DOCUMENT RESUME

ED 102 976 IR 001 658

TITLE	Design of Training Systems, Phase II Report, Volume II; Detailed Model Descriptions. TAEG Report No. 12-2.
INSTITUTION	Naval Training Equipment Center, Orlando, Fla. Training Analysis and Evaluation Group.
REPORT NO	NTEC-TAEG-12-2
PUB DATE	Dec 74
NOTE	151p.; For related documents see IR 001 657 and 659
EDRS PRICE	MF-$0.76 HC-$8.24 PLUS POSTAGE
DESCRIPTORS	Computer Oriented Programs; Computer Programs; *Data Bases; Data Processing; *Evaluation; Information Systems; *Instructional Systems; Management; Management Information Systems; *Mathematical Models; Military Organizations; *Military Training; Systems Analysis; Systems Development
IDENTIFIERS	Design of Training Systems; DOTS

ABSTRACT

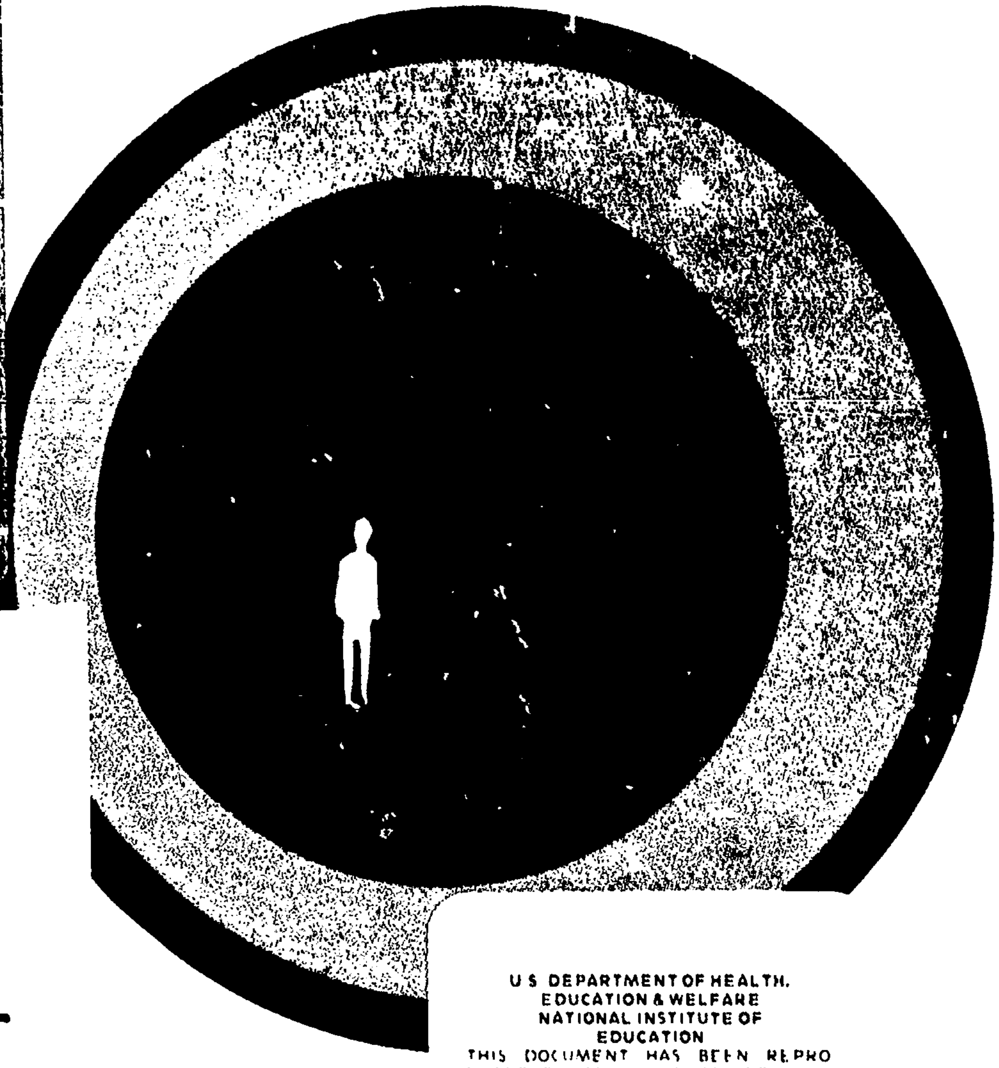
The Design of Training Systems (DOTS) project was initiated by the Department of Defense (DOD) to develop tools for the effective management of military training organizations. Phase 2 involved the design and development of three computer-based mathematical models, described in detail in this report. The models described are 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. Model test scenarios are described together with probable applications for the DOTS models. (DGC)

TAEG

TRAINING
ANALYSIS
AND
EVALUATION
GROUP

TAEG REPORT
NO. 12-2

DESIGN OF TRAINING SYSTEMS
PHASE II REPORT, Volume II
DETAILED MODEL DESCRIPTIONS



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).

TABLE OF CONTENTS

VOLUME II

SECTION PAGE

I INTRODUCTION

II SYSTEM CAPABILITIES/REQUIREMENTS AND RESOURCES MODEL

III EDUCATIONAL TECHNOLOGY EVALUATION MODEL

IV TRAINING PROCESS FLOW MODEL

V MODEL TEST APPLICATIONS SCENARIOS

LIST OF FIGURES

LIST OF TABLES

(THIS PAGE INTENTIONALLY LEFT BLANK)

SECTION I

INTRODUCTION

PURPOSE

Volume II presents a detailed description of the DOTS system. The term system is used because the models and the data base form an interacting and interdependent group of functional training management tools. It is the intent of Volume II to give the analyst sufficient information to allow a thorough understanding of the three DOTS models, to delineate the data requirements and data base communication, and to explain the logic design and the validation of that design during Phase II.

ORGANIZATION OF THIS VOLUME

Volume II is organized into sections for each model in the DOTS system; i.e., the System Capabilities/Requirements and Resources model, the Educational Technology Evaluation model, and the Training Process Flow model. Each model section follows the same format to allow the reader to make comparisons of similar aspects among the three models. Phase II validation scenarios are presented as an integral part of each model discussion. The proposed Phase III scenarios are presented separately.

(THIS PAGE INTENTIONALLY LEFT BLANK.)

SECTION II

SYSTEM CAPABILITIES/REQUIREMENTS AND RESOURCES MODEL

MODEL DESCRIPTION AND FUNCTIONAL SPECIFICATIONS

FUNCTIONAL SPECIFICATIONS. The objective of the System Capabilities/Requirements and Resources (SCRR) model is to provide Navy training complex officials with sufficient physical resource information (i.e., courses, instructors, classrooms, laboratories) and related analyses to:

a. Assess the feasibility of meeting annual training requirements at the training complex level.

b. Evaluate alternative plans for meeting both short and long-term training requirements.

c. Assess the utilization of existing resources in the daily operation of the training complex.

The SCRR model will perform the data analyses required to fulfill these objectives through the solution and subsequent sensitivity analysis of the following linear programming problem.

- Determine the maximum student throughput based on an optimal mix of course convenings which a training complex can achieve in a specified period of time, subject to either existing or projected physical resource constraints.

Specifically, a training complex official will be able to use the SCRR model to analyze the projected impact of modifications to training demand or resource availability on student throughput, course convenings, and resource utilization. The following are presented as examples of modifications which the SCRR model will evaluate.

a. Courses can be added to or deleted from the training complex schedule.

b. Course lengths can be increased or decreased.

c. Course convening frequencies can be altered.

d. Normal course capacities can be increased or decreased.

e. Student/instructor ratios can be modified.

f. Instructors can be added or deleted.

g. Instructor qualifications can be modified.

h. Instructor availability can be increased or decreased.

i. Classroom and laboratory availabilities can be increased or decreased.

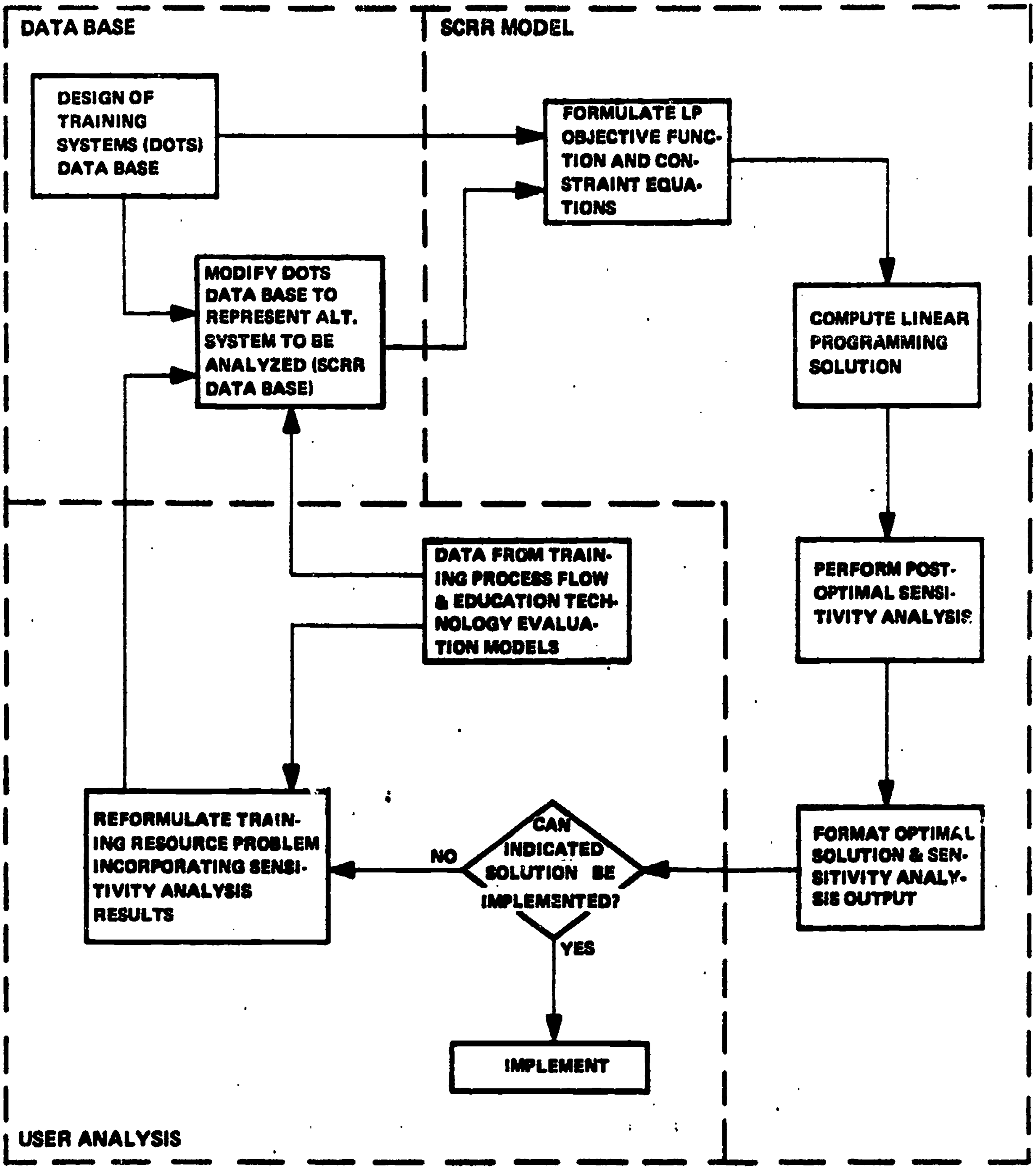


FIGURE II-1 SCRR MODEL FUNCTIONAL FLOW

In addition to optimizing student throughput, the SCRR model can also be used to calculate the quantity and mix of resources required to achieve a user-specified student throughput. The model user can specify student throughput by establishing the model parameter for number of course convenings as a fixed value equal to the current number of convenings.

The SCRR model can be run for an individual school (when teaching assignments do not cross school lines), for groups of schools, or for the total training complex.

SCRR MODEL DESCRIPTION. Figure II-1 depicts the SCRR model functional flow. The components of the functional flow can be divided into three distinct categories:

a. Data Base

b. SCRR Model

c. User Analysis.

The SCRR model will accept input data from two sources - the DOTS data base and the SCRR data base. The SCRR data base is a temporary copy of the DOTS data base which the model user can alter to represent projected training requirement/resource relationships, or to answer "what if" questions without destroying the data stored in the DOTS data base. Although the data base is not an integral part of the SCRR model, model operation is dependent upon the data base.

The four primary components of the SCRR model are:

a. Formulate LP objective function and constraint equations.

b. Compute linear programming solution.

c. Perform post-optimal sensitivity analysis.

d. Format optimal solution and sensitivity analysis output.

The remaining functional flow components fall into the user analysis category. The user must analyze the optimal solution and the sensitivity analyses results to determine if that solution can be implemented. If not, then he must consider the previous results together with information from other sources, including data from the Training Process Flow (TPF) and the Educational Technology Evaluation (ETE) models, to modify the resource mix, training requirements, or other model parameters.

Design of Training Systems (DOTS) Data Base. The DOTS data base provides a single data source for the SCRR model and significantly reduces the amount of data that must be entered each time the model is run. All input data required by the SCRR model, such as course data (length, capacity, convening frequency, instructor, classroom, lab, and equipment requirements), instructor data (qualifications, assignments, availability, rotation date), and classroom and laboratory data (location, capacity, availability, course assignments) are stored in the DOTS data base. The data base will be updated monthly to ensure that it depicts current training requirements and the resources available to the training complex. This design feature enables the SCRR model user to obtain an analysis of current resources as applied to current training requirements. The resource analysis includes instructor, classroom, and laboratory utilization as a percentage of total availability, the total number of convenings of each course which is feasible at the current resource level, and resource trade-offs for resources which are applied across two or more courses.

The user must modify the appropriate data base elements (utilizing the temporary SCRR data base) prior to initiating the LP problem formulation module to obtain an analysis for a resource level other than the current level, or for increased or decreased training requirements. The specified data base (either DOTS or temporary SCRR) is directly accessed by the LP problem formulation module. The formulation module operates on the data base contents, combining and reformatting elements to create both the objective function and all constraint equations to be processed by the linear programming module.

A detailed description of the DOTS data base can be found in Volume III, Section V, of the report.

Modify DOTS Data Base to Represent Alternative System to be Analyzed (SCRR Data Base). If the sole source of data input to the linear programming module were the current contents of the data base, SCRR model application would be restricted to analysis of the interaction of only those resources and requirements described in the data base. To extend the range of application of the model, the optional modify data base component (SCRR data base) has been inserted between the data base module and the LP problem formulation module in the functional flow depicted in Figure II-1.

Training complex officials have the option of proceeding directly from the DOTS data base component to the LP problem formulation module, thus generating an output which describes the utilization and interactions of current resource elements. However, the training official may elect to modify some or all of the existing data base, using the temporary SCRR data base, to determine the feasibility of a proposed modification to training demand or resource availability. Modifications to the data base might be made to:

a. Incorporate data from either the TPF or the ETE models.

b. Incorporate results of previous SCRR model runs.

c. Answer "what if" questions posed by training complex officials, COMTRALANT, or CNET.

Formulate LP Objective Function and Constraint Equations. Linear programming deals with the problems arising out of the need to allocate limited resource among competing activities to meet desired objectives. These problems are characterized by the large number of solutions that satisfy the basic conditions of each problem. The selection of a particular solution as the best solution to a problem depends on some aim or overall objective that is implied in the statement of the problem. A solution that satisfies both the conditions of the problem and the given objective is termed an optimum solution. The complete mathematical statement of a linear programming problem includes a set of simultaneous linear equations or inequalities which represent the conditions of the problem, and a linear function which expresses the objective of the problem.

The linear programming term "objective function" represents the target of the linear programming solution. The answer to the problem must satisfy this requirement. The objective function must be clearly stated and expressed as a linear mathematical function. The stated objective of the SCRR linear programming model is to maximize the student throughput which a school or training complex can achieve in a specified time period subject to existing physical resource constraints. This objective can be expressed mathematically as:

$$\text{MAXIMIZE} \sum_{j=1}^{J} C_j X_j$$

which is shorthand notation for saying

"MAXIMIZE $C_1X_1 + C_2X_2 + C_3X_3 + \ldots + C_JX_J$".

Where

X_j = number of annual convenings of course j.

C_j = normal capacity of students in course j based upon both training considerations and physical considerations.

The LP problem formulation module constructs the objective function based on the normal course capacities and reformats the function to satisfy the input requirements of the LP module.

Several conditions or restraints must be considered in the formulation of the SCRR linear programming problem.

Course syllabi require a specific amount of classroom instruction time from one or more instructors for each course convening. However, only a limited group of instructors is qualified to teach each course. Therefore, the total amount of time the group of instructors has available for classroom instruction limits the number of times the course can be convened. The product of the classroom instruction time and the number of convenings cannot exceed the total amount of time each group of instructors has available.

Each course syllabus also requires that classroom and/or laboratory space be available for each convening. The amount of time each facility is available also represents a limitation to the number of times a course can be convened. In addition to the constraints imposed by instructors, classrooms, and laboratories, most courses are further restricted in that they must be convened some minimum number of times to fulfill a minimum training requirement to train a minimum number of individuals.

These conditions can be mathematically stated as a set of simultaneous inequalities as follows:

(1) $$\sum_{j=1}^{J} a_{ij} X_j \leq TCH_i \quad i = 1, 2, \ldots I.$$

Where

a_{ij} = number of instructor contact hours required by course syllabus for the i^{th} group/category of instructors for one convening of course j.

TCH_i = total contact hours available per year for the i^{th} group/category of instructors.

(2) $$\sum_{j=1}^{J} b_{kj} X_j \leq TLA_k \quad k = 1, 2, \dots K.$$

Where

b_{kj} = number of hours of usage required from laboratory type k for each convening of course j.

TLA_k = total hours per year which laboratory type k is available for use.

(3) $$\sum_{j=1}^{J} d_{mj} X_j \leq CRA_m \quad m = 1, 2, \dots M.$$

Where

d_{mj} = number of hours of usage required from the type m classroom for one convening of course j.

CRA_m = total hours per year the type m classroom is available for use.

(4) $X_j > MIN_j$.

Where

MIN_j = minimum number of convenings per year for course j to meet a minimum training requirement.

The formulation module constructs the entire set of simultaneous inequalities described above, and reformats the constraints to conform to the input requirements of the LP module. The user must supply values for two program control parameters to initiate the LP formulation module: (1) Dept. - specify the name of one or more organizational departments (i.e., ASW, SUPPLY, TTM, etc.). If no departments are listed, all training center departments will be included in the model run; and (2) Objective - specify either "LO" to determine the maximum student throughput and maximum convenings for each course possible with the specified resources, or "FX" to determine the resources required to achieve a specified throughput or number of course convenings.

Compute Linear Programming Solution. The linear programming module accepts formatted input from the LP problem formulation module and calculates either the maximum student throughput and maximum convenings of each course possible per year subject to the expressed physical resource constraints, or the quantity of resources required to attain a specified throughput or convening schedule. Since many excellent texts which provide detailed methodology for linear programming computational procedures are available, these procedures and associated mathematical proofs will not be included in this report. Several of these books are listed in the bibliography (Volume III, Section VI). A more extensive linear programming bibliography (nearly 500 books and articles) can be found in Dantzig's Linear Programming and Extensions[1].

An IBM program product, Mathematical Programming System Extended (MPSX)[2], is utilized to perform the linear programming computations. The MPSX linear programming procedures use the bounded variable/product form of the inverse/revised simplex method.

Perform Post-Optimal Sensitivity Analysis. The purpose of the sensitivity analysis module is to provide information concerning the range of operations in the neighborhood of the optimum solution as calculated by the LP module. The sensitivity analysis will provide information relative to how changing instructor, classroom, or laboratory utilization effects the optimal student throughput, and the range of instructor, classroom, and laboratory utilization hours for which the solution, as originally stated, remains optimal. The sensitivity analysis will also generate information describing the effect of class size on the optimal solution as well as the feasible range of annual convenings, and the effect of changing the number of convenings on the optimal student throughput. The information obtained from the sensitivity analysis should prove to be as valuable as the specification of the optimum solution itself.

There are several reasons for performing a sensitivity analysis. Stability of the optimal solution under changes of parameters may be critical. For example, using the old optimum solution point, a slight variation in the required number of convenings or in instructor requirements may result in a large unfavorable difference in the objective function (student throughput), while a large variation in either of the parameters in another direction may result in only a small difference. The training center official may find it desirable to move away from the optimum solution when variables such as course demand, which are not considered in the SCRR model, are taken into account.

Instructor, classroom, laboratory requirements and availabilities, minimum convening frequencies, and class capacities are to some extent controllable and it would be advantageous to know the effects which would result from changing the values of these parameters. Determination of the range of values for each of the parameters for which the solution remains optimum will also identify those parameters to which the optimum solution is extremely sensitive.

---

[1] Linear Programming and Extensions, by G. B. Dantzig (Princeton University Press, Princeton, N.J., 1963).

[2] MPSX Linear and Separable Programming Program Description Manual (SH20-0968-1), (IBM Corporation, Revised August 30, 1973).

Format Optimal Solution and Sensitivity Analysis Output. From the operational point of view, the key component of any model is the output module. Model output represents the primary interface between the model and its user. The SCRR model output is divided into three segments:

a. Requirements Specification Listing

b. LP Optimum Solution and Sensitivity Analysis - Resource Data

c. LP Optimal Solution and Sensitivity Analysis - Course Data.

Requirements Specification Listing. The requirements specification listing describes the necessary interface between the resource data bank and the linear programming solution. The data for this segment of the SCRR output are generated by the LP problem formulation module.

The requirements specification listing will list, by name, the individual members of each instructor group. The annual availability of individual instructors and each instructor group will be noted. All courses instructed by the instructor group will be listed by course number for each instructor group. The contact hour requirement for that instructor group per convening, the current number of annual convenings, and the normal class capacity will be noted for each course. The listing will also show, by course number, all courses which utilize each individual classroom and laboratory facility. The number of hours per convening will be listed by course for each of the classrooms and labs.

LP Optimal Solution and Sensitivity Analysis - Resource Data. The LP module output and the sensitivity analysis module output have been combined into a single output format for all resource data. Instructor resources are identified by instructor group number. Classrooms and laboratories are identified by building and room number. The resource data output section lists the following for each resource:

a. Annual availability.

b. Annual utilization.

c. Hours per year not utilized.

d. Percent utilization.

e. Upper and lower limits of resource utilization hours.

f. Student throughput change per unit resource change.

g. Identification of variable which limits utilization range, and whose value will change as the resource level is modified.

LP Optimal Solution and Sensitivity Analysis - Course Data. As with the resource data, the output from both the LP module and the sensitivity analysis module is presented in a single report format for course data. Courses are identified by CDP numbers. The course data section lists the following for each course:

a. Maximum number of annual convenings.

b. Current number of scheduled convenings.

c. Normal course capacity.

d. Range of annual convenings.

e. Student throughput change per course convening change.

f. Range of course capacities to which indicated solution can be applied.

g. Identification of variable which limits convenings range, and whose value will change as the convening level is modified.

Can Indicated Solution be Implemented? After the training complex official has analyzed the linear programming optimal solution and the output from the sensitivity analysis, he is finally in a position to interpret and evaluate the model results. To successfully interpret the model results, the official must be familiar with the mathematical formulation of the linear programming problem. The objective of this familiarization requirement is not to understand the internal mathematical manipulations required to achieve the linear programming solution, but to be aware of simplifications and deviations from reality that were, of necessity, built into the initial linear programming formulations. Model results must be interpreted taking all assumptions and simplifications into full consideration.

Assuming that the official either accepts the model results or modifies the model output, based on his experience and intuitive feeling for the situation being analyzed, his next task is to evaluate the results in terms of implementation feasibility. If, because of some physical, monetary, or political restriction, full or partial implementation is not feasible, the problem statement must be reformulated utilizing any new data or insights resulting from the initial problem solution and sensitivity analysis.

Reformulate Training Resource Problem Incorporating Sensitivity Analysis Results. The problem reformulation module, together with the DOTS data base and data from the TPF and ETE models, feeds the data modification module (see Figure II-1). The reformulation component completes the iterative cycle. Based on SCRR model results, experience, and intuition, an official has the ability to modify initial problem statements or to develop new potential alternative solutions to be evaluated. At this point, the official need only remodify the DOTS data base to initiate an additional cycle of the iterative process.

Data From Training Process Flow and Education Technology Evaluation Models. The results of the TPF and the ETE models may suggest modifications to several of the SCRR model variables; e.g.:

a. Several courses should be individualized, reducing instructor requirements and calling for modifications to classroom and laboratory space requirements.

b. Student/instructor ratios should be increased for the lab sessions in several courses to reduce failure rates.

c. Convening frequencies should be increased to reduce the wait time required to attend several courses.

d. Convening frequencies should be reduced for low utilization courses.

The DOTS data base can be modified, using the temporary SCRR data base, to reflect changes such as those listed, prior to initiating the SCRR model.

INPUT PARAMETERS DESCRIPTION

SCRR model input parameters contained in the DOTS data base are described below.

COURSE DESCRIPTION (TEN POSITION CHARACTER FIELD - FORMAT = X-XXX-XXXX). Courses are identified by a seven or eight position alphanumeric designator. A prefix letter identifies the activity holding curriculum/eligibility control of the course; i.e., "A" for Bureau of Naval Personnel, "J" for Training Command, Atlantic, and "K" for Training Command, Pacific. A middle grouping will consist of a number and a letter or a three digit number. The number and letter indicate an officer skill. The three digit number indicates an enlisted course. A final grouping is made up of four digits which indicate the course sequence number.

CDP NUMBER (FOUR POSITION CHARACTER FIELD - FORMAT = XXXX). The CDP number is a four digit alphanumeric number used by NITRAS as a course identifier. Each course is assigned a unique CDP number. All data elements contained in the training resource data base are keyed to the CDP number.

COURSE LENGTH (THREE POSITION NUMERIC FIELD - FORMAT = XX.X). Course lengths are stored in weeks. One-half day is equivalent to 0.1 week.

CLASS INPUT CAPACITY (THREE POSITION NUMERIC FIELD - FORMAT = XXX). The planned maximum number of students that can attend any one convening of the course. Capacities are based upon training considerations such as instructor to student ratio, availability of training equipment, workshop, laboratories, and mock-up facilities, as well as physical considerations such as classroom size.

NUMBER OF CONVENINGS PER YEAR (THREE POSITION NUMERIC FIELD - FORMAT = XXX). The number of times each course is scheduled to convene over the next twelve months. Course schedules are based on course capacities and projected training requirements.

STUDENT/INSTRUCTOR RATIO (THREE POSITION NUMERIC FIELD - FORMAT = XX.X). A numerical index describing the number of trainees per instructor.

CONTACT HOURS (FIVE POSITION NUMERIC FIELD - FORMAT = XXXX.X). The number of instructional contact hours taught at a given ratio of trainees per instructor. A contact hour represents sixty minutes of instruction. This refers to clock hours of curriculum time devoted to actual instruction, exclusive of breaks, administrative time, lunch, medical, dental, etc.

NUMBER OF INSTRUCTORS (THREE POSITION NUMERIC FIELD - FORMAT = XXX). The number of instructors required to conduct the class for the indicated number of instructional contact hours. The number of instructors is determined by dividing the class capacity by the student/instructor ratio.

CONTACT HOUR TYPE (ONE POSITION CHARACTER FIELD - FORMAT = X). Contact hours are classified as either theory/classroom hours or laboratory hours. Theory hours refer to those hours spent in the presentation of subject matter primarily utilizing discussion, lecture, demonstration, or programmed instruction methods of presentation. Laboratory hours include those instructional hours involving actual or simulated job experience. In addition to laboratory, this includes shop, line, and field instruction.

INSTRUCTOR NUMBER (THREE POSITION NUMERIC FIELD - FORMAT = XXX). An identification number assigned to each instructor to simplify data manipulation.

CURRENT ASSIGNMENT (ONE POSITION CHARACTER FIELD - FORMAT = X). Denotes that an instructor is currently assigned to a particular course. An instructor may be assigned to more than one course in situations where course lengths are less than convening frequency. Thus, an instructor assigned to a one week course which is convened the first week of every month, could also be assigned to another one week course which is convened the third week of every month.

INSTRUCTOR AVAILABILITY (FOUR POSITION NUMERIC FIELD - FORMAT = XXXX). The number of hours per year an instructor has available for classroom instruction. The following activities are excluded from the contact hour availability figure: supervisory requirements; military duties; preparation for instruction; duties related to instruction; annual leave; illness; special training; and break-in time.

RELATED COURSE NUMBER (FOUR POSITION CHARACTER FIELD - FORMAT = XXXX). Identifies an additional course(s) which is also instructed by the same instructor group. An instructor group is comprised of one or more instructors, all of whom teach the same course or group of courses. The related course information is included in the data base to facilitate the formulation of the linear programming constraint equations.

INSTRUCTOR GROUP (THREE POSITION NUMERIC FIELD - FORMAT = XXX). The instructor group designator is used to subdivide total course instructor requirements between two or more instructors or groups of instructors. For example, a one week course is comprised of four days of classroom lecture and discussion with an instructor requirement of one, and one day of laboratory work with a requirement for two instructors. The total contact hour requirement for this course would be 36 hours [4 days x 6 hrs/day x 1 instructor] + [1 day x 6 hrs/day x 2 instructors]. Instructor A teaches both classroom and laboratory sections of the course and, therefore, is associated with thirty of the thirty-six required contact hours. The remaining six hours are associated with instructor B who assists with the lab portion of the course. The instructor group designator is used to subdivide the total thirty-six hour requirement between the two instructors. Instructor group one is assigned to instructor A and instructor group two is assigned to instructor B. All instructors are assigned an instructor group number. Each instructor can be a member of only one instructor group. The group number is used to relate specific instructors or groups of instructors to specific instructional requirements and to specified related courses. Assuming instructor A also teaches course X and instructor B also teaches course Y, both X and Y would be noted as related courses, course X through instructor group one and course Y through instructor group two. As with the related course number element, this data element is also included primarily to facilitate constraint equation formulation within the computation module.

CLASSROOM (EIGHT POSITION CHARACTER FIELD - FORMAT = XXXXX[BLDG]XXX[RM]). Classroom and laboratories are identified by both building and room number.

ROOM TYPE (ONE POSITION CHARACTER FIELD - FORMAT = X). Room type is used to further describe the available spaces. Type has been divided into three categories: (1) laboratory usage only - permanently installed equipment (includes training devices, simulators); (2) lecture usage only; and (3) both classroom and laboratory.

ROOM CAPACITY (THREE POSITION NUMERIC FIELD - FORMAT = XXX). The capacity represents the number of students that can be effectively instructed in the identified space. Room capacities are a function of the number of equipments installed in the space and/or the number of desks or chairs which can be positioned in the space. The equipment variable is incorporated into the description of the classrooms and laboratories, and equipment constraints are included, by definition, in room capacities.

REQUIRED HOURS (FIVE POSITION NUMERIC FIELD - FORMAT = XXXX.X). Required hours represent the number of hours the indicated space is required to convene one session of the referenced course.

AVAILABLE HOURS (FIVE POSITION NUMERIC FIELD - FORMAT = XXXXX). The number of hours, on an annual basis, the space is available for instructional purposes.

DATA ELEMENT SOURCE. Data elements in the DOTS data base which are utilized by the SCRR model are derived from two primary sources. The following data elements can be obtained from CNTECHTRA Instructor Computation form 5311-1.

a. Course Identification

b. Course Length

c. Class Input Capacity

d. Convenings Per Year

e. Student/Instructor Ratio

f. Contact Hours

g. Number of Instructors

h. Contact Hour Type.

A completed CNTECHTRA form 5311-1 for each course of instruction at FLETRACEN NORVA is on file with the center's Director of Training. The remaining data items, while not systematically maintained and not available from a single point of contact at the training center, are available from each of the center's eleven school directors. Training center officials will be responsible for the accuracy of the data base contents.

OUTPUT PARAMETERS DESCRIPTION

The SCRR model utilizes a linear programming technique to optimize student throughput, subject to limitations of resources required to convene training courses. One of the model output parameters, number of course convenings, provides the basis for the student throughput calculation for each model run. Class capacity is also a factor in the throughput calculation, but capacity remains constant for each model run. The levels of resources required to achieve the optimal student throughput are the only other model output parameters. One section of model output dealing with the LP optimal solution and the sensitivity analysis results is devoted to each type of parameter. The Requirements Specification Listing provides the model user with a cross-tabulation of courses and resource requirements. The Requirements Specification Listing is created by the LP problem formulation module. The objective of the listing is to correlate the DOTS data base input with the LP Optimal Solution and Sensitivity Analysis output. The two types of model output parameters will be described by an explanation of the three SCRR model output listings:

a. Requirements Specification Listing

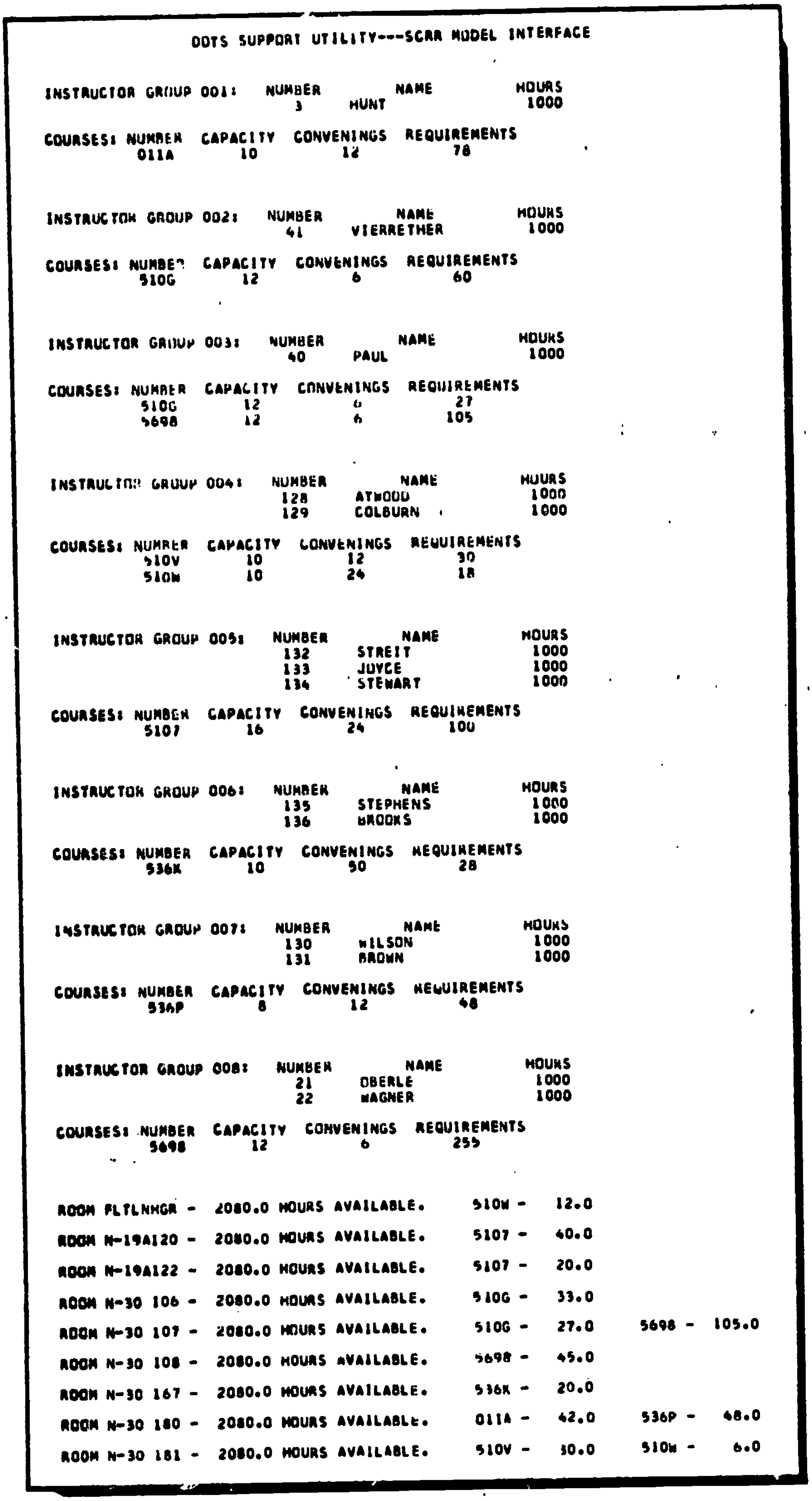
b. LP Optimal Solution and Sensitivity Analysis - Resource Data

c. LP Optimal Solution and Sensitivity Analysis - Course Data.

REQUIREMENTS SPECIFICATION LISTING. A sample printout of the Requirements Specification Listing is presented in Figure II-2. The listing correlates the training resources - instructors, classrooms, and laboratories - with specific course numbers. The DOTS data base is organized by course. It contains course statistics and delineates training resource requirements for each course. The Requirements Specification Listing is organized by resource. It denotes all courses which have a requirement for that particular resource. For example, from Figure II-2, instructor group 003 is required 27 hours per course 510G convening and 105 hours per course 5698 convening. Room 180 in building N-30 is required 42 hours per course 011A convening and 48 hours per course 536P convening.

The specification listing also identifies the members of each instructor group by instructor number and name. Total available contact hours per instructor are also noted. It should be pointed out that the instructor group numbers appearing in both the Requirements Specification Listing and the LP Optimal Solution and Sensitivity Analysis output are identical to each other, but are not related to the group number used in the DOTS data base.

Instructor group numbers are not permanently assigned. The numbers are assigned sequentially each time the SCRR model is run and are a function of the set of courses included in the model run. The members of the instructor group will remain constant unless modified in the DOTS data base. For example, in the SCRR model run from which Figure II-2 was extracted, instructor group 004 has two members -- Atwood and Colburn. If the SCRR model was run for a different set of courses, Atwood and Colburn may become instructor group 002 or group 037, or some other group number. However, regardless of the set of courses for which the SCRR model is run, Atwood and Colburn will always constitute one instructor group as long as they are assigned to courses 510V and 510W.



```
                    DOTS SUPPORT UTILITY---SCRR MODEL INTERFACE

INSTRUCTOR GROUP 001:    NUMBER          NAME            HOURS
                            3     HUNT                    1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           011A       10          12            78


INSTRUCTOR GROUP 002:    NUMBER          NAME            HOURS
                           41     VIERRETHER              1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           510G       12           6            60


INSTRUCTOR GROUP 003:    NUMBER          NAME            HOURS
                           40     PAUL                    1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           510G       12           6            27
           5698       12           6           105


INSTRUCTOR GROUP 004:    NUMBER          NAME            HOURS
                          128     ATWOOD                  1000
                          129     COLBURN                 1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           510V       10          12            30
           510W       10          24            18


INSTRUCTOR GROUP 005:    NUMBER          NAME            HOURS
                          132     STREIT                  1000
                          133     JOYCE                   1000
                          134     STEWART                 1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           5107       16          24           100


INSTRUCTOR GROUP 006:    NUMBER          NAME            HOURS
                          135     STEPHENS                1000
                          136     BROOKS                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           536K       10          50            28


INSTRUCTOR GROUP 007:    NUMBER          NAME            HOURS
                          130     WILSON                  1000
                          131     BROWN                   1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           536P        8          12            48


INSTRUCTOR GROUP 008:    NUMBER          NAME            HOURS
                           21     OBERLE                  1000
                           22     WAGNER                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
           5698       12           6           255


ROOM FLTLNHGR -  2080.0 HOURS AVAILABLE.     510W -   12.0

ROOM N-19A120 -  2080.0 HOURS AVAILABLE.     5107 -   40.0

ROOM N-19A122 -  2080.0 HOURS AVAILABLE.     5107 -   20.0

ROOM N-30 106 -  2080.0 HOURS AVAILABLE.     510G -   33.0

ROOM N-30 107 -  2080.0 HOURS AVAILABLE.     510G -   27.0     5698 -  105.0

ROOM N-30 108 -  2080.0 HOURS AVAILABLE.     5698 -   45.0

ROOM N-30 167 -  2080.0 HOURS AVAILABLE.     536K -   20.0

ROOM N-30 180 -  2080.0 HOURS AVAILABLE.     011A -   42.0     536P -   48.0

ROOM N-30 181 -  2080.0 HOURS AVAILABLE.     510V -   30.0     510W -    6.0
```

FIGURE II-2 REQUIREMENTS SPECIFICATION LISTING

LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS - RESOURCE DATA. The linear programming module calculates the number of course convenings required to maximize student throughput. This portion of the SCRR model output specifies the level of resources required to attain the optimal number of course convenings. The output specifies the levels to which each individual resource can increase and decrease before it is required to rerun the SCRR model. Also identified is the incremental student throughput change per unit increase or decrease up to those levels. This output assumes that the rest of the problem is unaltered; that is, the remaining input data are left constant, and the solution is adjusted as necessary to maintain feasibility and optimality.

Resource. An example of the LP Optimal Solution and Sensitivity Analysis - Resource Data output is shown in Figure II-3. The first column identifies the resources required by each of the courses processed by the model. The same resource name can be located in the Requirements Specification Listing which provides the model user with detailed resource data. For example, IG001 in Figure II-3, is identified as instructor group 001 in Figure II-2. From Figure II-2, only one instructor (No. 3, Hunt) belongs to the group. IG001 instructs only one course; 011A which requires 78 IG001 contact hours per convening.

Annual Availability. Column two in Figure II-3 (Annual Availability [Hours]) denotes the number of hours per year each resource is available to fulfill course requirements. Instructor group availability represents the sum of the availabilities of the individual members of the group. Individual instructor contact hour availability figures do not include the following activities: supervisory duties; military duties; preparation for instruction; duties related to instruction; annual leave; illness; special training; and break-in time.

Annual Utilization. The annual utilization column identifies the number of hours per year each resource is required to achieve the optimal number of course convenings.

Hours Underutilized. Hours underutilized or resource slack time represent the difference between annual availability and annual utilization.

Percent Utilization. Percent utilization is the ratio of utilization to availability.

Resource Utilization Range. The resource utilization range indicates the level to which each resource may be increased or decreased without rerunning the SCRR model. Changes in resource level beyond this range will necessitate modifying the data base to reflect the new resource levels, and rerunning the SCRR model. Resource utilization changes within the specified range will affect the value of the optimal solution which is stated in terms of optimal student throughput. The magnitude of this effect (either positive or negative) is indicated by the next column, Throughput Change Per Unit Resource Change.

An example will illustrate the above explanation. IG001 (from Figure II-3) utilization range is 936-2793 hours. IG001 optimum utilization level is equal to its annual availability, or 1000 hours. If IG001 availability were to decrease below 936 hours, the indicated optimal solution would change. From the Requirements Specification Listing (Figure II-2), it is seen that IG001 instructs course 011A. Since minimum IG001 requirements for course 011A are

936 hours (78 hours per convening X 12 convenings per year), a decrease below 936 hours would result in an infeasible solution. IG001 utilization also cannot be extended beyond 2793 hours without changing the optimal solution.

A utilization decrease in the range of 936-1000 hours would decrease the indicated optimum student throughput by 0.038 for each hour of decreased utilization. On the other hand, should utilization be allowed to increase beyond the 1000 hour level, the optimal student throughput would increase by .038 per hour of increased utilization.

Throughput Change Per Unit Resource Change. This column identifies change in the optimal student throughput which will result from a one hour change in resource utilization. As long as the resource utilization level remains within the indicated utilization range, the SCRR model need not be rerun. The effect of the resource change can be determined by a simple calculation using the throughput change per unit resource change.

The sensitivity analysis output, in particular the Throughput Change Per Unit Resource Change column, assumes a continuous relationship between the parameter representing the course convenings and the resource requirements parameter. For example, if 10 contact hours are required to convene a course one time, it is assumed that 11 contact hours will result in 1.1 course convenings, 15.5 contact hours will net 1.55 convenings, and 20 contact hours will provide 2 course convenings. Since all convenings are stated in terms of convenings per year, it is possible to interpret a fractional convening as a course which convenes prior to the end of the year but does not conclude until the following year; i.e., 0.5 convenings indicate that a course is one-half complete at the end of the year. However, except for this year-end interpretation, fractional convenings have no meaning in the real world. Once a course is convened it is always completed. Therefore, in reality the convening-resource relationship, although linear, is not continuous. It is important that the model user keep this fact in mind when interpreting the sensitivity analysis output.

Another example from the LP Optimal Solution and Sensitivity Analysis - Resource Data output (Figure II-3) will be used to demonstrate the significance of the throughput change per unit resource change. The utilization range of IG002 is indicated to be 392-822 hours. IG002 annual availability is equal to 1000 hours, while the indicated optimal solution requires a utilization level of 822 hours. If IG002 utilization were to decrease from 822 hours, the SCRR model would not have to be rerun since it can be seen from the throughput change column that student throughput will decrease by .149 for each hour of decreased IG002 utilization. However, since in reality, instructor resources are not applied or reduced on an hour by hour basis, let us examine the time consequence of the above statement. Examination of Figure II-2 indicates that IG002 instructs course 510G. Sixty IG002 contact hours are required for 510G convening. Therefore, IG002 resource will be used in 60 hour increments. A 60 hour decrease in IG002 utilization will decrease total student throughput by 8.9 (.149 per hour X 60 hours). This is an interesting result. Since we are decreasing total 510G convenings by one convening, we would expect the student throughput to decrease by 12 (510G class capacity). The Limiting Variable column (see explanation and example in following subsection) indicates that 5698 convenings will change as IG002 utilization is decreased. The connection becomes clear when we examine IG003 data in the Requirements Specification Listing (Figure II-2). Since IG003 instructs both 510G and 5698, 510G convenings decrease and 5698 convenings can be increased, although not on a one-to-one basis.

