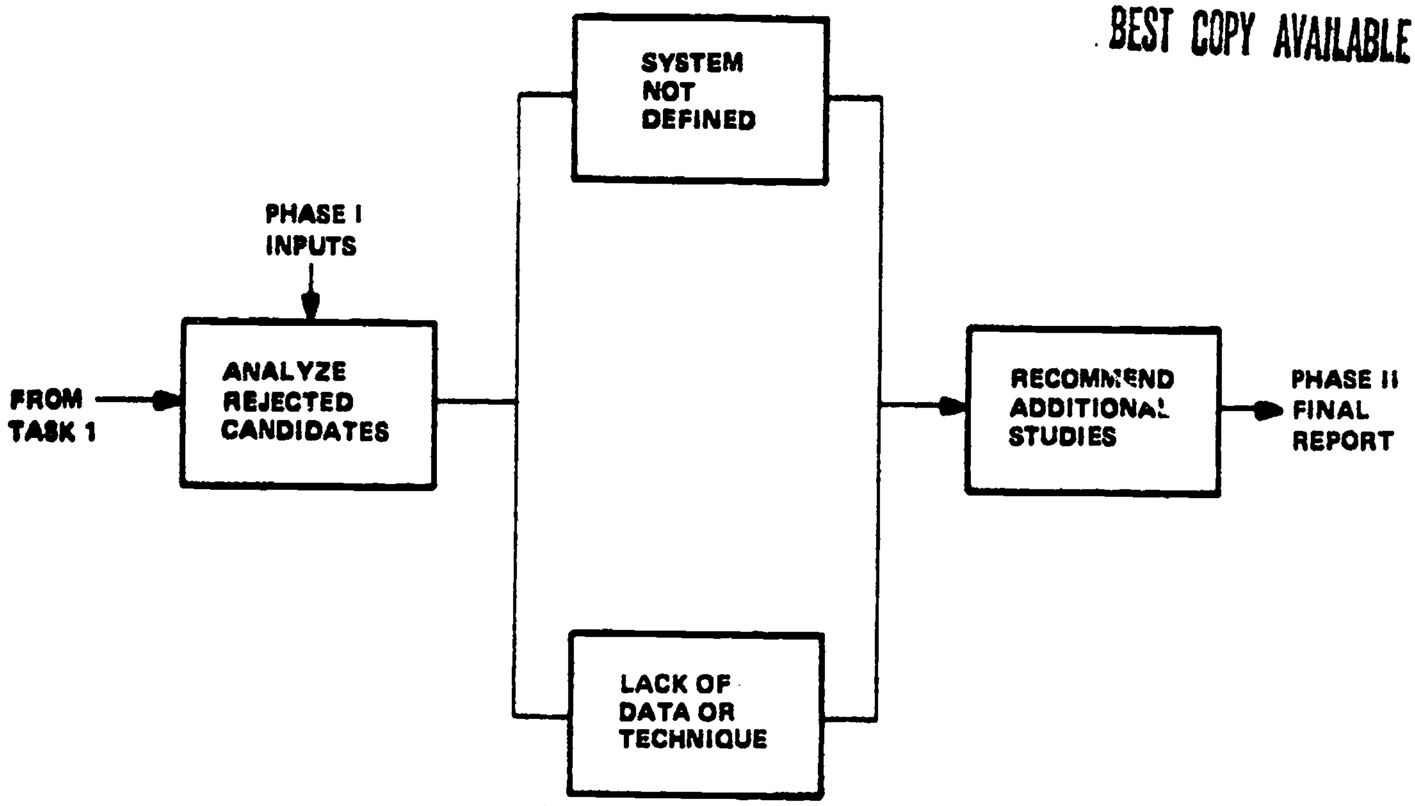


FIGURE IV-8 IDENTIFICATION OF DATA OR TECHNIQUE VOIDS
PHASE II, TASK 5

One of the Phase II, Task 5, objectives was to identify those key data or technique voids resulting in rejection of any of the twenty-one Phase I modeling candidates. The two subsections to follow address both the data base and technique support for the accepted models, as well as for those rejected. The absence of a data void does not necessarily imply that a data base could easily be developed for a given model, but that one could be reasonably constructed.

Data Base and Techniques - Accepted Models. There were no significant data base or technique voids identified during development of the SCRR, ETE, or TPF models. Originally, the Phase II validation runs were to have been accomplished with contrived data parameters, with use of live or historical data taking place during Phase III's predictive validation. However, due to the availability of historical data and the cooperation extended by COMTRALANT (Norfolk), it was possible to complete Phase II's logic validation using actual data.

To be effective, the ETE model does not require a constructed data base. Normally, its data requirements will be developed to fit the unique Individualized Learning System (ILS) problem being addressed. In any event, there is a paucity of historical data pertinent to ILS programs. This lack is not a problem, but as supporting ILS data are derived through use of the ETE model, it is recommended that they become a part of the data base.

The SCRR and TPF models both require basic data elements concerning training resources such as instructors, classrooms, student loads, course descriptions, etc. These elements form the majority of the data base developed during Phase II. Discussions of these data elements are included in Sections II and IV of Volume II, and Section V of Volume III, of this DOTS Phase II Final Report.

In developing the parameters driving the TPF model, a significant quantity of statistical data was developed, analyzed, and documented. These statistical runs will have value to many groups other than those specifically interested in the TPF model. They are documented in Volume III.

Data requirements and procedures for the three accepted models are covered in depth in DOTS Phase II Final Report, Volumes II and III. There were two major issues that evolved from the Phase II development effort, one a recommendation and the other a concern.

These were as follows:

a. Recommendation - After completion of DOTS Phase III, and after gaining some operational experience with the models and data base, serious consideration should be given to incorporation of the data base into the Navy Integrated Training and Resources Administration System (NITRAS), currently being developed as an application under the Naval Training Information System (NAVTIS).

   This transfer will facilitate future distribution of the models across the CNET functions and is compatible with the intent of NITRAS development. The delay in this transfer is desirable to permit a period of stabilization in the structure of the DOTS data base, as well as for the current development projects impacting NITRAS.

b. Concern - The TPF model development required analysis of raw data pertinent to individual student performance. Although the end objective was a collective indicator of performance by multiple students with common performance or background characteristics, the starting point had to necessarily be individual student records. Future use of the TPF model, and enhancement to its validity through reassessment of its key parameters, are both dependent on this type of analysis.

The second and third level modeling efforts projected in Figures IV-5 and IV-6, pages IV-8 and IV-10, will require similar data reductions.

It is anticipated that a growing concern will ultimately result in various privacy regulations that could have a detrimental impact on the Navy's authority to collect and store the types of data required to support future efforts exemplified by the TPF project's statistical analyses.

Data Base and Techniques - Rejected Models. Of the seventeen candidate models rejected for development in Phase II, only one was eliminated due to a data or technique void. This was the Physics of Learning model which was concerned with the relationship between training media and the learning rate of students. The original twenty-one candidate models were primarily concerned with the fundamental concern of basic resource management, and the essential elements of their quantification are defined in Volumes II and III of this report.

Significant voids were identified during development of recommendations for future multi-level modeling efforts. The void resulting in rejection of the Physics of Learning model is only one example of a family that must be filled if the ultimate objective of an integrated multi-level modeling system, based on more complex data elements than basic resources, is to be achieved. This family of data elements is concerned more with learning effectiveness factors than with training resources. No void is perceived to exist in mathematical modeling techniques if the effectiveness parameters can be quantified.

The DOTS Phase I and II studies highlighted the difficulty of a deterministic identification of learning factor type data voids, and the techniques required to fill them. However, if the Phase I recommendations pertinent to training measurement and control are to be applied through the development of higher level decision models, these difficulties must be overcome. As a result of this identified need, a task has been incorporated into the DOTS Phase IIA project, and is entitled Educational Technology Assessment Model (ETAM). One of the subtasks under ETAM is to provide a definitive assessment of the family of data elements categorized under the heading of Learning Conditions, and to incorporate them into a model design amenable to computerization.

The ETAM effort will result in specific recommendations and plans for quantification of the following data voids to a level enabling their incorporation as mathematical model parameters:

a. Training requirements expressed in terms of skills required on the job after completion of training.

b. Student and/or graduate competencies resulting from application of various existing training technologies, as well as those defined through futuristic speculative exercises.

c. Learning paradigms reflecting empirically derived assumptions pertinent to learning theory.

d. Cost formulae establishing a basis for forward estimation of the true costs of a given or projected training strategy.

ETAM will also address the techniques required to accomplish the preceding.

Summary - Development of Data Sources. No major data or technique voids, pertinent to the current DOTS modeling effort, were identified during the Phase II effort. Detailed descriptions of the data base developed during Phase II are incorporated as appropriate in Volumes II and III of this Phase II report.

In projecting long-range implications, significant data voids were defined. The ETAM task of the DOTS Phase IIA project is designed to provide a resolution to these voids. This resolution, in turn, will facilitate development of models incorporating parameters based on various human factors, as well as training resources.

PROJECTED OPERATIONAL RESPONSIBILITY

The purpose of this subsection is to provide a suggested pattern of responsibility and user assignments for the SCRR, ETE, and TPF models, and their supporting data base. These assignments are critical to the success of the DOTS modeling implementation. The types of decisions the DOTS models are designed to support are, for the most part, non-programmable and require the subjective judgment of a human being for their final resolution.