BEST COPY AVAILABLE

S C R R

LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

RESOURCE DATA

RESOURCE	ANNUAL AVAILABILITY (HOURS)	ANNUAL UTILIZATION (HOURS)	HOURS UNDER UTILIZED	PERCENT UTILIZATION	RESOURCE UTILIZATION RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER UNIT RESOURCE CHANGE	LIMITING VARIABLE
FLTLNMGR	2080	1093	987	53	288.0 1093.3	-0.333 -INFINITY	510V
IG001	1000	1000	0	100	936.0 2793.1	-0.038 0.038	011A 536P
IG002	1000	822	178	82	392.2 822.2	-0.149 -INFINITY	5698
IG003	1000	1000	0	100	792.0 1080.0	-0.444 0.444	510G IG002
IG004	2000	2000	0	100	792.0 3480.0	-0.556 0.556	510M FLTLNMGR
IG005	3000	3000	0	100	2400.0 5200.0	-0.160 0.160	5107 N-19A120
IG006	2000	2000	0	100	1400.0 2912.0	-0.357 0.357	536K N-30.167
IG007	2000	1542	458	77	576.0 1576.0	-0.167 -0.071	N-30.180 IG001
IG008	2000	1530	470	77	1530.0 2035.1	-INFINITY -0.136	 5698
N-19A120	2080	1200	880	58	960.0 1200.0	-0.400 -INFINITY	IG005
N-19A122	2080	600	1480	29	480.0 600.0	-0.800 -INFINITY	IG005
N-30.106	2080	452	1628	22	215.7 452.2	-0.270 -INFINITY	5698
N-30.107	2080	1000	1080	48	792.0 1000.0	-0.444 -INFINITY	IG003
N-30.108	2080	270	1810	13	270.0 352.9	-INFINITY -0.770	 5698
N-30.167	2080	1429	651	69	1000.0 1428.6	-0.500 -INFINITY	IG006
N-30.180	2080	2080	0	100	1114.5 2538.5	-0.167 0.167	536P IG007
N-30.181	2080	907	1173	44	504.0 1712.0	-1.667 -0.333	IG004 510V

FIGURE II-3 LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS - RESOURCE DATA

(THIS PAGE INTENTIONALLY LEFT BLANK.)

The minimum IG002 requirement for course 510G is 360 hours (60 hours per convening X 6 convenings per year). The difference between the optimal IG002 utilization level of 822 hours and the minimum 510G requirements is used to increase the number of 510G convenings and, therefore, the student throughput, since (from Figure II-2) IG002 is not qualified to instruct any other courses. The ability to increase 510G convenings is meaningful only if corresponding increases in demand for course 510G can be projected. If no increased demand can be projected for 510G, then 510G convenings should be maintained at the current level. If the decision is made to maintain the current level of 510G convenings, then IG002 will be underutilized 640 hours (1000 hours availability -360 hours required for 510G). These 640 hours could then be devoted to cross-training IG002 to qualify to instruct additional courses (the SCRR model can assist in the identification of courses which require additional instructors) or to perform other duties.

Limiting Variable. This column identifies the variable which limits the utilization range. Again referring to Figure II-3 and resource IG001, the column labeled "Limiting Variable" indicates that as IG001 utilization level is decreased from 1000 hours to a level of 936 hours, course 011A convenings will change. With the assistance of the Requirements Specification Listing (Figure II-2), this fact becomes obvious. As the instructor resource level is decreased, the number of course convenings must also decrease since these two variables are directly proportional. Similarly, as IG001 utilization is increased above the 1000 hours level, course 536P convenings will decrease. Since 011A and 536P share the same classroom (see Figure II-2), as 011A convenings increase, 536P convenings must decrease. The minimum 536P requirement for classroom 180 in building N-30 is 576 hours (48 hours per convening X 12 convenings per year). The remaining availability of room 180 becomes 1504 (2080-576) hours. Since 011A requires 42 hours per convening, course 011A can theoretically be convened 35.81 times in the remaining 1504 hours. 35.81 convenings X 78 hours per convening establishes the 2793 hour upper limit for IG001 utilization.

LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS - COURSE DATA. The optimal number of annual course convenings which will maximize student throughput is calculated by a linear programming technique. The sensitivity analysis provides information regarding the sensitivity of the optimal solution to changes in the input data, and the solutions that result from such changes. The levels to which the class capacity and the number of annual convenings can increase and decrease before the optimal solution changes are contained in the course data section of the LP Optimal Solution and Sensitivity Analysis output. It also gives the incremental change in student throughput per unit increase or decrease in course convenings up to these levels. As with the resource data output, the course data sensitivity analysis assumes that variables are changed individually and that the rest of the problem remains unaltered. A sample of the LP Optimal Solution and Sensitivity Analysis - Course Data output is shown in Figure II-4.

Course CDP Number. All courses are identified by the four digit CDP number.

Maximum Annual Convenings. This column lists the optimal number of annual course convenings for each course. The optimal number of convenings is that number of convenings which maximize total student throughput subject to the resource limitations identified in the previous output section. Any other combination of numbers of convenings for the same set of courses is either not feasible or will result in a lower student throughput. As an example, the

S C R R

LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

COURSE DATA

COURSE CDP NO.	MAXIMUM ANNUAL CONVENINGS	CURRENT SCHEDULED CONVENINGS	CLASS INPUT CAPACITY	ANNUAL CONVENINGS RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER COURSE CONVENING CHANGE	CLASS CAPACITY RANGE MINIMUM MAXIMUM	LIMITING VARIABLE
011A	12.8	12	10	1.9 12.8	-3.0 -INFINITY	7.0 +INFINITY	IG001
510G	13.7	6	12	6.5 13.7	-8.9 -INFINITY	3.1 +INFINITY	5698
510V	12.0	12	10	-37.3 52.3	6.7 -6.7	-INFINITY 16.7	FLTLNHGR 510W
510W	91.1	24	10	-6.7 91.1	-4.0 -INFINITY	6.0 +INFINITY	510V
5107	30.0	24	16	-INFINITY 30.0	-16.0 -INFINITY	0.0 +INFINITY	IG005
536K	71.4	50	10	-INFINITY 71.4	-10.0 -INFINITY	0.0 +INFINITY	IG006
536P	32.1	12	8	-INFINITY 32.8	-8.0 -3.4	0.0 11.4	N-30.180 IG001
5698	6.0	6	12	5.2 7.8	34.7 -34.7	-INFINITY 46.7	IG002 IG008

TOTAL CONVENINGS 269.2
TOTAL THOUGHPUT 2847.0

FIGURE II-4 LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS - COURSE DATA optimal number of convenings for course 011A is shown to be 12.8 (from Figure II-4). Since the number of convenings is established for a one year period, fractional convenings can be interpreted to mean that the course was convened but not completed in the same year. Therefore, 12.8 convenings are equivalent to 13 convenings with the last being eighty percent complete at the end of the year.

Current Scheduled Convenings. The current number of scheduled convenings listed in this column is identical to the number of convenings stored for each course in the DOTS data base. This number is established as a lower bound for the maximum annual convening parameters discussed above. In effect, the lower bound represents an additional constraint to the LP problem. The constraint to the variable representing the number of convenings for course 011A states that 011A convenings must be greater than or equal to 12.

Class Input Capacity. The Class Input Capacity is also retrieved from the DOTS data base. The class capacities are the LP objective function coefficients. Student throughput is established by multiplying the capacity of each class by the optimal number of convenings calculated for that course.

Capacities are based upon training considerations such as instructor to student ratio, availability of training equipment, workshop, laboratories, and mock-up facilities, as well as physical considerations such as classroom size.

Annual Convenings Range. The Annual Convenings Range indicates the upper and lower limits for the number of annual convenings parameter. The current LP solution remains optimal for all values of the convenings parameter within this range. However, as the number of annual convenings is varied from the indicated optimal, the maximum student throughput will either increase or decrease by the factor printed in the next column, Throughput Change Per Course Convening Change. The specified lower bound, which is the number of current scheduled convenings, is ignored in calculating the range of annual course convenings. For example, the range of annual convenings for course 510W is -6.7-91.1. The solution which maximizes student throughput is 91.1 convenings. The current number of scheduled convenings is 24 per year. If 10 convenings less than the optimal 91.1 were scheduled, the total student throughput would decrease by 40 (4 per convening). Note that the student throughput drops by only 4 per convening, in spite of the fact that 510W class capacity is 10. From Figure II-2 we see that courses 510V and 510W utilize the same instructor group. Therefore, as 510W convenings are decreased, additional convenings of 510V can be scheduled. But since 510V uses more instructor resource per convening, less 510V convenings can be scheduled with the resources made available by reducing 510W convenings.

The Annual Convenings Range also provides an indication of the effect of class size on the LP optimal solution. The current solution will remain optimal for class sizes in the range noted by the Class Capacity Range column. As the class size drops below the capacity range minimum, the optimal number of convenings will decrease to the convening range minimum, if that quantity is greater than the current number of scheduled convenings. If the convening range minimum is less than the Current Scheduled Convenings, then the optimal number of course convenings will be set equal to the Current Scheduled Convenings. For example, from Figure II-4, the optimal number of convenings for course 011A is 12.8 based on a class size of 10 students. Should the class size drop below seven (Class Capacity Range minimum), the optimal number of convenings would decrease to 12 since the Annual Convening Range minimum (1.9) is less than 12.

The optimal number of annual convenings for course 510G is 13.7 for a class size of 12. If the class size drops to three or less, the optimal convenings for that course will decrease to the Annual Convening Range minimum (6.5), rather than the Current Scheduled Convenings (6.0). The student throughput for the new optimal solution will decrease by 64.1 (decrease of 7.2 convenings X 8.9 student throughput decrease per convening).

Throughput Change Per Course Convening Change. This column indicates the change in the optimal student throughput which will result from a change in the number of course convenings. As long as the number of course convenings remains within the range indicated by the Annual Convening Range column, the SCRR model need not be rerun. The effect of a change in the number of convenings can be determined by a simple calculation using the Throughput Change Per Course Convening Change. Again, referring to Figure II-4, if course 5698 convenings were to increase from the six per year optimal to seven per year, the total student throughput would decrease by 34.7. From Figure II-2, courses 5698 and 510G share IG003. Increasing 5698 convenings from 6.0 to 7.8 shifts 189 hours of IG003 time from 510G to 5698. This 189 hour shift increases 5698 convenings by 1.8, but reduces possible 510G convenings by 7 (189 ÷ 27 hours per 510G convening). Therefore, student throughput will drop even though 5698 convenings are increased.

Class Capacity Range. This column indicates the range of class capacities for which the indicated optimal number of course convenings will remain unchanged. A decrease in class size to below the capacity range minimum will cause the optimal number of convenings to decrease to either the number of current scheduled convenings or the convening range minimum, whichever is greater. An increase in class size to beyond the capacity range maximum will increase the number of course convenings to the convening range maximum. Using course 510V from Figure II-4 as an example, if the class size were increased from the current level of 10, to 17 or more, the optimal number of convenings would increase to 52.3 per year from the current level of 12.

Limiting Variable. This column identifies the variable which limits the convenings range and whose value will change as a result of a variation from the optimal convening level within the course convening range. Several examples from Figure II-4 will clarify the significance of this column. As the number of course 011A convenings are decreased from the indicated optimum, IG001 utilization will decrease from the 100 percent shown in the SCRR output. This relationship is obvious since a decline in convenings will result in lower resource requirements.

As course 510G convenings decrease from the optimal, course 5698 convenings will increase from the Current Scheduled Convenings level. IG003 is shared by courses 510G and 5698. A decrease in 510G convenings, will increase the level of IG003 resources available for course 5698. Decreasing course 510G convenings will reduce the total student throughput by 8.9 per convening deleted.

Reducing course 5698 convenings from 6 to 5.2 will increase IG002 utilization. At 5.2 convenings, IG002 utilization will reach 100 percent. Therefore, a decrease in 5698 convenings below 5.2 will result in a Throughput Change Per Unit Resource Change other than 34.7. Similarly, 5698 convenings can be increased to 7.8 per year by increasing IG008 utilization to 100 percent.

MODEL/DATA BASE COMMUNICATION

The values for all input parameters which must be supplied to the SCRR model are stored in the data base. These parameter values are accessed and processed by the SCRR model component which formulates the LP objective function and constraint equations. The data accession process does not require user intervention, however, the user may limit the amount of data processed by the model to one or more schools. Unless specific school names are identified on the model control card, all training complex schools will be processed.

Data flow between the data base and the SCRR model is strictly one way. There is no direct feedback from the model to the data base. Data base maintenance is performed independently of model operation.

To demonstrate SCRR model and data base interaction, the resource requirement algorithm will be discussed in detail. The algorithm is implemented within the LP problem formulation module. The objective of the algorithm is to extract from the data base the data elements required to construct the Resource Requirement Matrix shown in Figure II-5.

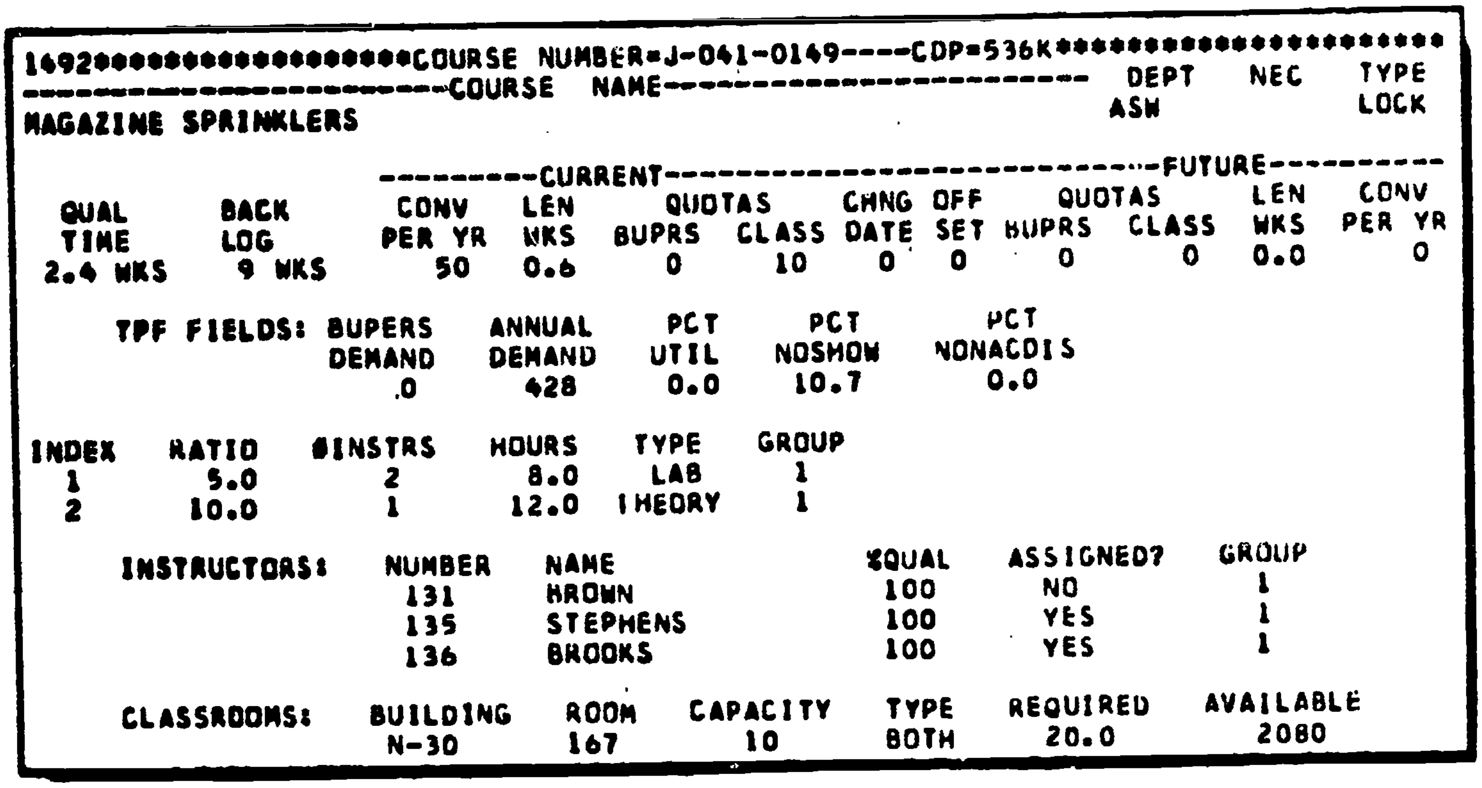
The data base printout for course (CDP number) 536K is presented in Figure II-6. The first step in the algorithm is to calculate the instructor requirement for the course. Two instructors are required for eight hours of lab work, and one instructor is required for twelve hours of classroom presentation. The total instructor contact hour requirement for course 536K is 28 hours. All requirements are fulfilled by instructor group 1. There are two instructors (135 and 136) currently assigned to course 536K who belong to instructor group 1. From the instructor data base (Figure II-7), it is determined that both instructor number 135 and 136 are available 1000 hours per year. Therefore, the total availability of instructor group 1 is 2000 hours. The absence of related course data for 536K indicates that instructors 135 and 136 are not currently instructing any additional courses. With this information, the first row of the Resource Requirement Matrix (Figure II-5) can be completed. Twenty-eight instructor group 1 contact hours are required per convening of course 536K. Instructor group 1 has a total annual availability of 2000 hours.

Returning to Figure II-6, it is seen that 536K has an additional requirement of 20 hours per convening for classroom 167 in building N-30. The same room is used for both classroom and lab sessions. It has an annual availability of 2080 hours. This information is also transferred to the requirements matrix.

Finally, the algorithm calls for the establishment of the minimum number of annual convenings for 536K. The number 50 is read from the data base and temporarily stored with the requirements matrix. When the requirements matrix has been established for all specified courses, the data are reformatted for input to the LP routine.

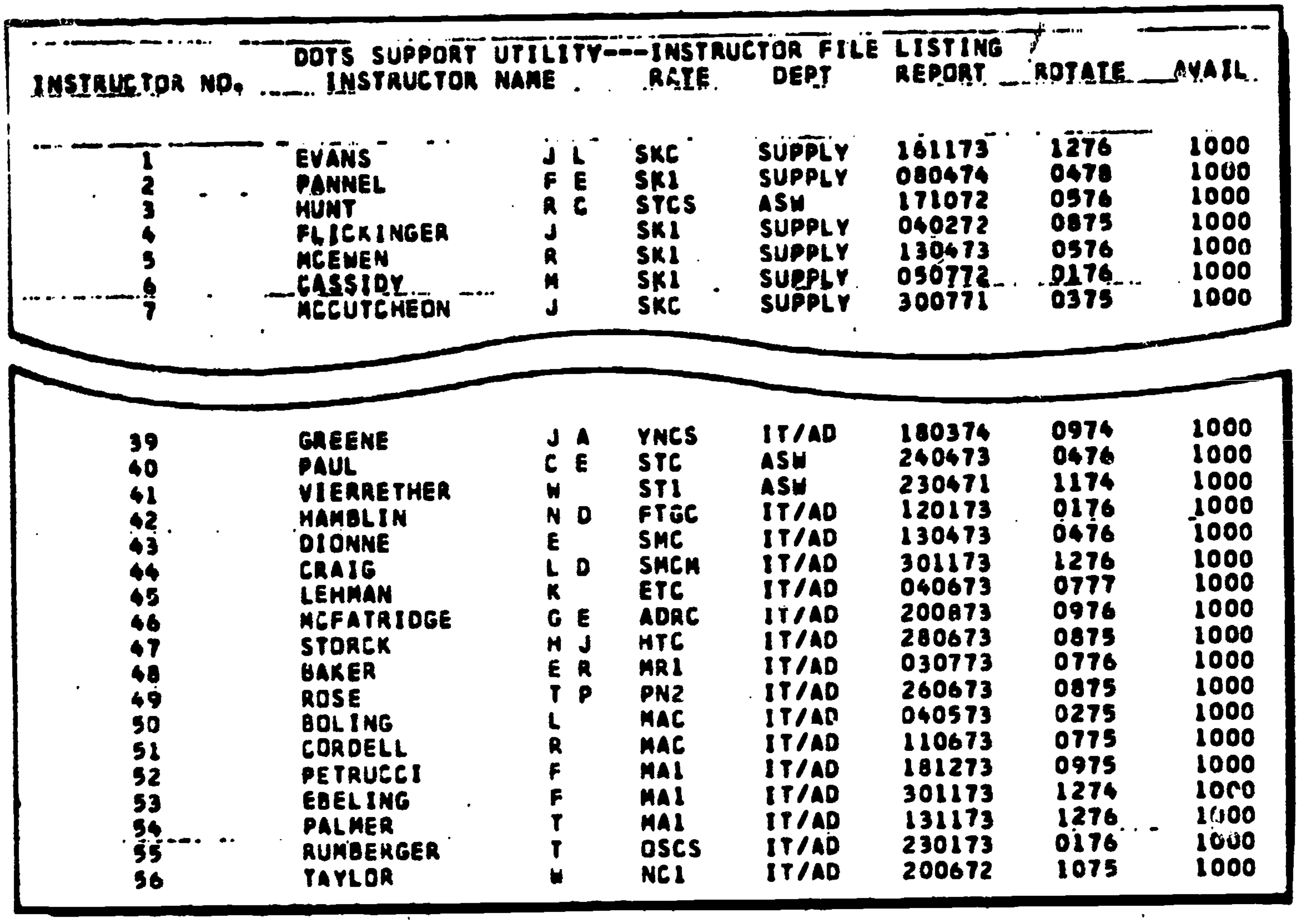
CONV	50	24	12	24	12	6	6	12		
RESOURCE COURSE	536K	5107	510V	510W	536P	510G	5698	011A		RESOURCE AVAILABILITY
INSTR GRP 1	28									2000
INSTR GRP 2		100								3000
INSTR GRP 3			30	18						2000
INSTR GRP 4					48					2000
INSTR GRP 5						60				1000
INSTR GRP 6						27	105			1000
INSTR GRP 7							255			2000
INSTR GRP 8								78		1000
N-30 167	20									2080
N-19A 120		40								2080
N-19A 122		20								2080
N-30 181			30	6						2080
FLTLN HGR				12						2080
N-30 180					48			42		2080
N-30 106						33				2080
N-30 107						27	105			2080
N-30 108							45			2080

FIGURE II-5 RESOURCE REQUIREMENT MATRIX



```
1692**********************COURSE NUMBER=J-041-0149----CDP=536K**********************
---------------------------COURSE  NAME--------------------------  DEPT    NEC    TYPE
MAGAZINE SPRINKLERS                                                ASW            LOCK

                    ---------CURRENT----------------------------FUTURE----------
  QUAL      BACK      CONV   LEN     QUOTAS      CHNG OFF    QUOTAS     LEN    CONV
  TIME      LOG      PER YR  WKS  BUPRS  CLASS   DATE SET  BUPRS  CLASS WKS   PER YR
 2.4 WKS    9 WKS      50    0.6    0      10      0   0     0      0   0.0      0

      TPF FIELDS: BUPERS    ANNUAL    PCT     PCT      PCT
                  DEMAND    DEMAND    UTIL    NOSHOW   NONACDIS
                    .0       428      0.0     10.7     0.0

INDEX    RATIO    #INSTRS    HOURS   TYPE    GROUP
  1       5.0        2        8.0    LAB       1
  2      10.0        1       12.0   THEORY     1

      INSTRUCTORS:    NUMBER    NAME                   %QUAL    ASSIGNED?    GROUP
                       131      BROWN                   100        NO          1
                       135      STEPHENS                100        YES         1
                       136      BROOKS                  100        YES         1

      CLASSROOMS:    BUILDING    ROOM    CAPACITY    TYPE    REQUIRED    AVAILABLE
                       N-30       167       10       BOTH      20.0        2080
```

FIGURE II-6 DATA BASE LISTING - COURSE 536K



```
                     DOTS SUPPORT UTILITY---INSTRUCTOR FILE LISTING
INSTRUCTOR NO.       INSTRUCTOR NAME          RATE      DEPT      REPORT    ROTATE    AVAIL

        1            EVANS           J L      SKC       SUPPLY    161173    1276      1000
        2            PANNEL          F E      SK1       SUPPLY    080474    0478      1000
        3            HUNT            R C      STCS      ASW       171072    0576      1000
        4            FLICKINGER      J        SK1       SUPPLY    040272    0875      1000
        5            MCEWEN          R        SK1       SUPPLY    130473    0576      1000
        6            CASSIDY         M        SK1       SUPPLY    050772    0176      1000
        7            MCCUTCHEON      J        SKC       SUPPLY    300771    0375      1000

       39            GREENE          J A      YNCS      IT/AD     180374    0974      1000
       40            PAUL            C E      STC       ASW       240473    0476      1000
       41            VIERRETHER      W        ST1       ASW       230471    1174      1000
       42            HAMBLIN         N D      FTGC      IT/AD     120173    0176      1000
       43            DIONNE          E        SMC       IT/AD     130473    0476      1000
       44            CRAIG           L D      SMCM      IT/AD     301173    1276      1000
       45            LEHMAN          K        ETC       IT/AD     040673    0777      1000
       46            MCFATRIDGE      G E      ADRC      IT/AD     200873    0976      1000
       47            STORCK          H J      HTC       IT/AD     280673    0875      1000
       48            BAKER           E R      MR1       IT/AD     030773    0776      1000
       49            ROSE            T P      PN2       IT/AD     260673    0875      1000
       50            BOLING          L        MAC       IT/AD     040573    0275      1000
       51            CORDELL         R        MAC       IT/AD     110673    0775      1000
       52            PETRUCCI        F        MA1       IT/AD     181273    0975      1000
       53            EBELING         F        MA1       IT/AD     301173    1274      1000
       54            PALMER          T        MA1       IT/AD     131173    1276      1000
       55            RUMBERGER       T        OSCS      IT/AD     230173    0176      1000
       56            TAYLOR          W        NC1       IT/AD     200672    1075      1000
```

FIGURE II-7 INSTRUCTOR FILE LISTING

The resource requirement algorithm is repeated for course 5107. The algorithm sequentially numbers the instructor groups as they are added to the requirements matrix. Course 5107 has a requirement of 100 instructor group 2 contact hours per convening. Instructor group 2 annual availability is 3000 hours. Classrooms 120 and 122 in building N-19A are required 40 and 20 hours respectively per convening. To fulfill minimum training requirements, course 5107 must convene at least 24 times per year.

One final example in which a single course is instructed by multiple instructor groups and a single instructor group instructs more than one course, will be examined. Referring again to the Resource Requirement Matrix, Figure II-5, it can be seen that both course 510G and 5698 have requirements for two instructor groups and that one of these groups instructs both courses. The requirements algorithm first calls the data elements describing course (CDP number) 510G from the data base (see 510G data printout, Figure II-8). Contact hour requirements are specified for two instructor groups. Instructor group 1 is required for 33 hours of classroom lecture, plus an additional 27 hours of lab, for a total of 60 hours per convening. Only one instructor (41) currently assigned to course 510G is included in instructor group 1. From the instructor file (Figure II-9), instructor 41 is available 1000 hours per year. Since no related courses are specified for instructor group 1, the above information is entered in the requirements matrix (Figure II-5) in the instructor group 5 row. Group numbers are sequentially assigned in the construction of the requirements matrix and have no meaning except to differentiate between groups.

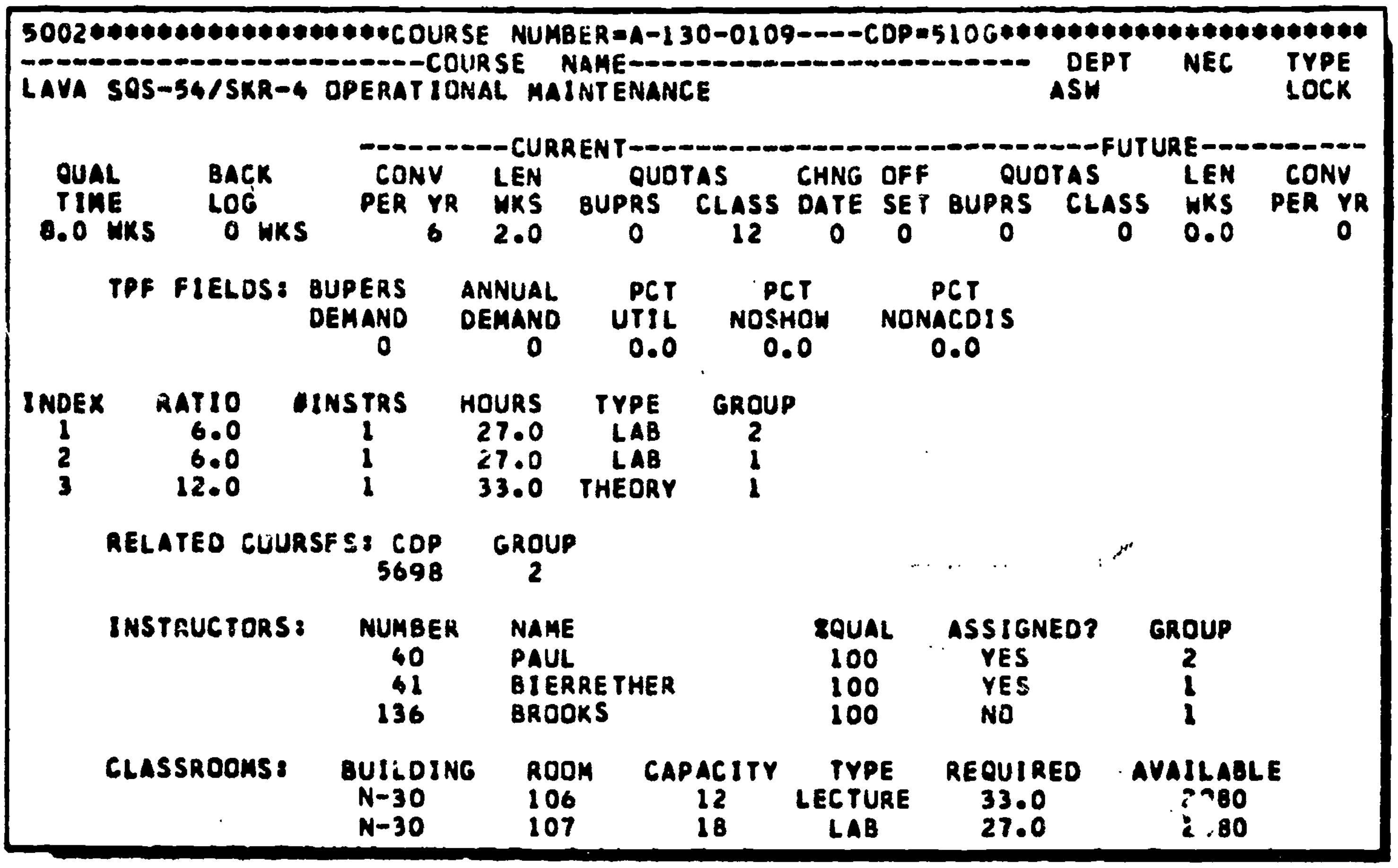
Referring back to Figure II-8, instructor group 2 is required 27 hours per convening for lab instruction. Instructor group 2 consists of only one instructor (40) who (from the instructor file, Figure II-7) is available 1000 hours per year. However, from the related course data, instructor group 2 is also utilized for course 5698. Course file data for course 5698 are presented in Figure II-9. Instructor group 2, whose sole member is instructor 40, is required 105 hours per convening of course 5698 for lab instruction. The requirements matrix shows a requirement of 27 hours per convening of course 510G and an additional requirement of 105 hours per course 5698 convening, against a total availability of 1000 hours for instructor group 6.

The convening frequencies and space requirements for courses 510G and 5698 were also read from the course file and entered in the requirements matrix according to the procedures previously described.

All Resource Requirement Matrix data plus the identification of instructor group members, are available to SCRR model users in the Requirements Specification Listing.

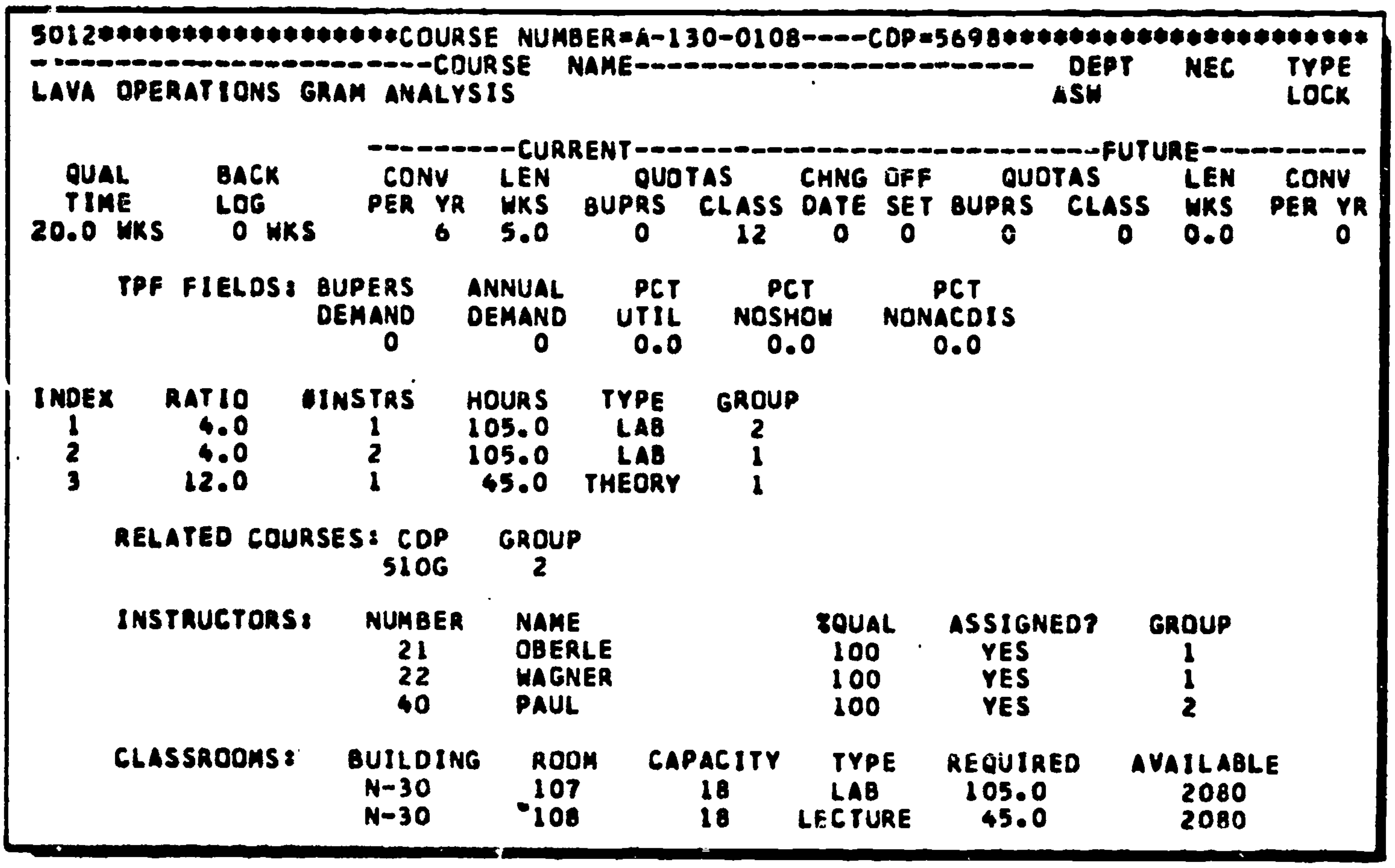
LOGIC DESIGN

A mathematical model of a system is a collection of mathematical relationships which characterize the feasible solutions of the system. By feasible solutions, is meant those solutions which can be carried out under the system's limitations. The technique utilized to solve the SCRR mathematical model is linear programming. Linear programming establishes the optimal system solution by iteratively evaluating feasible solutions against an expressed objective. Before the linear programming technique can be used, several basic requirements must be fulfilled. This section will discuss these basic requirements and demonstrate that these requirements are fulfilled by the



```
5002*******************COURSE NUMBER=A-130-0109----CDP=510G**********************
-----------------------COURSE  NAME-----------------------  DEPT   NEC   TYPE
LAVA SQS-56/SKR-4 OPERATIONAL MAINTENANCE                   ASW           LOCK

                     ---------CURRENT----------------------------FUTURE----------
 QUAL     BACK       CONV   LEN     QUOTAS     CHNG OFF    QUOTAS      LEN   CONV
 TIME     LOG        PER YR WKS  BUPRS  CLASS  DATE SET BUPRS  CLASS   WKS  PER YR
 8.0 WKS   0 WKS         6  2.0     0     12     0   0     0       0   0.0      0

    TPF FIELDS: BUPERS    ANNUAL   PCT    PCT      PCT
                DEMAND    DEMAND   UTIL   NOSHOW   NONACDIS
                  0         0      0.0    0.0       0.0

INDEX   RATIO   #INSTRS    HOURS   TYPE    GROUP
  1      6.0      1        27.0    LAB       2
  2      6.0      1        27.0    LAB       1
  3     12.0      1        33.0   THEORY     1

    RELATED COURSES: CDP    GROUP
                     5698     2

    INSTRUCTORS:     NUMBER   NAME                 %QUAL   ASSIGNED?   GROUP
                       40     PAUL                  100      YES         2
                       41     BIERRETHER            100      YES         1
                      136     BROOKS                100      NO          1

    CLASSROOMS:   BUILDING   ROOM   CAPACITY   TYPE     REQUIRED   AVAILABLE
                   N-30      106      12      LECTURE    33.0        2080
                   N-30      107      18       LAB       27.0        2080
```

FIGURE II-8 DATA BASE LISTING - COURSE 510G



```
5012*******************COURSE NUMBER=A-130-0108----CDP=5698**********************
-----------------------COURSE  NAME-----------------------  DEPT   NEC   TYPE
LAVA OPERATIONS GRAM ANALYSIS                               ASW           LOCK

                     ---------CURRENT----------------------------FUTURE----------
 QUAL     BACK       CONV   LEN     QUOTAS     CHNG OFF    QUOTAS      LEN   CONV
 TIME     LOG        PER YR WKS  BUPRS  CLASS  DATE SET BUPRS  CLASS   WKS  PER YR
20.0 WKS   0 WKS         6  5.0     0     12     0   0     0       0   0.0      0

    TPF FIELDS: BUPERS    ANNUAL   PCT    PCT      PCT
                DEMAND    DEMAND   UTIL   NOSHOW   NONACDIS
                  0         0      0.0    0.0       0.0

INDEX   RATIO   #INSTRS    HOURS   TYPE    GROUP
  1      4.0      1       105.0    LAB       2
  2      4.0      2       105.0    LAB       1
  3     12.0      1        45.0   THEORY     1

    RELATED COURSES: CDP    GROUP
                     510G     2

    INSTRUCTORS:     NUMBER   NAME                 %QUAL   ASSIGNED?   GROUP
                       21     OBERLE                100      YES         1
                       22     WAGNER                100      YES         1
                       40     PAUL                  100      YES         2

    CLASSROOMS:   BUILDING   ROOM   CAPACITY   TYPE     REQUIRED   AVAILABLE
                   N-30      107      18       LAB      105.0        2080
                   N-30      108      18      LECTURE    45.0        2080
```

FIGURE II-9 DATA BASE LISTING - COURSE 5698

SCRR model application. Also included in this section is a discussion of the real world interpretation of a linear programming optimal solution. Assumptions and limitations relative to the SCRR mathematical model variables are also discussed.

LINEAR PROGRAMMING BASIC REQUIREMENTS. As the name "linear programming" implies, both the objective function and every constraint function must be linear. Linearity is a primary requirement of linear programming. A linear relationship is essentially defined by two properties, proportionality and additivity. In addition to these two major characteristics, three additional requirements must be adhered to: nonnegativity; divisibility; and deterministic coefficients.

Proportionality. Linearity requires a proportionality or a simple multiplicative relationship between the units of resource requirements and the number of convenings of each course. For example, if six instructor 1 contact hours are required to convene course A one time, then 12 hours are required for two convenings, and 24 hours are required for four convenings, etc., assuming a constant class size. The amount of resource required is the same for the n-th convening as it is for the first. This is an important property of linearity from the practical point of view. If, for example, it was the case for some instructional curriculum that 60 hours of a given resource were required to attain 30 convenings of some course, but only 100 hours of the resource were required to attain 60 convenings of this course, then the proportionality assumption would not hold. It is obvious, assuming that class size is held constant for each model run that for the SCRR model application, the resource requirements are proportional to the number of course convenings and to the student throughput for a constant class size. The objective function of the current SCRR model formulation is to maximize student throughput based on specified course capacities. Course requirements are calculated based on a constant class capacity. Subsequent model runs may be made for different class sizes. Therefore, for each model run, throughput will be linearly related to resource requirements.

Additivity. The additivity property of linear relationships states that the measures of effect as calculated through the objective function, and the levels of resources as expressed in the constraint equations, must both be additive. The objective function measure of effect is student throughput, which is calculated by multiplying the course capacity by the number of convenings. Thus, if course A's capacity is 6 and it is convened 10 times each year, the annual throughput for A is 60, and if course B has a capacity of 20 and is convened 15 times per year, its throughput is 300. The additivity property states that the total throughput for the two courses is then 360. A similar example will demonstrate the additivity property's involvement in the constraints of the linear programming model. Instructor 1 teaches both courses A and B. Twenty-five hours of his time are required for each convening of course B. Since A meets ten times each year and B fifteen times, instructor 1's total requirement is 400 hours (250 for A and 150 for B). Like the above example, all SCRR model resource requirements are additive across all courses.

Nonnegativity. The nonnegativity property states that while any positive multiple of course convenings is possible, negative course convenings are not possible. Adherence to this restriction is ensured through the MPSX program. The MPSX program allows the user to specify both upper and lower bounds for the decision variables. If a lower bound is not specified, the program assumes a value of zero. Unspecified upper bounds are set equal to infinity. In the case of the SCRR model application, the LP problem formulation algorithm sets the lower bound for course convenings equal to the number of annual convenings (which is always a positive quantity) stored in the data base. A negative number of course convenings is meaningless.

Divisibility. The divisibility property requires that fractional levels of the decision variables be permissible. In many linear programming models, the decision variables would have physical significance only if they have integer values. There is no guarantee that the solution procedure utilized within the SCRR model will yield an integer solution. If an integer solution is required, the common procedure is to round the non-integer optimal solution down to the nearest integer. This course of action could produce two problems. First, this integer solution need not be feasible. Second, even if it is feasible, this solution need not be too near optimality. Since fractional values for the number of course convenings is interpretable, the SCRR model application fulfills the divisibility property requirement. A fractional course convening is interpreted as a course which is convened but is not completed in a calendar year. For example, 0.5 convenings could be associated with a two week course which is convened the last week of a calendar year. In the event that the decision is made sometime in the future to consider only integer-valued number of convenings, the SCRR model could be easily modified to handle this restriction, since MPSX has integer programming capability.

Deterministic Coefficients. All of the coefficients in a linear programming model are assumed to be known constants. In the SCRR model application, this includes class capacities, instructor and space requirements per convening, and instructor and space availabilities. The fact that any or all of the LP coefficients may not be known constants does not invalidate model results, but does require the expenditure of additional effort. (A sensitivity analysis is generally performed to determine the effect on the optimal solution if particular parameters take on other possible values.) Sensitivity analysis is employed to determine the effect of changing the value of a single parameter. It is often of interest to investigate making simultaneous changes in a number of parameters and to study what happens as the magnitude of these simultaneous changes increase. A systematic study of such changes in certain parameters of a linear programming model is the objective of parametric linear programming. A post optimal sensitivity analysis is built into the SCRR model. Sensitivity analysis results are included in the SCRR model output. Parametric programming may be performed by the model user by systematically varying the parameters of interest, rerunning the SCRR model, and comparing results.

INTERPRETATION OF LP OPTIMAL SOLUTION. The SCRR model can be operated in two different modes. The number of course convenings can be specified by the user. The model will then calculate the resources required to achieve that number of convenings, and compare the required resources with present resource capabilities. On the other hand, the SCRR model could be run against the data base which depicts current resource capabilities and specifies a minimum number of course convenings. The model will determine the maximum student throughput which could be attained with current resources. Model results from the former operating mode are straight-forward and require no additional explanation. Interpretation of model results in the latter case is more complex.

Consider the following example. Course A is currently scheduled to convene 24 times per year. The SCRR model is run to optimize throughput based on current resources. Model results indicate that course A should be convened 93.7 times per year! Since the user is aware that course A utilization is currently averaging about 70 percent and a reduction in convening frequency is being considered, the model results appear absurd. However, the objective of the SCRR model was to maximize throughput, which is defined as course capacity times the number of convenings, subject to current resource capabilities. Throughput can be increased only by increasing convening frequency. Convening frequency is limited only by available resources. Capability to increase convening frequency to nearly four times the current schedule implies that present course A resources are being utilized approximately 25 percent of the available time! Therefore, the question the SCRR model user should be considering is not should course A be convened 93 times per year, but how can course A resources be utilized more effectively? Resource availabilities stored in the data base should be examined. Perhaps the original availability estimate was too high. Frequent curricula updates may reduce the time available for classroom instruction. Or the instructor(s) could be cross-trained to instruct one or more additional courses. The same model output which indicated 93.7 convenings for course A, may also have pointed out other courses which could not meet minimum convening requirements because of lack of resources.

The user should investigate all the above possibilities. Model input parameters could be modified and the model rerun to assist in the evaluation of the feasible alternatives.

ASSUMPTIONS AND LIMITATIONS OF SCRR MODEL VARIABLES. The laboratory and classroom facilities; i.e., the number of spaces available for course presentation, lab equipment, training aids, and other major equipment installed in these spaces, are considered to be fixed in their availability in the short run (up to two years), but variable over longer time spans. Therefore, a time lag of from one to two years is assumed between a decision to procure major equipment or to construct classroom or lab facilities, and the completion of the installation or construction.