The recommended patterns of assignments are divided into two major categories. The first is concerned with the organizational assignment of the models to various CNET functions; the second with operational and managerial responsibilities within a given function, as appropriate to a decision analysis system. Although not all inclusive, the following key considerations are essential to any practical implementation of the assignment recommendations.

a. Currently, there is no standardized formatting of all data elements pertinent to training resources across CNET functions. Prior to a horizontal extension of models, this standardization must be completed.

b. Parameters supporting the models were based on various statistical analyses of data pertinent to the Norfolk FLETRACEN. Some of these parameters are directly transferable to other centers or functions, but in some cases new analyses will be required. Sufficient information is provided in this report for generation of these analyses.

c. In developing recommendations, it was assumed that the decision command levels identified currently have, or will be granted, the authority to make the training resource decisions supported by the models.

CATEGORY 1 ORGANIZATIONAL ASSIGNMENT. Category 1 provides a proposed distribution of organizational units utilizing model outputs. The organizations identified are those of a size and/or complexity standing to gain a significant benefit from application of the DOTS models. Omission of a given function is not intended to imply that use of the DOTS models would have no value, but that implementation cost may not be justifiable.

Figure IV-9, page IV-17, presents a proposed control and user structure. For the most part, the figure is self-explanatory. However, the levels of control require explanation. The following levels are indicated on the chart:

Level 1 CNET

Establishes the guiding principles and objectives of the total DOTS decision analysis system.

Level 2 CNET STAFF FUNCTION

Inspects to ensure that the models are being utilized effectively across the using commands, the principles defined by CNET are being supported, and the CNET objectives are being achieved.

Level 3 CNET STAFF FUNCTION

Converts CNET principles and objectives to operational systems tasks and assigns these tasks to CNTECHTRA, Memphis. CNTECHTRA, ADS, will have primary responsibility for horizontal extension of the software and hardware supporting the DOTS integrated system.

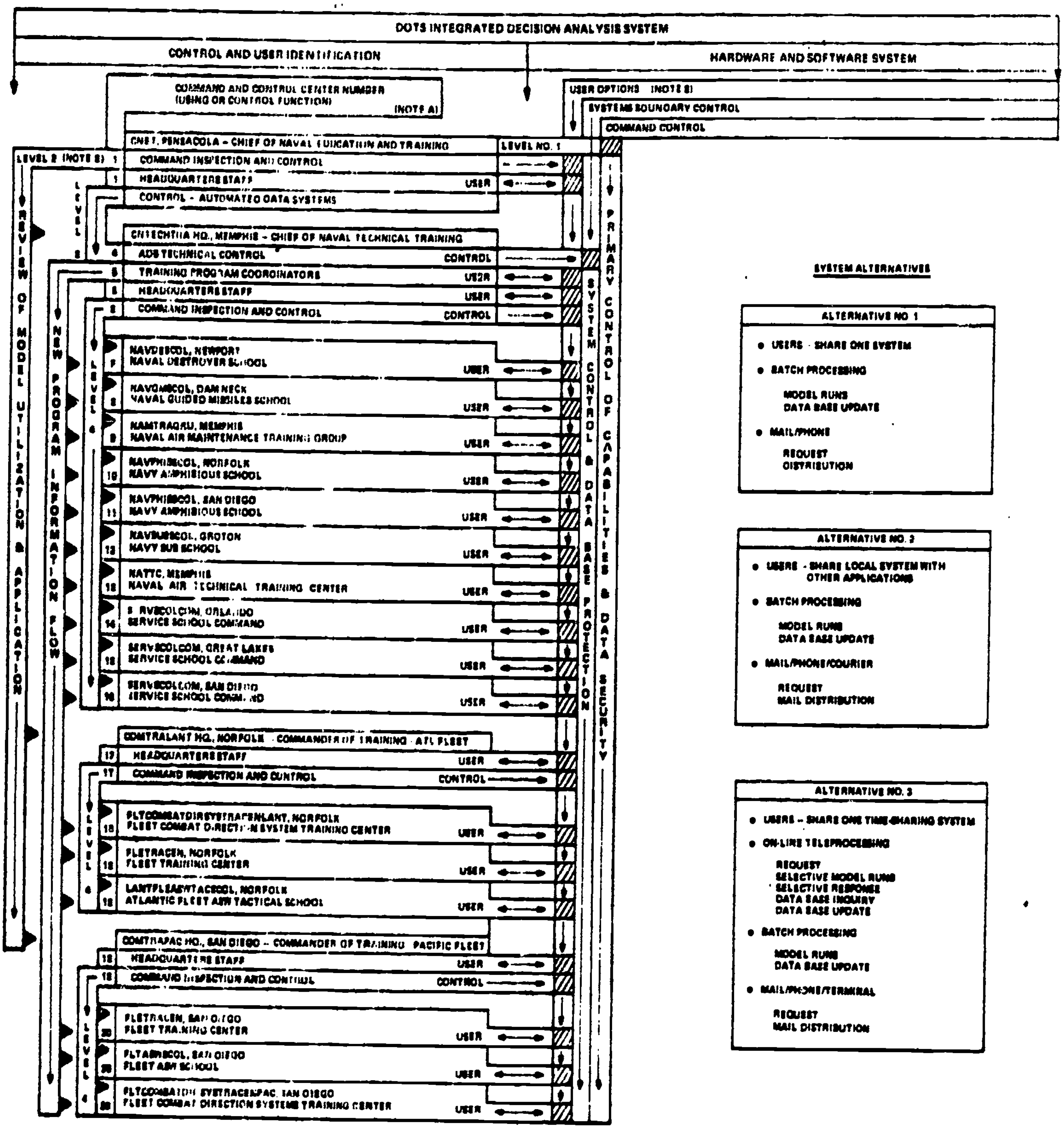
Level 4 CNET FUNCTIONAL COMMANDS

Level 4 is identical to Level 2, except for the level at which inspection and control is taking place.

The control boundaries on the right of the chart represent those pertinent to the technical control of the system, as opposed to management use of the models. Such areas as data protection, software modification, security codes, etc., are implied by this type of control.

CATEGORY 2 ASSIGNMENTS WITHIN FUNCTIONS. Category 1 was concerned with users within the CNET organization and control of the integrated system. This subsection is concerned with the organization of responsibilities within a using function's structure. It is this structure, in combination with the Category 2 relationships, which will make the integrated system supportive of a good decision analysis process.

Figure IV-10, page IV-18, identifies the key personnel required and provides descriptive data pertinent to their activities and responsibilities. An estimate of the man months required on an annual basis is also included. These estimates formed the basis for the estimate of user costs in Figure IV-7, page IV-11.



SYSTEM ALTERNATIVES

ALTERNATIVE NO. 1

- USERS – SHARE ONE SYSTEM
- BATCH PROCESSING
  - MODEL RUNS
  - DATA BASE UPDATE
- MAIL/PHONE
  - REQUEST
  - DISTRIBUTION

ALTERNATIVE NO. 2

- USERS – SHARE LOCAL SYSTEM WITH OTHER APPLICATIONS
- BATCH PROCESSING
  - MODEL RUNS
  - DATA BASE UPDATE
- MAIL/PHONE/COURIER
  - REQUEST
  - MAIL DISTRIBUTION

ALTERNATIVE NO. 3

- USERS – SHARE ONE TIME-SHARING SYSTEM
- ON-LINE TELEPROCESSING
  - REQUEST
  - SELECTIVE MODEL RUNS
  - SELECTIVE RESPONSE
  - DATA BASE INQUIRY
  - DATA BASE UPDATE
- BATCH PROCESSING
  - MODEL RUNS
  - DATA BASE UPDATE
- MAIL/PHONE/TERMINAL
  - REQUEST
  - MAIL DISTRIBUTION

NOTES:

A. A COMMAND AND CONTROL CENTER NUMBER INDICATES A SINGLE FACILITY SERVING AS AN OPERATIONAL INTERFACE BETWEEN A USER AND THE MODELING SYSTEM. ONE INTERFACE FACILITY MAY SUPPORT MORE THAN ONE USER. THE STRUCTURE AND COMPOSITION OF A FACILITY WILL BE DEPENDENT UPON THE SYSTEM ALTERNATIVE SELECTED.

NUMBERS 2 AND 3 ARE NOT INCLUDED, BUT ARE PROJECTED FOR CNO STAFF FUNCTIONS NOT CONSIDERED ORGANIC OR ESSENTIAL TO THE CNETS INTEGRATED SYSTEM.

B. CHANNELS LISTED ON THE LEFT ARE CONCERNED WITH FLOWS OF COMMAND AUTHORITY OR INFORMATION.

THOSE ON THE RIGHT ARE CONCERNED WITH CONTROL OF THE MODELING SYSTEM.

BOTH ARE DESCRIBED IN DETAIL IN THE SUPPORTING TEXT.