Although short-range availability of classrooms and laboratories is considered fixed, an estimate of the availability of individual classrooms or labs has not been attempted. A uniform availability of 40 hours per week for 52 weeks per year or a total of 2080 hours per year has been assumed for all classroom and laboratory spaces. The SCRR model user has three options relative to space availability: (1) maintain the assumption of a uniform 2080 hours per year availability; (2) establish the availability on a room by room basis for the training complex; or (3) utilize the SCRR model to perform parametric studies to determine the effect of facility availability.

The authorized allowance of instructors is considered to be fixed in the short run. The actual on-board count of instructors is considered variable in both the short and the long run. In the short run, variations in the on-board count may be caused by many factors (temporary additional duty, vacations, illness, time lag between assignment rotation and receipt of replacement). In the long run, higher authorities can change the instructor allowance as a function of major changes in curriculum or requirements, changes in command mission, or the general level of manpower authorizations.

On-board instructor count can be easily maintained within the data base. However, given on-board count, the key SCRR model variable becomes instructor availability. Instructor availability is the number of hours per year an instructor has available for classroom instruction. Availability does not include supervisory requirements, military duties, preparation for instruction, duties related to instruction, annual leave, illness, special training, or break-in time. Both average instructor availability and individual instructor availability are unknown at this time. Availability standards ranging from 750 hours per year up to 1250 hours per year have been used by various organizations at different points in time[3]. The current Design of Training System (DOTS) data base shows instructor availability equal to 1000 hours per instructor per year. This number was selected because it represents the average of two documented standards. The intention is not to establish 1000 hours per year as a new instructor availability standard, but to use this number as a point of departure from which a more meaningful standard can be derived.

Individual instructor availability could potentially range from as high as 1500 hours per year to a minimum in the range of 100-200 hours per year, as a function of the amount of course related duties, administrative duties, etc. Availabilities for all instructors should be established by their respective school directors and entered in the DOTS data base.

The SCRR model should be utilized to perform a parametric analysis of instructor availability. Varying instructor availabilities from 700 to 1500 hours in 100 hour increments will provide training complex officials with an estimate of the sensitivity of training complex capabilities to instructor availability.

It is assumed that budget does not constrain the SCRR model solution in the short run. However, in the long run, budget constraints of a capital nature may alter the SCRR optimal solution, in that student throughput could be affected by the funding available for new construction and/or procurement of new equipment.

Course curricula are considered fairly inelastic in the short run. Drastic curriculum changes require a considerable amount of time to determine new requirements, develop new material, and secure headquarters review and approval. However, numerous minor changes to courses take place frequently, and a course may be dropped as a result of sustained low utilization.

Student/instructor ratios are generally a function of curriculum requirements. The generally accepted rule used in the establishment of these ratios is that the ratio of trainees per instructor for each instructional situation, should be set at that point which yields the highest possible ratio without serious detriment to the quality of instruction.

The optimum ratio should be based on consideration of the type of equipment, safety, and teaching effectiveness for the particular teaching situation. Since no more specific procedures other than the above exist, the establishment of student/instructor ratios remains highly subjective, and should be closely monitored by training complex officials.

---

[3] These figures are from BUPERSINST 1510.150 and CNTECHTRAINST 5311.1A respectively.

The current version of the SCRR model calculates all instructor requirements assuming 100 percent course utilization. The result of this assumption is that requirements are overstated for those courses which are consistently underutilized and whose instructor requirement is a function of class size. For example, course number J-780-0406, Damage Control/Firefighting, Shipboard, has a 12:1 student/instructor ratio for 10 hours of the firefighting portion of the course. The normal class capacity is 144. Thus if the course were 100 percent utilized, 12 instructors would be required for that 10 hour section of the course. However, if the course were averaging only 50 percent utilization, the instructor requirement would drop to six for the same portion of the course.

The SCRR model will be modified to include the impact of course utilization during Phase III of this project.

LEVEL 1 VALIDATION SCENARIOS

The purpose of the level 1 validation scenarios is to objectively demonstrate that all subelements of the SCRR model will perform the functions identified in the model description section (page II-1). Four scenarios will be presented in this section. The first two will exercise the SCRR model against the total DOTS data base. These scenarios have been designed to test each model subroutine, while simultaneously establishing model limitations with respect to problem size. The last two scenarios will demonstrate how the SCRR model can be used to assist training officials in the analysis and solution of typical problems.

SCENARIO 1 - EXECUTE THE SCRR MODEL USING THE ENTIRE MASTER DOTS DATA BASE AS INPUT DATA. The objective of this validation scenario is threefold:

a. To determine if the SCRR model software can process the entire 125 course data base within the storage limitations (120K) of the development computer.

b. To audit the SCRR interface and output formatting programs.

c. To audit the data base contents.

Scenario Input Data. This scenario requires no input data preparation. The model user need only select the appropriate Job Control Language (JCL) card deck (see SCRR model operating procedures, Volume III, Section II), and specify the master DOTS data base as the data source. The SCRR model interface program will then access the master data base, select the data elements required to formulate the linear programming problem, and prepare the input data for the MPSX module. The MPSX module solves the linear programming problem and passes the solution to the output formatting program, which prints the LP solution and sensitivity analysis results.

Special Run Conditions. Scenario 1 will formally test the following SCRR model software:

a. JCL to execute SCRR model from master data base.

b. All SCRR model interface program codes.

c. MPSX control program.

d. All output formatting program codes.

Design Criterion Tested. The core of the SCRR model is a linear programming computational technique. Since the time of its development nearly 30 years ago, linear programming has become accepted and widely used by both theoretical and applied mathematicians. The software package used to calculate the linear programming solution for the SCRR model is MPSX (Mathematical Programming System Extended), an IBM Program Product. Neither the linear programming technique nor the MPSX software will be subjected to validation testing.

The application of the linear programming technique to the problem of determining the best use of resources to meet training requirements, has been initially discussed in the logic design section (page II-24). The SCRR model linear programming problem formulation fulfills the basic mathematical prerequisites of proportionality and additivity. An important part of the validation testing is the determination that the linear programming model formulation approximates the real world to an acceptable degree. Several discussions relative to the evaluation and interpretation of model results have been included in the output parameter description subsection and the logic design subsection. Comparisons of model solutions with expected results will be included in the discussion of test results.

The validation scenarios have, therefore, been designed to test the following design criterion:

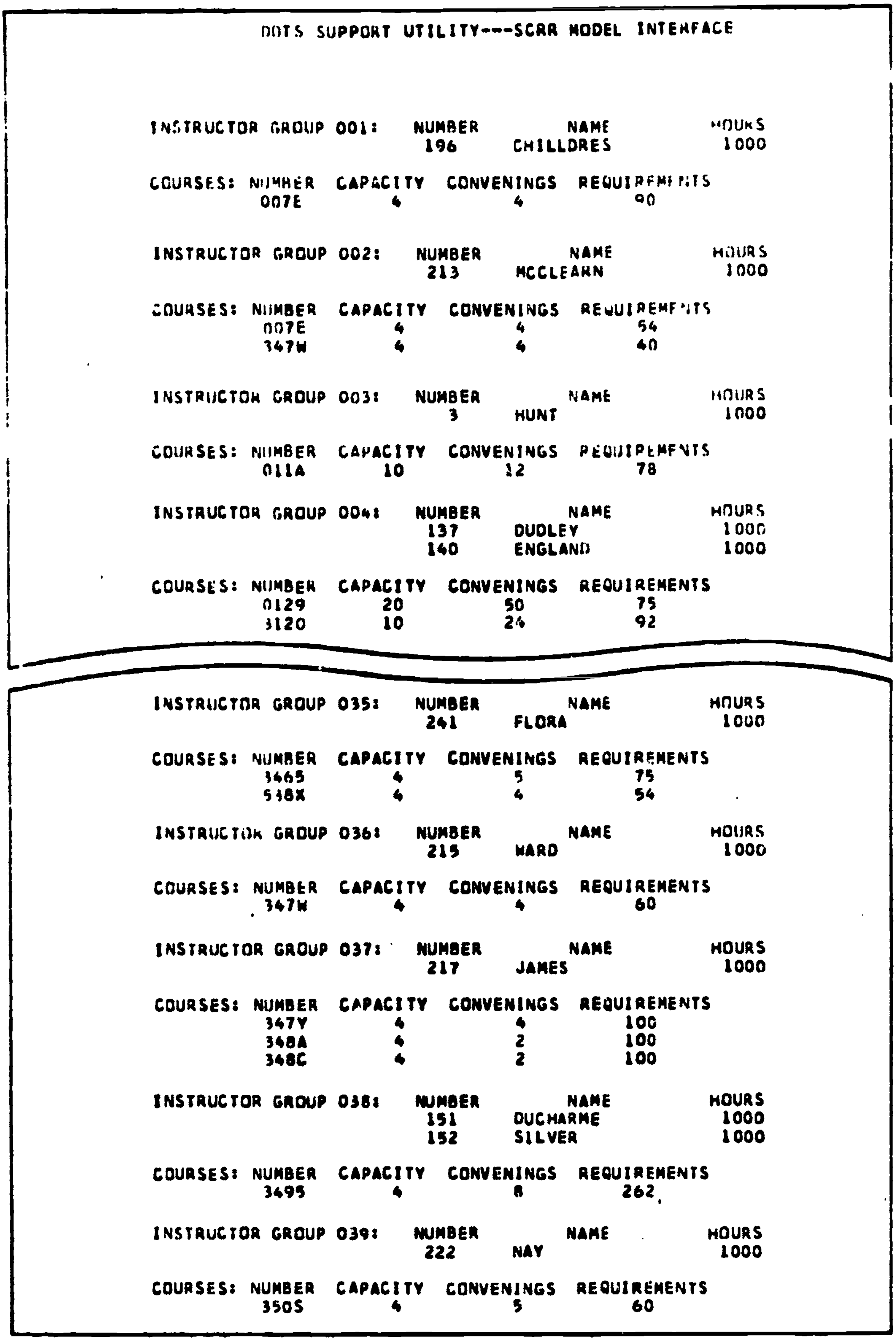
a. The SCRR model software must correctly manipulate the data elements in the process of formulating the LP problem.

b. The linear programming model must approximate the real world to an acceptable degree.

Test Run Output. Because of the volume of output data, the complete scenario I results will not be reproduced in this section. Excerpts from the SCRR model output will be provided to demonstrate that the model has met its design objectives.

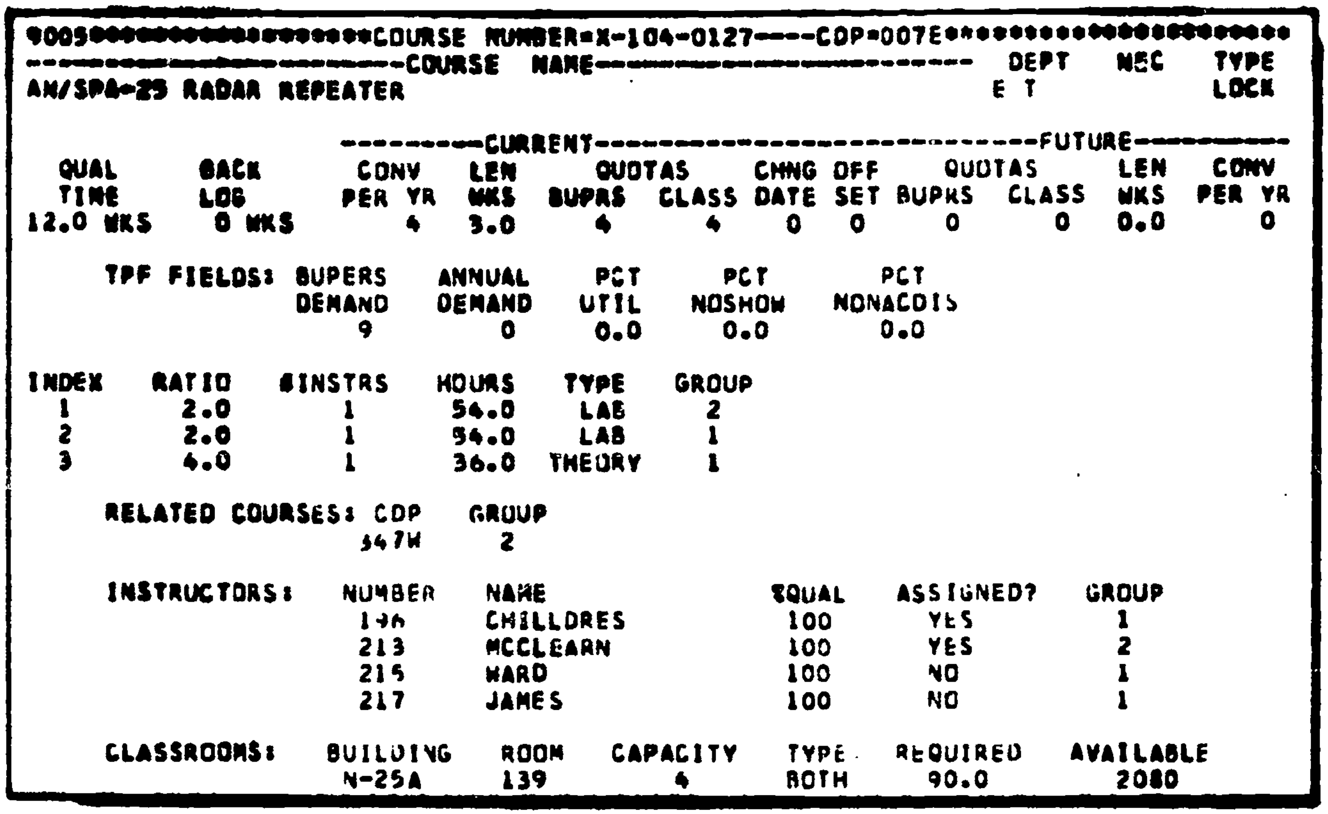
Requirements Specification Testing. Two pages of the Requirements Specification Listing are presented in Figure II-10. The accuracy of the data contained in this output listing can be verified by comparing them to a listing of the data base contents. For example, Figure II-10 indicates that instructor group 001 (IG001) has only one member - instructor number 196. IG001 instructs only course 007E. IG001 contact hour requirements for 007E is 90 hours per convening. The data base listing for course 007E is shown in Figure II-11. Instructor 196 is one of two instructors listed as currently assigned to course 007E. The two instructors are internally differentiated by the group designator. Instructor 196 is identified as group 1. Group 1 is required for 54 hours of lab and 36 hours of theory presentation, a total of 90 hours. Group 1 does not appear in the related course data, which indicates that instructor 196 is not instructing any additional courses.

Figure II-11 indicates that Instructor 213 is also assigned to course 007E. He is one of two instructors required for the 54 hours of lab instruction.



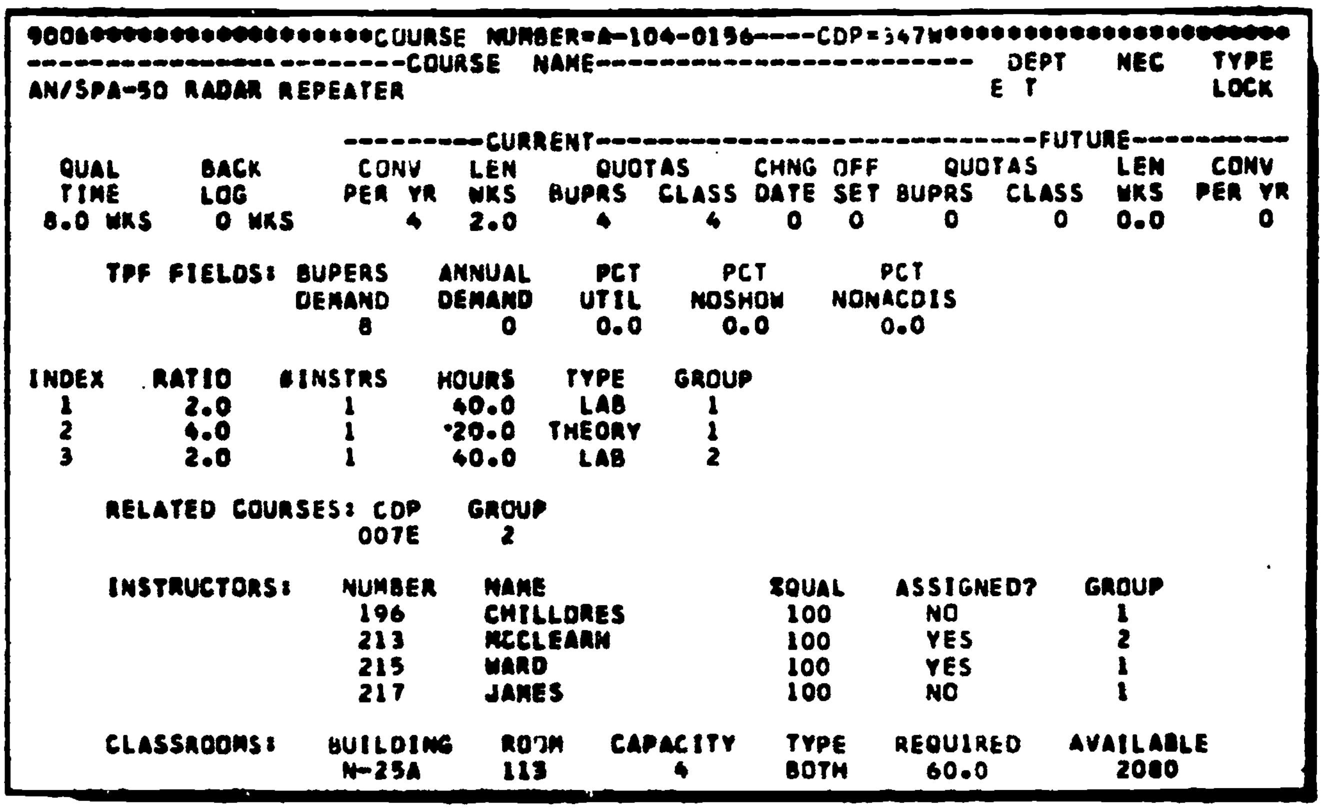
```
                      DOTS SUPPORT UTILITY---SCRR MODEL INTERFACE


INSTRUCTOR GROUP 001:    NUMBER           NAME             HOURS
                          196       CHILLDRES              1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          007E       4            4             90

INSTRUCTOR GROUP 002:    NUMBER           NAME             HOURS
                          213       MCCLEARN               1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          007E       4            4             54
          347W       4            4             40

INSTRUCTOR GROUP 003:    NUMBER           NAME             HOURS
                            3       HUNT                   1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          011A      10           12             78

INSTRUCTOR GROUP 004:    NUMBER           NAME             HOURS
                          137       DUDLEY                 1000
                          140       ENGLAND                1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          0129      20           50             75
          3120      10           24             92

INSTRUCTOR GROUP 035:    NUMBER           NAME             HOURS
                          241       FLORA                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3465       4            5             75
          548X       4            4             54

INSTRUCTOR GROUP 036:    NUMBER           NAME             HOURS
                          215       WARD                   1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          347W       4            4             60

INSTRUCTOR GROUP 037:    NUMBER           NAME             HOURS
                          217       JAMES                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          347Y       4            4            100
          348A       4            2            100
          348C       4            2            100

INSTRUCTOR GROUP 038:    NUMBER           NAME             HOURS
                          151       DUCHARME               1000
                          152       SILVER                 1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3495       4            8            262

INSTRUCTOR GROUP 039:    NUMBER           NAME             HOURS
                          222       NAY                    1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          350S       4            5             60
```

FIGURE II-10 SCENARIO 1 - REQUIREMENTS SPECIFICATION LISTING EXCERPT



```
9005**********************COURSE NUMBER=X-104-0127----CDP=007E**********************
-------------------------COURSE  NAME------------------------  DEPT    NEC    TYPE
AN/SPA-25 RADAR REPEATER                                        E T            LOCK

                           ---------CURRENT-------------------------------FUTURE----------
  QUAL       BACK        CONV   LEN      QUOTAS     CHNG OFF     QUOTAS       LEN    CONV
  TIME       LOG        PER YR  WKS   BUPRS   CLASS DATE SET BUPRS   CLASS    WKS   PER YR
12.0 WKS    0 WKS           4   3.0     4       4    0    0    0        0    0.0       0

     TPF FIELDS: BUPERS    ANNUAL    PCT     PCT       PCT
                 DEMAND    DEMAND    UTIL    NOSHOW    NONACDIS
                    9         0      0.0     0.0        0.0

INDEX    RATIO   #INSTRS    HOURS   TYPE    GROUP
  1       2.0       1       54.0    LAB       2
  2       2.0       1       54.0    LAB       1
  3       4.0       1       36.0   THEORY     1

     RELATED COURSES: CDP    GROUP
                      347W     2

     INSTRUCTORS:    NUMBER    NAME                  %QUAL    ASSIGNED?    GROUP
                      196      CHILLDRES              100       YES          1
                      213      MCCLEARN               100       YES          2
                      215      WARD                   100       NO           1
                      217      JAMES                  100       NO           1

     CLASSROOMS:    BUILDING    ROOM    CAPACITY    TYPE    REQUIRED    AVAILABLE
                     N-25A      139        4        BOTH      90.0        2080
```

FIGURE II-11 DATA BASE LISTING - COURSE 007E



```
9006**********************COURSE NUMBER=A-104-0156----CDP=347W**********************
-------------------------COURSE  NAME------------------------  DEPT    NEC    TYPE
AN/SPA-50 RADAR REPEATER                                        E T            LOCK

                           ---------CURRENT-------------------------------FUTURE----------
  QUAL       BACK        CONV   LEN      QUOTAS     CHNG OFF     QUOTAS       LEN    CONV
  TIME       LOG        PER YR  WKS   BUPRS   CLASS DATE SET BUPRS   CLASS    WKS   PER YR
 8.0 WKS    0 WKS           4   2.0     4       4    0    0    0        0    0.0       0

     TPF FIELDS: BUPERS    ANNUAL    PCT     PCT       PCT
                 DEMAND    DEMAND    UTIL    NOSHOW    NONACDIS
                    8         0      0.0     0.0        0.0

INDEX    RATIO   #INSTRS    HOURS   TYPE    GROUP
  1       2.0       1       40.0    LAB       1
  2       4.0       1       20.0   THEORY     1
  3       2.0       1       40.0    LAB       2

     RELATED COURSES: CDP    GROUP
                      007E     2

     INSTRUCTORS:    NUMBER    NAME                  %QUAL    ASSIGNED?    GROUP
                      196      CHILLDRES              100       NO           1
                      213      MCCLEARN               100       YES          2
                      215      WARD                   100       YES          1
                      217      JAMES                  100       NO           1

     CLASSROOMS:    BUILDING    ROOM    CAPACITY    TYPE    REQUIRED    AVAILABLE
                     N-25A      113        4        BOTH      60.0        2080
```

FIGURE II-12 DATA BASE LISTING - COURSE 347W

```
                         DOTS SUPPORT UTILITY---SCRR MODEL INTERFACE
ROOM N-19A216 -  2080.0 HOURS AVAILABLE.    325S -  105.0
ROOM N-19A217 -  2080.0 HOURS AVAILABLE.    510V -   18.0     5687 -    42.0
ROOM N-19A218 -  2080.0 HOURS AVAILABLE.    9317 -   10.0     9318 -     4.0
ROOM N-19A220 -  2080.0 HOURS AVAILABLE.    511T -   24.0     511Y -     6.0
ROOM N-19A221 -  2080.0 HOURS AVAILABLE.    510X -   12.0     5102 -    12.0
ROOM N-19A222 -  2080.0 HOURS AVAILABLE.    9317 -   16.5     9318 -    26.0
ROOM N-25AOPN -  2080.0 HOURS AVAILABLE.    4946 -   48.0
ROOM N-25A102 -  2080.0 HOURS AVAILABLE.    323Y -  300.0
ROOM N-25A104 -  2080.0 HOURS AVAILABLE.    350T -   60.0
ROOM N-25A106 -  2080.0 HOURS AVAILABLE.    7798 -  180.0
ROOM N-25A108 -  2080.0 HOURS AVAILABLE.    4970 -  240.0
ROOM N-25A109 -  2080.0 HOURS AVAILABLE.    0196 -  120.0     511X -    21.0
ROOM N-25A110 -  2080.0 HOURS AVAILABLE.    7746 -   60.0
ROOM N-25A112 -  2080.0 HOURS AVAILABLE.    511R -   12.0     7834 -   180.0
ROOM N-25A113 -  2080.0 HOURS AVAILABLE.    347W -   60.0     348C -    60.0
ROOM N-25A120 -  2080.0 HOURS AVAILABLE.    3416 -  180.0
ROOM N-25A122 -  2080.0 HOURS AVAILABLE.    538X -   90.0
ROOM N-25A125 -  2080.0 HOURS AVAILABLE.    347Y -   60.0
ROOM N-25A126 -  2080.0 HOURS AVAILABLE.    3543 -   60.0
ROOM N-25A127 -  2080.0 HOURS AVAILABLE.    7668 -  150.0
ROOM N-25A128 -  2080.0 HOURS AVAILABLE.    3690 -   60.0
ROOM N-25A130 -  2080.0 HOURS AVAILABLE.    3636 -  150.0
ROOM N-25A139 -  2080.0 HOURS AVAILABLE.    007E -   90.0
ROOM N-25A144 -  2080.0 HOURS AVAILABLE.    0402 -   60.0
ROOM N-25A147 -  2080.0 HOURS AVAILABLE.    350S -   60.0
ROOM N-25A148 -  2080.0 HOURS AVAILABLE.    4601 -   30.0     7754 -    77.0
ROOM N-25A150 -  2080.0 HOURS AVAILABLE.    5699 -   60.0
ROOM N-25A151 -  2080.0 HOURS AVAILABLE.    511V -   30.0
ROOM N-25A152 -  2080.0 HOURS AVAILABLE.    3232 -  240.0
```

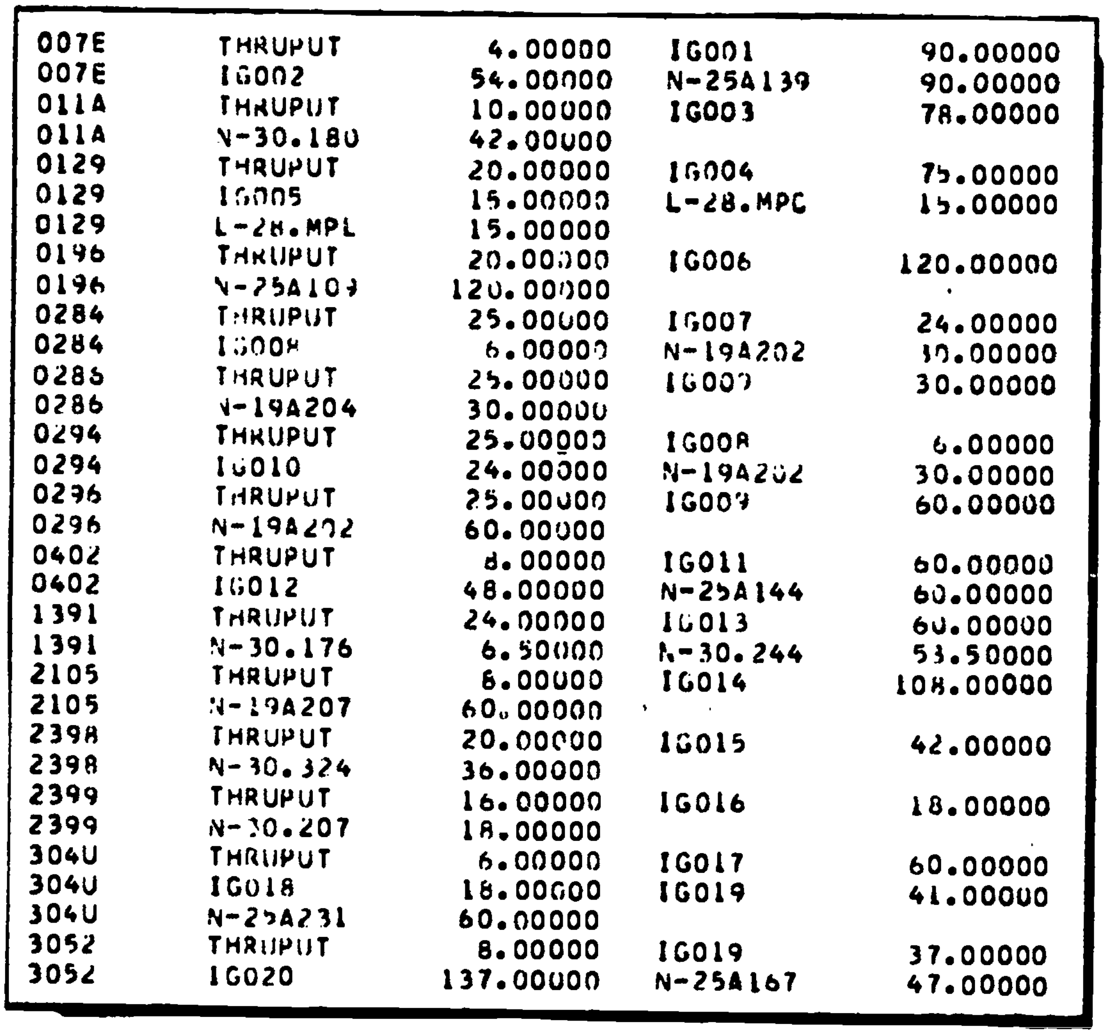
FIGURE II-13 SCENARIO 1 - REQUIREMENTS SPECIFICATION LISTING EXCERPT

From the related course data, instructor 213 also instructs course 347W. This information is duplicated in the specification listing. Examination of the data base listing for course 347W, indicates that instructor 213 is utilized for 40 hours of lab instruction and is also instructing course 007E.

Examination of Figure II-12 shows that instructor 215 is required for 20 hours of theory and 40 hours of lab instruction for each course 347W convening. He does not instruct any additional courses. Instructor 215 is the only member of IG036 (Figure II-10). Again, the SCRR interface output agrees with the data base listing.

Classroom and lab requirements are also compiled and summarized by the SCRR interface program. The data presented in Figure II-13 for classrooms N-25A 113 and N25A 139 agree with the data base listing for each course.

Formatted MPSX Input Data. The second phase of the SCRR interface program reformats the linear programming problem matrix, containing course requirements for instructors and classrooms, to meet MPSX input requirements. Examination of the formatted MPSX input (Figure II-14) will verify that the interface program has successfully manipulated the requirement matrix to provide the MPSX routine with accurate input data. The left column in Figure II-14 is the course number; class capacity is designated by "thruput"; instructor and classroom requirements are in hours per convening.



```
007E      THRUPUT        4.00000   IG001          90.00000
007E      IG002         54.00000   N-25A139       90.00000
011A      THRUPUT       10.00000   IG003          78.00000
011A      N-30.180      42.00000
0129      THRUPUT       20.00000   IG004          75.00000
0129      IG005         15.00000   L-28.MPC       15.00000
0129      L-28.MPL      15.00000
0196      THRUPUT       20.00000   IG006         120.00000
0196      N-25A109     120.00000
0284      THRUPUT       25.00000   IG007          24.00000
0284      IG008          6.00000   N-19A202       30.00000
0285      THRUPUT       25.00000   IG009          30.00000
0286      N-19A204      30.00000
0294      THRUPUT       25.00000   IG008           6.00000
0294      IG010         24.00000   N-19A202       30.00000
0296      THRUPUT       25.00000   IG009          60.00000
0296      N-19A202      60.00000
0402      THRUPUT        8.00000   IG011          60.00000
0402      IG012         48.00000   N-25A144       60.00000
1391      THRUPUT       24.00000   IG013          60.00000
1391      N-30.176       6.50000   N-30.244       53.50000
2105      THRUPUT        8.00000   IG014         108.00000
2105      N-19A207      60.00000
2398      THRUPUT       20.00000   IG015          42.00000
2398      N-30.324      36.00000
2399      THRUPUT       16.00000   IG016          18.00000
2399      N-30.207      18.00000
304U      THRUPUT        6.00000   IG017          60.00000
304U      IG018         18.00000   IG019          41.00000
304U      N-25A231      60.00000
3052      THRUPUT        8.00000   IG019          37.00000
3052      IG020        137.00000   N-25A167       47.00000
```

FIGURE II-14 FORMATTED MPSX INPUT EXCERPT

BEST COPY AVAILABLE

SCRR Output - Resource Data. The objective of the SCRR linear programming model was set to maximize student throughput (see operating procedures, Volume III, Section II, Page II-8). Because the availability of several resources was less than the minimum requirement, the MPSX routine could not identify a feasible solution to the stated problem. For example, Figure II-15 indicates that IG004 has a total availability of 2000 hours. IG004 utilization, which in this case is equivalent to the minimum IG004 requirement, is 5958 hours. A feasible solution cannot be identified until IG004 availability is equal to or greater than the specified minimum requirement. All negative quantities in the "hours under utilized" column in Figure II-15, represent insufficient resource availability. In all, 26 infeasibilities were discovered in the master data base. Each of these infeasibilities was checked to determine if the source of the error was the SCRR model software or the data contents of the master SCRR data base. In all cases, the SCRR output was found to be totally accurate.

The SCRR - Resource Data. The SCRR output from scenario 1 provides an excellent tool for auditing the master DOTS data base prior to installation of the model at the test location. Each of the resource infeasibilities should be examined to ascertain the possible cause or causes. Requirements could have been overstated because of a low student/instructor ratio. A low course utilization rate will also inflate requirements, since requirements are currently calculated based on class capacity and do not consider utilization rate. For example, IG062 and IG063 show requirements greatly in excess of availability. We find, from the specification listing, that both these instructor groups instruct course 509V (Damage Control/Firefighting, Shipboard). This course can handle up to 288 students simultaneously (144 in the Firefighting portion and 144 in the Damage Control section). Even with a student/instructor ratio of 24:1, six instructors from Firefighting and six instructors from Damage Control are required for this course. However, the utilization rate for this course is just over 50 percent. Reducing the class size by one-half will reduce the instructor requirements for 509V by one-half also. Although this example points out the need to modify the SCRR model to include course utilization rate (a change that is currently planned for Phase III), it also demonstrates that all model results should be interpreted and modified as required to account for simplification or assumptions built into the model.

In addition to overstating requirements, the infeasibilities may also result from understating availabilities. Perhaps one or more instructors have not been identified as available to instruct a course they are actually teaching, or individual instructor availabilities may exceed the average figure of 1000 hours per year currently assigned to all instructors in the master data base.

The existence of infeasibilities in the LP problem constraint equations does, however, facilitate the checking of several SCRR model software subroutines. The MPSX control language program did store the infeasible solution on disk storage and the output formatting program was able to interpret the stored infeasible solution (which did not include the sensitivity analyses results) and print only the LP solution results, leaving the sensitivity analysis results columns blank.

Resources listed at 100 percent utilization in Figure II-15 should not be interpreted to mean that those resources are currently 100 percent utilized.

```
                                               S C R R
                                  LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
RESOURCE DATA
                                                                              RESOURCE     THROUGHPUT
                ANNUAL         ANNUAL        HOURS        PERCENT        UTILIZATION      CHANGE        LIMITING
RESOURCE     AVAILABILITY    UTILIZATION     UNDER      UTILIZATION     ---RANGE---      PER UNIT       VARIABLE
               (HOURS)         (HOURS)      UTILIZED                      MINIMUM        RESOURCE
                                                                          MAXIMUM         CHANGE


FF...FLD        2080           2750          -670          132
FLTLNHGR        2080           1093           987           53
IG001           1000            556           444           56
IG002           1000           1000             0          100
IG003           1000           1000             0          100
IG004           2000           5958         -3958          298
IG005           1000           1446          -446          145
IG006           2000           2000             0          100
IG007           1000            312           688           31
IG008           1000           1000             0          100
IG009           2000           2000             0          100
IG010           1000            776           224           78
IG011           1000           1260          -260          126
IG012           1000           1026           -26          103
IG013           2000           2000             0          100
IG014           2000           2484          -484          124
IG015           7000           5533          1467           79
IG016           1000           1000             0          100
IG017           1000            979            21           98
IG018           1000            799           201           80
IG019           1000           1000             0          100
IG020           3000           3000             0          100
IG021           9000           9408          -408          105
IG022          14000          14000             0          100
IG023           8000           8000             0          100
IG024           3000           3000             0          100
IG025           3000           3000             0          100
IG026           4000           4000             0          100
IG027           2000           4032         -2032          202
IG028           2000           2123          -123          106
IG029           2000           2000             0          100
IG030          12000          16320         -4320          136
IG031           3000           3000             0          100
IG032           4000           3478           522           87
IG033           1000           1002            -2          100
IG034           1000            860           140           86
IG035           1000           1000             0          100
IG036           1000           1000             0          100
IG037           1000           1000             0          100
IG038           2000           2096           -96          105
IG039           1000           1000             0          100
IG040           1000           1000             0          100
IG041           1000           1435          -435          143
IG042           2000           3500         -1500          175
IG043           3000           3000             0          100
IG044           2000           2000             0          100
IG045           1000            960            40           96
IG046           1000            987            13           99
IG047           2000           2568          -568          128
```

FIGURE II-15 SCENARIO 1 - SCRR RESOURCE DATA OUTPUT EXCERPT

Since the objective of this problem formulation was to maximize student throughput, the resource data output represents the utilization that could be achieved if student throughput were maximized by establishing the number of course convenings indicated by the SCRR course data output.

SCRR Output - Course Data. The SCRR course data output depicts the number of convenings for each course which would result in maximum student throughput subject to current resource limitations. In the event of an infeasible solution, as is the case for scenario 1, the number of course convenings for those courses with insufficient resources is entered at the minimum requirement, even though sufficient resources to meet the requirement do not exist. Also, as with resource data, the sensitivity analysis results columns remain blank since no sensitivity analysis was performed.

Figure II-16 indicates that sufficient resources are available to convene course 007E 6.2 times per year. Practically speaking, unless 0.2 convenings is interpreted to represent a class which is convened but is only 20 percent complete at the end of the year, 6.2 convenings could be reduced to 6 convenings per year. This is 50 percent more than the presently scheduled 4 convenings per year. The formatted MPSX input (Figure II-14) indicates that IG001 and IG002 are both required for course 007E. Referring to the Requirements Specification Listing (Figure II-10), we note that, in addition to 007E, IG002 also instructs course 347W. The optimal number of convenings for 347W is 16.7, which requires 668 IG002 hours (16.7 convening x 40 hours per convening). IG002 has 332 hours (1000 minus 668) availability remaining to devote to course 007E, which at 54 hours per convening, can be convened 6.2 times. IG001 will utilize 556 hours (6.2 convenings x 90 hours per convening) of the total 1000 hour availability. The above calculations demonstrate that data base integrity is maintained throughout the entire SCRR model, from initial data base input through the specification listing and MPSX formatted input, to the final SCRR resource and course data outputs.

The SCRR course data output for scenario 1 indicates that sufficient resources are available to convene course 007E 6.2 times per year, and course 347W 16.7 times per year. The current number of convenings scheduled per year for both courses is 4. Both courses also have a student capacity of 4. Therefore, the current annual demand for these courses is 16. The SCRR output can be interpreted several ways. First, sufficient resources currently exist to quadruple course 347W throughput. Unless course 347W demand quadruples, this information is not utilized. Second, since the number of convenings can be quadrupled, current resource utilization must be about 25 percent. This becomes extremely useful information. The additional available time (500 hours from course 347W alone) could be utilized for cross-training, assisting in other teaching duties, or performing other duties as required.

General. 120K bytes was adequate space to execute the SCRR model for the total 125 course data base. However, because of the infeasible constraint equations in scenario 1, the SCRR model was not run to completion (the sensitivity analysis was not performed). Scenario 2 will attempt to amend all infeasible constraints encountered in scenario 1, thus generating an optimal solution and the sensitivity analysis. The assessment of storage requirements will be discussed in conjunction with scenario 2.

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

COURSE DATA

COURSE CDP NO.	MAXIMUM ANNUAL CONVENINGS	CURRENT SCHEDULED CONVENINGS	CLASS INPUT CAPACITY	ANNUAL CONVENINGS RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER COURSE CONVENING CHANGE	CLASS CAPACITY RANGE ~~MINIMUM~~ MAXIMUM	LIMITING VARIABLE
0071	6.2	4	4				
011A	12.8	12	10				
0129	50.0	50	20				
0196	4.0	4	20				
0284	13.0	13	25				
0286	18.4	14	25				
0294	32.3	13	25				
0296	12.0	12	25				
0402	12.0	12	8				
1391	24.0	24	24				
2105	1.0	1	8				
2398	23.6	17	20				
2399	31.6	12	16				
3040	4.6	1	6				
3052	21.9	12	8				
3102	24.0	24	16				
3120	24.0	24	10				
3150	12.1	4	15				
3189	14.8	10	20				
3192	49.1	37	20				
323V	6.2	4	8				
3232	5.2	5	8				
3244	11.7	6	8				
3255	24.0	24	8				
3259	11.0	11	12				
3262	22.0	22	8				
3263	13.8	12	8				
3400	48.0	48	30				
3401	27.8	24	25				
3416	11.6	6	15				
3453	6.0	6	8				
3465	5.7	5	4				
347W	16.7	4	4				
347Y	6.0	4	4				
348A	2.0	2	4				
348C	2.0	2	4				
3495	8.0	8	4				
3505	16.7	5	4				
3507	25.0	25	8				
3543	8.0	8	4				
3565	5.1	4	8				
3636	11.8	4	8				
3690	12.0	12	8				
3691	10.0	10	16				
3928	6.1	5	20				
4070	16.0	16	10				
4681	4.1	4	3				
4695	44.4	24	10				
4715	21.3	6	20				

FIGURE II-16 SCENARIO 1 - SCRR COURSE DATA OUTPUT EXCERPT

SCENARIO 2 - MODIFY MASTER DATA BASE CONTENTS: EXECUTE SCRR MODEL USING SCRATCH DATA BASE INPUT. The objectives of the second scenario are to:

a. Analyze scenario 1 output to determine the source of scenario 1 infeasibilities.

b. Create a scratch data base.

c. Modify the scratch data base to eliminate all infeasibilities.

d. Execute the SCRR model to obtain an optimal solution and sensitivity analysis report.

Scenario Input Data. For the purpose of this scenario, the data infeasibilities will be eliminated by increasing the availability of those resources for which requirements exceed availability, thus enabling the model to compute a sensitivity analysis report for illustrative purposes. As stated in the scenario 1 discussion, understatement of resource availability represents only one of several possible explanations. The data for all courses for which requirements exceed availability should be examined on an individual basis to ascertain the reason for the inconsistency. Increasing availabilities to equal requirements is not intended to represent a realistic solution to the problem.

Using the SCRR resource data output (Figure II-15) and the Requirements Specification Listing (Figure II-10) from scenario 1, the data base modifications required to eliminate the data inconsistencies can be determined. For example, IG004 availability is 3958 hours less than stated requirements. Figure II-10 indicates that instructors 137 and 140 make up IG004. Increasing the availability of each of these instructors to 2979 hours per year (one-half of the instructor group minimum requirement) will eliminate the IG004 infeasibility. Similarly, IG005 availability is 446 hours less than requirements. Increasing the availability of instructor 142 to 1446 hours will correct this inconsistency. The same procedure was followed for all negative entries in the "hours under utilized" column. The availabilities of 24 instructor groups, which include a total of 78 instructors, were modified following this technique.

The master data base should not be modified until the data base audit has been completed and the true causes for the data inconsistencies have been identified. Therefore, a scratch data base was created. Modifications can be made to the scratch data base while the master data base is left intact. To create a scratch data base, the user need only select the appropriate Job Control Language (JCL) card deck (see SCRR model operating procedures, Volume III, Section II). To make the required modifications, the user should use the Instructor File Load/Change Form (Figure II-17), making entries only in those columns for which changes are required. To change the availability of instructor 137 from the current 1000 hours to 2797 hours, a "C" is entered in column 1 of the change form to indicate that the entry represents a change; the instructor number is entered in columns 2-4, and the new availability is entered in columns 43-47. The data base course file can be updated using the course file change forms which are discussed in the data base section (Volume III, Section V).

Processing the JCL to execute the SCRR model, indicating the scratch data base as the data source, completes the input data requirements for scenario 2.

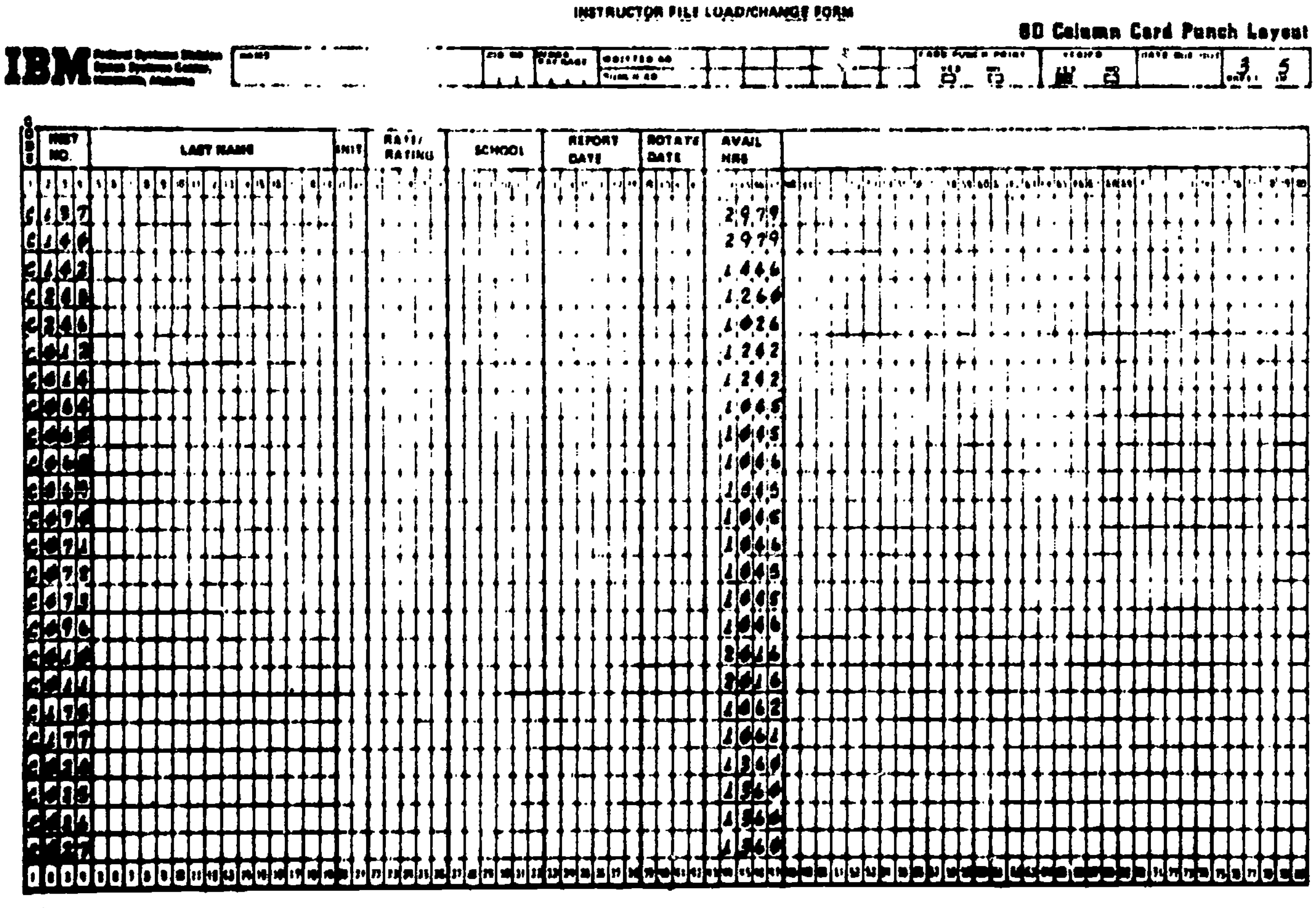


FIGURE II-17 INSTRUCTOR FILE LOAD/CHANGE CARD FORMAT

```
                    GOTS SUPPORT UTILITY---SCAR MODEL INTERFACE


INSTRUCTOR GROUP 001:   NUMBER          NAME              HOURS
                         196      CHILLDRES                1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          007E       4          4           90



INSTRUCTOR GROUP 002:   NUMBER          NAME              HOURS
                         213      MCCLEARN                 1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          007E       4          4           54
          347U       4          4           40



INSTRUCTOR GROUP 003:   NUMBER          NAME              HOURS
                         219      SWARTZ                   1000
                         240      DAVIS                    1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          0196      20          4          120
          511X      20          4           21



INSTRUCTOR GROUP 004:   NUMBER          NAME              HOURS
                         240      RAY                      1260

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          0402       8         12           60
          7826       8          4          135



INSTRUCTOR GROUP 005:   NUMBER          NAME              HOURS
                         246      KUHLMAN                  1826
```

FIGURE II-18 SCENARIO 2 - REQUIREMENTS SPECIFICATION LISTING EXCERPT

Special Run Conditions. Scenario 2 will formally test the following SCRR model software routines which were not exercised in scenario 1:

a. Scratch data base creation.

b. Data base modification.

c. MPSX sensitivity analysis.

d. Sensitivity analyses output formatting.

Test Run Output. The entire 125 course data base could not be processed by the SCRR model software because of insufficient storage availability on the computer used for model development. The problem occurred during the execution of the MPSX sensitivity analysis. Since MPSX source code was not available, internal storage allocations could not be modified. However, the ability to process all courses in the data base simultaneously is not essential to the operation of the SCRR model. The user has the capability to select, by school, which courses are to be copied from the master DOTS data base to the scratch data base. The SCRR model results will be identical whether the model is run for a single school or for all schools, since each school's resources are independent; i.e., instructors and classroom space are not shared between schools. Interdependencies do not cross school lines.

To obtain the final results for scenario 2, the SCRR model was run four times. A scratch data base consisting of courses from one to five schools was created for each run. It was not necessary to recreate the instructor file in the scratch data base for each run. Excerpts from scenario 2 SCRR results, including the sensitivity analysis, are presented in Figures II-18, II-19, and II-20. Computations similar to those described in the scenario 1 discussion were made to verify the accuracy of the model results.

SCENARIO 3 - REALLOCATE IT/AD SCHOOL RESOURCES TO MEET PRESENT TRAINING REQUIREMENTS. This scenario is presented to demonstrate the utility of the SCRR model in the analyses and solution of a typical management problem. The objective of the scenario is to present a problem-solving technique rather than to generate a solution to an existing problem.

The IT/AD school courses were selected from the master data base to form a scratch data base containing only IT/AD school courses. The SCRR model was executed using this scratch data base as input. The results of this model run are presented in Figures II-21, II-22, and II-23. The SCRR resource data output (Figure II-22) indicates two instructor groups for which requirements exceed availability.

IG002 consists of 12 instructors who teach only the Basic Instructor Training course (CDP - 3400). Assuming that the instructor requirements listed for this course are correct, an additional 4320 hours per year must be allocated to IG002. The first step is to examine the contact hour availability of each instructor in IG002 (see Figure II-21). Since the course material for course 3400 is relatively static, the course instructor's contact hour availability should be greater than average. For the purpose of this analysis, we will assume that the availability of each instructor in IG002 should be increased to 1100 hours. Since this adjustment still leaves IG002 total availability

```
                                             S C R R
                              LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
RESOURCE DATA
                                                                         RESOURCE      THROUGHPUT
              ANNUAL        ANNUAL         HOURS        PERCENT        UTILIZATION      CHANGE       LIMITING
RESOURCE   AVAILABILITY   UTILIZATION      UNDER      UTILIZATION     ---RANGE---     PER UNIT     VARIABLE
              (HOURS)       (HOURS)       UTILIZED                      MINIMUM        RESOURCE
                                                                        MAXIMUM         CHANGE


IG001         1000           556           444          56              360.0         -0.044       IG002
                                                                       1400.0         -0.016       IG017

IG002         1000          1000             0         100              882.7         -0.074       007F
                                                                       1266.7          0.074       IG001

IG003         2000          2000             0         100              564.0         -0.952       511X
                                                                       2080.0          0.952       N-25A109

IG004         1260          1260             0         100             1260.0      -INFINITY
                                                                       1260.0         -0.002       7826

IG005         1026          1026             0         100             1026.0         -0.189       3690
                                                                       1037.2          0.189       IG026

IG006         1000           979            21          98              761.2         -0.100       IG008
                                                                       1229.5         -0.048       IG009

IG007         1000           799           201          80              798.6         -0.067       3543
                                                                        804.9         -0.159       IG009

IG008         1000          1000             0         100              851.2         -0.146       304U
                                                                       1014.4          0.146       IG006

IG009         3000          3000             0         100             2946.8         -0.019       IG006
                                                                       3550.9          0.019       304U

IG010         3000          3000             0         100             1920.0         -0.017       323V
                                                                       3328.0          0.017       N-25A102

IG011         3000          3000             0         100             2910.0         -0.014       3232
                                                                       5044.0          0.014       N-25A152

IG012         4000          4000             0         100             2052.0         -0.023       3244
                                                                       9613.0          0.023       N-25A158

IG013         2000          2000             0         100             1740.0         -0.055       3263
                                                                       3351.1          0.055       N-25A162

IG014         1002          1002             0         100             1002.0         -0.092       3453
                                                                       1533.1          0.092       IG007

IG015         1000           870           130          87              750.0         -0.027       IG016
                                                                       1568.0         -0.010       IG033

IG016         1000          1000             0         100              940.0         -0.053       3465
                                                                       1065.0          0.053       IG015


IG017         1000          1000             0         100              600.0         -0.017       IG001
                                                                       1176.0          0.017       007E

IG018         1000          1000             0         100              800.0         -0.040       347V
                                                                       3866.7          0.040       N-25A125

IG019         1000           300           700          30              300.0      -INFINITY
                                                                       1005.0          0.000       3505

IG020         1000          1000             0         100              530.0         -0.100       4601
                                                                       2105.0          0.100       N-25A148

IG021         1435          1435            -0         100             1435.0         -0.200       IG022
                                                                       2408.6         -0.002       7754

IG022         3500          3500             0         100             3500.0         -0.057       3507
                                                                       3500.0          0.057       IG021

IG023         3000          3000             0         100             2368.0         -0.014       3565
                                                                       5330.6          0.014       N-25A153

IG024         2000          2000             0         100              680.0         -0.047       3636
                                                                       3357.3          0.047       N-25A130

IG025         1000          1000             0         100              960.0         -0.064       7746
                                                                       1024.0          0.064       IG026

IG026         1000           995             5         100              995.0         -0.016       7826
                                                                        995.0      -INFINITY

IG027         5000          5000             0         100             4332.0         -0.007       4784
                                                                       9347.1          0.007       N-25A208

IG028         1000          1000             0         100              348.0         -0.089       4931
                                                                       1040.7          0.089       IG006

IG029         2000          2000             0         100              192.0         -0.125       4946
                                                                       2080.0          0.125       N-25AOPN

IG030         3000          3000             0         100             2880.0         -0.014       4970
                                                                       4992.0          0.014       N-25A108

IG031         2000          2000             0         100             1362.0         -0.333       511R
                                                                       2530.0          0.333       N-25A112

IG032         2000          2000             0         100             1800.0         -0.200       511V
                                                                       4666.7          0.200       N-25A151

IG033         1000          1000             0         100              891.7         -0.012       IG015
```

FIGURE II-19 SCENARIO 2 - SCRR RESOURCE DATA OUTPUT EXCERPT

```
                                        S C R R
                        LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
COURSE DATA
                                                             ANNUAL      THROUGHPUT      CLASS
 COURSE       MAXIMUM       CURRENT        CLASS          CONVENINGS       CHANGE       CAPACITY      LIMITING
 COP NO.       ANNUAL      SCHEDULED       INPUT          __RANGE___    PER COURSE       RANGE        VARIABLE
             CONVENINGS    CONVENINGS     CAPACITY          MINIMUM      CONVENING      MINIMUM
                                                            MAXIMUM       CHANGE        MAXIMUM


 0071          6.2            4              4            -INFINITY        -4.0           0.0         IG002
                                                               11.1        -1.6           5.4         IG017

 0196          4.0            4             20            -INFINITY        94.1     -INFINITY
                                                               16.0       -94.1         114.3         511X

 0402         12.0           12              8                 11.8         0.9     -INFINITY         IG026
                                                               12.0        -0.9           8.9         IG004

 304U          4.6            1              6            -INFINITY        -6.0           0.0         IG008
                                                                5.0        -2.0           8.9         IG009

 3052         21.9           12              8                 21.5        -2.6           5.4         IG009
                                                               21.9   -INFINITY     +INFINITY

 323V          6.2            4              8            -INFINITY        -8.0           0.0         IG010
                                                                6.2   -INFINITY     +INFINITY

 3232          5.2            4              8            -INFINITY        -8.0           0.0         IG011
                                                                5.2   -INFINITY     +INFINITY

 3244         11.7            6              8            -INFINITY        -8.0           0.0         IG012
                                                               11.7   -INFINITY     +INFINITY

 3263         13.8           12              8            -INFINITY        -8.0           0.0         IG013
                                                               13.8   -INFINITY     +INFINITY

 3453          6.0            6              8                  5.4        -2.2           5.8         3543
                                                                6.0   -INFINITY     +INFINITY

 3469          5.8            5              4            -INFINITY        -4.0           0.0         IG016
                                                                6.7        -1.6           5.6         IG033

 347U         16.7            4              4                 10.0        -1.0           3.0         IG017
                                                               16.7   -INFINITY     +INFINITY

 347Y          6.0            4              4                -26.7         0.0           4.0         348A
                                                                6.0   -INFINITY     +INFINITY

 348A          2.0            2              4                -26.7         0.0     -INFINITY         N-25A125
                                                                4.0        -0.0           4.0         347Y

 348C          2.0            2              4                -26.7         0.0     -INFINITY         N-25A125
                                                                4.0        -0.0           4.0         347Y

 3505          5.0            5              4                -22.6         0.0     -INFINITY         N-25A148
                                                               16.7        -0.0           4.0         IG019

 3507         25.0           25              8            -INFINITY        -8.0           0.0         IG022
                                                               25.0   -INFINITY     +INFINITY

 3543          8.0            8              4                 -0.9         1.5     -INFINITY         IG007
                                                                8.0        -1.5           5.5         3453

 3565          5.1            4              8            -INFINITY        -8.0           0.0         IG023
                                                                5.1   -INFINITY     +INFINITY

 3636         11.8            4              8            -INFINITY        -8.0           0.0         IG024
                                                               11.8   -INFINITY     +INFINITY

 3690         12.0           12              8                 12.0        -0.2           7.8         7826
                                                               12.0   -INFINITY     +INFINITY

 4601         19.7            4              3                  4.1         0.0           3.0         3505
                                                               19.7   -INFINITY     +INFINITY

 4784          4.6            4              8            -INFINITY        -8.0           0.0         IG027
                                                                4.6   -INFINITY     +INFINITY

 4931         17.2            6              4            -INFINITY        -4.0           0.0         IG028
                                                               17.2   -INFINITY     +INFINITY

 4946         41.7            4              6            -INFINITY        -6.0           0.0         IG029
                                                               41.7   -INFINITY     +INFINITY

 4970          5.2            5              8            -INFINITY        -8.0           0.0         IG030
                                                                5.2   -INFINITY     +INFINITY

 511R         54.2            1              4            -INFINITY        -3.8           0.2         7834
                                                               54.2   -INFINITY     +INFINITY

 511V         16.0           12             10                -29.3        -5.0           5.0         5699
                                                               16.0   -INFINITY     +INFINITY

 511X         72.4            4             20            -INFINITY       -16.5           3.5         0196
                                                               72.4   -INFINITY     +INFINITY

 538X         10.5            4              4                 10.5        -1.1           2.9         7826
                                                               10.6       -27.7          31.7         IG025

 5699         12.0           12             10                -14.7        10.0     -INFINITY         N-25A151
                                                               14.0       -10.0          20.0         511V

 7668          6.7            6              4            -INFINITY        -4.0           0.0         IG034
                                                                6.7   -INFINITY     +INFINITY

 7746          4.7            4              4                 -3.3        -3.8           0.2         IG025
```

FIGURE II-20 SCENARIO 2 - SCRR COURSE DATA OUTPUT EXCERPT

```
                        DOTS SUPPORT UTILITY---SCHH MODEL INTERFACE


INSTRUCTOR GROUP 001:   NUMBER        NAME           HOURS
                          31     JOHNSON              1000
                          55     RUMBERGER            1000
                          56     TAYLOR               1000
                          57     BULLOCK              1000
                          58     TOLSON               1000
                          59     KELLY                1000
                          60     WOOD                 1000
                          61     PAMP                 1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          3192      20         37          173


INSTRUCTOR GROUP 002:   NUMBER        NAME           HOURS
                          24     BROWN                1000
                          25     CRISMAN              1000
                          26     COFFEY               1000
                          27     HOTGRASS             1000
                          28     ELWELL               1000
                          29     MAYO                 1000
                          30     COOPER               1000
                          32     PEARSON              1000
                          33     RICHEY               1000
                          34     RODE                 1000
                          36     TRENT                1000
                          37     WILLIAMS             1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          3400      30         48          340


INSTRUCTOR GROUP 003:   NUMBER        NAME           HOURS
                          18     BOWMAN               1000
                          19     FIFER                1000
                          35     GOOCH                1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          3401      25         24          108


INSTRUCTOR GROUP 004:   NUMBER        NAME           HOURS
                          38     SHERMAN              1000
                          39     GREENE               1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          3641      16         10          234
          9498      16          4           57


INSTRUCTOR GROUP 005:   NUMBER        NAME           HOURS
                          42     HAMBLIN              1000
                          43     DIONNE               1000
                          44     CRAIG                1000
                          45     LEHMAN               1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          4890      20         24           90


INSTRUC"OR GROUP 006:   NUMBER        NAME           HOURS
                          50     BOLING               1000
                          51     CORDELL              1000
                          52     PETRUCCI             1000
                          53     CRELING              1000
                          54     PALMER               1000

COURSES' NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          536L      20         24           58
          536M      20         24           58


INSTRUCTOR GROUP 007:   NUMBER        NAME           HOURS
                          46     MCIATRIDGE           1000
                          47     STORCK               1000
                          48     BAKER                1000
                          49     ROSE                 1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          5360      15         25           36


INSTRUCTOR GROUP 008:   NUMBER        NAME           HOURS

                          62     OSBORNE              1000
                          63     PUCKETT              1000

COURSES: NUMBER  CAPACITY  CONVENINGS  REQUIREMENTS
          9410      20         24           30
```

FIGURE II-21 SCENARIO 3 - REQUIREMENTS SPECIFICATION LIST - IT/AD SCHOOL

RESOURCE DATA

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

RESOURCE	ANNUAL AVAILABILITY (HOURS)	ANNUAL UTILIZATION (HOURS)	HOURS UNDER UTILIZED	PERCENT UTILIZATION	RESOURCE UTILIZATION ---RANGE--- MINIMUM MAXIMUM	THROUGHPUT CHANGE PER UNIT RESOURCE CHANGE	LIMITING VARIABLE
IG001	8000	8000	0	100			
10002	12000	16320	-4320	136			
IG003	3000	3000	0	100			
IG004	2000	2568	-568	128			
IG005	4000	3120	880	78			
IG006	5000	5000	0	100			
IG007	4000	2496	1504	62			
IG008	2000	2000	0	100			
L-28..A1	2080	1632	448	78			
L-28..A2	2080	1632	448	78			
L-28..C1	2080	1020	1060	49			
L-28..C2	2080	1440	640	69			
L-28..C3	2080	1440	640	69			
L-28..C4	2080	1440	640	69			
L-28..C5	2080	1139	941	55			
L-28..C7	2080	1440	640	69			
L-28..C9	2080	720	1360	35			
L-28.C12	2080	1632	448	78			
L-28.C13	2080	2080	0	100			
L-28.C15	2080	1632	448	78			
L-29.C16	2080	417	1663	20			
L-28.C17	2080	1632	448	78			
L-28.C18	2080	417	1663	20			
L-28.C21	2080	2000	80	96			
L-28.C22	2080	1632	448	78			
L-28.C23	2080	2080	0	100			
L-28.C9.	2080	1866	214	90			
N-25A201	2080	1472	608	71			
N-25A202	2080	1472	608	71			
N-25A203	2080	1472	608	71			
N-25A204	2080	1472	608	71			
N-25A222	2080	1472	608	71			

FIGURE II-22 SCENARIO 3 - SCRR RESOURCE DATA OUTPUT - IT/AD SCHOOL

COURSE DATA

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

COURSE CDP NO.	MAXIMUM ANNUAL CONVENINGS	CURRENT SCHEDULED CONVENINGS	CLASS INPUT CAPACITY	ANNUAL CONVENINGS --RANGE--- MINIMUM MAXIMUM	THROUGHPUT CHANGE PER COURSE CONVENING CHANGE	CLASS CAPACITY RANGE MINIMUM MAXIMUM	LIMITING VARIABLE
3192	49.1	37	20				
3400	48.0	48	30				
3401	27.8	24	25				
3691	10.0	10	16				
4090	34.7	24	20				
536L	24.0	24	20				
536M	62.7	24	20				
5360	69.3	25	15				
9410	66.7	24	20				
9498	4.0	4	16				

FIGURE II-23 SCENARIO 3 - SCRR COURSE DATA OUTPUT - IT/AD SCHOOL more than 3000 hours short of the course requirement, further adjustments will have to be made.

The next step is to examine course utilization, which for course 3400 averages about 85 percent. Considering course utilization, the actual class size is approximately 25 rather than the listed capacity of 30 students. Referring to the data base listing for 3400 (Figure II-24), it is noted that 27.0 hours are required with a 5:1 student/instructor ratio. Taking the utilization into account reduces the instructor requirement from 6 to 5 for that portion of the course. The annual requirement for the course can be reduced by 1296 hours (27 hours per convening x 48 convenings per year).

Initial analysis has resulted in increasing the availability of IG002 by 1200 hours and decreasing course 3400 annual requirement by 1296 hours. The next step is to examine the resource-requirement relationship of other IT/AD school courses. Figure II-23 indicates that courses 536M, 536Q, and 9410 have sufficient resources available to more than double the number of annual convenings. Since the utilization for these courses averages 45, 65, and 75 percent respectively, it seems reasonable to assume that the demand for these courses will not double in the near future. This assumption allows us to recalculate the requirements for these courses based on current scheduled convenings.

Course 536M instructor requirements drop to 40 hours per convening when the calculation is based on average class size rather than class capacity. The total annual requirement for 536M becomes 960 hours (40 hours per convening x 24 convenings per year). IG006 (see Figure II-21) also instructs course 536L. The annual requirement for 536L is 1392 hours (58 hours per convening x 24 convenings per year). Summing the requirements for 536L and 536M, IG006 minimum total requirements become 2352 hours per year. Current IG006 availability is equal to 5000 hours per year. From the instructor file listing, it is noted that instructor 53 will be rotated within two months. Instructor 54 (a random selection from four remaining IG006 instructors) will be assigned to course 3400.

Course 536Q has a minimum annual requirement of 900 hours (36 hours per convening x 25 convenings per year). IG007 teaches only course 536Q and has a total annual availability of 4000 hours (Figure II-21). Since 536Q has a requirement for two instructors for one-half day of the one week course, IG007 will be reduced to two instructors with a total availability of 2000 hours (still double the minimum requirement). Instructor 48 will be reassigned to course 3400. Instructor 49 will be reassigned to course 3691.

Returning to Figure II-22, the second resource for which availability is less than total requirements is IG004. IG004 consists of two instructors, 38 and 39. A check of the instructor file listing shows that instructor 39 is scheduled to be rotated within the next two weeks. Therefore, instructor 39 will be removed from the course file; he will be replaced by instructor 49 who will be reassigned from course 536Q.

Course 3691 has a class capacity of 16, but an average utilization of 35 percent. Therefore, the average class size for this course will be adjusted to 6 per convening. Course 3691 has a 4:1 student/instructor ratio for 48.0

```
0302*********************COURSE MUMBER=A-012-0011----CDP=3400***********************
-----------------------CUURSE  NAME-------------------------  DEPT   NEC   TYPC
BASIC INSTRUCTOH THAINING (ALPHA)                             IT/AD  9502  LOCK

                      ---------CURRENT---------------------------FUTURE----------
  QUAL      BACK      CONV   LEN     QUOTAS    CHNG OFF    QUOTAS      LEN    CONV
  TIME      LOG      PER YR  WKS   RUPRS CLASS DATE SET BUPRS   CLASS   WKS   PER YR
16.0 WKS   10 WKS       48   4.0    21    30    0    0    0        0    0.0       0

     TPF FIELDS: RUPERS   ANNUAL   PCT     PCT      PCT
                 DEMAND   DEMAND   UTIL   NOSHOW   NONACDIS
                  985      220     2.2     0.0      10.2

INDEX   RATIO   #INSTRS   HOURS   TYPE   GROUP
  1      9.0      6       27.0    LAB      1
  2     10.0      3       45.0    LAR      1
  3     30.0      1       43.0  THEORY     1

     INSTRUCTORS:    NUMBER   NAME                 %QUAL   ASSIGNED?   GROUP
                       23     PARDUN                100       NU         1
                       24     BROWN                  25       YES        1
                       25     CRISMAN                40       YES        1
                       26     COFFEY                 30       YES        1
                       27     NOTGRASS               20       YES        1
                       28     ELWELL                 60       YES        1
                       29     MAYO                   10       YES        1
                       30     COOPER                 25       YES        1
                       32     PEARSON                25       YES        1
                       33     RIGHEY                 60       YES        1
                       34     RODE                   75       YES        1
                       36     TRENT                  25       YES        1
                       37     WILLIAMS               65       YES        1

     CLASSROOMS:    BUILDING   ROOM   CAPACITY   TYPE     REQUIRED   AVAILABLE
                      L-28      A1       15      BOTH       34.0       2080
                      L-28      A2       15      BOTH       34.0       2080
                      L-28      C2       30     LECTURE     30.0       2080
                      L-28      C3       30     LECTURE     30.0       2080
                      L-28      C4       30     LECTURE     30.0       2080
                      L-28      C7       30     LECTURE     30.0       2080
                      L-28      C12      15      BOTH       34.0       2080
                      L-28      C15      15      BOTH       34.0       2080
                      L-28      C17      15      BOTH       34.0       2080
                      L-28      C22      15      BOTH       34.0       2080
```

FIGURE II-24 DATA BASE LISTING - COURSE 3400

```
0302*********************COURSE NUMBER=A-012-0036----CDP=3691************ **********
-----------------------COURSE  NAME-------------------------  DEPT   NEC   TYPE
PROGRAMMED INSTRUCTION TECHNIQUES (OSCAR)                     IT/AD  9506  LOCK

                      ---------CURRENT---------------------------FUTURE----------
  QUAL      BACK      CONV   LEN     QUOTAS    CHNG OFF    QUOTAS      LEN    CONV
  TIME      LOG      PER YR  WKS   BUPRS CLASS DATE SET BUPRS   CLASS   WKS   PER YR
12.0 WKS    0 WKS       10   3.0     0    16    0    0    0        0    0.0       0

     TPF FIELDS: BUPERS   ANNUAL   PCT     PCT      PCT
                 DEMAND   DEMAND   UTIL   NOSHOW   NONACDIS
                    0       55     0.0    18.5      0.0

INDEX   RATIO   #INSTRS   HOURS   TYPE   GROUP
  1     16.0      1       39.0  THEORY     1
  2      4.0      4       48.0    LAB      1
  3     16.0      1        3.0    LAR      1

     RELATED COURSES: CDP   GROUP
                      3498    1

     INSTRUCTORS:    NUMBER   NAME                 %QUAL   ASSIGNED?   GROUP
                       38     SHERMAN               100       YES        1
                       39     GREENE                100       YES        1

     CLASSROOMS:    BUILDING   ROOM   CAPACITY   TYPE     REQUIRED   AVAILABLE
                      L-28      C1       16      BOTH       90.0       2080
```

FIGURE II-25 DATA BASE LISTING - COURSE 3691 hours of lab instruction (Figure II-25). Based on a class capacity of 16, a total of four instructors is required for the lab period. However, this requirement is reduced to two instructors when the course utilization is considered. Recalculating the instructor requirement for course 3691, based on a course utilization of 35 percent reduces the requirement per convening from 234 hours to 138 hours (1 instructor x 39 hours + 2 instructors x 48 hours + 1 instructor x 3 hours).

Course 9498 is also instructed by IG004. Based on an average utilization rate of 5 percent, the instructor requirement per convening can be reduced from 57 hours to 30 hours. The number of course convenings should also be decreased from 4 to 1 time per year.

The data modifications suggested by the preceding analysis will ensure that all IT/AD school resource availabilities are greater than or equal to their requirements. It is fully admitted that some of the assumptions which were included in the analysis may be unrealistic; and that the personnel transfers which were indicated may not be feasible. However, as was pointed out earlier, the objective of this scenario is not to solve an existing real-world problem, but to demonstrate how the SCRR model data might be used to solve such a problem.

Scenario Input Data. The data modifications resulting from the preceding analysis are summarized below. These changes were made to the scratch data base, both the course and the instructor file. The SCRR model was then rerun against the updated scratch data base.

a. All members of IG002 - increase availability to 1100 hours.

b. Delete instructor 048 from 536Q; add instructor 048 to course 3400; instructor 048 availability = 1100.

c. Delete instructor 054 from 536M; add instructor 054 to course 3400; instructor 054 availability = 1100.

d. Course 3400 - decrease instructor requirement to account for utilization rate.

e. Delete instructor 039 from 3691.

f. Delete instructor 049 from 536Q; add instructor 049 to course 3691.

g. Course 3691 - decrease instructor requirement to account for utilization rate.

h. Course 9498 - decrease instructor requirement to account for utilization rate.

i. Course 9498 - decrease number of annual convenings.

Special Run Condition. The SCRR model was executed using the updated scratch data base previously described as input data.

Design Criterion Tested. Scenario 3 required a management analysis of an initial SCRR model run. The scratch data base was then modified and the SCRR model rerun to verify that the modification produced the desired effect. An important operational feature of the SCRR model is the ability to easily and quickly modify the input data and rerun the model.

Test Run Output. The results of implementing the suggested modifications can be easily assessed from the SCRR model output presented in Figures II-26, 27, and 28.

SCENARIO 4 - PERFORM INSTRUCTOR AVAILABILITY PARAMETRIC ANALYSIS. The objective of this scenario is to present an information-oriented application of the SCRR model, as opposed to the problem-solving application demonstrated by scenario 3. Perhaps the most significant variable considered in the SCRR model is instructor availability. Instructor availability is defined as the number of hours per year an instructor is available for classroom instruction. Specification of availability is meaningless unless a requirement to utilize the available time can be identified. All course descriptions identify very specific instructor contact hour requirements. The problem we are faced with is that although contact hour requirements are very specific, contact hour availability has been difficult to evaluate. Several attempts have been made to set standards for contact hour availability, but because of the high variability in requirements of activities outside the classroom, these standards have met with little acceptance.

Each instructor entry in the master DOTS instructor file has an availability figure associated with it. Initially, all availabilities were set equal to 1000 hours per year (1000 hours represents an approximate average of existing availability standards). The ultimate goal of the data base is to establish availability on an individual basis. Availability, although tailored to the individual, will be a function of the set of jobs the individual is responsible for performing.

A parametric study of availability can achieve two objectives:

a. The total impact of instructor availability on the training complex capabilities will be dramatically demonstrated.

b. The study can help to establish some acceptable limits of instructor availability within which the training complex can operate effectively.

Scenario Input Data. To limit the data input requirements as well as the volume of model output, the parametric study is limited to a single school. The courses for the ASW school are first transferred to the scratch data base along with the instructor file contents. The availabilities of the 14 ASW instructors are initially set equal to 700 hours per year. The SCRR model is run using the scratch data base as input. Instructor availabilities are increased in increments of 100 hours per year to a total of 1200 hours. Each change requires only a simple modification of the scratch data base instructor file. The course file does not have to be modified. The SCRR model is executed after each instructor file update.

```
                    DOTS SUPPORT UTILITY---SCRR MODEL INTERFACE


INSTRUCTOR GROUP 001:   NUMBER        NAME              HOURS
                          11      JOHNSON               1000
                          55      RUMBERGER             1000
                          56      TAYLOR                1000
                          57      BULLOCK               1000
                          58      TOLSON                1000
                          59      KELLY                 1000
                          60      WOOD                  1000
                          61      PAMP                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3192       20          37           163


INSTRUCTOR GROUP 002:   NUMBER        NAME              HOURS
                          24      BROWN                 1100
                          25      CRISMAN               1100
                          26      COFFEY                1100
                          27      HOTGRASS              1100
                          28      ELWELL                1100
                          29      MAYO                  1100
                          30      COOPER                1100
                          32      PEARSON               1100
                          33      RICHEY                1100
                          34      RODE                  1100
                          36      TRENT                 1100
                          37      WILLIAMS              1100
                          48      BAKER                 1100
                          54      PALMER                1100

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3400       30          48           313


INSTRUCTOR GROUP 003:   NUMBER        NAME              HOURS
                          18      BOWMAN                1000
                          19      FIFER                 1000
                          35      GOUCH                 1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3401       25          24           108


INSTRUCTOR GROUP 004:   NUMBER        NAME              HOURS
                          38      SHIPMAN               1000
                          49      ROSE                  1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          3691       16          10           138
   [illegible]       16           1            30


INSTRUCTOR GROUP 005:   NUMBER        NAME              HOURS
                          42      HAMBLIN               1000
                          43      DIONNE                1000
                          44      CRAIG                 1000
                          45      LEHMAN                1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          4890       20          24            90


INSTRUCTOR GROUP 006:   NUMBER        NAME              HOURS
                          50      BOLING                1000
                          51      CORDELL               1000
                          52      PETRUCCI              1000
                          53      EBELING               1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          536L       20          24            58
          536M       20          24            58


INSTRUCTOR GROUP 007:   NUMBER        NAME              HOURS
                          46      MCFATRIDGE            1000
                          47      STORCK                1000

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          536Q       15          25            36
```

FIGURE II-26 SCENARIO 3 - REQUIREMENTS SPECIFICATION LISTING - FINAL RESULTS

BEST COPY AVAILABLE

```
                                              S C R R
                              LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
RESOURCE DATA
                                                                                 RESOURCE      THROUGHPUT
                  ANNUAL          ANNUAL         HOURS        PERCENT           UTILIZATION      CHANGE        LIMITING
RESOURCE       AVAILABILITY    UTILIZATION       UNDER       UTILIZATION      ____RANGE____    PER UNIT       VARIABLE
                 (HOURS)         (HOURS)        UTILIZED                          MINIMUM      RESOURCE
                                                                                  MAXIMUM       CHANGE


IG001             8000            8000              0            100              6031.0        -0.123       3192
                                                                                 11301.3         0.123       N-25A222

IG002            15400           15400              0            100             15024.0        -0.096       3400
                                                                                 19148.2         0.096       L-28.C22

IG003             3000            3000              0            100              2592.0        -0.231       3401
                                                                                  5479.0         0.231       L-28..C5

IG004             2000            2000              0            100              1410.0        -0.533       9498
                                                                                  2560.0         0.533       L-28..C1

IG005             4000            3120            880             78              2160.0        -0.222       L-28.C23
                                                                                  3120.0      -INFINITY

IG006             4000            4000              0            100              2784.0        -0.345       536M
                                                                                  5413.3         0.345       L-28.C9.

IG007             2000            2000              0            100               900.0        -0.417       536U
                                                                                  2496.0         0.417       L-28.C13

IG008             2000            2000              0            100               720.0        -0.667       9410
                                                                                  2080.0         0.667       L-28.C21

L-28..A1          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1672.8      -INFINITY

L-28..A2          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1672.8      -INFINITY

L-28..C1          2080            1520            560             73               930.0        -0.533       IG004
                                                                                  1520.0      -INFINITY

L-28..C2          2080            1476            604             71              1440.0        -1.000       IG002
                                                                                  1476.0      -INFINITY

L-28..C3          2080            1476            604             71              1440.0        -1.000       IG002
                                                                                  1476.0      -INFINITY

L-28..C4          2080            1476            604             71              1440.0        -1.000       IG002
                                                                                  1476.0      -INFINITY

L-28..C5          2080            1139            941             55               984.0        -0.610       IG003
                                                                                  1138.9      -INFINITY

L-28..C7          2080            1476            604             71              1440.0        -1.000       IG002
                                                                                  1476.0      -INFINITY


L-28..C9          2080             720           1360             35               720.0      -INFINITY
                                                                                  1349.0         0.000       536L

L-28.C12          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1672.8      -INFINITY

L-28.C13          2080            1667            413             80               750.0        -0.500       IG007
                                                                                  1666.7      -INFINITY

L-28.C15          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1673.8      -INFINITY

L-28.C16          2080             417           1663             20               360.0        -1.667       IG003
                                                                                   416.7      -INFINITY

L-28.C17          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1672.8      -INFINITY

L-28.C18          2080             417           1663             20               360.0        -1.667       IG003
                                                                                   416.7      -INFINITY

L-28.C21          2080            2000             80             96               720.0        -0.667       IG008
                                                                                  2000.0      -INFINITY

L-28.C22          2080            1673            407             80              1632.0        -0.882       IG002
                                                                                  1672.8      -INFINITY

L-28.C23          2080            2080              0            100              1440.0        -0.333       4890
                                                                                  2166.7         0.333       IG005

L-28.C9.          2080            1349            731             65               720.0         0.000       536L
                                                                                  1349.0      -INFINITY

N-25A201          2080            1472            608             71              1110.0        -0.667       IG001
                                                                                  1472.4      -INFINITY

N-25A202          2080            1472            608             71              1110.0        -0.667       IG001
                                                                                  1472.4      -INFINITY

N-25A203          2080            1472            608             71              1110.0        -0.667       IG001
                                                                                  1472.4      -INFINITY

N-25A204          2080            1472            608             71              1110.0        -0.667       IG001
                                                                                  1472.4      -INFINITY

N-25A222          2080            1472            608             71              1110.0        -0.667       IG001
                                                                                  1472.4      -INFINITY
```

FIGURE II-27 SCENARIO 3 - SCRR RESOURCE DATA OUTPUT - FINAL RESULTS

```
                                              S C R R
                            LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
COURSE DATA

                                                          ANNUAL      THROUGHPUT      CLASS
 COURSE      MAXIMUM      CURRENT        CLASS        CONVENINGS      CHANGE        CAPACITY      LIMITING
 CDP NO.     ANNUAL       SCHEDULED      INPUT        __RANGE__     PER COURSE       RANGE        VARIABLE
            CONVENINGS    CONVENINGS    CAPACITY       MINIMUM       CONVENING       MINIMUM
                                                       MAXIMUM        CHANGE         MAXIMUM


 3197         49.1          37            20         -INFINITY        -20.0            0.0        1G001
                                                          49.1      -INFINITY      +INFINITY
 3400         49.2          48            30         -INFINITY        -30.0            0.0        1G002
                                                          49.2      -INFINITY      +INFINITY
 3401         27.8          24            25         -INFINITY        -25.0            0.0        1G003
                                                          27.8      -INFINITY      +INFINITY
 3691         10.0          10            16              -1.7         57.6      -INFINITY        L-28..C1
                                                          14.3        -57.6           73.6        9498
 4890         34.7          24            20         -INFINITY        -20.0            0.0        L-28.C23
                                                          34.7      -INFINITY      +INFINITY
 536L         24.0          24            20              -0.4          0.0      -INFINITY        L-28.C9.
                                                          45.0         -0.0           20.0        536M
 536M         45.0          24            20              -0.4          0.0           20.0        536L
                                                          45.0      -INFINITY      +INFINITY
 536Q         55.6          25            15         -INFINITY        -15.0            0.0        1G007
                                                          55.6      -INFINITY      +INFINITY
 9410         66.7          24            20         -INFINITY        -20.0            0.0        1G008
                                                          66.7      -INFINITY      +INFINITY
 9498         20.7           1            16         -INFINITY        -12.5            3.5        3691
                                                          20.7      -INFINITY      +INFINITY

 TOTAL CONVENINGS     382.6
 TOTAL THOUGHPUT     7882.1
```

FIGURE II-28 SCENARIO 3 - SCRR COURSE DATA OUTPUT - FINAL RESULTS

Test Run Output. The results of the instructor availability parametric study are presented in Figures II-29 through II-37.

```
                              DOTS SUPPORT UTILITY---SCRR MODEL INTERFACE



INSTRUCTOR GROUP 001:    NUMBER          NAME            HOURS
                            3     HUNT                     700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          011A       10          12             78



INSTRUCTOR GROUP 002:    NUMBER          NAME            HOURS
                           41     VIERRETHER               700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          5106       12           6             60



INSTRUCTOR GROUP 003:    NUMBER          NAME            HOURS
                           40     PAUL                     700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          5106       12           6             27
          5698       12           6            105



INSTRUCTOR GROUP 004:    NUMBER          NAME            HOURS
                          128     ATWOOD                   700
                          129     COLBURN                  700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          510V       10          12             30
          510W       10          24             18



INSTRUCTOR GROUP 005:    NUMBER          NAME            HOURS
                          132     STREIT                   700
                          133     JOYCE                    700
                          134     STEWART                  700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          5107       16          24            100



INSTRUCTOR GROUP 006:    NUMBER          NAME            HOURS
                          135     STEPHENS                 700
                          136     BROOKS                   700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          536K       10          50             28



INSTRUCTOR GROUP 007:    NUMBER          NAME            HOURS
                          130     WILSON                   700
                          131     BROWN                    700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          536P        8          12             48



INSTRUCTOR GROUP 008:    NUMBER          NAME            HOURS
                           81     OBERLE                   700
                           82     WAGNER                   700

COURSES: NUMBER   CAPACITY   CONVENINGS   REQUIREMENTS
          5698       12           6            255
```

FIGURE II-29 SCENARIO 4 - REQUIREMENTS SPECIFICATION LISTING - 700 HOURS AVAILABILITY

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

RESOURCE DATA

RESOURCE	ANNUAL AVAILABILITY (HOURS)	ANNUAL UTILIZATION (HOURS)	HOURS UNDER UTILIZED	PERCENT UTILIZATION	RESOURCE UTILIZATION RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER UNIT RESOURCE CHANGE	LIMITING VARIABLE
FLTLNMGR	2080	288	1792	14			
IG001	700	936	-236	134			
IG002	700	360	340	51			
IG003	700	792	-92	113			
IG004	1400	1400	0	100			
IG005	2100	2400	-300	114			
IG006	1400	1400	0	100			
IG007	1400	1400	0	100			
IG008	1400	1530	-130	109			
N-19A120	2080	960	1120	46			
N-19A122	2080	480	1600	23			
N-30.106	2080	198	1882	10			
N-30.107	2080	792	1288	38			
N-30.108	2080	270	1810	13			
N-30.167	2080	1000	1080	48			
N-30.180	2080	1904	176	92			
N-30.181	2080	1112	968	53			

FIGURE II-30 SCENARIO 4 - SCRR RESOURCE DATA OUTPUT - 700 HOURS AVAILABILITY

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

RESOURCE DATA

RESOURCE	ANNUAL AVAILABILITY (HOURS)	ANNUAL UTILIZATION (HOURS)	HOURS UNDER UTILIZED	PERCENT UTILIZATION	RESOURCE UTILIZATION RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER UNIT RESOURCE CHANGE	LIMITING VARIABLE
FLTLNMGR	2080	288	1792	14			
IG001	900	936	-36	104			
IG002	900	360	540	40			
IG003	900	900	0	100			
IG004	1800	1800	0	100			
IG005	2700	2700	0	100			
IG006	1800	1800	0	100			
IG007	1800	1576	224	88			
IG008	1800	1792	8	100			
N-19A120	2080	1080	1000	52			
N-19A122	2080	540	1540	26			
N-30.106	2080	198	1882	10			
N-30.107	2080	900	1180	43			
N-30.108	2080	316	1764	15			
N-30.167	2080	1286	794	62			
N-30.180	2080	2080	0	100			
N-30.181	2080	1512	568	73			

FIGURE II-31 SCENARIO 4 - SCRR RESOURCE DATA OUTPUT - 900 HOURS AVAILABILITY

S C R R
LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

RESOURCE DATA

RESOURCE	ANNUAL AVAILABILITY (HOURS)	ANNUAL UTILIZATION (HOURS)	HOURS UNDER UTILIZED	PERCENT UTILIZATION	RESOURCE UTILIZATION RANGE MINIMUM MAXIMUM	THROUGHPUT CHANGE PER UNIT RESOURCE CHANGE	LIMITING VARIABLE
FLTLNMGR	2080	1093	987	53	288.0 1093.3	-0.333 -INFINITY	510V
1G001	1000	1000	0	100	936.0 2793.1	-0.018 0.018	011A 516P
1G002	1000	822	178	82	392.2 822.2	-0.149 -INFINITY	5698
1G003	1000	1000	0	100	792.0 1080.0	-0.444 0.444	5100 1G002
1G004	2000	2000	0	100	792.0 3480.0	-0.556 0.556	510W FLTLNMGR
1G005	3000	3000	0	100	2400.0 5200.0	-0.160 0.160	5107 N-19A120
1G006	2000	2000	0	100	1400.0 2912.0	-0.357 0.357	[illegible] [illegible]
1G007	2000	1542	458	77	576.0 1576.0	-0.167 -0.071	[illegible] [illegible]
1G008	2000	1530	470	77	1530.0 2035.1	-INFINITY -0.136	 5698
N-19A120	2080	1200	880	58	960.0 1200.0	-0.400 -INFINITY	1G005
N-19A122	2080	600	1480	29	480.0 600.0	-0.800 -INFINITY	1G005
N-30.106	2080	452	1628	22	215.7 452.2	-0.270 -INFINITY	569P
N-30.107	2080	1000	1080	48	792.0 1000.0	-0.444 -INFINITY	1G0[illegible]
N-30.108	2080	270	1810	13	270.0 352.9	-INFINITY -0.770	 5698
N-30.167	2080	1429	651	69	1000.0 1428.6	-0.500 -INFINITY	1G006
N-30.180	2080	2080	0	100	1114.5 2538.5	-0.167 0.167	516P 1G007
N-30.181	2080	907	1173	44	504.0 1712.0	-1.667 -0.333	1G004 510V

FIGURE II-32 SCENARIO 4 - SCRR RESOURCE DATA OUTPUT - 1000 HOURS AVAILABILITY

```
                                                   S C R R
                                  LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
RESOURCE DATA
                                                                                  RESOURCE     THROUGHPUT
                  ANNUAL          ANNUAL         HOURS         PERCENT       UTILIZATION     CHANGE       LIMITING
  RESOURCE     AVAILABILITY    UTILIZATION       UNDER       UTILIZATION     ---RANGE---    PER UNIT      VARIABLE
                 (HOURS)         (HOURS)       UTILIZED                        MINIMUM      RESOURCE
                                                                               MAXIMUM       CHANGE


  FLTLNMGR         2080            1360           720            65             320.0       -0.333      510V
                                                                               1360.0      -INFINITY

  1G001            1200            1200             0           100             936.0       -0.038      011A
                                                                               2793.1        0.038      536P

  1G002            1200            1200             0           100             470.4       -0.149      1G008
                                                                               1266.7        0.149      569B

  1G003            1200            1200             0           100            1170.0       -0.114      569B
                                                                               1528.2        0.114      1G008

  1G004            2400            2400             0           100             792.0       -0.556      510W
                                                                               3480.0        0.556      FLTLNMGR

  1G005            4800            4800             0           100            2400.0       -0.160      5107
                                                                               5200.0        0.160      N-19A120

  1G006            2400            2400             0           100            1400.0       -0.357      536K
                                                                               2912.0        0.357      N-30.167

  1G007            2400            1434           966            60             576.0       -0.167      N-30.180
                                                                               1576.0       -0.071      1G001

  1G008            2400            1603           797            67            1530.0       -0.047      1G003
                                                                               2520.9       -0.136      1G002

  N-19A120         2080            1440           640            69             960.0       -0.400      1G005
                                                                               1440.0      -INFINITY

  N-19A122         2080             720          1360            35             480.0       -0.800      1G005
                                                                                720.0      -INFINITY

  N-30.106         2080             660          1420            32             258.8       -0.270      1G002
                                                                                660.0      -INFINITY

  N-30.107         2080            1200           880            58            1170.0       -0.114      1G003
                                                                               1200.0      -INFINITY

  N-30.108         2080             283          1797            14             270.0       -0.267      1G003
                                                                                423.5       -0.770      1G002

  N-30.167         2080            1714           366            82            1000.0       -0.500      1G006
                                                                               1714.3      -INFINITY

  N-30.180         2080            2080             0           100            1222.2       -0.167      536P
                                                                               3046.2        0.167      1G007

  N-30.181         2080            1040          1040            50             504.0       -1.667      1G004
                                                                               2112.0       -0.333      510V
```

FIGURE II-33 SCENARIO 4 - SCRR RESOURCE DATA OUTPUT - 1200 HOURS AVAILABILITY

```
                                                    S C R R
COURSE DATA                      LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

   COURSE      MAXIMUM        CURRENT        CLASS        ANNUAL       THROUGHPUT      CLASS
   CDP NO.      ANNUAL       SCHEDULED       INPUT      CONVENINGS       CHANGE       CAPACITY        LIMITING
              CONVENINGS     CONVENINGS     CAPACITY      RANGE       PER COURSE       RANGE          VARIABLE
                                                         MINIMUM       CONVENING      MINIMUM
                                                         MAXIMUM        CHANGE        MAXIMUM


   011A          12.0           12             10
   510G           6.0            6             12
   510V          32.1           12             10
   510W          24.0           24             10
   5107          24.0           24             16
   536K          50.0           50             10
   536P          29.2           12              8
   569B           6.0            6             12

   TOTAL CONVENINGS    183.4
   TOTAL THOUGHPUT    1944.0
```

FIGURE II-34 SCENARIO 4 - SCRR COURSE DATA OUTPUT - 700 HOURS AVAILABILITY

```
                                                    S C R R
COURSE DATA                      LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS

   COURSE      MAXIMUM        CURRENT        CLASS        ANNUAL       THROUGHPUT      CLASS
   CDP NO.      ANNUAL       SCHEDULED       INPUT      CONVENINGS       CHANGE       CAPACITY        LIMITING
              CONVENINGS     CONVENINGS     CAPACITY      RANGE       PER COURSE       RANGE          VARIABLE
                                                         MINIMUM       CONVENING      MINIMUM
                                                         MAXIMUM        CHANGE        MAXIMUM


   011A          12.0           12             10
   510G           6.0            6             12
   510V          45.6           12             10
   510W          24.0           24             10
   5107          27.0           24             16
   536K          64.3           50             10
   536P          32.8           12              8
   569B           7.0            6             12

   TOTAL CONVENINGS    218.7
   TOTAL THOUGHPUT    2309.0
```

FIGURE II-35 SCENARIO 4 - SCRR COURSE DATA OUTPUT - 900 HOURS AVAILABILITY

BEST COPY AVAILABLE

```
                                          S C R R
                          LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSI
COURSE DATA

  COURSE      MAXIMUM      CURRENT       CLASS       ANNUAL      THROUGHPUT     CLASS      LIMITING
  COP NO.     ANNUAL      SCHEDULED      INPUT    CONVENINGS      CHANGE      CAPACITY     VARIABLE
            CONVENINGS   CONVENINGS    CAPACITY   __RANGE___   PER COURSE      RANGE
                                                    MINIMUM     CONVENING     MINIMUM
                                                    MAXIMUM      CHANGE       MAXIMUM


  011A         12.8          12.          10           1.7         -3.0          7.0      IG001
                                                      12.0     -INFINITY    +INFINITY

  510G         13.7           6           12           6.5         -8.9          3.1      569B
                                                      13.7     -INFINITY    +INFINITY

  510V         12.0          12           10         -37.3          6.7    -INFINITY      FLTLNHGR
                                                      52.3         -6.7         16.7      510W

  510W         91.1          24           10          -6.7         -4.0          6.0      510V
                                                      91.1     -INFINITY    +INFINITY

  510T         30.0          24           16     -INFINITY        -16.0          0.0      IG005
                                                      30.0     -INFINITY    +INFINITY

  536K         71.4          50           10     -INFINITY        -10.0          0.0      IG006
                                                      71.4     -INFINITY    +INFINITY

  536P         32.1          12            8     -INFINITY         -8.0          0.0      N-30.180
                                                      32.8         -3.4         11.4      IG001

  569B          6.0           6           12           5.2         34.7    +INFINITY      IG002
                                                       7.8        -34.7         45.7      IG008

  TOTAL CONVENINGS     269.2
  TOTAL THROUGHPUT    2847.0
```

FIGURE II-36 SCENARIO 4 - SCRR COURSE DATA OUTPUT - 1000 HOURS AVAILABILITY

```
                                          S C R R
                          LP OPTIMAL SOLUTION AND SENSITIVITY ANALYSIS
COURSE DATA

  COURSE      MAXIMUM      CURRENT       CLASS       ANNUAL      THROUGHPUT     CLASS      LIMITING
  COP NO.     ANNUAL      SCHEDULED      INPUT    CONVENINGS      CHANGE      CAPACITY     VARIABLE
            CONVENINGS   CONVENINGS    CAPACITY   __RANGE___   PER COURSE      RANGE
                                                    MINIMUM     CONVENING     MINIMUM
                                                    MAXIMUM      CHANGE       MAXIMUM


  011A         15.4          12           10          -7.6         -3.0          7.0      IG001
                                                      15.4     -INFINITY    +INFINITY

  510G         20.0           6           12           7.8         -0.9          3.1      IG002
                                                      20.0     -INFINITY    +INFINITY

  510V         12.0          12           10         -24.0          6.7    +INFINITY      FLTLNHGR
                                                      64.0         -6.7         16.7      N-30.181

  510W        113.3          24           10          26.7         -4.0          6.0      510V
                                                     113.3     -INFINITY    +INFINITY

  510T         36.0          24           16     -INFINITY        -16.0          0.0      IG005
                                                      36.0     -INFINITY    +INFINITY

  536K         85.7          50           10     -INFINITY        -10.0          0.0      IG006
                                                      85.7     -INFINITY    +INFINITY

  536P         29.9          12            8     -INFINITY         -8.0          0.0      N-30.180
                                                      32.8         -3.4         11.4      IG001

  569B          6.3           6           12     -INFINITY        -12.0          0.0      IG003
                                                       9.4        -34.7         46.7      IG002

  TOTAL CONVENINGS     318.6
  TOTAL THROUGHPUT    3394.7
```

FIGURE II-37 SCENARIO 4 - SCRR COURSE DATA OUTPUT - 1200 HOURS AVAILABILITY

(THIS PAGE INTENTIONALLY LEFT BLANK.)