FIGURE IV-9 CNET INTEGRATED DOTS SYSTEM

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ACTIVITIES AND FUNCTIONS	ESTIMATE ANNUAL RESOURCES	
	ANNUAL MONTHS PER LOCATION	ANNUAL TOTAL 18 USER LOCATIONS
USER MANAGEMENT DEFINES DECISION REQUIRED DEFINES MODELING INFORMATION REQUIRED CONSIDERS MODEL RESPONSE IN DECISION PROCESS MAKES DECISION BASED ON MODEL RESPONSE AND OTHER PERTINENT INFORMATION	1	18
USER ANALYST ADVISE MANAGER ON TOTAL SYSTEM CAPABILITY SUGGEST MODEL APPLICATION AS APPROPRIATE AND SURVEY HISTORICAL MODELING RUNS ON STATISTICAL DATA FORMULATE RESPONSE TO MANAGEMENT REQUESTS BASED ON PRIOR DATA OR STRUCTURE REQUEST BASED ON MODELING CAPABILITY FORMULATE RESPONSE TO MANAGER BASED ON RESPONSE	2	36
USER ADMINISTRATOR FORMAT AND INITIATE REQUESTS TO SYSTEM FORMAT AND INPUT DATA BASE UPDATE OPERATE TERMINAL – (IF ALTERNATIVE NO. 3) FORMAT AND SUBMIT RESPONSES TO ANALYST	4	72

USER INTERFACE

DIRECT, PHONE, MAIL, COURIER, TERMINAL

USER OPTIONS

ALTERNATIVE NO. 1 CENTRALIZED SYS	ALTERNATIVE NO. 2 MULTI-SYSTEM	ALTERNATIVE NO. 3 TIME SHARE

HARDWARE – SOFTWARE OPTIONS

TOTAL ANNUAL MANMONTHS – ADS PERSONNEL
ASSUMES ALL USING LOCATIONS OPERATIONAL

SYSTEMS SUPPORT	ALT 1	ALT 2	ALT 3
ADS MANAGEMENT	12	12	1
SYSTEMS ANALYST/PROGRAMMER	8	8	4
OPERATORS	12	18	0
CLERICAL	12	12	0

FIGURE IV-10

DOTS INTEGRATED DECISION ANALYSIS SYSTEM
RESPONSIBILITY ASSIGNMENTS WITHIN A USING FUNCTION

The systems support personnel identified at the bottom of Figure IV-10, do not represent user resources, but increased requirements of the ADS activity.

ESTIMATED COST SAVINGS AND AVOIDANCES

A decision to implement the DOTS models at the eighteen user locations identified in the preceding Projected Operational Responsibility subsection, should be based on a thorough cost versus savings and avoidance justification. That justification and decision should not be made prior to the completion of DOTS Phase III and an assessment of actual operating results at the Norfolk Fleet Training Center test site.

The Phase II DOTS validation exercise did provide sufficient indicators for a preliminary projection of cost savings and avoidances. Necessarily, this analysis had to be based primarily on subjective opinion and assumptions, due to lack of objective operational data.

POTENTIAL FOR SAVINGS. The most significant potential for savings through integration of the DOTS models into the CNET decision analysis process is in the following areas:

a. Increased efficiency in the utilization of available training resources.

- Increased capacity.
- Reduced resource requirements.

b. Optimization of student flow through the training system.

- Improved quota control - reduced "no-shows".
- Improved application of substitute quotas.
- Reduced incompletes and "set backs".
- Reduced "wait time" prior to course convenings.

c. Permit realization of efficiencies projected for the Individualized Learning System strategy.

- Reduced student flow restriction due to resource contention.
- Optimized ILS resource requirements.

There are other significant tangible and intangible benefits anticipated from integration of DOTS models, but those listed are the ones that can be reasonably quantified for justification purposes at this time.

TRAINING COST STANDARD MODEL. As a first step in projecting savings, a cost model of the recruit and specialized training activities was developed. Figure IV-11, page IV-20, portrays this model in terms of student flow and resource requirements. Although based on actual historical and planning data, the standard is not intended to reflect any given fiscal year. The model does not contain all CNET students and resources, but only those providing potential savings through application of the DOTS models.

Figure IV-11 is self-explanatory. Factors in this cost standard will be reflected in the savings analysis in Figure IV-12, page IV-22.