SECTION III

EDUCATIONAL TECHNOLOGY EVALUATION MODEL

MODEL DESCRIPTION AND FUNCTIONAL SPECIFICATIONS

With the increasing emphasis on self-paced, individualized instruction in naval training, there is a requirement for a method for predicting the resources necessary to support individualized instruction and for evaluating different types of administration for such systems.

The Educational Technology Evaluation (ETE) model is a generalized, discrete simulation model designed to simulate the flow of students through an Individualized Learning System (ILS). Its purpose is to permit simulation of a variety of ILS configurations, student flows, and course strategies by manipulation of input data alone rather than by modification of the model itself. It is the generality of the model that is the key factor in its design.

The ETE model is not intended for use in evaluating educational media or techniques with regard to training effectiveness. It is designed to evaluate the effectiveness of different strategies (e.g., computer managed instruction or instructor managed instruction), with regard to throughput and resource utilization efficiency. Given curricula and media descriptions, an estimate of the input rate for different student types, and an inventory of available instructors, learning modules, and facilities, the ETE model will project system output, average time-to-complete, and instructor and facility utilization.

The primary problem arising in the design of a generalized simulation model lies in balancing model capability with ease of use. Theoretically, it is possible at least to approximate every combination of events and resource usage that the analyst can envision. However, every additional level of complexity which exists internal to the model demands, at a minimum, a control or selection type input. Since all inputs must be specified by the user, the complexity of input data rises as a direct function of the level of detail contained in the model. Consequently, models that contain highly detailed representations of internal system activities may require input data so complex as to discourage the potential user.

One way to avoid this problem is to construct simulation models which are tailored to a particular system or activity. Such models can contain explicit and complex mechanizations which do not require extensive input data for support. On the other hand, highly specific models are rarely applicable to other systems without revision. The disadvantages of constructing a new model for each system configuration to be simulated include: delays in constructing and testing the models, a continuing need for qualified personnel to construct the models; and constantly changing input requirements imposed on the mode users.

ASSUMPTIONS NECESSARY FOR GENERALITY. In order to model certain aspects of an ILS without tailoring the model to a specific system, it is necessary to assume that generalized representations can be made which are applicable in a number of cases. In general, these assumptions center around criteria for deciding when certain activities are required and the activity patterns for certain facilities.

Some areas which present difficulties in generalized representation are: (1) instructor/student interaction; (2) remedial activities involving instructional matter in a different medium; (3) conditional branching within a course of instruction; and (4) preemption of facilities by students designated as having priority over other students. Detailed information on the particular methods used to model each of these activities, or the rationale for exclusion of a particular form of simulated activity, can be found in Section III, Logic Design.

There are other activities which are so basic to the operation of an ILS that their inclusion in the model is mandatory. These include:

a. A single course, or multiple courses.

b. Different media characteristics specified by module.

c. Individual and team training modules.

d. Instructors assigned by qualifications and responsible for specific modules.

e. Remediation activities, including probability of occurrence and required support.

The basic technique used to achieve generality of application was to designate all student activities, whether learning or administrative, as "modules." Each of these modules is tagged with an identification code which designates the type of support required for that module. Since all parts of the ILS, excluding the students, can be thought of as resources to be used in support of the student, contention between students and the demand level for each type of resource comprise the basic content of the model. For example, the student sign-in procedure referenced in Figure III-1 can be represented as a module which every student must complete first, and which requires the support of ancillary personnel. By following this approach, the user can simulate different administrative procedures without supplying data in a multitude of forms. The use of module code numbers is explained beginning on page III-7.

The ETE model was written using the General Purpose Simulation System (GPSS)[4] which consists of a high level simulation language, the language compiler, and a model execution control program. Although GPSS designates a specific IBM-developed program package, other versions have been developed by other manufacturers and include the GPS K (Honeywell) and Flow Simulator (RCA). Both Univac and Control Data Corporation also have GPSS compilers .

As might be expected, GPSS has certain characteristics and limits as to model execution time and model size. These characteristics did not impact model design to any significant extent but do carry implications regarding model usage. These implications are discussed on page III-31, Validation Results.

---

[4] GPSS Primer, Stanley Greenberg

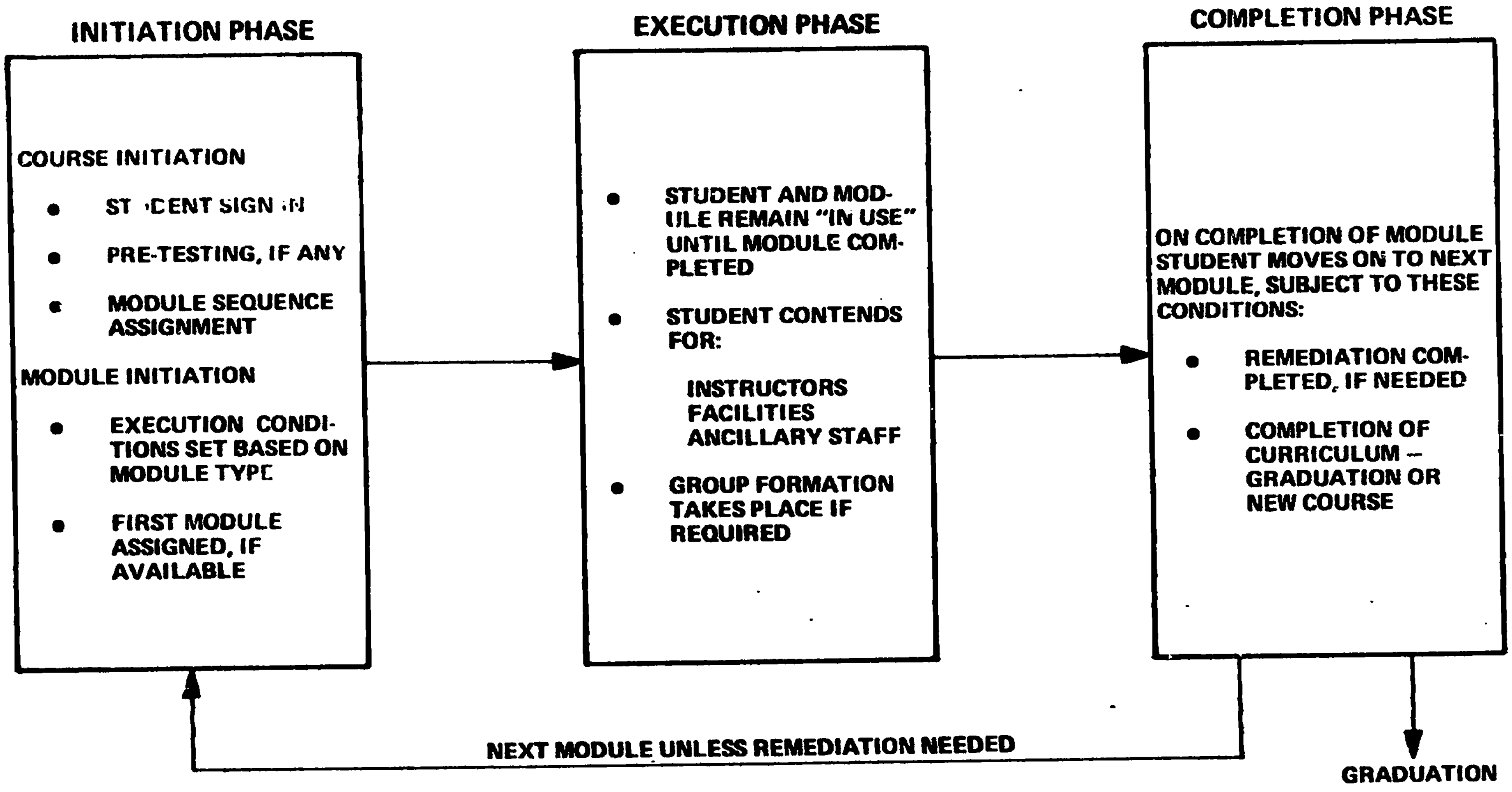


FIGURE III-1 EDUCATIONAL TECHNOLOGY MODEL MACRO LOGIC

INPUT PARAMETERS DESCRIPTION

In general, inputs are required to define the learning system configuration; i.e., curricula, number of instructors, module completion times, etc., of the courses being simulated. This section is divided into two parts. The first part describes each of the required input parameters. The second part defines the required format of the input data. It should be noted that the format specified applies to the model as it currently exists. A simplified input format will be generated during Phase III. The method for insertion of the formatted input data in the model is covered in Volume III of the report.

REQUIRED INPUT DATA. Listed below are the parameters required to formulate an ILS model.

a. Rate of student input.

b. Number of student types and distribution - Student type is directly related to the curriculum to be followed by that student. Student distribution is the percent of all incoming students assigned to each type.

c. Curricula - A curriculum, which consists of the sequence of module numbers to be completed by the student, must be supplied for each student type. For example:

Student type I: Modules 1, 3, 6, 7, 9 and 11.

Student type II: Modules 2, 3, 4, 5, 7, 8 and 9.

d. Module type code - Each module must be assigned a code number between 0 and 31. This code number describes the support requirements for the module (e.g., instructor required, other equipment, etc.), over and above the availability of the module itself.

e. Instructor qualifications - Available instructors are grouped according to the modules they are qualified to teach. For example, modules 1-4 may be assigned to instructor group I, modules 5-10 to instructor group II, etc.

f. Number of instructors - The number of instructors in each instructor group must be specified.

g. Available modules - The number of copies of the instructional matter for each module must be specified. For example, if module number 3 is a video tape cassette, the number of cassettes in the inventory is supplied here.

h. Number of students per team - If any of the modules in a course require a team of students, the number of team members is specified here.

i. Remedial modules - Where a module is designated as having remedial matter which is not self-contained, a corresponding remedial module type must be designated.

j. Number of remedial modules - The number of available remedial modules of each type must be specified in the same way as the primary modules.

k. Projected completion times - Each module, both primary and remedial, must have an estimate of time-to-complete.

l. Completion spread - The completion time (item k.) for each module may be modified by a spread value. For example, if the projected time-to-complete for a given module is two hours, the factor may be modified by a spread so that completion time becomes two hours plus or minus thirty minutes. If no spread is supplied, a zero value is assumed.

m. Available facilities - Where other facilities (such as carrels or power supplies) are required for completion of a particular module, the number of available facilities must be specified.

Care must be exercised in supplying consistent input data. If, for example, seven different student types are defined, seven curricula must also be defined. Otherwise, an execution error will result.

Required Input Data Format. With the exception of the student input rate, all required input data are in the form of tables. These tables all have similar formats consisting of a single table definition card, called a FUNCTION card, and as many additional cards as are needed to supply the required entries to fill the table.

Curriculum tables are designated by number (1 through n, where n is the same as the number of student types), all other tables are designated by alphabetic mnemonics. The easiest way to describe the required input formats is to define a hypothetical ILS which is to be modeled, and then to describe the tables required to define this system.

The hypothetical system has the following characteristics:

a. Three types of students.

b. A maximum of eight instructional modules.

c. Two groups of instructors; group 1 qualified to teach modules 1-4, group 2 qualified to teach modules 5-8. There will be three instructors in each group.

d. Modules 5 and 6 are team modules requiring two students and four students respectively.

e. The three student types are distributed as follows: 30% type I; 45% type II; and 25% type III.

Other system characteristics will be discussed in connection with the construction of the appropriate table.

Figure III-2 shows the required card layout for all of the inputs required for the hypothetical ILS. Each of the card types will be discussed as they appear in the figure.

INPUT CARD SPECIFICATIONS

TABLE NAME	
CURRICULUM CARDS	1 FUNCTION A9,L6
	1,4/2,3/3,4/4,6
	2 FUNCTION A9,L5
	1,2/2,4/3,5/4,6/5,7
MODULE TYPE CARDS	MDT FUNCTION A2,L8
	1,9/2,17/3,0/4,4/5,10/6,3/7,4/8,16
COMPLETION TIME CARDS	TYPE FUNCTION A8,L8
	1,4/2,9/3,4/4,1/5,8/6,4/7,8/8,3
COMPLETION TIME VARIATION CARDS	SPRD FUNCTION A2,L8
	1,8/2,3/3,1/4,1/5,2/6,1/7,1/8,1
INSTRUCTOR ASSIGNMENT CARDS	INST FUNCTION A2,L8
	1,3/2,3/3,3/4,3/5,6/6,6/7,6/8,6
INSTRUCTOR QUALIFICATION CARDS	INSTQ FUNCTION A2,L8
	1,2/2,2/3,2/4,2/5,2/6,2/7,2/8,2
MODULE LOCATION CARDS	MODFL FUNCTION A2,L8
	1,30/2,45/3,55/4,70/5,75/6,90/7,115/8,160
MODULE INVENTORY CARDS	MOIN FUNCTION A2,L8
	1,10/2,10/3,5/4,10/5,5/6,15/7,20/8,15
REMEDIAL MODULE LOCATION CARDS	MODRL FUNCTION A2,L8
	1,0/2,100/3,0/4,0/5,0/6,0/7,0/8,150
REMEDIAL MODULE INVENTORY CARDS	MODRN FUNCTION A2,L8
	1,0/2,15/3,0/4,0/5,0/6,0/7,0/8,10
REMEDIAL MODULE TYPE CARDS	MODR FUNCTION A2,L8
	1,0/2,1/3,8/4,0/5,0/6,0/7,0/8,1
OTHER FACILITIES ASSIGNMENTS	FACT FUNCTION A2,L8
	1,1/2,0/3,0/4,0/5,2/6,0/7,0/8,0
STUDENT DISTRIBUTION CARDS	STUDT FUNCTION AN2,D3
	.30,1/.75,2/1.0,3
OTHER FACILITIES INVENTORY	STORAGE S1,50/S2,75-,-
TEAM DEFINITION CARDS	TEAM FUNCTION A2,L8
	1,0/2,0/3,0/4,0/5,2/6,4/7,4/8,0

FIGURE III-2 INPUT CARD SPECIFICATIONS

Curriculum Cards. The format of these cards as regards card columns, and the use of commas and slashes as separators, is the same for all table entries and need be discussed only once.

The first curriculum card defines the number of the curriculum (card column 2). The word FUNCTION always appears in card columns 8-15 as does P9 in card columns 19-20. The symbol L4 in card columns 22-23 specifies the length (number of modules) of the curriculum. For other curricula, only the curriculum number and the number of modules will change.

The second curriculum card specifies the module number that corresponds to each step in that particular curriculum. If more than one card is required to define a curriculum, the card layout is always the same. Entries always begin in column 1 and there are no blank spaces in the body of the input data.

Each pair of numbers; e.g., 1, 2, designate first the step number and then its associated module number. The slashes serve to separate the pairs of values. The number of pairs of values must equal the curriculum length specified in the first curriculum card.

In the example given in Figure III-2, the first two curriculum cards contain the following specifications:

a. Curriculum number is 1.

b. Curriculum length is 4 modules.

c. The curriculum consists of modules 1, 3, 4, and 5, in that order.

Module Type Cards. Module type cards are used to relate the module type code with the module number. The type code designates the support requirements for the particular module. Table III-1 lists 31 type codes and shows the requirements specified by each type code. A type code of zero is also permissible and designates a module with no outside support requirements (a programmed instruction manual would be a type zero module).

The first module type card has the same format as the first curriculum card, except that the function is designated by the mnemonic MODT instead of a number. Note that the length designator (column 23) equals 8, the number of modules available for the course. Every module specified for a course must have a corresponding module type code.

The second and subsequent module type cards follow the same format as comparable curriculum cards. The first digit of each pair designates the module number and the second module type.

In the example given, the first module type code specifies a module requiring instructor assistance and facilities such as a video tape player (see Table III-1). The second type code designates a module requiring instructor assistance and one in which remedial matter is not self-contained. Note that modules 5 and 6 both have codes which identify them as group modules per the problem statement.

MODULE TYPE CODE DEFINITIONS

MODULE TYPE	REQUIREMENT
1	INSTRUCTOR
2	GROUP
3	INSTRUCTOR, GROUP
4	STAFF
5	INSTRUCTOR, STAFF
6	GROUP, STAFF
7	INSTRUCTOR, GROUP, STAFF
8	FACILITIES (FACIL)
9	INSTRUCTOR, FACIL
10	GROUP, FACIL
11	INSTRUCTOR, GROUP, FACIL
12	STAFF, FACIL
13	INSTRUCTOR, STAFF, FACIL
14	GROUP, STAFF, FACIL
15	INSTRUCTOR, GROUP, STAFF, FACIL
16	REMEDIAL (REM)
17	INSTRUCTOR, REM
18	GROUP, REM
19	INSTRUCTOR, GROUP, REM
20	STAFF, REM
21	INSTRUCTOR, STAFF, REM
22	GROUP, STAFF, REM
23	INSTRUCTOR, GROUP, STAFF, REM
24	FACILITIES, REM
25	INSTRUCTOR, FACIL, REM
26	GROUP, FACIL, REM
27	INSTRUCTOR, GROUP, FACIL, REM
28	STAFF, FACIL, REM
29	INSTRUCTOR, STAFF, FACIL, REM
30	GROUP, STAFF, FACIL, REM
31	INSTRUCTOR, GROUP, STAFF, FACIL, REM

TABLE III-1

Completion Time Cards. Completion time cards are used to specify the average expected completion time for each module. Time is stated as an integer number representing the number of times the internal model clock will "tick" before the module is completed. The user must relate the internal clock to external time by deciding what period of real-time is represented by each tick of the internal clock. For example, if each tick of the internal clock represents one half-hour of external time, then a module whose expected average completion time is two hours would be given a completion time of 4. The user must take care to maintain consistency in using the internal clock. Student input to the system is also governed by the internal clock and the same ratio of internal to external time must be maintained for student input as for module completion time.

The first completion time card is identical in format to the first module type card except for the acronym change.

The second completion time card is similar in format to the second module type card and, in the example, specifies module 1 as requiring 6 internal time increments, module 2 as requiring 9, and so forth.

Completion Time Variation Cards. Each module, in addition to the average time to complete, can also have a range of variation around the average. When specified, the range causes the average completion time to be modified so that completion times range between the average minus a specified delta, and the average plus that same delta. The completion time is modified on a random basis so the average completion time, over a sufficient sample, remains as specified, but individual completion times can vary between the limits set by these cards.

The format of these cards is the same as those for the completion time cards. The example given in Figure III-2 would yield a completion range for module 1 of 6 ± 2 internal clock increments. The completion time variation must always be equal to, or less than, completion time itself.

Instructors and Modules. Before discussing the input cards which govern the availability of instructors, modules, remedial modules, etc., it is necessary to explain the way in which the model handles these different entities.

With the exception of "Other Facilities" (which are discussed later in this section), all resources for which the student may contend, are considered by the model to be a single table of resources. It is the position within the table that identifies the type of resource under consideration. The user specifies which type of resource occupies a particular area of the resource table and the number of resource items available.

For example, in a table of 200 resource units positions, 1-12 might be set aside for instructors, 13-150 for instructional modules, and 151-200 for remedial modules.

In the example system under consideration, there are to be two instructor groups. If each instructor group has a maximum of three instructors, then the maximum number of instructors will be six. Consequently, positions 1-6 in the resource table are set aside for instructors (in practice, it is a good idea to allow a margin for change in case the initial estimate of a "maximum" turns out to be too low).

Instructor Assignment Cards. This function carries the mnemonic INSTT and the card formats are the same as those previously discussed. In the second (and subsequent) instructor assignment card, the first of each pair of numbers is the module number and the second shows the assigned position of the first instructor in the group within the resource table. Note that modules 1-4 all point to position 3 in the resource table and 5-8 all point to position 6. This coincides with the requirement that there be two instructor groups qualified to handle modules 1-4 and 5-8, respectively.

Instructor Qualification Cards. These cards define the number of members in each instructor group and are designated INSTN. As the second card indicates, the number of qualified instructors is specified for each module. In this way, it is possible to simulate instructor groups in which all members are not qualified to teach all modules.

Module Location and Inventory Cards. These two tables (MODFL and MODN) perform exactly the same function with respect to modules as INSTT and INSTN do for instructors. The first function (MODFL) specifies the resource table location of the module and the second (MODN) specifies the number of available modules.

Remedial Module Type Cards. Remedial modules are treated in the same fashion as regular instruction modules, except that the module number referred to is that of the primary module, so a function to supply the module number is not needed. MODR supplies a type code for each remedial module, MODRL locates the module in the resource table, and MODRN carries the available module inventory.

Other Facilities Assignment Cards. As previously mentioned, other facilities are not included in the table of resources. They occupy their own table, but the method for relating module number to resource group is the same as that for any other resource. Similar facilities, such as carrels or terminals, are arranged in groups and a module requiring these facilities is related to the group number of the appropriate facility.

The other facilities function is called FACT and its format is the same as other tables in this series. In the example, modules 1 and 5 are associated with facilities groups 1 and 2, respectively. Modules which do not require other facilities have a zero entry in the facilities group number.

Student Distribution Cards. Both the first card and the subsequent cards in this group differ in format from those discussed so far. The first card can be reproduced one for one with the example, except that the digit following the letter D must equal the number of pairs of arguments appearing in the following cards.

Team Definition Cards. Like the module type cards and the completion time cards, the team definition cards relate module number to a particular module attribute. In this case, the attribute in question is the number of members required for a team-type module. The card format is the same as that of MODT, TYME, and several other functions.

The illustration in Figure III-2 allocates two team members to module five, and four to module six. Again, note that the modules specified correspond to those designated by the module type code as being team modules. In the event of erroneous data entry causing a team to have zero members, the model will still process a single individual in place of that team.

The second card differs from those previously discussed in that the first number of each pair is no longer an integer but a decimal fraction. Each decimal fraction represents the cumulative total of percentages for each student type. In the example, the first decimal fraction (.30) corresponds to the stated requirement that 30% of the input students are type I. The next argument (.75) is the total of 30% for type I and 45% for type II.

Other Facilities Inventory Cards. As noted, other facilities are not included in the standard resources table. This difference is also evident in the cards required to define the facilities inventory. All inventory cards have the same format (there is no difference between the first and subsequent cards). In each pair of arguments, the first argument, Sn, designates the facilities group (S1 is group 1, S2 group 2, etc.). The second number in the pair is the number of items available in that group. In the example, group 1 has 50 items, group 2 has 75. As many different types of facilities may be defined as are required.

OUTPUT PARAMETERS DESCRIPTION

GPSS provides certain standard outputs which are described in this section. Three additional outputs have been programmed into the ETE model. Others can be added as operational need dictates.

An alternate output format is available which yields the same data as the standard package, but with labels which are specific to ILS.

STANDARD OUTPUTS. The standard GPSS outputs include the following:

a. Facility utilization - Facility, in this sense, is a general term covering instructors, learning modules, and support facilities. In all cases, number of students using, average time of use, and percent utilization are given.

b. Queue statistics - Whenever a student is required to wait for any reason, whether for group formation or instructor availability, certain statistics are gathered by the model. These include:

    Maximum queue length
    Average queue length
    Total student entries in the queue
    Average waiting time.

c. Entry counts - These statistics indicate the number of students who pass through each part of the system. While primarily useful in logic validation, they can also indicate unsuspected paths through the system and point to potential overload conditions.

d. Additional outputs - Average time-to-complete: the average time-to-complete for each student type is computed and output. Number of completions: the number of student completions, arranged by student type, is supplied.

The format for the standard output is illustrated in Figure III-3. In the standard format, none of the facilities or queues are identified by number.

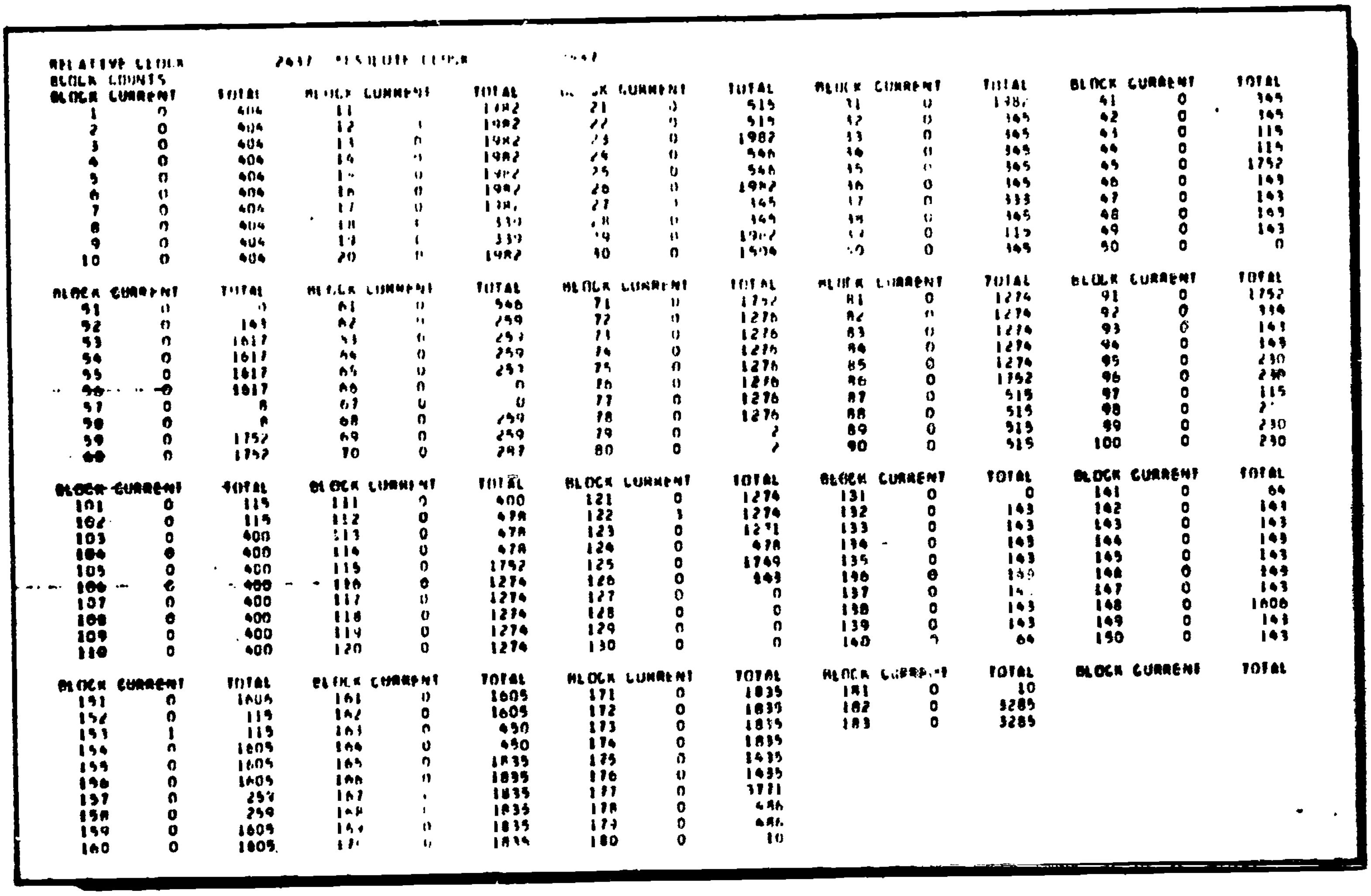
```
                                        ****************************************
                                        *                                      *
                                        *             FACILITIES               *
                                        *                                      *
                                        ****************************************


                                          -AVERAGE  UTILIZATION  DURING-
FACILITY     NUMBER       AVERAGE           TOTAL   AVAIL.   UNAVAIL.     CURRENT       PERCENT       TRANSACTION NUMBER
             ENTRIES      TIME/TRAN          TIME    TIME     TIME        STATUS     AVAILABILITY     SEIZING  PREEMPTING
    5            2           .000            .000                                       100.0
    6          218           .071            .014                                       100.0
   13            8           .375            .002                                       100.0
   14          217           .155            .027                                       100.0
   19            6           .167            .000                                       100.0
   20          116           .448            .044                                       100.0
   27            8          3.625            .025                                       100.0
   30           74          4.041            .257                                       100.0        188
   37            3          1.000            .002                                       100.0
   40           78          1.000            .067                                       100.0
   48            1          2.000            .001                                       100.0
   49           25          1.840            .039                                       100.0
   50          132          1.970            .224                                       100.0
   59           10          2.700            .023                                       100.0
   60           81          2.975            .207                                       100.0        186
   70           52          1.000            .044                                       100.0
   78            4          5.000            .017                                       100.0
   79           10          4.100            .111                                       100.0
   80           50          4.160            .179                                       100.0
   88           14          5.571            .067                                       100.0
   89           10          4.311            .127                                       100.0
   90           78          4.837            .329                                       100.0
   98            2          2.000            .003                                       100.0
   99           11          2.000            .018                                       100.0
  100           65          2.000            .112                                       100.0
  118            1          6.000            .005                                       100.0
  119           24          2.875            .059                                       100.0
  120          112          2.857            .276                                       100.0        186
  139            2          3.500            .006                                       100.0
  140           67          2.246            .132                                       100.0
```

```
                                        ****************************************
                                        *                                      *
                                        *               QUEUES                 *
                                        *                                      *
                                        ****************************************


QUEUE      MAXIMUM      AVERAGE      TOTAL        ZERO      PERCENT      AVERAGE       $AVERAGE       TABLE     CURRENT
          CONTENTS     CONTENTS     ENTRIES     ENTRIES      ZEROS     TIME/TRANS     TIME/TRANS      NUMBER    CONTENTS
    1          1         .000          82          82        100.0         .000           .000
    3          1         .000         158         158        100.0         .000           .000
    5          3        1.036         158          53         33.5        7.601         11.438                        2
   13          2         .089         104                       .0        1.000          1.000
   90        184       90.980         194                       .0      573.075        573.075                      184
  126          1         .000         240         240        100.0         .000           .000
  139          4        1.742         230         225         97.8        8.782        404.000                        3
  140          1         .000         122         122        100.0         .000           .000
$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES
```

```
                                        ****************************************
                                        *                                      *
                                        *         FULLWORD SAVEVALUES          *
                                        *                                      *
                                        ****************************************


     NUMBER - CONTENTS    NUMBER - CONTENTS    NUMBER - CONTENTS    NUMBER - CONTENTS    NUMBER - CONTENTS    NUMBER - CONTENTS
        1           1        2          16        3           8        4           4        5           2        6           1
       26          44       27          29       28          22       29          53       30          40
```

```
                                        ****************************************
                                        *                                      *
                                        *              STORAGES                *
                                        *                                      *
                                        ****************************************


                                                            -AVERAGE  UTILIZATION  DURING-
STORAGE     CAPACITY      AVERAGE     ENTRIES     AVERAGE      TOTAL   AVAIL.   UNAVAIL.  CURRENT     PERCENT       CURRENT    MAXIMUM
                          CONTENTS               TIME/UNIT      TIME    TIME     TIME     STATUS   AVAILABILITY    CONTENTS   CONTENTS
    1            3          .283         82        4.000        .094                                  100.0            1          2
    3           10          .266        158        1.949        .026                                  100.0                       3
```

FIGURE III-3 STANDARD GPSS OUTPUT



```
RELATIVE CLOCK          2437   ABSOLUTE CLOCK          [illegible]
BLOCK COUNTS
BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL
   1     0       404      11     0       1982     21     0       515      31     0       1982     41     0       345
   2     0       404      12     0       1982     22     0       515      32     0       345      42     0       345
   3     0       404      13     0       1982     23     0       1982     33     0       345      43     0       115
   4     0       404      14     0       1982     24     0       546      34     0       345      44     0       115
   5     0       404      15     0       1982     25     0       546      35     0       345      45     0       1752
   6     0       404      16     0       1982     26     0       1982     36     0       345      46     0       143
   7     0       404      17     0       1982     27     0       345      37     0       333      47     0       143
   8     0       404      18     0       339      28     0       345      38     0       345      48     0       143
   9     0       404      19     0       339      29     0       1982     39     0       115      49     0       143
  10     0       404      20     0       1982     30     0       1594     40     0       345      50     0       0

BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL
  51     0       0        61     0       546      71     0       1752     81     0       1274     91     0       1752
  52     0       143      62     0       259      72     0       1276     82     0       1274     92     0       334
  53     0       1617     63     0       253      73     0       1276     83     0       1274     93     0       143
  54     0       1617     64     0       259      74     0       1276     84     0       1274     94     0       143
  55     0       1617     65     0       253      75     0       1276     85     0       1274     95     0       230
  56     0       1617     66     0       0        76     0       1276     86     0       1752     96     0       230
  57     0       8        67     0       0        77     0       1276     87     0       515      97     0       115
  58     0       8        68     0       259      78     0       1276     88     0       515      98     0       2
  59     0       1752     69     0       259      79     0       2        89     0       515      99     0       230
  60     0       1752     70     0       297      80     0       2        90     0       515     100     0       230

BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL
 101     0       115     111     0       400     121     0       1274    131     0       0       141     0       64
 102     0       115     112     0       478     122     1       1274    132     0       143     142     0       143
 103     0       400     113     0       478     123     0       1271    133     0       143     143     0       143
 104     0       400     114     0       478     124     0       478     134     0       143     144     0       143
 105     0       400     115     0       1752    125     0       1749    135     0       143     145     0       143
 106     0       400     116     0       1274    126     0       143     136     0       139     146     0       143
 107     0       400     117     0       1274    127     0       0       137     0       14      147     0       143
 108     0       400     118     0       1274    128     0       0       138     0       143     148     0       1606
 109     0       400     119     0       1274    129     0       0       139     0       143     149     0       143
 110     0       400     120     0       1274    130     0       0       140     0       64      150     0       143

BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL   BLOCK CURRENT   TOTAL
 151     0       1605    161     0       1605    171     0       1835    181     0       10
 152     0       115     162     0       1605    172     0       1835    182     0       3285
 153     1       115     163     0       450     173     0       1835    183     0       3285
 154     0       1605    164     0       450     174     0       1835
 155     0       1605    165     0       1835    175     0       1435
 156     0       1605    166     0       1835    176     0       1435
 157     0       259     167     0       1835    177     0       3771
 158     0       259     168     0       1835    178     0       486
 159     0       1605    169     0       1835    179     0       486
 160     0       1605    170     0       1835    180     0       10
```

FIGURE III-3 (CONTINUED)

The user, in the process of specifying the number of instructors, modules, etc., during input preparation (see page III-5), automatically selects the range of numbers which designate those facilities which represent instructors, modules, etc. Queue numbers and facility numbers correspond; i.e., if facilities 105-110 are designated as representing a group of six instructors, the queues 105-110 represent the waiting lines for those instructors.

ALTERNATE OUTPUT. In the alternate output format, the output data described in the preceding paragraphs are broken out and labeled according to their specific function. Facilities utilization data are output as "Instructor Utilization," "Module Utilization," and "Other Facilities Utilization."

Queue statistics are output as "Time Waiting for Instructor" and "Time Waiting for Module."

Student statistics are output in matrix form with student type designating the columns and number of students completing and average completion time comprising the two rows.

Figure III-4 illustrates the alternate output format.

LOGIC DESIGN

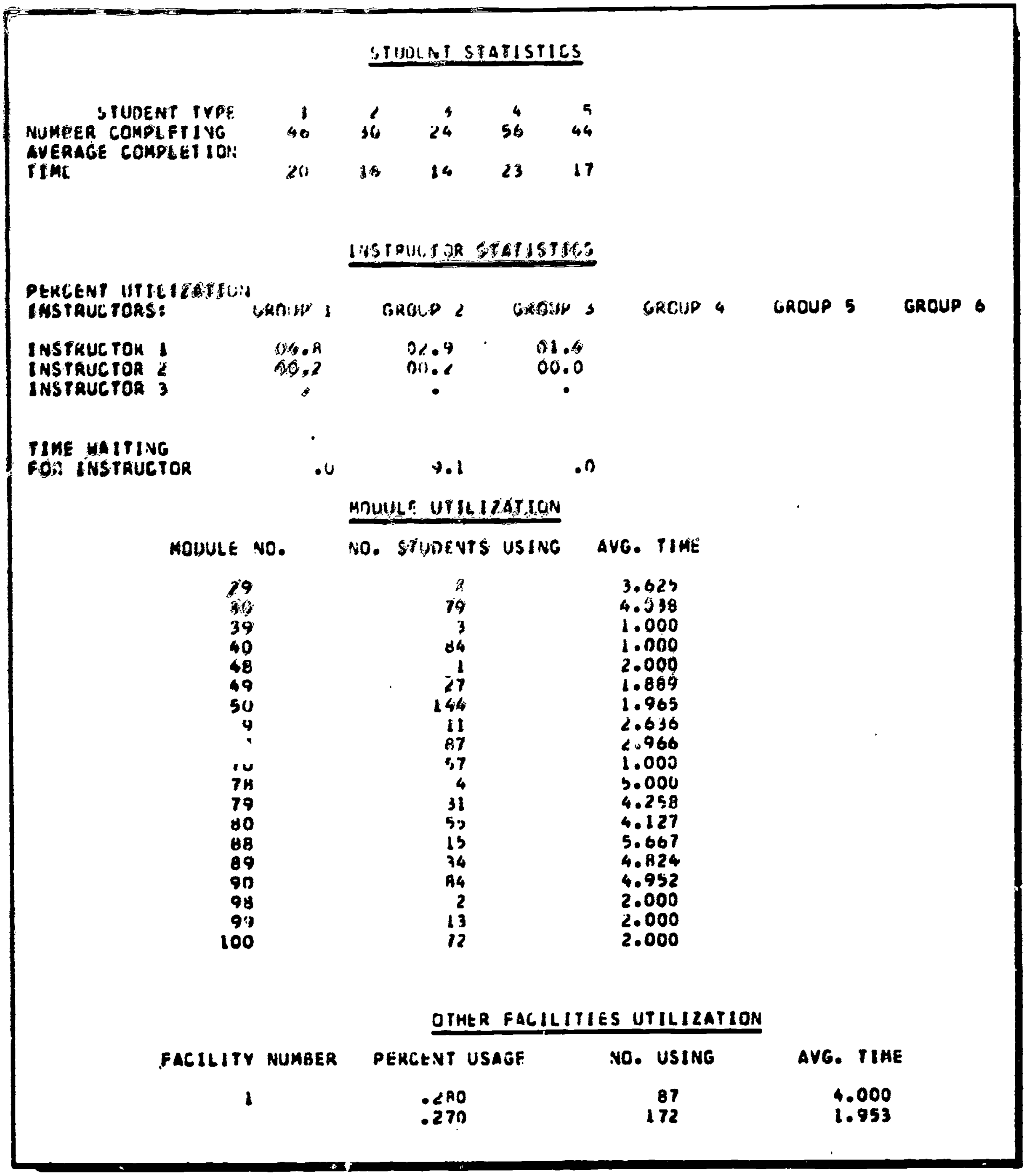
The purpose of the ETE model is to project the performance of Individualized Learning Systems (ILS) using different administrative practices and various combinations of instructors, curricula, and resources.

MODEL TECHNIQUE SELECTION. Certain aspects of the problem addressed preclude the use of some analysis techniques but lend themselves to others. Since the systems to be investigated, in many cases do not yet exist and empirical historical data are nonexistent, mathematical analysis to identify relationships between variables is not possible. Similarly, optimization where the relationships between variables are not known to be linear is also unattractive.