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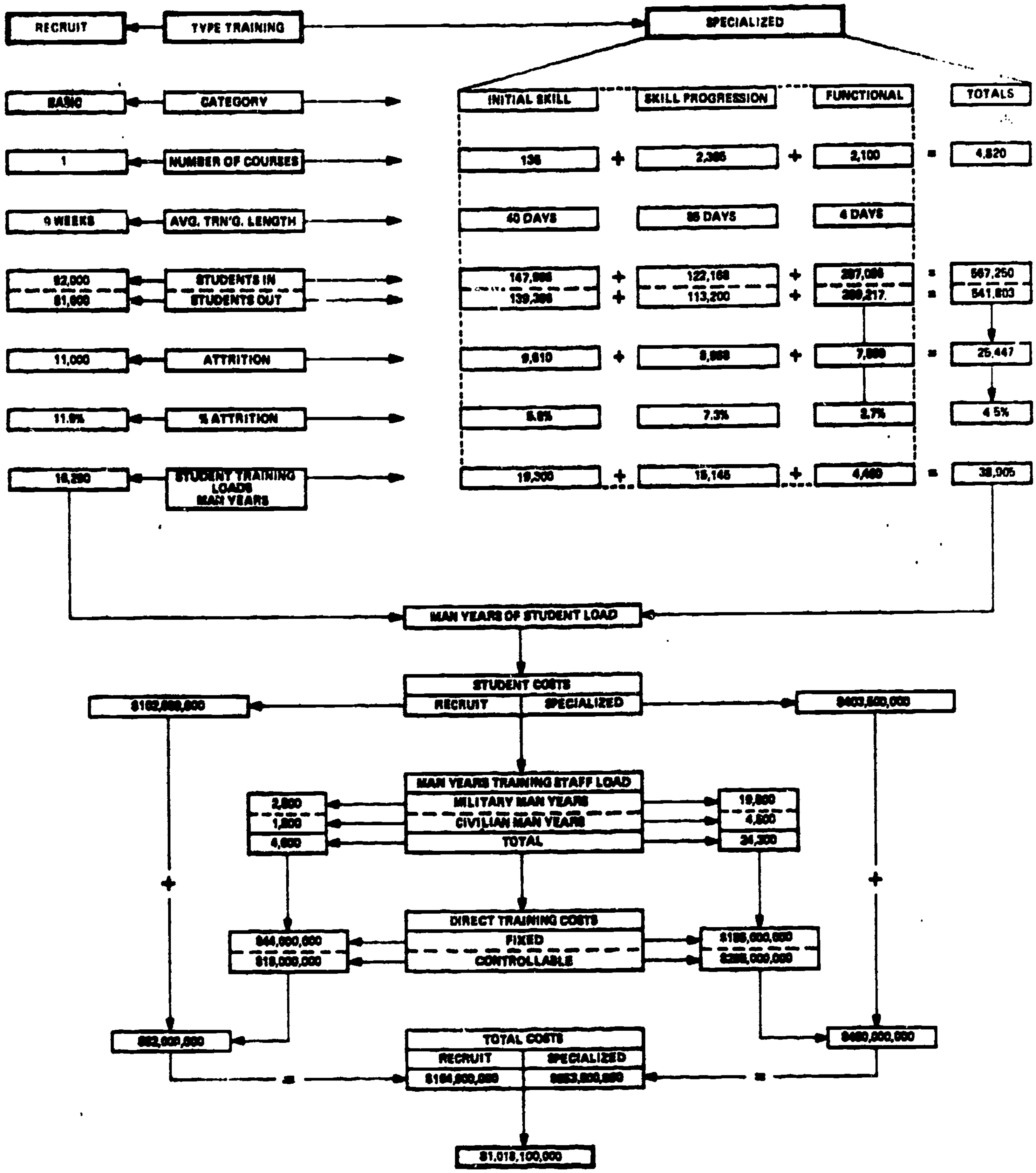

FIGURE IV-11 TRAINING COST STANDARD MODEL

SAVINGS AND AVOIDANCES. A five year projection of savings and avoidances expected to result from the DOTS implementation, was developed based on the cost standard model in Figure IV-11, and the Phase II model validation outcome. The resultant was used as a financial base for assessing probable actual impact over the same period.

Estimates of net savings ranged from $1,975,768 for the first year of implementation, to $17,969,727 for the fifth year. Figure IV-12 presents, in addition to the financial base, a matrix covering the first year of implementation and extending through the fourth year of fully integrated operations. In addition to time, the matrix anticipates three possible levels of individualized instruction curriculum, as well as the three DOTS operational alternatives outlined in Figures IV-7 and IV-9, pages IV-11 and IV-17.

The following comments should be considered in interpreting Figure IV-12:

a. Savings and avoidances were predicted for specialized training direct and student costs only. Recruit training was excluded, since the models will have their greatest impact on specialized training.

b. The fact that only a portion of training costs can be reasonal controlled was considered.

c. The cost of impleme ting and operating the three DOTS models was subtracted to arrive at a net savings amount. These DOTS costs included manpower as well as computer systems.

d. The estimates assume implementation of the three DOTS models by eighteen users as defined in Figures IV-9 and 10, pages IV-17 and IV-18.

e. The financial base amounts were significantly discounted to anticipate unpredictable events tending to reduce potential savings and avoidances. For example, those projected for the first year, the year of phased implementation, were reduced by 90 percent. Each of the five years was assigned a "most probable achievement" factor expressed as a percentage of the base amounts.

   1st year - 10%
   2nd year - 20%
   3rd year - 35%
   4th year - 55%
   5th year - 65%

   The learning curve in using the models and the effect of delayed impacts were also considered in developing these percentages.

f. As previously stated, this exercise should be repeated after more objective data have been developed during Phase III predictive validation of the three models.