For these reasons, some form of simulation appeared to be the most reasonable approach. Given that simulation of proposed ILS was to be attempted, it remained to choose between continuous flow and entity type simulation. Continuous flow implies that a deterministic approach can be taken, at least insofar as simulation of student flow through parts of the system is concerned. Even where branches within the flow are simulated by probabilistic means, the flow between branches must still be approximated based on some form of relationship, either historical or assumed.

Inasmuch as most of the ILS to be simulated will consist of a set of assumptions on the part of the course designer, the combination of an assumed course configuration plus assumed flow characteristics is not likely to produce results upon which design decisions can be based. If ILS were common within the naval training system and historical data plentiful, the ETE model might well have taken the form of a deterministic flow simulation.

Where the system can be defined in terms of available resources and course steps, and the system to be simulated consists of a course, or courses, with a limited number of students on board at any one time, entity flow constitutes a viable technique.



```
                          STUDENT STATISTICS


     STUDENT TYPE           1      2      3      4      5
NUMBER COMPLETING          46     30     24     56     44
AVERAGE COMPLETION
TIME                       20     16     14     23     17



                        INSTRUCTOR STATISTICS

PERCENT UTILIZATION
INSTRUCTORS:        GROUP 1     GROUP 2     GROUP 3     GROUP 4     GROUP 5     GROUP 6

INSTRUCTOR 1          04.8        02.9        01.6
INSTRUCTOR 2          00.2        00.2        00.0
INSTRUCTOR 3           .           .           .


TIME WAITING
FOR INSTRUCTOR         .0          9.1         .0
                        MODULE UTILIZATION

          MODULE NO.       NO. STUDENTS USING    AVG. TIME

              29                   8               3.625
              30                  79               4.538
              39                   3               1.000
              40                  84               1.000
              48                   1               2.000
              49                  27               1.889
              50                 144               1.965
               9                  11               2.636
    [illegible]                   87               2.966
    [illegible]                   57               1.000
              78                   4               5.000
              79                  31               4.258
              80                  55               4.127
              88                  15               5.667
              89                  34               4.824
              90                  84               4.952
              98                   2               2.000
              99                  13               2.000
             100                  72               2.000



                                 OTHER FACILITIES UTILIZATION

         FACILITY NUMBER   PERCENT USAGE         NO. USING         AVG. TIME

               1               .280                 87               4.000
                               .270                172               1.953
```

FIGURE III-4 ALTERNATE OUTPUT FORMAT

The average-on-board for the course or school being simulated is probably the key variable in deciding whether entity flow is applicable to a particular class of problems. Regardless of the complexity of the model itself, each entity (student) active in the system requires memory space to track status, position in the logic flow, etc. As the AOB grows, the demand for computer memory grows and the execution time required to scan the status of all students increases. Eventually, the computer system itself will place a limit on the number of students that can be processed.

The results to be derived from the simulation also bear on the selection of the technique for simulation. If, for example, the only parameter of interest was the output of a collection of courses over time, then some form of deterministic model could be postulated which would produce estimates of system performance. If, however, the course designer wishes to derive estimates of the effect of individual parameters within the system (such as the number of instructors available to teach a particular course), then such a highly aggregated approach would not be useful. Therefore, since the ETE model is intended for initial use as a course design tool, a discrete entity simulation approach was selected.

IMPLICATIONS OF ENTITY FLOW SIMULATION. It is implicit in the selection of entity flow simulation such as the ETE modeling technique, that the events which take place as the student passes through the system can be described quantitatively. That is: (1) the student must follow a path whose logic is definable; (2) the student must obtain resources and use them for a specified length of time; and (3) the resources used must be grouped according to a defined taxonomy.

Logic Data Definition. It is quite likely that in a true ILS, students may branch to certain modules based on their performance on previous modules. This works both for remedial matter and for matter by-passed because of pretesting or a higher than normal score. In any event, since the type (i.e., level) of student input to the system is not predictable, these conditional branches must be handled in such a way that the pattern of students branching or not branching is random. This random branching should be constrainable by a percentage factor so that, for example, 60% of the students branch one way and 40% the other.

The most straightforward way to build this capability into the model would be to include conditional branches in line with model logic. However, as previously stated (Model Description and Functional Specifications), the design goal of the ETE model was to produce a generalized entity flow model.

Inclusion of explicit conditional branches would reduce the generality of the model and require the user to be familiar with the internal logic of the model. The ETE model addresses the problem of conditional branches by having the user specify an exact (by percentage) distribution of student types and the curricula they follow. Where conditional branches exist in a curriculum, the user specifies two or more curricula (one representing each path) and applies any percentage constraint to the distribution of input students by type.

This approach increases the volume but not the logical complexity of the input data, and maintains the generality of the model.

Resource Grouping. The resources used by the student can be divided into two basic categories: those which he obtains from a central store and keeps with him (such as lesson plans or manuals); and those which he uses in serial fashion with other students. In this context, there is no difference between an instructor and other training equipment.

At first glance it might seem that there is a great deal of difference between an instructor and a video tape player. However, from a quantitative, logical standpoint they are similar. The student either has access to the instructor (or the tape player) or he waits. Once he obtains use of the resource, he occupies it fully until finished, at which time the resource becomes available to others. There is one major difference between the instructor and any other resource - the instructor is assumed not to be required for the complete duration of the module (as would be the case with an equipment-type resource). The length of time for which the instructor is occupied (when required) is calculated on a stochastic basis and is discussed later in this section under Model Assumptions.

Equipment-type resources might also seem to require complex modeling treatment because of the variety of types of equipment and training media available. However, these differences are of more concern to the course designer during the media selection phase than during the phase in which the course is simulated for over-all performance. There may be a significant difference in the training effectiveness or training objectives of a recognition study card set and a game study card set, but these differences are not quantitative from a simulation standpoint. As far as the ETE model is concerned each is a portable resource which is either available or not available.

Equipment-type resources do have some differences which are of consequence in use of the model. For example, there is a difference in the user approach to a lesson available only via a computer terminal and one recorded on video tape. The model considers each module to have two possible levels of equipment requirements designated as the "module" itself and "other facilities." In the case of the computer terminal lesson, the terminal becomes the "module" even though that same terminal might give access to a number of different lessons. The telephone line linking the terminal to the computer and the computer itself are considered together as "other facilities."

The video tape lesson is handled as follows: the video tape is the "module" and the video unit itself is "other facilities."

As can be seen from the foregoing, the quantitative description of different modules is the responsibility of the user. After analyzing each module, the user can describe them logically by means of the type codes outlined under Input Parameters Description in this section.

SOURCE LANGUAGE SELECTION. Considering the languages available for the computer system to be used for model development, the choice of source language resolved itself to using either the General Purpose Simulation System (GPSS) or another high level language such as FORTRAN or PL1.

GPSS is a high level programming language designed for developing entity flow simulation models. It consists of a language translator and the control and output programs necessary to support model execution. This combination of programs enables the modeler to implement a model in much less time than it would take to develop a model of the same level of complexity in some other high level language.

GPSS is not without disadvantages. Because it is a highly general approach to simulation, the models produced are not as efficient as models written specifically for a particular application. Furthermore, the model must be constructed according to the conventions of GPSS with the result that some forms of mechanization may not be as exact as would be mechanization via a tailored program. A single example will suffice to illustrate this point. GPSS produces models which are entirely transaction driven. This means that all events which occur within the system occur because a student reaches some point within the model.

In such a conceptualization, the instructor, for example, is a passive entity reacting to the demands of a student. It is cumbersome to include activities which are instructor initiated. Once the student begins study of a module, he cannot be interrupted from an external source. Any breaks in module study must be set up prior to initiation of the model.

While troublesome, these limitations do not preclude the use of GPSS as the simulation language. Experience to date (see Level 1 Validation Results in this section) indicates that attempting to simulate detailed types of activity does not yield a significant change in model output. Highly detailed simulation is more appropriate for intensive study of a single course rather than for parametric studies of a number of courses. Furthermore, detailed activity simulation demands precise and extensive data on the activities which take place in a particular course. Unless such data are available, it is not possible to justify the effort required to produce a detailed activity simulation.

GPSS was selected as the ETE model source language because the objective of the ETE model was to provide a tool which could be tested for operational usefulness. Therefore, the primary thrust of the effort was to produce a model which could be maintained by the user and which employed conventions common to other such models. Had the project been oriented toward the production of elegant algorithms aimed at precise replication of detailed activities, GPSS would not have been selected.

ETE MODEL ASSUMPTIONS. On page III-2, four areas are listed which were considered troublesome to mechanize. Of the four areas, three were included in the ETE model and the fourth was not implemented. The activity not included in the model was that of preemption of facilities by students having priority over other students.

Preemption of Facilities. Preemption was not excluded because GPSS has no provision for activities of this type. On the contrary, preemption is explicitly included in the GPSS activity set. It was the lack of a set of general rules for preemption which precluded its mechanization. In order to include any activity in a general simulation model, it is necessary to describe those conditions under which the activity will take place. If preemption takes place at all, will it be on the basis of rank, student type, time of day, or some other factor? Since these conditions are apt to vary significantly depending on the organization of the school being simulated, it was not possible to decide on an acceptable set of general rules for preemption and this activity was not included in the ETE model.

Conditional Branching. Conditional branching is discussed under Logic Data Definition in this section.

Instructor/Student Interaction. As stated in the Input Parameters Description, the user specifies which modules, if any, will require instructor/student interaction. As with each of the areas discussed here, the problem arises not in mechanization but in deciding what constitutes a reasonable approximation of the activity in question.

In an ILS, it can be assumed that the instructor will be occupied with the student for significantly less than the full duration of the learning module. Since the fraction of completion time during which the instructor will interact with the student cannot be predicted, it is determined probabilistically. A random number between zero and one is chosen and, based on that random number, a value is derived from a curve like the one shown in Figure III-5. According to this distribution, the maximum fraction of completion time in which the instructor is involved is 50%. On the average, the instructor will be required for 25% of the module completion time. Note that this distribution can be easily changed to reflect other time distributions.

Remedial Activities. When the user specifies that remedial matter exists in a medium outside the module under study, he also supplies the data necessary to define the type and duration of such remedial matter (see Input Parameters Description, Page III-4). The only assumption required in this area is the frequency of use of the remedial matter.

This frequency is also done on a probabilistic basis with 40% of the students requiring remediation. This percentage distribution is arbitrary and, like the distribution of instructor time, can readily be changed.

LEVEL 1 VALIDATION SCENARIOS

Before beginning any detailed discussion of level I validation for the ETE model, two points must be emphasized.

First, the ETE model really consists of two parts: the logic section and the system description (input) section. The logic used to process the input data remains the same from run to run but the input data, which describes the ILS to be simulated, change significantly. It cannot be over-emphasized that the system being simulated dictates the results obtained from the model. Model characteristics such as sensitivity, are characteristic of the ILS being simulated, not of the ETE logic.

The other point requiring emphasis is that the ETE model is intended to be a general purpose system, providing an efficient means for simulating a variety of different IL systems. Viewed in this light, validation of the ETE model should demonstrate two things: (1) that the simulation of a given ILS is accurate enough to produce useful results; and (2) that the ETE model was able to simulate the system in question, given only the input data necessary to describe the ILS under study.

STEPS IN ETE VALIDATION. The primary steps in the ETE validation scenario are:

a. Discussion of methods used to replicate different activities within any ILS.

BEST COPY AVAILABLE

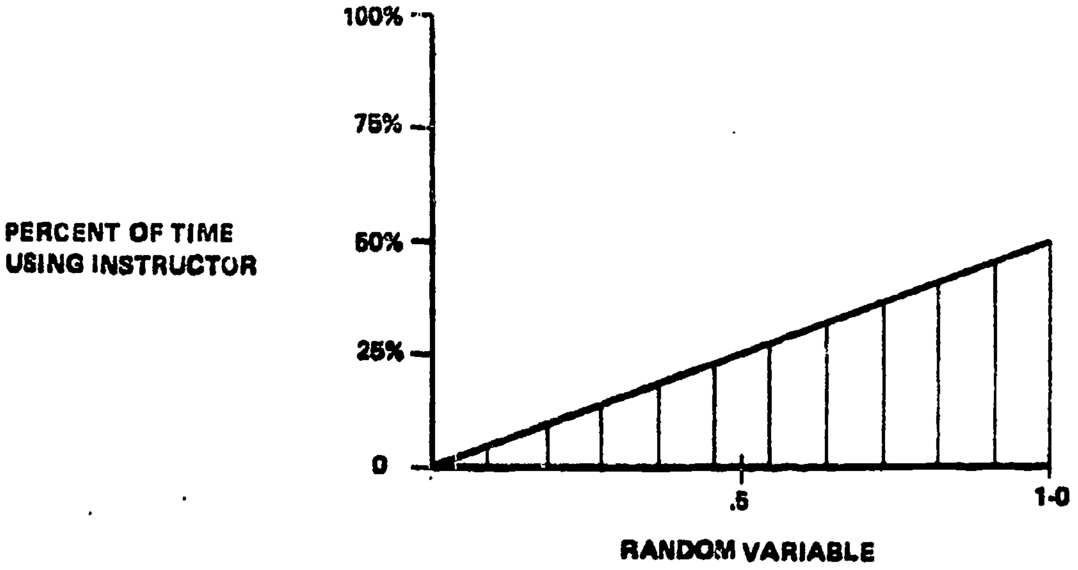


FIGURE III-5 ASSUMED DISTRIBUTION OF INSTRUCTOR ASSISTANCE TIMES

b. Review of ETE logic to assure that it reflects accurately the methods derived in step a.

c. Test runs to ascertain that the GPSS program follows the logic design.

d. Test runs using different combinations of input data to assess reasonableness of results.

e. Simulation of a known ILS to provide comparisons of ETE model output with a known data source.

Methods for Simulating ILS Activities. The basic activities required for an ILS simulation are enumerated under Model Description and Functional Specifications in this section. Also in the same paragraphs, other activities which were considered to represent problem areas for simulation were also listed.

The logic for simulating the basic activities is straightforward and is described under both Model Description and Input Parameters Description. Detailed flow charts of the program logic appear in Volume III. Of primary concern during the design phase were those activities considered to present difficulties in mechanization. These activities and the decisions regarding their mechanization are covered under Logic Design.

Initial Program Testing. The initial ETE test runs were designed solely to test all possible program paths. Curricula for five student types were set up, and included modules representing each type of support requirement. These runs indicated that model problems existed when team modules were encountered and also when team activities were followed by remedial activities. The latter problem required a change in model logic. In order to identify the basic problem in team module processing, it was necessary to employ a GPSS debugging aide called Trace. When Trace is used, it causes a print-out each time a student moves from one model block to the next. Figure III-6 shows part of a Trace output. Each transaction represents a single student. By checking the parameter values, it is possible to determine all conditions pertinent to that particular student, such as: step number within course; current module number and type; equipment requirement flags; and number of students in a team.

Although this method produces voluminous output, it does provide a complete and accurate picture of model execution. By checking the printed parameter values, the accuracy of the current state of the student, and to some extent his recent history, can be checked. The Trace runs represented the most stringent test of model logic conducted.

Reasonableness, Variability and Sensitivity Testing. Of these three types of testing, reasonableness and sensitivity testing can be considered together. Variability testing will be discussed first.

Variability testing was accomplished by running a series of runs, each of which was started with all initial conditions the same except the random number seeds. Random numbers are used in the following model functions:

a. To vary the student generation times about an average value.

b. To assign a student type to newly generated students.

BEST COPY AVAILABLE

```
 TRANS     2 FROM      16 TO      17 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         16           17                       14          0                13         2              X       X       C

          HALFWORD PARAMETERS

   1 -   10               1          2          3          4           5           6          7          8          9          10
  11 -   20               5          4          5          0           0           0          0          0          2           0
                          0          3         50          6           2           1         36         79          6           0

 TRANS     2 FROM      17 TO      20 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         17           20                       14          0                13         2              X       X       C

          HALFWORD PARAMETERS

   1 -   10               1          2          3          4           5           6          7          8          9          10
  11 -   20               5          4          5          0           0           0          0          0          2           0
                          0          3         50          6           2           1         36         79          6           0

 TRANS     2 FROM      20 TO      23 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         20           23                       14          0                13         2              X       X       C

          HALFWORD PARAMETERS

   1 -   10               1          2          3          4           5           6          7          8          9          10
  11 -   20               5          4          5          0           0           0          0          0          2           0
                          0          3         50          6           2           1         36         79          6           0

 TRANS     2 FROM      23 TO      24 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         23           24                       14          0                13         2              X       X       C

          HALFWORD PARAMETERS

   1 -   10               1          2          3          4           5           6          7          8          9          10
  11 -   20               5          4          5          0           0           0          0          0          2           0
                          0          3         50          6           2           1         36         79          6           0

 TRANS     2 FROM      24 TO      25 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         24           25                       14          0                13         2              X       X       C

          HALFWORD PARAMETERS

   1 -   10               1          2          3          4           5           6          7          8          9          10
  11 -   20               5          4          5          0           0           1          0          0          2           0
                          0          3         50          6           2           1         36         79          6           0

 TRANS     2 FROM      25 TO      26 CLOCK              14  TERMINATIONS TO GO            1
*TRANS    CUR BLOCK    NEXT BLOCK    ADV BLK DEPART        PRIORITY     MARK TIME    ASSEM SET    SEL   TRACE   DELAY   CHAIN     PREEMPT COUNT/FLAG
    2         25           26                       14          0                13         2              X       X       C
```

FIGURE III-6 TRACE SAMPLE OUTPUT

c. To provide a 60/40 distribution of students requiring remediation.

d. To assign the length of time spent by an instructor assisting a student.

e. To vary module completion times about an average.

If the model is highly sensitive to the particular distribution of random numbers encountered during a run, the results of these runs, using different random numbers seeds, could differ significantly in: (1) distribution of student types produced; (2) change in average time-to-complete due to change in remediation requirements and change (bias) in module completion times; and (3) change in instructor utilization.

Table III-2 is a composite of three runs made to test variability. A hypothetical system was simulated, so no significance should be attached to any of the outputs insofar as real world systems are concerned (for example, it is to be expected that instructors will be utilized more than 3%-4% of the time). Each run was made with all initial conditions set to zero except the random number seed, and run until four hundred students had been processed. Module types specified included groups, and those requiring instructor assistance, remediation, and other facilities.

The data presented in Table III-2 show little variation in either average completion time or instructor utilization. Only in the distribution of students generated is there significant variation.

Just how significant this variation is in terms of model results is a function of the type of ILS configuration being simulated. If one particular student type tends to tie up large quantities of system resources, a twenty percent variation in the number of these students (with respect to other student types) could produce unexpected changes in model output. For the system used in this test, the different student types tended to be similar in their demands on the system. Consequently, little variation was encountered as a result of the changes in student type distribution.

None of the results of these runs or other runs indicated any variability problems which would prohibit the use of the ETE model. However, the user should be cautious in applying model results under the following conditions:

a. If the sample size is small (e.g., runs in which fewer than one hundred students are processed), variability in student input distribution can be high.

b. When the primary objective of the study is to obtain a student output profile over time, multiple runs should be made (following the technique described above) to check for possible variability.

Reasonableness and Sensitivity Testing. Ideally, reasonableness should be measurable by a quantitative standard with the quantitative standard being historical data from a real world system. Those IL systems currently in place in the naval training system are either too new or too limited in scope (e.g., an AOB of five students), to provide the desired quantitative standard. Furthermore, application of the ETE to an existing system would not necessarily test

NUMBER OF STUDENTS GENERATED

STUDENT TYPE	I	II	III	IV	V
RUN 1	99	60	51	112	81
RUN 2	100	59	49	111	85
RUN 3	86	79	38	123	78
EXPECTED VALUE	100	60	40	120	80

AVERAGE COMPLETION TIME

STUDENT TYPE	I	II	III	IV	V
RUN 1	20	16	13	23	16
RUN 2	20	17	14	22	16
RUN 3	19	17	12	23	17

INSTRUCTOR UTILIZATION (%)

INSTRUCTOR GROUP	I	II	III
RUN 1	4.6	2.8	1.4
RUN 2	4.3	2.2	3.1
RUN 3	4.4	3.1	2.2

TABLE III-2 VARIABILITY TEST RESULTS

generality. That is, it would be difficult to show that the model constructed and the results obtained did not represent the application of a special purpose, ad hoc model of the type discussed under Model Description.

These conditions dictated a somewhat unorthodox approach to validation of the ETE model. Concurrent with Phase I of the DOTS project, an in-house Navy study of a proposed consolidated Electronic Warfare (EW) school was conducted. Early in this study, the decision was made to construct a detailed, entity flow simulation model of the proposed system. This model was completed in early 1974 and has been in use since then. At the time that the problem of ETE model validation was being addressed, a requirement was generated by the EW school designers to make parametric runs using different numbers of student trainers, and a different student input distribution. This requirement represented an opportunity to accomplish both validation objectives at the same time. By applying the ETE model and the existing special purpose EW model to the same problem, it would be possible, by comparing results, to check the ETE model for reasonableness and also to test its ease of use vis a vis a special purpose model.

Objections could be raised to validating a simulation model by testing it against another simulation model, but the techniques employed in the two models are sufficiently different to pinpoint any major discrepancies in either model. If the two models produce similar results, then questions regarding the validity of the results can be considered questions regarding the validity of entity flow simulation as a basic design tool. Of prime importance in the selected approach, is the opportunity presented to compare the length of time required to produce a working simulation when using the ETE model, as opposed to construction of a special purpose model. If the time required to obtain results is significantly lowered, one of the basic design objectives would be fully demonstrated.

Consolidated EW School Model Description. The consolidated EW school has the following characteristics:

a. Seven types of students.

b. Nineteen possible curriculum steps.

c. Four of the seven curricula have optional modules.

d. There are three equipment facilities: carrels; student trainers; and aircraft.

e. Each curriculum step can include the use of both carrels and trainers.

f. One category of student has the ability to preempt equipment when necessary.

The EW school model has each of these characteristics explicitly mechanized in the model. Where students move between carrel and trainer (and back) during a curriculum step, this movement is specifically provided for. Optional modules are handled using conditional, probabilistic branches coded in-line.

There are other model features which were not specifically required in the problem statement but which were added for completeness. These features include: model operation on a twenty-four hour basis, with students leaving for lunch, and at the end of a school day.

Problem Statement Using the ETE Model. As has already been discussed (see Logic Design), the ETE model does not include explicit capabilities for conditional branches in a curriculum or for preemption of facilities. Optional modules were handled by creating separate curricula and by subdividing the input student classifications according to the stated probabilities that certain modules would be used. Preemption was not included.

Although it would have been possible to define submodules which would have provided for student movement back and forth between carrels and trainers during a single module, this would have required definition of about two-hundred submodules. Instead, carrel time and trainer time were defined as single events during any one module. Even then, as many as fifty-six modules (vice the nineteen in the problem statement) were required for some curricula. Figure III-7, sheets 1-3, show the input data required to simulate the EW school.

The ETE model operates on a continuous time basis. Hence, there is no provision for idle time in the school, and results are given in total school hours rather than calendar days. This difference also required a change to the ETE model student generation function in order to achieve the same input rate as the EW school model. Note that this change was required to duplicate the EW school model for comparison purposes and would not normally arise when the user formulates a problem for the ETE model.

With these stated exceptions, the ETE model had all the requisite capabilities to duplicate a highly specialized simulation model.

RESULTS COMPARISON. Table III-3 shows a comparison of two runs made on the EW School model and the ETE model. The differences between the two models with regard to time per school day, previously discussed, required that outputs from one model be translated into the same units as the other. It is for this reason that the principal outputs were condensed in tabular form rather than being presented directly as computer print-outs.

Little commentary is required concerning the comparison of results. Where translated results permitted comparison, a deviation of 4.9% in average time to complete was the worst case. Even this discrepancy is probably due to the fact that that particular student type comprised only 3.2% of the student input and, as such, represented too small a sample (only a single student for the special purpose EW model) to permit valid comparison.

The fact that the ETE model did not include preemption, student movement between carrels and trainers during a single lesson plan, or simulation of a twenty-four hour day, did not materially affect the results obtained.

Problem Formulation Time. Since one of the design objectives of the ETE model was to provide a rapid means for applying simulation to IL systems, the time required to obtain useful results, given a specific problem statement, is highly important. The EW school problem took about five days to prepare and run on

```
*************************************************************************************

***                   LISTING OF INPUT TABLES
***                   REQUIRED TO RUN EW
***                   MODEL USED FOR VALIDATION
 TESTN FUNCTION   RN4,C3          DIFFERENT RATE OF INPUT
0,1.0/.67,1.0/1.0,.7
 FACT  FUNCTION    P2,L55      FACILITIES STORAGE VS MODULE TYPE
,1/,1/,1/,1/,3/,1/,1/,1/,1/,1/,2/,1/,2/,1/,2/,1/,2/,1/,2/,1/,2/,1/,2/,1/
,2/,1/,2/,1/,1/,1/,2/,1/,1/,2/,1/,1/,2/,1/,2/,1/,2/,1/,2/,1/,1/,2/,1/,2/
,1/,2/,1/,1/,2/,1/,1
 STUDT FUNCTION   RN6,D25        STUDENT TYPE DISTRIBUTION
.0832,1/.0874,2/.0929,3/.0952,4/.0971,5/.0999,6/.1052,7/.1075,8/
.1119,9/.1185,10/.1683,11/.2171,12/.2574,13/.3178,14/.5013,15/.5800,16/
.6484,17/.6768,18/.7005,19/.7259,20/.8020,21/.8312,22/.8860,23/
.9684,24/1.0,25
* STUDT RELATES STUDENT TYPE (1-5) TO RANDOM DISTRIBUTION
* MODT RELATES MODULE NUMBER TO MODULE TYPE
 MODT  FUNCTION    P2,L55
,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/
,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/,8/
,8/,8/,8/,8/,8/,8/,8
 TYME  FUNCTION    P2,L55
,8/,88/,68/,36/,17/,16/,15/,36/,37/,20/,12/,8/,6/,4/,12/,4/,6/,8/,6/,4/
,6/,8/,6/,12/,6/,4/,12/,8/,42/,20/,16/,5/,15/,28/,5/,20/,5/,5/,10/,10/
,10/,5/,10/,10/,16/,24/,18/,25/,6/,20/,12/,14/,25/,24/,9
 SPRD  FUNCTION    P2,L55
,2/,44/,34/,9/,3/,8/,6/,18/,13/,5/,4/,2/,2/,1/,4/,1/,2/,2/,2/,1/,2/,2/
,2/,3/,2/,1/,4/,2/,21/,4/,1/,1/,3/,8/,1/,4/,1/,1/,2/,2/,2/,1/,2/,2/,4/,4/
,3/,5/,1/,4/,2/,4/,5/,6/,3
 1      FUNCTION    P9,L47       SW EW TRNG OFFICER
,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/,21/,22/,23/
,24/,25/,26/,27/,28/,29/,30/,31/,32/,36/,37/,38/,39/,40/,41/,42/,43/,44/
,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 2      FUNCTION    P9,L45       SURFACE EWO
,3/,4/,6/,7/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/,21/,22/,23/
,24/,25/,26/,27/,28/,29/,30/,31/,32/,36/,37/,38/,39/,40/,41/,42/,43/,44/
,47/,48/,49/,50/,51/,54/,55/,56
 3      FUNCTION    P9,L56       MARINES-ALL MODULES
,1/,2/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 4      FUNCTION    P9,L53       MARINES-NO OPTIONAL MODULES
,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
```

FIGURE III-7 EW SCHOOL SIMULATION INPUT

```
 5      FUNCTION    P9,L54        MARINES-OPTIONAL # 1 ONLY
,1/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 6      FUNCTION    P9,L54        MARINES - OPTION # 2 ONLY
,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 7      FUNCTION    P9,L54        MARINES - OPTION # 3 ONLY
,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 8      FUNCTION    P9,L55        MARINES - OPTION #1 & # 2
,1/,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 9      FUNCTION    P9,L55        MARINES - OPTION #1 & #3
,1/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 10     FUNCTION    P9,L55        MARINES - OPTION #2 & #3
,2/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 11     FUNCTION    P9,L51        CTT (ELINT) - ALL MODULES
,1/,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,47/,48/,49/,50/,51/,54/,55/,56
 12     FUNCTION    P9,L49        CTT (ELINT) NO OPTIONS
,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,47/,48/,49/,50/,51/,54/,55/,56
 13     FUNCTION    P9,L50        CTT (ELINT) OPTION #1
,1/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,47/,48/,49/,50/,51/,54/,55/,56
 14     FUNCTION    P9,L50        CTT (ELINT) OPTION #2
,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,47/,48/,49/,50/,51/,54/,55/,56
```

FIGURE III-7 (CONTINUED)

```
 15     FUNCTION    P9,L56        NFO - ALL MODULES
,1/,2/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 16     FUNCTION    P9,L55        NFO - W/O OPTION
,1/,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,52/,53/,54/
,55/,56
 17     FUNCTION    P9,L54        EW - ALL MODULES
,1/,2/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 18     FUNCTION    P9,L51        EW - NO OPTIONAL MODULES
,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 19     FUNCTION    P9,L52        EW - OPTION # 1
,1/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 20     FUNCTION    P9,L52        EW - OPTION #2
,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 21     FUNCTION    P9,L52        EW - OPTION #3
,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 22     FUNCTION    P9,L53        EW - OPTIONS 1 & 2
,1/,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 23     FUNCTION    P9,L53        EW - OPTIONS 1 & 3
,1/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 24     FUNCTION    P9,L53        EW - OPTIONS 2 & 3
,2/,3/,4/,5/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,19/,20/
,21/,22/,23/,24/,25/,26/,27/,28/,29/,30/,31/,32/,33/,34/,35/,36/,37/
,38/,39/,40/,41/,42/,43/,44/,45/,46/,47/,48/,49/,50/,51/,54/,55/,56
 25     FUNCTION    P9,L25        PCO
,6/,7/,9/,12/,30/,31/,32/,36/,37/,38/,39/,40/,41/,42/,43/,44/
,47/,48/,49/,50/,51/,52/,53/,54/,56
```

FIGURE III-7 (CONTINUED)

AVERAGE TIME TO COMPLETE (DAYS)

STUDENT TYPE	1	2	3	4	5	6	7
ETE MODEL	38.8	38.9	50.2	46.6	54.2	48.4	21.6
SPECIAL PURPOSE MODEL	37.5	37.0	49.5	45.3	53.4	47.6	22.3
% DIFFERENCE	3.4	4.9	1.4	2.8	1.5	1.7	3.1

EQUIPMENT USAGE

	CARREL		TRAINER		AIRCRAFT	
	AVERAGE HRS/ STUDENT	% UTILIZATION	AVERAGE HRS/ STUDENT	% UTILIZATION	AVERAGE HRS/ STUDENT	% UTILIZATION
ETE MODEL	9.2	69.8	5.7	53.9	8.5	5.5
SPECIAL PURPOSE MODEL	10.0	70.4	5.9	52.1	8.5	5.4

TABLE III - 3

COMPARISON OF ETE MODEL VS. SPECIAL PURPOSE MODEL the ETE model, with some loss of time in obtaining problem statement data. Given a problem statement formulated in accordance with the requirements of the ETE model, two or three days should be adequate for a problem of this magnitude.

With the exception of the ETE model change required to match the student input rate of the special purpose EW school model (see Problem Statement Using the ETE Model), problem formulation consisted entirely of input data preparation.

MODEL SENSITIVITY. As previously stated, sensitivity is more a function of the ILS being simulated than it is of the ETE model itself. The EW ILS is highly sensitive to input student rate. For example, a change of 11% in the input rate causes a greater change in system performance than a change of 20%-25% in the number of available trainers.

This phenomenon was also experienced when earlier test runs, using other types of ILS, were made. All ILS configurations so far simulated, have exhibited a "layering" effect in sensitivity. This layering effect causes a single variable to mask the sensitivity of the system to another variable.

For example, in the EW School ILS, the system proved relatively insensitive to the number of trainers available (which was the parameter of interest to the designers), because the student input rate, the number of study carrels, and the length (in time) of the lesson plans combined to mask the effect of the variable in question. If the number of carrels was increased or the length of time spent in the carrels decreased, the system would then become sensitive to the number of student trainers available.

LEVEL 1 VALIDATION RESULTS

All of the numeric results of ETE model testing were presented under Validation Scenarios. It remains to summarize those results and to point out any significant factors regarding the ETE model, its performance, and its application.

ETE MODEL PERFORMANCE. A significant difference exists between the special purpose model and the ETE model. The special purpose model took 3 hours and 20 minutes of computer time to simulate 80 days of school time. The ETE model took 35 minutes to simulate the 80 days of school time. The implications of this difference will be discussed in the summary at the end of this section.

The ETE model did exhibit sufficient variability to warrant a caution to be issued to the user.

Model performance, with respect to problem preparation time and problem execution time, appears to be acceptable and warrants use of the ETE model for any further EW school studies. Model sensitivity and reasonableness were the same for both the special purpose model and the ETE model.

SUMMARY. Experience gained in testing the ETE model leads to the following statements concerning the application of simulation to IL systems.

Complexity of Representation. The almost seven to one reduction in execution time exhibited by the ETE model when applied to the EW school problem, results from its relatively simple system representation. Complex problem mechanizations are costly and should only be used when the system under study is very precisely defined.

System Sensitivity. The sensitivity of the EW ILS to input rate indicates that the initial problem statement should have included a student AOB. This would have made the system less sensitive to input rate and more sensitive to school configuration. The conclusion to be drawn from this is that the user must review the results obtained from any simulation, so that studies are conducted in step-wise fashion. When one variable appears to be the principal system driver, additional parametric studies involving other variables will not yield meaningful results.

Because of its generality, the ETE model provides an effective tool for conducting initial sensitivity studies on any ILS. When sufficient system data exist to justify very detailed simulation, special purpose models can be developed beginning at a high level of system definition.

SECTION IV

TRAINING PROCESS FLOW MODEL

MODEL DESCRIPTION AND FUNCTIONAL SPECIFICATIONS

FUNCTIONAL SPECIFICATIONS. The objectives of the Training Process Flow model are:

a. To provide training management with an ability to assess the effects upon the training system of projected changes in:

- Demand
- Scheduling
- Capacities
- Student Attributes.

b. To develop model output data formats that provide high informational content to training management, so that effective decisions can be made for maximizing the utilization of training complex resources.

The TPF model will be capable of assessing the impact of changes in certain input characteristics at the course level, and of showing the effects of these changes at the school and complex levels. Some examples of the course modifications which can be entered into the TPF model are:

a. Annual demand

b. Class capacity

c. Annual number of convenings

d. Course length

e. No-show rates

f. Student failure rate

g. Student setback rate

h. Selected student attributes; e.g., average GCT scores.

The model is intended to have two levels of data access; one level is into the existing DOTS data base which is also used by the SCRR model; the other is into the Statistics data base. Operation of the model at course, school, or complex level is possible through selective transfers of data from the DOTS data base to a Scratch data base which can also be accessed by the TPF model.

The final output effects of the model are measured in terms of:

a. Average-on-board (AOB)

b. Utilization

c. Backlog.

Intermediate effects available as model output are:

a. Pass/fail rates

b. Setback rates

c. No-show rates.

The Model Description section expands upon these areas and provides examples of output reports which present these types of data.

MODEL DESCRIPTION. Figure IV-1 shows an outline of the TPF model, and the major support programs integral to the overall TPF model system.

Model Programs. The TPF model is designed to be operated as a stand-alone model, or in conjunction with the integrated system shown in Figure IV-1. The purpose of the TPF model is to analyze individual course demands, schedules, capacities, and student attributes as known at the beginning of a fiscal year, and project these data for periods of up to three years. Specifically, the inputs required concern course capacities, lengths, convening schedules, local and BUPERS demand, and historical rates for no-shows, failures, and non-academic dropouts. These inputs are based on current or projected schedules and loads, and are readily available from existing printouts, reports, and plans. One final group of input data elements concerns student attributes. This includes characteristics such as the student's scores on the various Armed Forces entrance exams, rate, age, service time, and other parameters. This statistical input is discussed in detail in Volume III, Section IV. It was decided to analyze this large amount of statistical data offline, rather than as an online component of the TPF model. However, the results of this offline analysis are made available to the TPF model as an input.

The TPF model will accept data from two main sources; first, the DOTS or modified DOTS data base, and secondly, from card input. This dual input capability is important to the user. The DOTS data base interface allows the user to analyze projections based on the current operational plan, including the latest revisions. The capability of modifying this data base allows the testing of alternate plans within the overall system. The alternate card input allows the studying of several alternate plans, without the need to update the data base.

Any input parameter to the model can be considered a variable for manipulation to achieve the desired end results. Any course length, capacity, schedule, demand, or attrition rate can be modified for detailed analysis. The model also allows the operation of a course with one set of characteristics for part of a model run, and an entirely different set of characteristics for the remainder of the run.

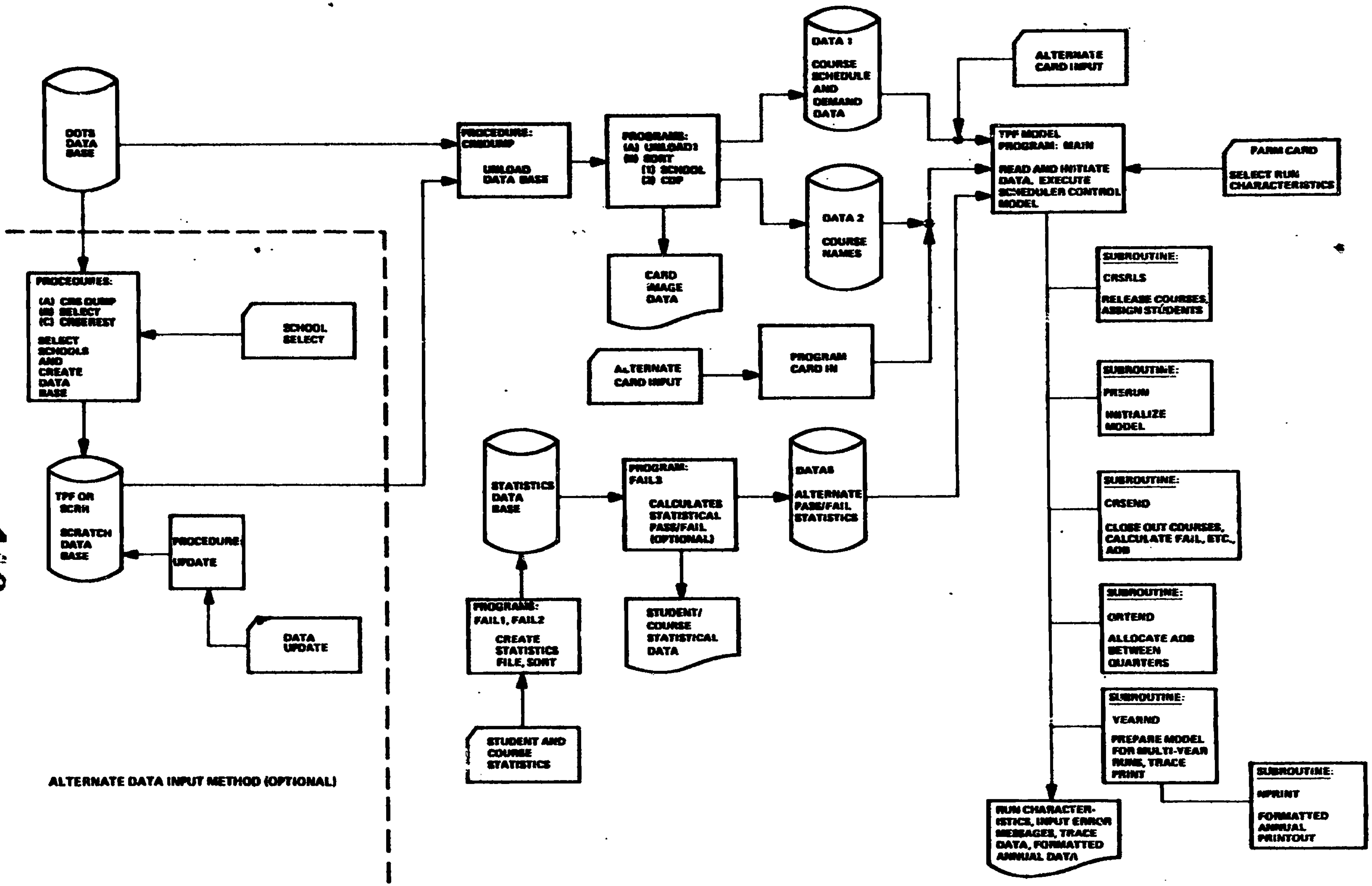


FIGURE IV-1 TPF SYSTEM INTEGRATED FLOW

The TPF model print format contains a synopsis of the input data on the left side of the page and quarterly projections on the right. See Figure IV-2. The courses are normally grouped by schools, with a school summary report following each group of courses. A Center report is also printed to allow evaluation of any changes on the overall Center totals. The model also allows execution of the same course under different configurations in one model execution to give side by side comparison of the effects of alternate inputs.

Support Programs. The support programs fall into three categories, those programs that interface with and support the data base, those that provide formatted inputs to the model, and those that support the statistical analysis.

The programs that support the DOTS data base, provide update capability, and allow the creation of a scratch data base, are covered in Volume III, Section V, of this report.

Two programs support the interface between the TPF model and the data base parameters. The first program, UNLOAD 1, allows the model to execute with current or scratch data base inputs, with additional steps required by the user. This program formats the data base parameters into "card image" records, which are compatible with the alternate TPF model input formats.

The third group of support programs correlates the student statistical averages with the significant coefficients from offline regression analysis programs, and provides statistical failure rates for those courses undergoing the analysis. This allows the user to modify such student attributes as average rate, average age, or average test scores, and automatically update the TPF model failure rates. The support programs that provide this function are called FAIL1, FAIL2, and FAIL3.

INPUT PARAMETERS DESCRIPTION

Four primary input parameters were defined and analyzed during the design portion of the Training Process Flow model effort. The four inputs, student, demand (or load), behavior, and delivery system, were further subdivided into a number of specific attributes for detailed study. During this detailed study, it became obvious that these inputs fell into two specific categories; those that pertained to student behavioral characteristics, and those that made up the mechanics of the schoolhouse operation. It was decided at this point to study these two categories as separate entities. The analysis of the student characteristics was carried out, in part, using various programs in the Statistical Package for the Social Sciences. Data were gathered from several sources, and a major effort went into this portion of the study. A detailed discussion of these efforts may be found in Volume III, Section IV, of this report. During the entire study, however, there was much interplay between the two fields of study, as the statistical analysis often answered questions as to what affected certain elements in the training complex operation; and likewise, understanding the mechanics of the Fleet Training Center, Norfolk, Virginia, gave much insight into the nature of the statistics obtained.

The first part of this discussion will center on the various elements considered as potential inputs to the TPF model, followed by a description and format of those inputs actually required for operation of the model in its current form.

```
                                   TPF MODEL -- FISCAL YEAR 1975 SUMMARY
                                          SCHOOL CODE  IT/AD

NAVAL RESERVE ADMIN & INSTR PROCED (FOXTROT)

CDP     J NO    CATALOG NO     NEC
3081    0322

--- COURSE DATA ---     INITIAL  CHANGE

ANNUAL CONVENINGS           12       0
COURSE LENGTH WKS          1.0     0.0
COURSE CAPACITY             25       0
BUPERS SEATS                 0       0

ANNUAL DEMAND      60  CHANGE WEEK  18
BUPERS DEMAND       0  OFFSET   WKS  0
INITIAL BKLOG       0  BACKLOG  WKS  0

                                      QUARTERLY PROJECTIONS
                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
---------------------|-------------|-------------|-------------|-------------|--------------|
NUMBER OF CONVENINGS|     3 |      |     1 |      |     0 |      |     0 |      |     4 |      |
COURSE CAPACITY      |    75 |      |    25 |      |     0 |      |     0 |      |   100 |      |
UTILIZATION          |    15 | 20.0%|     5 | 20.0%|     0 |  0.0%|     0 |  0.0%|    20 | 20.0%|
NO SHOWS             |     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
BACKLOG-STUDENTS/WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|
STUDENT DAYS / ADB   |    75 |  0.8 |    25 |  0.3 |     0 |  0.0 |     0 |  0.0 |   100 |  0.3 |
                     |       |      |       |      |       |      |       |      |       |      |
TOTAL PASS           |    15 |100.0%|     5 |100.0%|     0 |  0.0%|     0 |  0.0%|    20 |100.0%|
TOTAL FAIL           |     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
ACADEMIC  SETBACK    |     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
NON-ACADEM DISENROLL|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
-------------------------------------------------------------------------------------------------


CAREER INFORMATION AND COUNSELING

CDP     J NO    CATALOG NO     NEC
3192    0342    A-500-0011     9588

--- COURSE DATA ---     INITIAL  CHANGE

ANNUAL CONVENINGS           37       0
COURSE LENGTH WKS          3.0     0.0
COURSE CAPACITY             20       0
BUPERS SEATS                 0       0

ANNUAL DEMAND     626  CHANGE WEEK   0
BUPERS DEMAND       0  OFFSET   WKS  0
INITIAL BKLOG     236  BACKLOG  WKS 16

                                      QUARTERLY PROJECTIONS
                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
---------------------|-------------|-------------|-------------|-------------|--------------|
NUMBER OF CONVENINGS|     9 |      |     9 |      |     9 |      |    10 |      |    37 |      |
COURSE CAPACITY      |   180 |      |   180 |      |   180 |      |   200 |      |   740 |      |
UTILIZATION          |   177 | 98.3%|   177 | 98.3%|   177 | 98.3%|   196 | 98.0%|   727 | 98.2%|
NO SHOWS             |    21 | 10.6%|    21 | 10.6%|    21 | 10.6%|    28 | 12.5%|    91 | 11.1%|
BACKLOG-STUDENTS/WKS|   180 |12 WKS|   135 | 9 WKS|    89 | 6 WKS|    38 | 2 WKS|    38 | 2 WKS|
STUDENT DAYS / ADB   |  3873 | 42.4 |  3546 | 38.9 |  3372 | 37.0 |  3795 | 41.6 | 14586 | 40.0 |
                     |       |      |       |      |       |      |       |      |       |      |
TOTAL PASS           |   127 | 71.8%|   132 | 74.6%|   132 | 74.6%|   151 | 77.0%|   542 | 74.6%|
TOTAL FAIL           |    42 | 23.7%|    38 | 21.5%|    38 | 21.5%|    38 | 19.4%|   156 | 21.5%|
ACADEMIC  SETBACK    |    20 | 11.3%|    18 | 10.2%|    18 | 10.2%|    18 |  9.2%|    74 | 10.2%|
NON-ACADEM DISENROLL|     8 |  4.5%|     7 |  4.0%|     7 |  4.0%|     7 |  3.6%|    29 |  4.0%|
-------------------------------------------------------------------------------------------------


BASIC INSTRUCTOR TRAINING (ALPHA)

CDP     J NO    CATALOG NO     NEC
3400    0302    A-012-0011     9502

--- COURSE DATA ---     INITIAL  CHANGE

ANNUAL CONVENINGS           48       0
COURSE LENGTH WKS          4.0     0.0
COURSE CAPACITY             30       0
BUPERS SEATS                21       0

ANNUAL DEMAND     220  CHANGE WEEK   0
BUPERS DEMAND     985  OFFSET   WKS  0
INITIAL BKLOG      86  BACKLOG  WKS 10

                                      QUARTERLY PROJECTIONS
                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
---------------------|-------------|-------------|-------------|-------------|--------------|
NUMBER OF CONVENINGS|    12 |      |    12 |      |    11 |      |    13 |      |    48 |      |
COURSE CAPACITY      |   360 |      |   360 |      |   330 |      |   390 |      |  1440 |      |
UTILIZATION          |   368 |102.2%|   302 | 83.9%|   275 | 83.3%|   327 | 83.8%|  1272 | 88.3%|
NO SHOWS             |     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
BACKLOG-STUDENTS/WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|     0 | 0 WKS|
STUDENT DAYS / ADB   |  9832 |107.7 |  7985 | 87.5 |  7169 | 78.6 |  8490 | 93.0 | 33476 | 91.7 |
                     |       |      |       |      |       |      |       |      |       |      |
TOTAL PASS           |   322 | 87.5%|   263 | 87.1%|   241 | 87.6%|   287 | 87.8%|  1113 | 87.5%|
TOTAL FAIL           |     8 |  2.2%|     7 |  2.3%|     6 |  2.2%|     7 |  2.1%|    28 |  2.2%|
ACADEMIC  SETBACK    |     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|     0 |  0.0%|
NON-ACADEM DISENROLL|    38 | 10.3%|    32 | 10.6%|    28 | 10.2%|    33 | 10.1%|   131 | 10.3%|
-------------------------------------------------------------------------------------------------
```

FIGURE IV-2 SAMPLE TPF FORMAT

Nearly all of the data and statistics gathered pertain to the Fleet Training Center, Norfolk, Virginia, which, for the remainder of this section, will be referred to as the "Center."

TPF CANDIDATE COURSE DATA INPUTS. The course, combined with the school facilities, has been termed for this study, the delivery system. Several parameters were singled out for study as to their inclusion in the TPF model. These parameters are:

a. Course type

b. Course complexity

c. Course length

d. Instructors

e. Facilities

f. Materials

g. Media

h. Training aids and devices

i Support personnel

j. Shift work requirements

k. Location of training

l. Outside as ignments

m. Degree of remediation

n. Relevancy to job

o. Testing system.

<u>Course Type</u>. This refers to the type of course and the teaching method. The courses studied at the Center fell generally into two categories, team or ungraded training and lockstep. A team course can be categorized as one that in most cases produces no failures. Examples of this are course 510B, Firefighting Team Training, which processed approximately 2275 students during the last fiscal year without a failure, and course 509N, Damage Control Repair Party Team Training, which processed approximately 4075 students without a failure. Indoctrination, orientation, and refresher courses also fell in the team or ungraded category. At this Center, students attending these types of courses are approximately one-third of the total students. However, these types of courses tend to be short, and the Average On-Board (AOB) they contribute is nearer 10 percent of the total. One of the primary objectives of this study was to suggest methods to improve throughput of the courses through the analysis of failures. Obviously, courses that don't produce failures defy this portion of the study. On the other hand, these courses contribute heavily to the inefficient use of certain resources

due to the high no-show rate experienced. Thus, these courses were inputted to the model as team courses (type code) to indicate their non-graded policy, and will be discussed again in the section covering demand.

By far, the largest category of courses could be termed conventional or lockstep. It was out of this group that courses were chosen for statistical analysis. The majority used some method of grading, although there were several grading systems in use. The reason for this non-standardization in grading could perhaps be attributed to the fact that neither the grade nor the student's standing is recorded in the data base maintained for the Fleet Training Center by DPSCLANT as part of the student data system. Instead, this data base contains a Student Action Code, or SAC, which indicates such status as student on-board, enrolled, disenrolled for academic reasons, accelerated, or set back. This code gave some insight into certain activities of the students, but again failed to provide a dependent variable with which to measure student success. Thus it was decided to obtain the actual grades and standing of students in a representative sample of these lockstep courses in order to run the desired analysis. This was accomplished by obtaining copies of all course records for 42 of these courses for the last six months of fiscal year 1974. The numerical data gathered were used as inputs to the statistical analysis study, while the instructor's notes and subsequent interviews were used to determine portions of the model scheduling and disenrollment logic. Another type of training conducted at the Center is ILS, or Individualized Learning System. ILS may take two forms at the Center, scheduled instruction and Programmed Instruction (PI). Only one course is currently held at the Center using ILS, and the model makes no special provision for this type of training. On the other hand, once a course is converted to PI, its administration is no longer a responsibility of the Center, and the course does not appear in the model. As the TPF model is a flow, rather than Center resource model, no provision is made to include the effort expended to convert the course to a PI format.

Course Complexity. It was felt that the model should use as an input parameter, some factor to indicate course complexity. However, no relationships between actual complexity and failure rates could be determined. For example, course 0286, General Technical Stores Operation, produced a 35.4 percent failure rate, while the failure rate for all courses in the technically more complex ET school is between 1 and 2 percent. This is attributed largely to relevant schooling and student preselection, and thus course complexity was removed from our model input parameter list. NAVMACLANT has been doing studies that involve the area of course complexity, and it is recommended that this area be pursued further.

Course Length. Course length was initially included as an input parameter with the belief that the longer the course, the higher the possibility for non-academic disenrollments for personal or operational reasons. Although course length does offer a variable window for these conditions to exist, again no usable relationship was found to exist directly. In longer courses, the increased potential for dropout appeared to be overshadowed by the course's relevancy to the job or challenging technical content, as well as by improved student selection. Also, it was concluded that, by and large, for courses greater than two weeks, students dropping out for non-academic reasons had similar characteristics as those who fail. For shorter courses, especially those where the training is not overly critical to the operation of a ship, the non-academic dropouts are more aligned with immediate operational demands. Length is also not used in calculating pass/fail statistics, but is in the data base as an independent variable for statistical study. The TPF model does use course length as an input for scheduling and AOB purposes.

Facilities. The facilities used to conduct classes were used as inputs to the TPF model only to the extent they affected course capacity. These facility capacities are also inputs to the SCRR model. No analysis is made as to the type or quality of these facilities and their subsequent impact on the course failure rate.

Media and Training Aids. As stated earlier, the studies centered on the characteristics of the students, and the attempt was made to relate the failure rate to the characteristics of the student. Quite obviously, much can be done to improve the course content through the use of various training aids or devices, and during the study many indications of this were found. However, the impact on failure rate from the introduction of new or improved training aids and methods is an offline study. Thus, the use of these aids might revise the failure rates for input to the model, rather than being a direct input.

Support Personnel/Shift Work. The SCRR model determines the feasibility of accomplishing the desired training plan with the direct teaching resources available. Thus, any proposed convening schedule should be verified using this model. Neither model makes an attempt to analyze other support personnel, or the effect of possible reorganizations on these resources. Also, as only a small fraction of the training at this Center is conducted in the evening, no attempt was made in this study to analyze the relative effectivenes of training on different shifts.

Location of Training. This data element refers to the location of the training relative to the student's base location. The most common interpretation refers to a student stationed in the Norfolk area, versus one sent from outside the area to attend schools. One class of this latter group of students, those students on PCS orders, was extracted and subjected to statistical study. PCS code exists as part of the statistical data external to the model. Another interpretation of location code found to have some significance was the fact that the student was aboard ship or on shore duty. Again, this factor was made part of the statistical analysis and not entered directly as a model input. A third location code was identified, that of TYCOM sending the student. This TYCOM code again is used in the statistical analysis.

Outside Assignments/Degree of Remediation. Several of the courses require outside assignments, and some identifiable percentage of the failures are caused by lack of successful completion of these assignments. Likewise, most instructors were willing to spend considerable time and effort on remedial activities. However, these parameters are not loaded directly into the model. This is because these factors are adequately covered by the student characteristics already available. In the first case, outside assignments, a high correlation was found between lack of experience and the amount of outside effort necessary to assure success; likewise, in the same courses there was a similar correlation between experience and success. In the second case, remediation, this remediation was available to all students, and thus, success when remediation was required depended again on a combination of other factors. In summary, the lack or availability of remediation may vary the overall course failure rates. However, this failure rate is a TPF model input.

Relevancy to Job. This factor stood out quite strongly in the studies of historical failure rates. Probably the most striking example was the comparison of course 3150, Storekeeper, Independent Duty, with a failure rate of 2.9 percent, with similar course 4700, Storekeeper, Dependent Duty, with a failure rate of 14.6 percent. These courses are quite similar, cover the same fields, both award NEC's, and in fact have common sections. The difference in failure rate must be attributed primarily with the relevancy to the job, coupled with the obvious preselection of students. Again, this element is not used as a direct entry to the model, but is considered as a statistical input.

Testing System. Finally, the method of grading came under review. As stated earlier, several methods are used for grading. They vary from ungraded, to arbitrary attitude decisions, to outstanding/good/weak systems, to point and percentage. The method of grading was not analyzed as to its effect upon student progress. Rather, it was necessary to standardize these inputs in the statistical data base so that valid comparisons between courses could be made.

TPF CANDIDATE DEMAND DATA INPUTS. As with the course data, several initial assumptions were made as to student input demand parameters. They were:

a. Number contending for training

b. Fallout during enrollment window

c. No-shows

d. Unplanned inputs

e. Attritions

f. Setbacks

g. Average-on-board

h. Timing of arrivals

i. Fleet movements

j. Weapons systems cycle.

A discussion of these potential inputs follows.

Number Contending for Training. This term is analogous to demand. Demand itself, during the study, was shown effectively to consist of two components at the Center; that controlled by local quota control, and that controlled or scheduled by all other agencies. The large majority of this latter demand is controlled by BUPERS and, for purposes of this study, all students not scheduled by local quota control were grouped for demand purposes into the BUPERS category. This included students from the Coast Guard, Marines, Federal Bureau of Investigation, and other Governmental and civilian agencies.

Fallout During Enrollment Window. This input element was intended to show those quotas requested and then cancelled prior to the course start. However, it proved impractical to collect these data, so the item was dropped as an input. One rationalization for this was the fact that during the initial appraisal of the input parameters, it was felt that this fallout would increase as the course backlog, or length of time till next quota, increased. During analysis, this was found not to be so. Fallout and no-shows were more a factor of relevancy to job than to any wait time to attend a course.

No-Shows. Many data were gathered to ascertain no-show figures for the school. DPSCLANT maintains a file as part of the Student Data System containing all local quotas requested and, subsequently, those quotas that are utilized. A program was written at IBM's Cape Kennedy Facility, and through the cooperation of DPSCLANT, these data were reduced for model input. A sample printout of this report is shown in Figure IV-3. No-shows were an important part of the study as they steal capacity and, in some instances, cause backlogs for critical courses. The data obtained from DPSCLANT not only contain the numbers of no-shows, but ship type, lead time, TYCOM, and numbers of quotas actually utilized. Only no-show percentages were used as model inputs, but it is believed that additional statistical analysis of this area will prove useful.

There is an indication that a strong statistical relationship exists between non-academic dropouts and failures for courses greater than one week. This was one of the areas, however, that because of time limitations, could not be pursued. Therefore, the model presently uses historical non-academic rates as an input, with other provisions for future updating through the statistical program interface. One problem area uncovered in the statistical analysis of failures was actually defining "what is a failure." The best example of this is in course 536N, Boiler Feedwater and Test. During the last six months of fiscal year 1974, this course recorded one failure, while a much higher percentage of the students were not certified upon course completion. This again points to the desirability for standardization in grading systems.

Average On Board. At the beginning of the study, this variable was considered an input to be used by the model as a control figure. During the development, however, it was dropped as it was felt more desirable to calculate the AOB based on demands and convening, and let the user interpret the results and manually adjust the inputs to achieve the desired results.

Timing of Arrivals. One problem confronting the Center is the extreme variations and seemingly unpredictable arrival rate of students for training. This unpredictable nature of the inputs is compounded by Fleet movements, the number of sources of students, and the variety of priority schemes. Fleet makeup and

```
  1    N 1C P CECILDD853  LT PATTERSON          J-38/580-     1    0    1
  2    N 1MEREDITH DD890  ENS HANNUM            J-38/500-     1    0    1
  3    N 1VOGELGESADD862  ENS SHACKELFORD       J-38/580-     2    1    1
  4    N 3SARATOGA CV60   CH SANDERTER          J-38/580-     1    0    1
  5    N 4PORTLAND LSD37  53                    J-38/580-     1    0    1
  6    N 4M WHITNEYLCC20  PN2 BROWN 1510        J-38/580-     3    2    1
  7    N 5CALOOSAHAAO98   ENS IRLAN             J-38/580-     1    0    1
  8    N 5SAN DIEGOAFS6   PN2 ROHLFLING         J-38/500-     1    0    1
  9    N 5SHAKORI  ATF162 ENS SPANGLER          J-38/580-     1    0    1
 10    N 6L Y SPEARAS36   PN3 FRYDAY            J-38/580-     1    0    1
 11    N 9NAVWEPSTADALGRENENS RICHIE            J-38/500-     1    0    1

 COURSE: 8202  QUOTA REQ:   14  QUOTA UTIL:    3  NOSHO:   11


  1    N 1CORRY     DD817  ENS LASKINS              J-201-     1    0    1
  2    N 1CONYNGHAMDDG17  101                       J-201-     2    0    2
  3    N 4F MARION LPA249 LT JOHNSON                J-201-     1    0    1
  4    N 4INCHON   LPH14  LCDR GILLEN               J-201-     3    2    1
  5    N 4HARLAN COLST1196ENS DUDUY                 J-201-     1    0    1
  6    N 4BOULDER  LST1190LT FREEHILL               J-201-     1    0    1
  7    N 5SYLVANIA AFS2   LTJG BLAKESLEY            J-201-     3    0    3
  8    N 5BUTTE     AE27  LT BUTLER                 J-201-     1    0    1
  9    N 5BUTTE     AE27  LT BUTLER                 J-201-     1    0    1
 10    N 5OPPORTUNEARS41  LTJG BROWN                J-201-     1    0    1
 11    N 5SEATTLE  AOE3   LT PLANTE                 J-201-     4    2    2
 12    N 5SHANKORI ATF162 LT ALM                    J-201-     1    0    1
 13    N 5SEATTLE  AOE3   LT PLANTE                 J-201-     2    0    2
 14    N 6KITTIWAKEASR13  PNC FIELD                 J-201-     1    0    1
 15    N 9COMMSTA  NORVA  CH COBERS                 J-201-     2    0    2

 COURSE: 8272  QUOTA REQ:   25  QUOTA UTIL:    4  NOSHO:   21


  1    N 1AYLWIN   DE1081 ENSDENEGRE                J-201-     1    0    1
  2    N 1R E BYRD DDG23  LT MILLER                 J-201-     2    0    2
  3    N 1R E BYRD DDG23  LT MILLER                 J-201-     1    0    1
  4    N 1TALBOT   DEG4   ENS CHAMBERS              J-201-     1    0    1
  5    N 1VREELAND DE1068 111746Z DEC 73            J-201-     1    0    1
  6    N 1VOGELGESADD862  433                       J-201-     1    0    1
  7    N 1WAINWRIGHLDG28  RM1 STELSER               J-201-     2    0    2
  8    N 4SAGINAW  LST1188ENS ELAM                  J-201-     2    0    2
  9    N 4CORONADO LPD11  RMC SMALLACOMBE           J-201-     1    0    1
 10    N 4BRNSTBL CLST1197PN2 OLEGARIO              J-201-     1    0    1
 11    N 7MORGENTHAWHEC722154220                    J-201-     2    0    2
 12    N 7MIDGETT  WHEC726LT OLSEN                  J-201-     1    0    1

 COURSE: 8282  QUOTA REQ:   16  QUOTA UTIL:    0  NOSHO:   16
```

FIGURE IV-3 SAMPLE NO-SHOW SUMMARY PRINTOUT movements offer one potential for a model to be associated with the TPF model. Through the study of historical data, it is possible to predict the demand for many of the courses based on ship type and TYCOM. However, a large portion of the students at the Center are detailed from BUPERS, whose planning cycle is outside the present scope of the TPF model. Secondly, many students are seasonal, such as midshipmen and reservists, which again would form another input to any Fleet model. Another complexity to a Fleet model is the priority schemes for quotas among and within TYCOMS. Finally, precommissioning activities impose demands that are unique in nature and add to the complexity. During Phase I of this study, a Fleet model was discarded as of limited value in a model system of this type. During this study, it again became apparent that the benefits to be obtained by the dynamics of an input Fleet model are not presently worth the large additional effort.

Weapons System Cycle. This input again represents an attempt to automatically introduce dynamics to the input demand. However, this input requires offline analyses, and the demands imposed by the various stages of the weapons cycle can manually be inputted through the standard model schedule and demand inputs.

DATA BASE INPUTS

All model parameters for the TPF model can be stored in the DOTS data base. Volume III contains the complete format and update procedures for loading and updating. However, certain of these data elements should be defined in this model to assure proper operation of the TPF model. Also, all formats and further definition are found in Volume III, Section IV, of this report.

Many of the data aggregated for the current TPF model have been obtained from several sources. A program was written to assist the gathering effort, and to analyze the differences in data from alternate sources. An example of the data gathering format is shown in Figure IV-4.

CDP. The CDP number is the new 4 character data processing code for all courses. This code is required for data base input, but is used for printout identification only in the TPF model.

SCHOOL. The school code is the 6 character code for schools of the Fleet Training Center. The TPF model calculates totals upon encountering a new school code in the input stream. Thus, it is important that care be taken that the correct code is entered, and that the courses be entered in sorted course order.

CHANGE DATE. The change date allows the model to represent course changes. The "A" convenings, lengths, and capacities will be used by the model prior to the change week, and the "B" convenings, lengths, and capacities will be used following the change week. The data entry for change week itself is the week of model run in which the "A" schedule should be dropped and the "B" schedule picked up.

An entry of 53 (first week of second year), for example, would indicate that the "A" schedule should be used for the first year, and the "B" schedule for subsequent years.

```
                          TRAINING PROCESS FLOW MODEL - COURSE DEMAND AND NO SHOW SUMMARY

COURSE  COURSE NAME       DPSCLANT DATA  3 QUARTER 73    4 QUARTER 73    1 QUARTER 74    2 QUARTER 74      ANNUAL UTILIZATION
 NO                       CONV LEN CAP   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT       CAP  UTIL  PCT

8072  COM PRDC ADV/SPR    24  1.0  15     90   35  38.9   75   13  17.3   75   35  46.7   75   27  36.0      315   110  34.9

COP                       SCHOOL DATA    CALC NO SHOWS    DP NO SHOWS     NON - GRADS     FAILURES         BACKLOG SCHOOL UTIL
 NO                       CONV LEN CAP   ACT PROJ  PCT   ACT  PCT SCHL   DROP  PCT INC   TOTAL PCT SCHOOL    WKS    CODE PCT

512A                      24  1.0  15     0    0   0.0     7  11.3   8      0   0.0   0     1  1.6   02       6     COM   39

                           BUPERS DATA   ANNUAL
                          CONV LEN INPUT DEMAND   AOI  AEI  GCT  ARI  MECH CLER SHOP AFQT ETST AGE RATE NEC  MGR  ASB  NASB NADS PRTY

                            0  0.0   0      0      0   11                                          05   0    1   00   00    03   30

                          NOTE: 1 CONV CANCELLED LACK STUDENTS. CONV FREQ UNDER REVIEW


COURSE  COURSE NAME       DPSCLANT DATA  3 QUARTER 73    4 QUARTER 73    1 QUARTER 74    2 QUARTER 74      ANNUAL UTILIZATION
 NO                       CONV LEN CAP   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT       CAP  UTIL  PCT

8092  MODEL 28 ASR        10  9.0  20     60   50  83.3   40   39  97.5   80   71  88.7  100   84  84.0      280   244  87.1

COP                       SCHOOL DATA    CALC NO SHOWS    DP NO SHOWS     NON - GRADS     FAILURES         BACKLOG SCHOOL UTIL
 NO                       CONV LEN CAP   ACT PROJ  PCT   ACT  PCT SCHL   DROP  PCT INC   TOTAL PCT SCHOOL    WKS    CODE PCT

3189                      16  9.0  20     0    0   0.0    0   0.0  12     11   7.1   2    19 12.3   10        0     TTM   86

                           BUPERS DATA   ANNUAL
                          CONV LEN INPUT DEMAND   AOI  AEI  GCT  ARI  MECH CLER SHOP AFQT ETST AGE RATE NEC  MGR  ASB  NASB NADS PRTY

                          10  9.0  17    171       0   20   57   55    52   53   53   65   56  24   04   1    0   04   02    02   20

                           BUPERS CONTROLLED
                           NOTE: LESS CONV. 1974 3 AUG. 9 SEP. 15 OCT. 18 NOV


COURSE  COURSE NAME       DPSCLANT DATA  3 QUARTER 73    4 QUARTER 73    1 QUARTER 74    2 QUARTER 74      ANNUAL UTILIZATION
 NO                       CONV LEN CAP   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT   CAP UTIL  PCT       CAP  UTIL  PCT

8102  LOW LEVEL KEYING    11  3.0  12     36   18  50.0   36   18  50.0   36   21  58.3   60   29  48.3      168    86  51.2

COP                       SCHOOL DATA    CALC NO SHOWS    DP NO SHOWS     NON - GRADS     FAILURES         BACKLOG SCHOOL UTIL
 NO                       CONV LEN CAP   ACT PROJ  PCT   ACT  PCT SCHL   DROP  PCT INC   TOTAL PCT SCHOOL    WKS    CODE PCT

3259                      16  3.0  12     0    0   0.0    0   0.0   0      6  12.0   0     0  0.0   00        0     TTM   52

                           BUPERS DATA   ANNUAL
                          CONV LEN INPUT DEMAND   AOI  AEI  GCT  ARI  MECH CLER SHOP AFQT ETST AGE RATE NEC  MGR  ASB  NASB NADS PRTY

                          11  3.0   9    102       0   12   57   57    53   52   56   80   60  26   05   1    0   09   00    00   20

                           BUPERS CONTROLLED
                           NOTE: 15 JUL. 5 & 26 AUG. 7 OCT. 11 NOV. 16 DEC. 3 FEB. 10 MAR. 14 APR.
                           NOTE: 19 MAY. 23 JUN
```

FIGURE IV-4 SAMPLE TPF DATA COLLECTION PROGRAM FORMAT

CONVENINGS (A AND B). This represents the annual convenings per year for a course or, in the case of a course undergoing a change, the convening frequency. For example, if a course convenes every other week for the next three months, then ends, the "A" convenings should be entered as 50, the change week entered as 13, and "B" convenings should be entered as 0, which will terminate the course.

LENGTH (A AND B). Length represents the actual course length in weeks, and is entered in the data base with 1.0 representing a one week course, and 0.2 representing a one day course. "A" represents the course length prior to a course change, and "B" represents the length subsequent to a change. Only the "A" length is required if no change is indicated. The TPF model executes using course length in either weeks or days, depending on the option chosen through the AOB constant parameter. If the days option is chosen, a two week course (2.0) will be converted to a twelve day course by the model (10 school days plus two weekend days).

CAPACITY (A AND B). This represents the current limiting student capacity, per class, of the course. "A" represents the length prior to a change date, while "B" represents the length subsequent to the change date. This capacity is the maximum allowable student input, and includes locally scheduled students, as well as BUPERS scheduled students.

BUPERS CAPACITY (A AND B). This is the number of seats controlled by BUPERS or other agencies, and is a portion or all of the capacity of the class for those courses under BUPERS control. If a BUPERS demand is indicated with no BUPERS seats, a warning message will be printed and the BUPERS demand will be honored.

BACKLOG. This represents the length of time in weeks a student must wait for a scheduled quota in a course whose nearest convening is totally booked. This backlog in weeks is converted to students backlogged during the TPF model initialization. The TPF report lists the backlog in both weeks and students. Some intuition must be used to resolve those unique cases where the actual backlog in weeks is not clear. Examples of this situation are courses that may convene very infrequently, or those courses with quotas reserved by TYCOM, such as where all quotas are booked except for COMSUBLANT. It is anticipated that the data base will be modified to allow the backlog input to be in students during the Phase III effort.

DEMAND. This represents the planned annual input to the course for students booked through local quota control. It does not include students scheduled through BUPERS.

BUPERS DEMAND. This input represents the planned BUPERS annual demand for the course. This annual demand will be honored by the TPF model, even if overbooking of classes is involved.

FAIL RATE. This represents the historical failure rate for the class, including academic dropouts. Statistical inputs can overwrite these data for selected courses.

NO-SHOW RATE. This is the historical no-show rate for students scheduled through local quota control. This is defined as "No-Show Rate = No Shows/(No-shows plus utilization)."

NON-ACADEMIC DISENROLLMENT RATE. This represents the historical dropout rate for non-academic reasons.

J NUMBER. This is the last 4 digits of the J numbering system (presently being replaced by CDP designations). All J numbers for the Center end in 2. This number is used both for reference purposes, and also to load statistical data, as DPSCLANT historical data files have not been converted to CDP numbers.

OFFSET. Offset is an optional input and is used to modify the schedule matrix to allow fine tuning of the actual convening date of courses with low convening frequencies. The primary purpose of offset is to assure that the AOB created by a course convening is allocated to the proper quarter. Courses with convening frequencies between 1 and 50, will convene according to the matrix shown in Figure IV-5. Offset allows the user to shift this matrix to the right or left. For example, an offset of 3 will subtract 3 from the actual week in session. Thus, week 4 of the model run would use week 1 of the matrix; model run week 5 would use matrix week 2, and so forth. This matrix should be considered a "wrap around" matrix, that is, week 53 should be treated as week 1.

THIS PAGE INTENTIONALLY LEFT BLANK.

```
                         TPF MODEL COU[illegible]

ANNUAL   ●●● 1ST QTR  ●●●     ●●● 2ND QTR  ●●●     ●●● 3RD QTR  ●●●     ●●● 4TH QTR  ●●●
 CONV      (WKS 1-13)           (WKS 1-13)           (WKS 1-13)           (WKS 1-13)

   1     X ---- ---- ----     - ---- ---- ----     - ---- ---- ----     - ---- ---- ----
   2     X ---- ---- ----     - ---- ---- ----     - X--- ---- ----     - ---- ---- ----
   3     X ---- ---- ----     - ---X ---- ----     - ---- ---- -X--     - ---- ---- ----
   4     X ---- ---- ----     X ---- ---- ----     - X--- ---- ----     X ---- ---- ----
   5     X ---- ---- -X--     - ---- --X- ----     - ---- -X-- ----     - --X- ---- ----
   6     X ---- ---- X---     - ---X ---- ----     - X--- ---- -X--     - ---- X--- ----
   7     - X--- ---X ----     - -X-- ---- X---     - ---- X--- ---X     - ---- -X-- ----
   8     X ---- --X- ----     X ---- -X-- ----     - X--- ---X ----     - X--- --X- ----
   9     - X--- -X-- ---X     - ---X ---- -X--     - ---X ---- -X--     - -X-- ---X ----
  10     X ---- X--- -X--     - -X-- --X- ----     - X--- -X-- --X-     - --X- ---X ----
  11     X ---- X--- -X--     - -X-- -X-- -X--     - ---X ---- X---     - X--- X--- X---
  12     - X--- X--- X---     X ---X ---X ----     - X--- -X-- -X--     - X--- X--- X---
  13     - X--- X--- X--X     - --X- --X- --X-     - ---X ---X --X-     - -X-- -X-- -X--
  14     X ---X ---X --X-     - -X-- X--- X---     - -X-- X--- X--X     - --X- -X-- -X--
  15     X --X- --X- -X--     X ---X --X- -X--     - --X- -X-- X---     X --X- -X-- -X--
  16     X --X- --X- -X--     X --X- -X-- X---     - X--- X--X --X-     - X--X --X- -X--
  17     - X--X --X- -X-X     - -X-- X--X --X-     - --X- -X-- X--X     - -X-- X--X --X-
  18     X --X- -X-- X--X     - -X-- X-X- -X--     - -X-- X--X --X-     - X-X- -X-- X-X-
  19     - X-X- X--- X-X-     - X-X- -X-X --X-     - --X- -X-X --X-     - X-X- -X-- X--X
  20     X --X- X--X -X--     X -X-- X-X- -X--     - X--X -X-- X-X-     - X-X- -X-X --X-
  21     - X-X- X--X -X-X     - -X-X -X-- X-X-     - -X-- X-X- -X-X     - X--X -X-X --X-
  22     - X-X- X--X -X-X     - -X-X -X-X -X--     - -X-X -X-X -X-X     - -X-X --X- X-X-
  23     - X-X- X-X- X-X-     - X-X- X-X- X-X-     - ---X X-X- X-X-     - X-X- X-X- X-X-
  24     - X-X- X-X- X-X-     X -X-X -X-X -X--     - -X-X -X-X -X-X     - X-X- X-X- X-X-
  25     X -X-X -X-X -X-X     - X-X- X-X- X-X-     - -X-X -X-X -X-X     - X-X- X-X- X-X-
  26     X X-X- X-X- X-X-     X -X-X -X-X -X--     - X-X- X-X- X-X-     X -X-X -X-X -X-X
  27     X X-X- X-X- X-X-     X -X-X -XX- X-X-     - X-X- X-XX -X-X     - X-X- X-X- X-X-
  28     X -X-X -XX- X-X-     X X-X- X-X- X-X-     - X-X- X-X- X-X-     X X-X- XX-X -X-X
  29     X -X-X -XX- X-X-     X X-X- X-XX -X--     - X-XX -X-X X-X-     X -XX- X-X- XX-X
  30     - XX-X -XX- X-XX     - X-XX -X-X X-X-     - -XX- X-XX -X-X     X -X-X X-X- XX-X
  31     X -X-X X-XX -X-X     X -X-X X-X- XX--     - XX-X X-X- XX-X     X -X-X X-XX -XX-
  32     - XX-X X-XX -XX-     X X-XX -X-X X-X-     - X-XX -XX- XX-X     X -X-X X-XX -XX-
  33     X -XX- XX-X X-X-     X X-XX -XX- XX--     - XX-X X-XX  XX-     X X-XX -XX- XX-X
  34     - XX-X XX-X X-XX     - XX-X X-XX -XX-     - -XXX -XX-   -X     X -XX- XX-X X-XX
  35     - XX-X XX-X X-XX     - XXX- XX-X X-X-     - XX-X X-XX -  XX    - XX-X X-XX X-XX
  36     - XXX- XXX- XX-X     X X-XX -XXX -XX-     - X-XX -XXX -XX-     X XX-X X-XX X-XX
  37     X -XXX -XXX -XX-     X XX-X XX-X XX--     - XXX- XXX- XX-X     X X-XX X-XX X-XX
  38     X -XXX -XXX -XXX     - XXX- XXX- XXX-     - -XXX X-XX X-XX     X -XXX -XXX -XXX
  39     - XXXX -XXX X-XX     X X-XX X-XX X-X-     - XXX- XXXX -XXX     X -XXX -XXX -XXX
  40     - XXXX -XXX X-XX     X X-XX XX-X XXX-     - -XXX X-XX XX-X     X XX-X XXX- XXXX
  41     X -XXX X-XX XXX-     X XXX- XXXX X-X-     - XXX- XXXX X-XX     X X-XX XXX- XXXX
  42     - XXXX XX-X XXXX     - XXXX X-XX XXX-     - -XXX XXX- XXXX     X -XXX XX-X XXXX
  43     X -XXX XXX- XXXX     X X-XX XXXX -XX-     - XXXX -XXX XXX-     X XXXX X-XX XXXX
  44     - XXXX XXXX -XXX     X XXX- XXXX XXX-     - XXXX -XXX X-XX     X XXXX -XXX XXXX
  45     - XXXX XXXX X-XX     X XXXX XX-X XXX-     - XXXX X-XX XXXX     X XX-X XXXX XXXX
  46     - XXXX XXXX XXXX     - XXXX XXXX XXX-     - -XXX XXXX XXXX     - XXXX XXXX XXXX
  47     - XXXX XXXX XXXX     X XXX- XXXX XXX-     - XXXX XXXX X-XX     X XXXX XXXX XXXX
  48     - XXXX XXXX XXXX     X XXXX XXXX XXX-     - -XXX XXXX XXXX     X XXXX XXXX XXXX
  49     - XXXX XXXX XXXX     X XXXX XXXX XXX-     - XXXX XXXX XXXX     X XXXX XXXX XXXX
  50     X XXXX XXXX XXXX     X XXXX XXXX XXX-     - XXXX XXXX XXXX     X XXXX XXXX XXXX

FOR EACH WEEK IN THIS SCHEDULE:    AN 'X' INDICATES THE COURSE WILL BE RELEASED
                                   A  '-' INDICATES THE COURSE WILL NOT BE RELEASED

NOTE: IF ANNUAL CONVENINGS FOR A COURSE IS GREATER THAN 50, THE COURSE WILL BE TREATED
      AS MULTIPLE COURSES,EACH HAVING 50 OR LESS CONVENINGS PER YEAR.
```

FIGURE IV-5 COURSE RELEASE SCHEDULER

NEC/CATALOG NUMBER. These two elements are printed in the TPF model report for references. They are obtained from the DOTS data base, are not used in processing, and are not considered model inputs.

OUTPUT PARAMETERS DESCRIPTION

The primary TPF model output is the yearly course summary format, shown in Figure IV-2. This format is broken into two parts; the left portion which gives a synopsis of the input data, and the right hand side which tabulates the fiscal year projections based, in part, on those input data. The data elements on the left have been previously described. The following discussion will, therefore, concentrate on the yearly course projections.

FORMAT. The output is broken into 4 quarters of equal length (13 weeks). The first quarter is assumed to start 1 July of the fiscal year. This is significant as the model will not run courses during the Christmas period, which is assumed to be the last week of the second quarter, and the first week of the third quarter. Annual totals, as well as percentages, are printed for applicable data elements.

NUMBER OF CONVENINGS. This represents the total convenings of the course, by quarter. A convening date is defined as the day of the first class for a course section. Thus, convenings are accumulated for a quarter based on the beginning date of the class. For example, if a course with a length of 11.0 weeks convened in the 13th week of the 1st quarter, the convening will be counted in the first quarter, even though the bulk of the student AOB falls in the second quarter. The model calculates course convenings based on annual convening frequency, the current model week, offset, and change week. An example in the use of change week to terminate a course can be found in Figure IV-2. The first course, CDP number 3081, is scheduled for disestablishment approximately 7 November. A change week of 18 is entered with a new convening frequency of zero, and it can be seen that the course is terminated with only one convening in the second quarter and none thereafter.

COURSE CAPACITY. This represents a total of the limiting student capacities on the day each course was released, by quarter. On the day a course convenes, the model tests if this convening is prior to or after a schedule change date, and the current capacity is used.

UTILIZATION. This is the total number of class seats occupied on the day the course convened. That is, it is a total of the local quotas granted, minus no-shows, plus BUPERS input, plus substitute quotas. The exact algorithm that controls this is discussed in the Program Description portion of this section. This algorithm does make allowance for overbooking of critical courses. An example of this is course 3400, in Figure IV-2, which shows that during the first quarter this course ran at an average of 102.2 percent capacity to work off a schedule backlog.

NO-SHOWS. This is an historical average of students not showing up for the course who had previously been granted quotas. Only that portion of students scheduled through local quota control is counted in the no-show figure.

Students scheduled from BUPERS do not contribute to no-shows in this model as: (1) they are usually under TAD orders; and (2) the school has no record of these students until they arrive. No-shows also are not derived from substitute quotas for obvious reasons. Based on this use of no-show rates, it is important that the historical no-show rate entered in the model be based on the sum of no-shows and utilization, and not on utilization alone.

BACKLOG. Backlog is defined as the time a student must wait for a confirmed quota in a course that is booked. The backlog printout is a snapshot of the actual backlog on the last day of the quarter. The model input portion of the format gives the initial, or beginning backlog, while that contained in the annual totals column is the ending backlog, which is identical to the 4th quarter backlog. Backlog is entered in weeks and is converted to students who hold quotas. The output report shows backlog in both weeks and numbers of students.

AOB STUDENT DAYS. Student days is the total, by quarter, of the number of days each student has spent in a course that quarter. Thus, it is possible to show student days in a quarter that had no convenings. Students set back to a course do not count as utilizations, but the student days spent in that convening are totaled. Two methods of calculating student days are available in the TPF model, with the method decided by the value of AOB constant entered. If this constant is less than 300, student days is the total of class days times students, adjusted for setbacks and quarters. If the AOB constant is 300 or greater, student days include weekend days for courses longer than one week. If a course spans two quarters, the weekend days for that week the span occurred are charged to the quarter in which the course convened. AOB is the student days divided by the AOB constant, which is a model input parameter. This AOB is multiplied by 4 for the quarterly outputs.

PASS/FAIL, ETC. These are historical pass/fail and non-academic disenrollment percentage rates. Updates to these factors require additional statistical analysis of current data. Academic setbacks are hard coded into the logic of the model and are based on the fail percentages. The criteria for setbacks are discussed under the logic design portion of this section.

MODEL/DATA BASE COMMUNICATION

Communication with the data base is a one way flow, utilizing a group of support programs to make data base parameters available to the model. This flow can be seen in Figure IV-1. The flow initiates with the procedure to create a temporary, or scratch data base. This gives the user a capability of modifying the temporary data base to run the model. A program, UNLOAD1, exists to reformat these data for input to the TPF model. This program breaks data base parameters into two data sets. The TPF model utilizes multiple input data sets to minimize both core storage requirements and execution time. The only calculation occurring during this operation is the blanking of the NEC code, should the number 0 occur. The program also makes available a card image of each of the data sets. The user can either print or punch these data by changing the JCL control card. Thus, the user can obtain a punched deck of all TPF model inputs from the data base. This in turn allows the user an alternate method of modifying data for direct input to the TPF model. Finally, this interface exists in its present configuration as this is the planned "port" for direct communication with the model through a terminal communication system.

The statistical data gathered in this exercise consists of two data sets, the longest containing over 27,000 physical records of 40 data elements each. This collection of data has been termed the statistical data base and is explained fully in Volume III, Section IV, under Statistical Data. As these statistical data are refined, it is anticipated this data base will be utilized on line.

LOGIC DESIGN

In general, the design of the TPF model is such that it might be termed a front-end loaded model. That is, all schedule and demand conditions for a course are loaded at the beginning of the year, and the model then projects the resultant conditions for the remainder of the year. Likewise, the basic model projects, rather than predicts. That is, the model itself is a true simulation, or mathematical representation of the mechanics of the overall scheduling function for the Center. All major functions that affect student flow are modeled to a detail similar to the actual operations at the Center, which include quota control, BUPERS detailing, scheduling, failures, and setbacks. The model outputs, however, can be predictive if the inputs themselves are predictive. To use the model for decision making purposes, the user must input his predictions of demands, schedule changes, new courses, etc., and the model then projects the annual throughputs, failures, AOB's, and such, based on these predictions. Likewise, a simulation model is not an optimization model; the large number of variable input parameters precludes this. The user can manipulate the model inputs to achieve optimal results.

PROGRAM LOGIC DESIGN. The TPF model consists of a main control program and six subroutines, all coded in the FORTRAN language. This structure was chosen for several reasons. All input data enter through the main control program, which edits the input data and builds a matrix for communication between the subroutines. Thus, if input methods should be changed, such as entering backlog as students rather than the present method of entering weeks, only one routine would require a minor change and no revalidation of the other subroutines would be required. As another example, the entire scheduling routine is contained in subroutine CRSRLS. This subroutine represents the methods and procedures currently in use at the Center. Should it be desirable to represent other centers with different methods and procedures, a new subroutine to represent that center could be written, and the appropriate subroutine could be linked to the model at execute time. In summary, the model has been written in a modular form so as to allow adaptability and ease of modification without extensive rewrite.

One final factor was paramount to the design of the model, that of execution speed. Other languages, such as Dynamo and GPSS, could have been adapted to the problem at hand. However, each of these is a general simulation, and compromises would have been required in a model of this size. Probably the greatest compromise would have been in execution time. The TPF model currently requires 3.6 minutes elapsed time for an annual process of all 126 courses presently active at the Fleet Training Center, and to print the 54 page summary report. This execution speed is due in part to the fact that all model run data are stored in a matrix that is core resident, with no disk access required. Also, special attention has been paid to real-time programming techniques, such as the use of the "arithmetical if" rather than the "logical if", the latter being more convenient to use but substantially slower in execution.

Program - MAIN. The program MAIN is the control portion of the model. The first consideration in the design of this program was that it was to be the primary interface with the outside world. All input data and control inputs enter through this program. One requirement placed upon this program was that the model should execute even if an invalid parameter is specified on an input card. Nothing is more discouraging than sending a job to the computer center, waiting two days for the turnaround, and then finding that the job was not run because of a keypunch error on an input card. Because of this, over 50 percent of the program MAIN is spent in editing input data. An example of the logic used for data error detection and correction can be found in the entry for years of the run. The feature of entering years of the run is somewhat cosmetic in nature, as these figures are not used for input calculations, but are printed on the output report to identify the years of the run. The number of years of the run (or model yearly cycles) is determined by subtracting the first year from the last year; if the result is negative the result is made positive and the years interchanged. If only one year input is present, the model will run only one year; if no years are present, the model will default to 1975 and run for one year; if the years of the run are greater than three, the run will be clamped to three years. Most other data elements go through some sort of error checking, especially tests for invalid, negative, out-of-range, or logically invalid conditions. The data elements found in error are zeroed or clamped at some value, an error or warning message printed, and processing continues.

The program MAIN also sets the run condition flags for communication with the subroutines. Nearly all of this communication is through the use of FORTRAN common, rather than subroutine parameter passing. This is to aid documentation and assure ease of modification. The name PASS in one subroutine means the same thing as the name PASS in any other subroutine, reducing the need for redefinition within each subroutine.

Except for one routine, the rest of the MAIN program logic is straightforward, using standard FORTRAN coding techniques. Three major cycling paths exist in the model; the year loop, the quarter loop, and the week loop. One of these, the quarter loop, can undergo alteration to initialize the model. The TPF model does not snapshot existing conditions, but rather it views conditions over a period of time. It considers the schedule and classes as they are today, and projects for one year. One important factor must be recognized. There may be 70 courses in session that were started in a preceding period and which, because of their length, terminate in the first quarter being projected. To represent this, the quarter loop can reconfigure and, for the initialization phase, the model operates as though it were the quarter prior to model start. No totals are accumulated for the run; the only effect is to release courses so that they may be active at model start. Subroutine PRERUN is used to accomplish this, and this initialization will be discussed in further detail in that segment. This initialization is important to properly calculate AOB and establish initial student flow.

The lowest order cycling loop in the model is the week loop. This loop first scans each course loaded in the model, one at a time, for a course that should convene that week. It does this by testing the convening frequency of the course against a matrix loaded in core, for convening frequencies of 1 to 50 convenings per year. Before this comparison is made, the matrix is rationalized for offset, change week, and multiple convenings. This routine is described immediately following this segment, but for now, all that is necessary to know is that if this matrix returns a code that the course should start, subroutine PRERUN will be called and the course started. When a course is started, it is placed in an active matrix, which is described in the subroutine PRERUN segment. Upon completion of the test for possible convening of all courses, the MAIN program then tests all active courses to see if any end in that week. As the model cycles on a weekly basis, many courses will begin and end in the same weekly loop. When a course is found to end, subroutine CRSEND is called which closes out the course, allocates the AOB, and calculates attrition. When all of the 300 possible active courses have been tested, the weekly loop recycles to run another week.

Every 13 weeks the quarter loop cycles, calling subroutine QRTEND, to allocate AOB against quarters and accumulate totals. Finally, after 4 quarters, the year loop cycles, calling subroutine YEARND, which controls printout for the yearly report.