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STANDARD TRAINING COSTS	DOTS OPERATING COSTS
BASED ON COST MODEL-FIG IV-11	BASED ON FIGURE IV-7

($ IN 000's)

STANDARD COST YEAR	RECRUIT	SPECIALIZED	TOTAL
STUDENT MANPOWER	102,600	403,500	506,100
DIRECT - FIXED	44,000	155,000	199,000
DIRECT - CONTROLLABLE	18,000	295,000	313,000
TOTALS	164,600	853,500	1,018,100

($ IN 000's)

DOTS INSTALL AND OPERATING COSTS	ALT. 1	ALT. 2	ALT. 3
FIRST FISCAL YEAR OF IMPLEMENTATION	821	1,117	848
OPERATIONAL YEARS - 18 USERS	715	1,306	781

<u>ASSUMPTION</u>
SAVINGS AND AVOIDANCE PROJECTED FOR SPECIALIZED STUDENT AND CONTROLLABLE DIRECT COSTS ONLY

MODEL APPLICATION AND IDENTIFICATION CODES

#	DESCRIPTION
	OPTIMIZE TRAINING RESOURCE UTILIZATION
1	INSTRUCTIONAL STAFF-OPTIMIZE SIZE
	CLASS SCHEDULING - OPTIMIZE STUDENT FLOW
2	• IMPROVED QUOTA CONTROL (REDUCED NO-SHOWS AND IMPROVED APPLICATION OF SUBSTITUTE QUOTAS)
3	• REDUCE INCOMPLETES AND SET-BACKS (CAUSE IDENTIFICATION)
4	• OPTIMIZE I.L.S. STUDENT PROGRESSION
5	INSTRUCTIONAL DEVICES AND FACILITIES - OPTIMIZE USE
	OPTIMIZE MANPOWER UTILIZATION
6	REDUCE PRE-TRAINING WAIT TIME
7	IMPROVED MATCH OF MAN TO TRAINING
8	IMPROVED MATCH OF TRAINING CAPABILITY TO FLEET NEED
	NOTE: NO SAVINGS INCLUDED UNDER THIS CATEGORY, ALTHOUGH SIGNIFICANT AMOUNTS ARE ANTICIPATED.

PROJECTED COST SAVINGS AND AVOIDANCES - POTENTIAL FROM SPECIALIZED TRAINING CATEGORY

MODEL	APPLICATION CODES		% OF TOTAL SPECIALIZED CURRICULUM IN I.L.S. MODE		
	NO CLAIM	CLAIMED	25%	50%	75%
SCRR	#5 + 8	#1	7,517,812	5,011,875	2,505,937
ETE	#5 + 6 + 8	#1 + 4	7,691,118	15,382,237	23,073,355
TPF	#5 + 7 + 8	#1 + 2 + 3	4,559,923	3,307,601	2,067,543
TOTAL BASE POTENTIAL			19,768,853	23,701,7'3	27,646,835

PROBABLE NET COST SAVING AND AVOIDANCE - FIRST FIVE YEARS - DOTS EXPENSE CONSIDERED

FIRST YEAR - PHASED IMPLEMENTATION	10% OF BASE LINE MINUS DOTS COST		
ALTERNATIVE - 1	1,976,064	2,369,350	2,763,862
ALTERNATIVE - 2	1,975,768	2,369,054	2,763,566
ALTERNATIVE - 3	1,976,037	2,369,323	2,763,835

SECOND YEAR - FULLY OPERATIONAL	20% OF BASE LINE MINUS DOTS COST		
ALTERNATIVE - 1	3,953,055	4,739,627	5,528,651
ALTERNATIVE - 2	3,952,464	4,739,036	5,528,060
ALTERNATIVE - 3	3,952,989	4,739,561	5,528,585

THIRD YEAR - FULLY OPERATIONAL	35% OF BASE LINE MINUS DOTS COST		
ALTERNATIVE - 1	6,918,383	8,294,884	9,675,677
ALTERNATIVE - 2	6,917,792	8,294,293	9,675,086
ALTERNATIVE - 3	6,918,317	8,294,818	9,675,611

FOURTH YEAR - FULLY OPERATIONAL	55% OF BASE LINE MINUS DOTS COST		
ALTERNATIVE - 1	10,872,154	13,035,227	15,205,044
ALTERNATIVE - 2	10,871,563	13,034,636	15,204,453
ALTERNATIVE - 3	10,872,088	13,035,161	15,204,978

FIFTH YEAR - FULLY OPERATIONAL	65% OF BASE LINE MINUS DOTS COST		
ALTERNATIVE - 1	12,849,039	15,405,398	17,969,727
ALTERNATIVE - 2	12,848,448	15,404,807	17,969,136
ALTERNATIVE - 3	12,848,973	15,405,332	17,969,661

FIVE YEAR ACCUMULATIVE - NET COST SAVING AND AVOIDANCE			
ALTERNATIVE - 1	36,568,695	43,844,486	51,142,961
ALTERNATIVE - 2	36,566,035	43,841,826	51,140,301
ALTERNATIVE - 3	36,568,404	43,844,195	51,142,670

FIGURE IV-12 PROJECTED COST SAVINGS AND AVOIDANCES

DEVELOPMENT SCHEDULE

A suggested schedule for implementation of a multi-level DOTS modeling system was presented in Figure IV-6, page IV-10. The major decision and phase schedules are covered here.

a. Complete Phase III
SCRR, ETE, and TPF Validation/Verification — 1 Oct 75*

b. Implement DOTS Phase III Models
Eighteen User Locations — From 1 Oct 75 - 1 Oct 76

c. Study and Design Level II Feasibility (ETAM)
From 1 Sep 74 - 1 Aug 75*

d. Develop and Validate Level II Model (ETAM)
From 1 Aug 75 - 1 Aug 77*

e. Implement Level II Model (ETAM) — From 1 Aug 77 - 1 Feb 78

f. Justify Level III Potential — From 1 Feb 76 - 1 Oct 76*

g. Design, Develop, and Validate Level III Model
From 1 Oct 76 - 1 Oct 79*

h. Complete DOTS Multi-Level Integrated System
All defined implementation activities — 1 May 80

The suggested schedule is based on a phased implementation strategy. Asterisks (*) indicate major decision points. Each phase should be validated and cost justified before a decision to move to the next.

IDENTIFICATION OF AREAS OF EDUCATION AND TRAINING REQUIRING ADDITIONAL RESEARCH

The DOTS Phase I functional analysis of the naval training system resulted in identification of a number of problem areas requiring additional research if they are to be resolved. These were documented in the Phase I report[15] and subsequently amplified in a summary document[16] produced by the Training Analysis and Evaluation Group located at the Naval Training Equipment Center, Orlando, Florida. These recommendations will not be repeated in this section.

Two major gaps identified in Phase I were highlighted again during Phase II. These were related to predicting student failure and training effectiveness. Both will be covered in this subsection.

STUDENT STATISTICS. Phase II's TPF model was designed to project training program yield in numbers of students graduating. Significant numbers of

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[15] Design of Training Systems, Phase I Final Report, TAEG Report No. 12-1, December 1973.

[16] Design of Training Systems, Phase I Summary Report, TAEG Report 11-1, December 1973.

analyses of student background were conducted during Phase II to establish relationships between past profiles of students and their training completion rates.

Based on the Phase II experience, it is suggested that additional research in correlating various background experiences or characteristics to actual performance in school and in the Fleet, could result in a significant enhancement of the Navy's ability to achieve a good match of men to training and to subsequent assignments.

The results achieved with the TPF model on an experimental basis, and observation of examples where in operational practice some key background element is being used to determine training assignments, tend to validate this suggestion.

In any event, the cost projections for implementing the DOTS models across the system include the necessary resources to perform the analysis required to support the TPF model at the new user locations.

TRAINING EFFECTIVENESS. The three Phase II models do not include predictive parameters dealing with the training effectiveness of various media and educational technologies. If these elements are to be considered in future modeling efforts, it is suggested that research leading to development of effectiveness parameters be initiated.

DOTS Phase IIA includes tasks leading to a feasibility determination and preliminary logic design for an effectiveness model, as well as a more precise definition of the additional research required to develop effectiveness parameters to at least a minimum level of validation. This effort is entitled, Educational Technology Assessment Model, ETAM.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

SECTION INTRODUCTION

The purpose of Section V is to summarize the results of the DOTS Phase II effort. The details of these conclusions and recommendations are covered in the three volumes of this report.

CONCLUSIONS

Based on the combined Phase I and II resultants, the following conclusions were drawn:

a. The Naval Education and Training System can improve the effectiveness of its decisions pertinent to resource planning and control through use of computerized mathematical models. This can be accomplished with reasonable changes to the current management system and practices.

b. The SCRR, ETE, and TPF models are logically valid and do perform as designed. Phase III predictive validation will prove their degree of accuracy in reflecting actual events.

c. Sufficient historical and operational data are available in existing records to enable operational implementation of the DOTS models.

RECOMMENDATIONS

a. Assuming successful predictive validation in Phase III, initiate a carefully controlled implementation of the SCRR, ETE, and TPF models.

b. Concurrent with model implementation, make the changes to the management system required to permit effective implementation of resource decisions. This implies granting various levels of training officials more authority over the use of training resources than they now have.

c. Continue the current thrust towards a multi-level modeling system integrated into an organized decision analysis process spanning the CNET Command.

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