Scheduling Algorithm. Several scheduling algorithms were studied as candidates for this model. One of the most common schemes uses a calendar and requires some form of input date for each convening. This is suitable for a simulation of construction projects or other projects with few convenings and absolute accuracy requirements. However, it is not usable when there is the possibility that a Fleet course may have over 400 convenings per year. Thus, an accurate but efficient routine was needed. As part of the design effort, the actual convening dates for many of the courses were plotted. These plots were then analyzed and an allowance was made for common holidays. The data were then transferred to the matrix shown in Figure IV-5. This shows the scheduled convening weeks for courses with a convening frequency of 1 to 50 per year. Many courses convened more frequently than this, and these are handled by breaking them into multiple courses, each with convening frequencies of less than 50, but whose overall convenings are the same as the original. For example, a course with 51 annual convenings is handled as two courses, one that convenes 26 times annually, and one that convenes 25 times annually. Using this technique, the TPF model can handle courses with up to 500 annual convenings. The convening matrix itself is stored in core and named ISCHED, with data loaded in hexidecimal format - FORTRAN allows the loading of hexidecimal data, but does not allow individual bit testing or manipulating. Therefore, a synthetic method of bit testing was developed. This technique involves extracting the proper bit pattern by division by various constants based on week and quarter, which leaves a 1 in the low order bit position if the course is to start, or 0 if it should not. This extracted bit pattern is then tested to determine whether the low order bit is a 0 or 1, which is accomplished by a division by integer 2, and then a multiplication by integer 2. If the result is the same as the original, the low order bit was 0 and the course is not released. Two rationalizations must be made prior to lookup in this table. First, if a course convenes only once a year, the matrix will start it the first week of the model run. In reality, this course may convene on the 21st week. Offset was introduced as an input to the model to allow fine tuning of the course release date. An offset of 20, for example, will tell the model to enter the schedule matrix as week 1 when the model is in the 21st week. This is useful to assure that student AOB is allocated to the proper quarter. The second parameter that may modify the schedule algorithm is "change week". This parameter allows a course to run for part of a year under one set of conditions, and the remainder of the year under a second set of conditions.

As this technique uses matrix lookup, the table must be protected for invalid entries while preserving flexibility. If the convening frequency is 0, the matrix will be bypassed and the course is not run. If the week is greater than 52, 52 is subtracted from the week until it is less than 52. If offset is positive, such as 21, no courses will be released until the 22nd week, regardless of the convening frequency. On the other hand, a negative offset of 31 would accomplish the same schedule shift, and courses could be released from the start of the model run.

<u>Subroutine CRSRLS</u>. The course release subroutine contains the scheduling logic for the Center. This includes keeping backlog counts, scheduling only local seats, and overbooking certain courses with high no-show rates. The logic of this subroutine schedules the BUPERS students based on the annual BUPERS plan, divided by current convening frequency. This is done even if the result exceeds the seats controlled by BUPERS. Next, local quotas are released. This is accomplished by releasing students to a backlog pool based on local demand, divided by current convenings. This pool is released to the course up to the local capacity. No-shows are then calculated using historical no-show percentages. Only local students are used for this calculation as BUPERS students generally are on TAD or PCS orders, and are not identifiable as no-shows. Finally, for courses running near capacity, up to 10 percent of the capacity is released from the backlog pool as substitute quotas. This routine then builds an entry in the course active matrix. Included is utilization, weeks till termination, and a term to allocate AOB between quarters and between classes if a student should be set back. This subroutine closely represents the scheduling methods in use at the Center. If other centers, with different algorithms, should be studied, this subroutine would most likely be replaced by one representing the location under study.

<u>Subroutine Prerun</u>. As mentioned previously, the model can run in an initialization mode for one quarter prior to the actual model run. Subroutine PRERUN is called by CRSRLS any time the model is in the initialization mode. It is required for two functions. First, courses are tested prior to release to ascertain whether they should be running at model start or not at all. Second, this subroutine allocates AOB for those courses to assure that AOB applicable to the first quarter is charged to the first quarter.

Subroutine CRSEND. This subroutine is called any time a course is found to end. Three functions are performed by this subroutine, closing out the active course, disposing of the students, and allocating AOB. The first function merely consists of deleting all reference to the course from the active matrix. Disposing of the students is more difficult. Failures are calculated first, using the current failure rate. This is either the historical rate or a revised failure rate, calculated by the statistical update program. Whichever failure rate is selected, it is constant for the model run. Two avenues for further study have been apparent during the design of this model. First, it is believed that the interface with the statistical data could be made dynamic, giving individual classes individual characteristics. Second, no provision is made to show reduction in AOB due to a failure dropping out of a course prior to its completion. There are two reasons for this latter condition. First, the dropout rates have a relevance to the job the student is to perform. In the case of a supply clerk, he may complete the course even though he is an obvious failure, because despite the failure, he will be doing the job. Second, over 85 percent of the failures are from courses one week or shorter where the early termination is insignificant.

The second student category calculated is non-academic disenrollments. Again, these students are calculated from static percentages, and as no data were yet available, no reduction was made to AOB.

The last student category is setbacks. Setback logic currently allows setbacks for those courses three weeks or longer, and where more than one convening is in session at a time. This setback rate is currently based on a fixed percentage of failures per class. AOB for setback is allocated between the "entered in" and "finished in" convening. Finally, this subroutine calculates AOB based on the current calculation method in effect.

Subroutine QTREND. This short subroutine is used to accurately allocate AOB between quarters. Only the active courses are tested at the end of a quarter, the accumulated AOB is charged to the current quarter, and the active course AOB is adjusted accordingly.

Subroutine YEARND. This subroutine is used to print a short form printout of quarterly model data. This printout can be called by a Trace flag on the parameter card. If this Trace flag is not ON, subroutine NPRINT is called.

Subroutine NPRINT. This subroutine accumulates annual data, prints the annual course, school, and Center quarterly reports, and restores the model for execution in multiple years. A sample of the course formats is shown in Figure IV-2 while a sample of the school and Center formats is shown in Figure IV-6.

LEVEL 1 VALIDATION SCENARIOS

The TPF model is a simulation program representing the physical operation of the Fleet Training Center, Norfolk, Virginia, and is written in the FORTRAN language. Unlike the other models discussed in this report, the TPF model uses no predeveloped programs as part of the simulation. Thus, the entire mechanics of the model required validation, along with the validation of the simulation algorithm.

MODEL ARITHMETICAL VALIDATION. The first step in validating the TPF model was to exercise the model in all possible modes. The first run consisted of running the models with course convenings of 1 to 200, and then verifying that the proper number of convenings occurred. Next, the lengths were varied, and one student placed in each convening to verify the AOB calculations. The offset was validated for both positive and negative values of up to one year. Each of

```
SCHOOL CODE AC&R    SUMMARY

                                          QUARTERLY PROJECTIONS
                    |  1 QTR FY 75    |  2 QTR FY 75    |  3 QTR .FY 75   |  4 QTR FY 75    |  ANNUAL  TOTAL  |
--------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
NUMBER OF CONVENINGS|     25 |        |     27 |        |     25 |        |     28 |        |    105 |        |
COURSE CAPACITY     |    364 |        |    396 |        |    364 |        |    412 |        |   1536 |        |
UTILIZATION         |    278 |  76.4%|    299 |  75.5%|    276 |  75.8%|    314 |  76.2%|   1167 |  76.0%|
NO SHOWS            |     52 |  15.8%|     62 |  17.2%|     53 |  16.1%|     65 |  17.2%|    232 |  16.6%|
STUDENT DAYS / AOB  |   5646 |  61.9  |   5550 |  60.8  |   5166 |  56.6  |   6002 |  65.8  |  22364 |  61.3  |
                    |        |        |        |        |        |        |        |        |        |        |
TOTAL PASS          |    256 |  92.1%|    276 |  92.3%|    253 |  91.7%|    290 |  92.4%|   1075 |  92.1%|
TOTAL FAIL          |     12 |   4.3%|     13 |   4.3%|     13 |   4.7%|     14 |   4.5%|     52 |   4.5%|
ACADEMIC SETBACK    |      6 |   2.2%|      6 |   2.0%|      6 |   2.2%|      6 |   1.9%|     24 |   2.1%|
NON-ACADEM DISENROLL|     10 |   3.6%|     10 |   3.3%|     10 |   3.6%|     10 |   3.2%|     40 |   3.4%|
--------------------------------------------------------------------------------------------------------------


                          TPF MODEL -- FISCAL YEAR 1975 SUMMARY

                  ******** TOTALS FOR FLEET TRAINING CENTER ********


                                          QUARTERLY PROJECTIONS
                    |  1 QTR FY 75    |  2 QTR FY 75    |  3 QTR  FY 75   |  4 QTR FY 75    |  ANNUAL  TOTAL  |
--------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
NUMBER OF CONVENINGS|    779 |        |    722 |        |    727 |        |    755 |        |   2983 |        |
COURSE CAPACITY     |  19827 |        |  18556 |        |  18415 |        |  19690 |        |  76488 |        |
UTILIZATION         |  15025 |  75.8%|  11391 |  61.4%|  10924 |  59.3%|  11562 |  58.7%|  48902 |  63.9%|
NO SHOWS            |   2298 |  13.3%|   1884 |  14.2%|   1773 |  14.0%|   1922 |  14.3%|   7877 |  13.9%|
STUDENT DAYS / AOB  |  85084 | 932.4  |  72006 | 789.1  |  69943 | 766.5  |  74122 | 812.3  | 301155 | 825.1  |
                    |        |        |        |        |        |        |        |        |        |        |
TOTAL PASS          |  14107 |  93.9%|  10614 |  93.2%|  10207 |  93.4%|  10765 |  93.1%|      0 |   0.0%|
TOTAL FAIL          |    692 |   4.6%|    576 |   5.1%|    533 |   4.9%|    585 |   5.1%|   2386 |   4.9%|
ACADEMIC SETBACK    |     34 |   0.2%|     33 |   0.3%|     31 |   0.3%|     34 |   0.3%|    132 |   0.3%|
NON-ACADEM DISENROLL|    226 |   1.5%|    201 |   1.8%|    184 |   1.7%|    212 |   1.8%|    823 |   1.7%|
--------------------------------------------------------------------------------------------------------------
```

FIGURE IV-6 TPF SCHOOL AND CENTER FORMATS the other algorithms, such as those for BUPERS control, no-shows, substitute quotas, dropouts, setbacks, etc., were exercised one at a time and in combinations to verify that the desired results were obtained. The listings for these validations are lengthy, however, and are not included as part of this report.

VALIDATION SCENARIOS. General validation runs were executed utilizing the TPF model to verify the utility of this model as a tool for evaluating change. Four of these runs are presented here.

Excessive No-Show Rates. The course, Boiler Feedwater and Test, was used as an example to show the utility of the model in evaluating the real cost of no-shows. The data used in this example are not current since this course has been totally restructured. The prior data, however, are useful for this example. In this hypothetical example, the course was operating with a backlog of about 20 weeks, but was running at only about 80 percent capacity because of a high no-show rate.

The TPF model was executed to show the improvement that could be expected by cutting the current no-show rate by 25 percent and 50 percent. The results of this experiment are shown in Figure IV-7. The top portion of this figure illustrates the results obtained by executing the model with all course data drawn directly from the data base, so as to show quarterly and annual predictions for the course under existing conditions. The center portion shows the results with the no-show rate cut to 18.3 percent, while the bottom portion shows the results with the no-show rate cut to 12.1 percent. All other parameters were held constant. Under existing conditions, it is projected that 618 students will utilize the course annually, with the reduced no-show rates improving this utilization to 667 in the second case, and to 717 with the no-show rate cut to 12.1 percent (50 percent of the original rate).

It was then decided to establish the number of additional convenings necessary to achieve the higher utilization if the no-show rate could not be reduced. The convenings were increased in increments of 4 until the desired utilization was obtained. The results of this experiment can be seen in Figure IV-8. Again, in the top portion of this figure, the model was executed under existing conditions to establish the baseline. In the center portion, the convening frequency was increased by 4 to 52, and in the bottom portion it was again increased by 4 to 56 annual convenings. The bottom portion gives a projected utilization of 720, which is close to the 717 utilization obtained by reducing the no-show rate by 50 percent. Thus, it can be predicted that the cost of just half of these no-shows, in terms of resource impact, is 8 convenings per year.

Variation in Student Characteristics. In this example, it was desired to observe the variation in the throughput that might be expected if the average of certain student characteristics were varied by plus and minus 5 percent. The course chosen for study was Air Conditioning and Refrigeration. The student characteristics varied were the average GCT and ARI test scores.

This example required a two part solution. The first portion of this can be seen in Figure IV-9. This figure shows this course (number 4552) with the failure rate calculated on the left, the GCT and ARI scores increased by 5 percent in the center using existing averages, and on the right with the GCT and ARI scores decreased by 5 percent. The programs used in this example were the off-line FAIL1, FAIL2, and FAIL3. These programs predicted that the failure rate would decrease to 7.9 percent with a 5 percent increase of the test scores (as compared to an existing failure rate of 11.6 percent), and would increase to 15.3 percent with a decrease in test scores of 5 percent.

These new failure rates were introduced as inputs to the TPF model to establish the corresponding throughputs. The results of this experiment may be seen in Figure IV-10. All other input parameters were held constant. In the top example, the lower failure rate was used, giving a throughput of 325 passing students. The center example used the existing failure rate, predicting a throughput of 309 passing students, while the bottom example, using the higher failure rate, resulted in 293 passing students. Thus, it can be predicted that a change of 3 percent in test scores will modify the failure rate by approximately 3.7 percent, resulting in a change of about 16 passing students annually under current conditions.

Backlog Reduction. This example illustrates how the TPF model can be used to evaluate course changes required by temporary impacts. It is assumed that the course, Introduction to 3-M, has been impacted as a result of an extremely large number of students requesting the course due to precommissioning activities, resulting in a current backlog of 10 weeks, or over 1400 students. It has been decided to immediately increase the convening frequency to 4 per week (176 annually) to work off this backlog. However, the peak demand is assumed to be temporary, and the demand figures from the original plan are believed to be valid.

The TPF model was used to establish the effects of first, continuing this higher convening rate indefinitely; second, returning to the original schedule in 6 months; and finally, returning to the original schedule in 3 months. The TPF model results may be seen in Figure IV-11. The top example shows the results obtained by continuing the course indefinitely at the higher convening frequency, resulting in an annual utilization rate of 74.7 percent. In the center example, the convening frequency was cut to 3 per week (132 annually) at the end of 26 weeks. This resulted in an annual utilization of 85.6 percent, with the backlog totally eliminated by the end of the second quarter. In the bottom example, the course was reduced to its original convening frequency at the end of the first quarter (13 weeks). This resulted in a utilization rate of 91.3 percent, but still showed a 4 week backlog at the end of the second quarter. These figures present some of the insight necessary to choose the proper course of action.

Align Capacity to Demand. In this example, the TPF model is used to evaluate the effects of reducing course convenings in order to bring utilization to a more favorable percentage. In the example, the course has been experiencing a utilization rate of less than 50 percent, and it is desired to increase this by a reduction in convenings. However, the situation is clouded somewhat by a relatively high no-show rate and a current temporary demand caused by precommissioning activities.

The TPF model was run to test the results of reducing the convening frequency immediately to 20 annual convenings and 16 annual convenings. The results of this are shown in Figure IV-12. In this figure, the top example shows existing conditions as a baseline, indicating an annual utilization rate of only 50.7 percent. In the second example, the convening frequency is immediately cut to 20, giving an annual utilization rate of 61.2 percent. In the bottom example, the convening frequency is immediately cut to 16, resulting in a more favorable utilization rate of 77.1 percent, without an excessive wait time (backlog).

```
                                  TPF MODEL -- FISCAL YEAR 1975 SUMMARY                                   PAGE   1
                                           SCHOOL CODE  AC&R

BOILER / FEEDWATER TEST
                                                                       QUARTERLY PROJECTIONS
CDP      J NO    CATALOG NO      NEC                   | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL  TOTAL |
536N     4522    A-651-0019                 -----------|-------------|-------------|-------------|-------------|---------------|
                                 NUMBER OF CONVENINGS|   12 |       |   12 |       |   11 |       |   13 |       |   48 |        |
--- COURSE DATA ---   INITIAL CHANGE COURSE CAPACITY |  192 |       |  192 |       |  176 |       |  208 |       |  768 |        |
                                 UTILIZATION         |  155 | 80.7% |  154 | 80.2% |  141 | 80.1% |  168 | 80.8% |  618 | 80.5%  |
ANNUAL CONVENINGS      48     0  NO SHOWS            |   49 | 24.0% |   50 | 24.5% |   46 | 24.6% |   53 | 24.0% |  198 | 24.3%  |
COURSE LENGTH WKS     1.0   0.0  BACKLOG-STUDENTS/WKS|  313 |20 WKS |  320 |20 WKS |  326 |21 WKS |  334 |21 WKS |  334 |21 WKS  |
COURSE CAPACITY        16     0  STUDENT DAYS / ADB  |  775 |  6.5  |  770 |  8.4  |  705 |  7.7  |  840 |  9.2  | 3090 |  8.5   |
BUPERS SEATS            0     0                      |      |       |      |       |      |       |      |       |      |        |
                                 TOTAL PASS          |  155 |100.0% |  154 |100.0% |  141 |100.0% |  167 | 99.4% |  617 | 99.8%  |
ANNUAL DEMAND   843 CHANGE WEEK   0 TOTAL FAIL       |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    1 |  0.6% |    1 |  0.2%  |
BUPERS DEMAND     0 OFFSET  WKS   0 ACADEMIC  SETBACK|    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
INITIAL BKLOG   307 BACKLOG WKS  20 NON-ACADEM DISENROLL|  0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
                                 ----------------------------------------------------------------------------------------------
```

```
BOILER / FEEDWATER TEST
                                                                       QUARTERLY PROJECTIONS
CDP      J NO    CATALOG NO      NEC                   | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL  TOTAL |
536N     4522    A-651-0019                 -----------|-------------|-------------|-------------|-------------|---------------|
                                 NUMBER OF CONVENINGS|   12 |       |   12 |       |   11 |       |   13 |       |   48 |        |
--- COURSE DATA ---   INITIAL CHANGE COURSE CAPACITY |  192 |       |  192 |       |  176 |       |  208 |       |  768 |        |
                                 UTILIZATION         |  167 | 87.0% |  167 | 87.0% |  152 | 86.4% |  181 | 87.0% |  667 | 86.8%  |
ANNUAL CONVENINGS      48     0  NO SHOWS            |   37 | 18.1% |   37 | 18.1% |   35 | 18.7% |   40 | 18.1% |  149 | 18.3%  |
COURSE LENGTH WKS     1.0   0.0  BACKLOG-STUDENTS/WKS|  313 |20 WKS |  320 |20 WKS |  326 |21 WKS |  334 |21 WKS |  334 |21 WKS  |
COURSE CAPACITY        16     0  STUDENT DAYS / ADB  |  835 |  9.2  |  835 |  9.2  |  760 |  8.3  |  905 |  9.9  | 3335 |  9.1   |
BUPERS SEATS            0     0                      |      |       |      |       |      |       |      |       |      |        |
                                 TOTAL PASS          |  166 | 99.4% |  166 | 99.4% |  152 |100.0% |  180 | 99.4% |  664 | 99.6%  |
ANNUAL DEMAND   843 CHANGE WEEK   0 TOTAL FAIL       |    1 |  0.6% |    1 |  0.6% |    0 |  0.0% |    1 |  0.6% |    3 |  0.4%  |
BUPERS DEMAND     0 OFFSET  WKS   0 ACADEMIC  SETBACK|    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
INITIAL BKLOG   307 BACKLOG WKS  20 NON-ACADEM DISENROLL|  0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
                                 ----------------------------------------------------------------------------------------------
```

```
BOILER / FEEDWATER TEST
                                                                       QUARTERLY PROJECTIONS
CDP      J NO    CATALOG NO      NEC                   | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL  TOTAL |
536N     4522    A-651-0019                 -----------|-------------|-------------|-------------|-------------|---------------|
                                 NUMBER OF CONVENINGS|   12 |       |   12 |       |   11 |       |   13 |       |   48 |        |
--- COURSE DATA ---   INITIAL CHANGE COURSE CAPACITY |  192 |       |  192 |       |  176 |       |  208 |       |  768 |        |
                                 UTILIZATION         |  180 | 93.8% |  179 | 93.2% |  164 | 93.2% |  194 | 93.3% |  717 | 93.4%  |
ANNUAL CONVENINGS      48     0  NO SHOWS            |   24 | 11.8% |   25 | 12.3% |   23 | 12.3% |   27 | 12.2% |   99 | 12.1%  |
COURSE LENGTH WKS     1.0   0.0  BACKLOG-STUDENTS/WKS|  313 |20 WKS |  320 |20 WKS |  326 |21 WKS |  334 |21 WKS |  334 |21 WKS  |
COURSE CAPACITY        16     0  STUDENT DAYS / ADB  |  900 |  9.9  |  895 |  9.8  |  820 |  9.0  |  970 | 10.6  | 3585 |  9.4   |
BUPERS SEATS            0     0                      |      |       |      |       |      |       |      |       |      |        |
                                 TOTAL PASS          |  179 | 99.4% |  178 | 99.4% |  164 |100.0% |  193 | 99.5% |  714 | 99.6%  |
ANNUAL DEMAND   843 CHANGE WEEK   0 TOTAL FAIL       |    1 |  0.6% |    1 |  0.6% |    0 |  0.0% |    1 |  0.5% |    3 |  0.4%  |
BUPERS DEMAND     0 OFFSET  WKS   0 ACADEMIC  SETBACK|    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
INITIAL BKLOG   307 BACKLOG WKS  20 NON-ACADEM DISENROLL|  0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0% |    0 |  0.0%  |
                                 ----------------------------------------------------------------------------------------------
```

FIGURE IV-7 SCENARIO - EXCESSIVE NO-SHOW RATES - REDUCTION OF NO-SHOWS TO ACHIEVE THROUGHPUT RATES

SCHOOL CODE [illegible]

BOILER / FEEDWATER TEST

CDP	J NO	CATALOG NO	NEC
536N	4522	A-651-0019	

--- COURSE DATA ---

	INITIAL	CHANGE
ANNUAL CONVENINGS	48	0
COURSE LENGTH WKS	1.0	0.0
COURSE CAPACITY	16	0
BUPERS SEATS	0	0

ANNUAL DEMAND	843	CHANGE WEEK	0
BUPERS DEMAND	0	OFFSET WKS	0
INITIAL BKLOG	307	BACKLOG WKS	20

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	12		12		11		13		48	
COURSE CAPACITY	192		192		176		208		768	
UTILIZATION	155	80.7%	154	80.2%	141	80.1%	168	80.8%	618	80.5%
NO SHOWS	49	24.0%	50	24.5%	46	24.6%	53	24.0%	198	24.3%
BACKLOG-STUDENTS/WKS	313	20 WKS	320	20 WKS	326	21 WKS	334	21 WKS	334	21 WKS
STUDENT DAYS / AOB	775	8.5	770	8.4	705	7.7	840	9.2	3090	8.5
TOTAL PASS	155	100.0%	154	100.0%	141	100.0%	167	99.4%	617	99.8%
TOTAL FAIL	0	0.0%	0	0.0%	0	0.0%	1	0.6%	1	0.2%
ACADEMIC SETBACK	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NON-ACADEM DISENROLL	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

BOILER / FEEDWATER TEST

CDP	J NO	CATALOG NO	NEC
536N	452?	A-651-0019	

--- COURSE DATA ---

	INITIAL	CHANGE
ANNUAL CONVENINGS	48	52
COURSE LENGTH WKS	1.0	1.0
COURSE CAPACITY	16	16
BUPERS SEATS	0	0

ANNUAL DEMAND	843	CHANGE WEEK	1
BUPERS DEMAND	0	OFFSET WKS	0
INITIAL BKLOG	307	BACKLOG WKS	20

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	14		12		12		14		52	
COURSE CAPACITY	224		192		192		224		832	
UTILIZATION	180	80.4%	155	80.7%	154	80.2%	180	80.4%	669	80.4%
NO SHOWS	58	24.4%	49	24.0%	50	24.5%	58	24.4%	215	24.3%
BACKLOG-STUDENTS/WKS	296	19 WKS	286	18 WKS	277	18 WKS	266	17 WKS	266	17 WKS
STUDENT DAYS / AOB	900	9.9	775	6.5	770	8.4	900	9.9	3345	9.2
TOTAL PASS	179	99.4%	155	100.0%	154	100.0%	179	99.4%	667	99.7%
TOTAL FAIL	1	0.6%	0	0.0%	0	0.0%	1	0.6%	2	0.3%
ACADEMIC SETBACK	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NON-ACADEM DISENROLL	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

BOILER / FEEDWATER TEST

CDP	J NO	CATALOG NO	NEC
536N	4522	A-651-0019	

--- COURSE DATA ---

	INITIAL	CHANGE
ANNUAL CONVENINGS	48	56
COURSE LENGTH WKS	1.0	1.0
COURSE CAPACITY	16	16
BUPERS SEATS	0	0

ANNUAL DEMAND	843	CHANGE WEEK	1
BUPERS DEMAND	0	OFFSET WKS	0
INITIAL BKLOG	307	BACKLOG WKS	20

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	14		14		12		16		56	
COURSE CAPACITY	224		224		192		256		896	
UTILIZATION	180	80.4%	180	80.4%	155	80.7%	205	80.1%	720	80.4%
NO SHOWS	58	24.4%	58	24.4%	49	24.0%	67	24.6%	232	24.4%
BACKLOG-STUDENTS/WKS	279	18 WKS	252	16 WKS	229	14 WKS	198	12 WKS	198	12 WKS
STUDENT DAYS / AOB	900	9.9	900	9.9	775	8.5	1025	11.2	3600	9.3
TOTAL PASS	179	99.4%	179	99.4%	155	100.0%	204	99.5%	717	99.6%
TOTAL FAIL	1	0.6%	1	0.6%	0	0.0%	1	0.5%	3	0.4%
ACADEMIC SETBACK	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NON-ACADEM DISENROLL	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

FIGURE IV-8 SCENARIO - EXCESSIVE NO-SHOW RATES - INCREASE CONVENINGS TO ACHIEVE THROUGHPUT RATES

BEST COPY AVAILABLE

```
R         SCHOOL NAME: AIR CONDITIONING / REFRIGERATION
E         SCHOOL CODE: B
F
****************************** AVERAGE  X  COEFF  =  TERM ****** AVERAGE  X  COEFF  =  TERM ****** AVERAGE  X  COEFF  =  TERM *****
 1                  NUMBER:    4552                         *  4552                           *  4552
 2             DAYS LENGTH:    40.0      0.000     0.000    *  40.0      0.000     0.000      *  40.0      0.000     0.000
 3                CAPACITY:    16        0.000     0.000    *  16        0.000     0.000      *  16        0.000     0.000
 4            AV OFF INPUT:    0         0.000     0.000    *  0         0.000     0.000      *  0         0.000     0.000
 5            AV ENL INPUT:    16        0.000     0.000    *  16        0.000     0.000      *  16        0.000     0.000
 6       CONVENE PER YEAR:     25        0.000     0.000    *  25        0.000     0.000      *  25        0.000     0.000

 7           QUOTA CONTROL:    2         0.000     0.000    *  2         0.000     0.000      *  2         0.000     0.000
 8        COURSE AGE (YRS):    37.0      0.000     0.000    *  37.0      0.000     0.000      *  37.0      0.000     0.000
 9       MODEL MNGR (CCMM):    1         0.000     0.000    *  1         0.000     0.000      *  1         0.000     0.000
10             COURSE TYPE:    1         0.000     0.000    *  1         0.000     0.000      *  1         0.000     0.000
11                PRIORITY:    14        0.000     0.000    *  14        0.000     0.000      *  14        0.000     0.000

12                   % LAB:    40.0      0.000     0.000    *  40.0      0.000     0.000      *  40.0      0.000     0.000
13          CHANGEABILITY:      7.0      0.000     0.000    *   7.0      0.000     0.000      *   7.0      0.000     0.000
14             GRADE TYPE:      3        0.000     0.000    *   3        0.000     0.000      *   3        0.000     0.000
15 C           PASS LEVEL:     75.0      0.000     0.000    *  75.0      0.000     0.000      *  75.0      0.000     0.000
16 O            NEC AWARD:      1        0.000     0.000    *   1        0.000     0.000      *   1        0.000     0.000
   U
17 R          % UTILIZED:     94.0      0.000     0.000    *  94.0      0.000     0.000      *  94.0      0.000     0.000
18 S          % NO SHOWS:       0.0      0.000     0.000    *   0.0      0.000     0.000      *   0.0      0.000     0.000
19 E      BACKLOG (WEEKS):     30.0      0.000     0.000    *  30.0      0.000     0.000      *  30.0      0.000     0.000
20           % SUB QUOTAS:      4.0      0.000     0.000    *   4.0      0.000     0.000      *   4.0      0.000     0.000
21 D     % ACAD SETBACKS:      33.0      0.000     0.000    *  33.0      0.000     0.000      *  33.0      0.000     0.000
   A
22 T   % NONAC SETBACKS:        7.0      0.000     0.000    *   7.0      0.000     0.000      *   7.0      0.000     0.000
23 A  % NONAC DISENROLE:        2.0      0.000     0.000    *   2.0      0.000     0.000      *   2.0      0.000     0.000
24          AV GCT SCORE:      63.0     -0.004    -0.269    *  60.0     -0.004    -0.256      *  57.0     -0.004    -0.243
25          AV ARI SCORE:      60.0     -0.008    -0.482    *  57.0     -0.008    -0.458      *  54.0     -0.008    -0.434
26         AV MECH SCORE:       0.0      0.000     0.000    *  56.0      0.000     0.000      *  56.0      0.000     0.000

27         AV CLER SCORE:       0.0      0.000     0.000    *  51.0      0.000     0.000      *  51.0      0.000     0.000
28         AV SHOP SCORE:       0.0      0.000     0.000    *  57.0      0.000     0.000      *  57.0      0.000     0.000
29         AV AFQT SCORE:       0.0      0.000     0.000    *  73.0      0.000     0.000      *  73.0      0.000     0.000
30         AV ETST SCORE:       0.0      0.000     0.000    *  60.0      0.000     0.000      *  60.0      0.000     0.000
31       AV STUDENT AGE:        0.0      0.000     0.000    *  24.0      0.000     0.000      *  24.0      0.000     0.000

32      AV STUDENT RATE:        0.0      0.000     0.000    *   5.0      0.000     0.000      *   5.0      0.000     0.000
33   INSTR ROTATION RATE:       0.0      0.000     0.000    *  30.0      0.000     0.000      *  30.0      0.000     0.000
34   AV INSTRS PER CLASS:       0.0      0.000     0.000    *   2.0      0.000     0.000      *   2.0      0.000     0.000
35  INSTR AV PAY GRADE:         0.0      0.000     0.000    *   7.0      0.000     0.000      *   7.0      0.000     0.000
*****************************************************************************************************************************
36 S            AV GRADE:      86.3      0.000     0.000    *  86.3      0.000     0.000      *  86.3      0.000     0.000
37 T    AV YRS IN SERVICE:      4.2      0.000     0.000    *   4.2      0.000     0.000      *   4.2      0.000     0.000
38 U       AV YRS IN RATE:      1.1      0.000     0.000    *   1.1      0.000     0.000      *   1.1      0.000     0.000
39 D   AV YRS IN PAYGRADE:      0.0      0.000     0.000    *   0.0      0.000     0.000      *   0.0      0.000     0.000
40 E    PRI NEC? (1 = YES):     0.8      0.000     0.000    *   0.8      0.000     0.000      *   0.8      0.000     0.000
   N
41 T   AV YRS IN PRI NEC:       0.5      0.000     0.000    *   0.5      0.000     0.000      *   0.5      0.000     0.000
42     AV YRS FORMAL EDUC:     12.0      0.000     0.000    *  12.0      0.000     0.000      *  12.0      0.000     0.000
43 D          DEGREE CODE:      1.7      0.000     0.000    *   1.7      0.000     0.000      *   1.7      0.000     0.000
44 A  DUTY TYPE (1 = SHIP):     0.9      0.000     0.000    *   0.9      0.000     0.000      *   0.9      0.000     0.000
45 T       PCS DUTY CODE:       1.9      0.000     0.000    *   1.9      0.000     0.000      *   1.9      0.000     0.000
   A
46     AV YRS CURRENT ENL:      1.7      0.000     0.000    *   1.7      0.000     0.000      *   1.7      0.000     0.000
47   AV # PRIOR SCHOOLS:        2.4     -0.016    -0.038    *   2.4     -0.016    -0.038      *   2.4     -0.016    -0.038
*****************************************************************************************************************************
       COLUMN PRODUCT SUM:                        -0.789    *                     -0.752      *                     -0.715
*****************************************************************************************************************************
       COEFFICIENT OF
          ADJUSTMENT:                              0.868    *                      0.868      *                      0.868
*****************************************************************************************************************************
     COMPUTED FAILURE RATE:                        0.079    *                      0.116      *                      0.153
                                                            *                                 *
```

FIGURE IV-9 SCENARIO - VARIATION IN STUDENT CHARACTERISTICS - CALCULATE FAILURE RATES FOR REVISED GCT AND ARI AVERAGES

SCHOOL CODE ACER

AIR CONDITIONING AND REFRIGERATION

COP	J NO	CATALOG NO	NEC
3102	4552	A-720-0010	4294

--- COURSE DATA ---	INITIAL	CHANGE
ANNUAL CONVENINGS	24	0
COURSE LENGTH WKS	7.0	0.0
COURSE CAPACITY	16	0
BUPERS SEATS	13	0

ANNUAL DEMAND	75	CHANGE WEEK	0
BUPERS DEMAND	326	OFFSET WKS	0
INITIAL BKLOG	43	BACKLOG WKS	30

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	6		6		6		6		24	
COURSE CAPACITY	96		96		96		96		384	
UTILIZATION	100	104.2%	99	103.1%	100	104.2%	99	103.1%	398	103.6%
NO SHOWS	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
BACKLOG-STUDENTS/WKS	44	30 WKS	45	30 WKS	45	30 WKS	46	30 WKS	46	30 WKS
STUDENT DAYS / ADB	4862	53.3	4736	51.9	4415	48.4	5093	55.8	19106	52.3
TOTAL PASS	82	82.0%	81	81.8%	81	81.0%	81	81.8%	325	81.7%
TOTAL FAIL	8	8.0%	8	8.1%	8	8.0%	8	8.1%	32	8.0%
ACADEMIC SETBACK	6	6.0%	6	6.1%	6	6.0%	6	6.1%	24	6.0%
NON-ACADEM DISENROLL	10	10.0%	10	10.1%	11	11.0%	10	10.1%	41	10.3%

AIR CONDITIONING AND REFRIGERATION

COP	J NO	CATALOG NO	NEC
3102	4552	A-720-0010	4294

--- COURSE DATA ---	INITIAL	CHANGE
ANNUAL CONVENINGS	24	0
COURSE LENGTH WKS	7.0	0.0
COURSE CAPACITY	16	0
BUPERS SEATS	13	0

ANNUAL DEMAND	75	CHANGE WEEK	0
BUPERS DEMAND	326	OFFSET WKS	0
INITIAL BKLOG	43	BACKLOG WKS	30

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	6		6		6		6		24	
COURSE CAPACITY	96		96		96		96		384	
UTILIZATION	100	104.2%	99	103.1%	100	104.2%	99	103.1%	398	103.6%
NO SHOWS	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
BACKLOG-STUDENTS/WKS	44	30 WKS	45	30 WKS	45	30 WKS	46	30 WKS	46	30 WKS
STUDENT DAYS / ADB	4806	52.7	4675	51.2	4357	47.7	5032	55.1	18870	51.7
TOTAL PASS	78	78.0%	77	77.8%	77	77.0%	77	77.8%	309	77.6%
TOTAL FAIL	12	12.0%	12	12.1%	12	12.0%	12	12.1%	48	12.1%
ACADEMIC SETBACK	6	6.0%	6	6.1%	6	6.0%	6	6.1%	24	6.0%
NON-ACADEM DISENROLL	10	10.0%	10	10.1%	11	11.0%	10	10.1%	41	10.3%

AIR CONDITIONING AND REFRIGERATION

COP	J NO	CATALOG NO	NEC
3102	4552	A-720-0010	4294

--- COURSE DATA ---	INITIAL	CHANGE
ANNUAL CONVENINGS	24	0
COURSE LENGTH WKS	7.0	0.0
COURSE CAPACITY	16	0
BUPERS SEATS	13	0

ANNUAL DEMAND	75	CHANGE WEEK	0
BUPERS DEMAND	326	OFFSET WKS	0
INITIAL BKLOG	43	BACKLOG WKS	30

	QUARTERLY PROJECTIONS									
	1 QTR FY 75		2 QTR FY 75		3 QTR FY 75		4 QTR FY 75		ANNUAL TOTAL	
NUMBER OF CONVENINGS	6		6		6		6		24	
COURSE CAPACITY	96		96		96		96		384	
UTILIZATION	100	104.2%	99	103.1%	100	104.2%	99	103.1%	398	103.6%
NO SHOWS	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
BACKLOG-STUDENTS/WKS	44	30 WKS	45	30 WKS	45	30 WKS	46	30 WKS	45	30 WKS
STUDENT DAYS / ADB	4752	52.1	4617	50.6	4303	47.2	4974	54.5	18646	51.1
TOTAL PASS	74	74.0%	73	73.7%	73	73.0%	73	73.7%	293	73.6%
TOTAL FAIL	16	16.0%	16	16.2%	16	16.0%	16	16.2%	64	16.1%
ACADEMIC SETBACK	6	6.0%	6	6.1%	6	6.0%	6	6.1%	24	6.0%
NON-ACADEM DISENROLL	10	10.0%	10	10.1%	11	11.0%	10	10.1%	41	10.3%

FIGURE IV-10 SCENARIO - VARIATION IN STUDENT CHARACTERISTICS - COURSE THROUGHPUT USING REVISED FAILURE RATES

```
                                                 TPF MODEL -- FISCAL YEAR 1975 SUMMARY                                              PAGE  2
                                                           SCHOOL CODE  3-M

INTRODUCTION TO 3-M
                                                                                   QUARTERLY PROJECTIONS
CDP    J NO   CATALOG NO     NEC                                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
5085   0232   J-500-0023                    -------------------------|-------------|-------------|-------------|-------------|--------------|
                                            NUMBER OF CONVENINGS     |   44 |      |   44 |      |   40 |      |   48 |      |  176 |       |
--- COURSE DATA ---   INITIAL  CHANGE       COURSE CAPACITY          | 1760 |      | 1760 |      | 1600 |      | 1920 |      | 7040 |       |
                                            UTILIZATION              | 1607 | 91.3%| 1607 | 91.3%|  942 | 58.9%| 1104 | 57.5%| 5260 | 74.7% |
ANNUAL CONVENINGS        176       0        NO SHOWS                 |  329 | 17.0%|  329 | 17.0%|  215 | 18.6%|  254 | 18.7%| 1127 | 17.6% |
COURSE LENGTH WKS        0.2     0.0        BACKLOG-STUDENTS/WKS     |  716 | 5 WKS|   25 | 0 WKS|    0 | 0 WKS|    0 | 0 WKS|    0 | 0 WKS |
COURSE CAPACITY           40       0        STUDENT DAYS / ADB       | 1607 | 17.6 | 1607 | 17.6 |  942 | 10.3 | 1104 | 12.1 | 5260 | 14.4  |
BUPERS SEATS               0       0                                 |      |      |      |      |      |      |      |      |      |       |
                                            TOTAL PASS               | 1448 | 90.1%| 1448 | 90.1%|  849 | 90.1%|  995 | 90.1%| 4740 | 90.1% |
ANNUAL DEMAND   4980  CHANGE WEEK   0       TOTAL FAIL               |  157 |  9.8%|  157 |  9.8%|   92 |  9.8%|  108 |  9.8%|  514 |  9.8% |
BUPERS DEMAND      0  OFFSET  WKS   0       ACADEMIC  SETBACK        |    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0% |
INITIAL BKLOG   1407  BACKLOG WKS  10       NON-ACADEM DISENROLL     |    2 |  0.1%|    2 |  0.1%|    1 |  0.1%|    1 |  0.1%|    6 |  0.1% |
                                            ------------------------------------------------------------------------------------------------


INTRODUCTION TO 3-M
                                                                                   QUARTERLY PROJECTIONS
CDP    J NO   CATALOG NO     NEC                                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
5085   0232   J-500-0023                    -------------------------|-------------|-------------|-------------|-------------|--------------|
                                            NUMBER OF CONVENINGS     |   44 |      |   44 |      |   30 |      |   33 |      |  151 |       |
--- COURSE DATA ---   INITIAL  CHANGE       COURSE CAPACITY          | 1760 |      | 1760 |      | 1200 |      | 1320 |      | 6040 |       |
                                            UTILIZATION              | 1607 | 91.3%| 1607 | 91.3%|  944 | 78.7%| 1012 | 76.7%| 5170 | 85.6% |
ANNUAL CONVENINGS        176     132        NO SHOWS                 |  329 | 17.0%|  329 | 17.0%|  213 | 18.4%|  233 | 18.7%| 1104 | 17.6% |
COURSE LENGTH WKS        0.2     0.2        BACKLOG-STUDENTS/WKS     |  716 | 6 WKS|   25 | 0 WKS|    0 | 0 WKS|    0 | 0 WKS|    0 | 0 WKS |
COURSE CAPACITY           40      40        STUDENT DAYS / ADB       | 1607 | 17.6 | 1607 | 17.6 |  944 | 10.3 | 1012 | 11.1 | 5170 | 14.2  |
BUPERS SEATS               0       0                                 |      |      |      |      |      |      |      |      |      |       |
                                            TOTAL PASS               | 1448 | 90.1%| 1448 | 90.1%|  850 | 90.0%|  912 | 90.1%| 4658 | 90.1% |
ANNUAL DEMAND   4980  CHANGE WEEK  27       TOTAL FAIL               |  157 |  9.8%|  157 |  9.8%|   93 |  9.9%|   99 |  9.8%|  506 |  9.8% |
BUPERS DEMAND      0  OFFSET  WKS   0       ACADEMIC  SETBACK        |    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0% |
INITIAL BKLOG   1407  BACKLOG WKS  10       NON-ACADEM DISENROLL     |    2 |  0.1%|    2 |  0.1%|    1 |  0.1%|    1 |  0.1%|    6 |  0.1% |
                                            ------------------------------------------------------------------------------------------------


INTRODUCTION TO 3-M
                                                                                   QUARTERLY PROJECTIONS
CDP    J NO   CATALOG NO     NEC                                     | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
5085   0232   J-500-0023                    -------------------------|-------------|-------------|-------------|-------------|--------------|
                                            NUMBER OF CONVENINGS     |   44 |      |   30 |      |   33 |      |   27 |      |  134 |       |
--- COURSE DATA ---   INITIAL  CHANGE       COURSE CAPACITY          | 1760 |      | 1200 |      | 1320 |      | 1080 |      | 5360 |       |
                                            UTILIZATION              | 1607 | 91.3%| 1096 | 91.3%| 1205 | 91.3%|  986 | 91.3%| 4894 | 91.3% |
ANNUAL CONVENINGS        176     132        NO SHOWS                 |  329 | 17.0%|  224 | 17.0%|  247 | 17.0%|  202 | 17.0%| 1002 | 17.0% |
COURSE LENGTH WKS        0.2     0.2        BACKLOG-STUDENTS/WKS     |  716 | 6 WKS|  528 | 4 WKS|  321 | 3 WKS|  152 | 1 WKS|  152 | 1 WKS |
COURSE CAPACITY           40      40        STUDENT DAYS / ADB       | 1607 | 17.6 | 1096 | 12.0 | 1205 | 13.2 |  986 | 10.8 | 4894 | 13.4  |
BUPERS SEATS               0       0                                 |      |      |      |      |      |      |      |      |      |       |
                                            TOTAL PASS               | 1448 | 90.1%|  988 | 90.1%| 1086 | 90.1%|  888 | 90.1%| 4410 | 90.1% |
ANNUAL DEMAND   4980  CHANGE WEEK  14       TOTAL FAIL               |  157 |  9.8%|  107 |  9.8%|  118 |  9.8%|   97 |  9.8%|  479 |  9.8% |
BUPERS DEMAND      0  OFFSET  WKS   0       ACADEMIC  SETBACK        |    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0%|    0 |  0.0% |
INITIAL BKLOG   1407  BACKLOG WKS  10       NON-ACADEM DISENROLL     |    2 |  0.1%|    1 |  0.1%|    1 |  0.1%|    1 |  0.1%|    5 |  0.1% |
                                            ------------------------------------------------------------------------------------------------
```

FIGURE IV-11 SCENARIO - BACKLOG REDUCTION-TEMPORARILY INCREASE CONVENINGS TO WORK OFF BACKLOG

```
                                        TPF MODEL --- FISCAL YEAR 1975 SUMMARY
                                                SCHOOL CODE  COMM

RADIO TRANSCIEVERS (AN/SRC-20 & 21) OP/MAINT
                                                                            QUARTERLY PROJECTIONS
CDP     J NO   CATALOG NO     NEC                      | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
512K    8522   J-201-0866                  ------------|-------------|-------------|-------------|-------------|--------------|
                                           NUMBER OF CONVENINGS|  6 |        |  6 |        |  6 |        |  6 |        |  24 |        |
--- COURSE DATA ---     INITIAL  CHANGE    COURSE CAPACITY     | 72 |        | 72 |        | 72 |        | 72 |        | 288 |        |
                                           UTILIZATION         | 58 |  80.6% | 31 |  43.1% | 29 |  40.3% | 28 |  38.9% | 146 |  50.7% |
ANNUAL CONVENINGS          24       0      NO SHOWS            | 20 |  25.6% | 11 |  26.2% | 11 |  27.5% | 12 |  30.0% |  54 |  27.0% |
COURSE LENGTH WKS         0.2     0.0      BACKLOG-STUDENTS/WKS|  2 |  0 WKS |  0 |  0 WKS |  0 |  0 WKS |  0 |  0 WKS |   0 |  0 WKS |
COURSE CAPACITY            12       0      STUDENT DAYS / AOB  | 58 |   0.6  | 31 |   0.3  | 29 |   0.3  | 28 |   0.3  | 146 |   0.4  |
BUPERS SEATS                0       0                          |    |        |    |        |    |        |    |        |     |        |
                                           TOTAL PASS          | 58 | 100.0% | 31 | 100.0% | 29 | 100.0% | 28 | 100.0% | 146 | 100.0% |
ANNUAL DEMAND     160  CHANGE WEEK    0    TOTAL FAIL          |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
BUPERS DEMAND       0  OFFSET   WKS   0    ACADEMIC  SETBACK   |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
INITIAL BKLOG      40  BACKLOG WKS    7    NON-ACADEM DISENROLL|  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
                                           ---------------------------------------------------------------------------------------


RADIO TRANSCIEVERS (AN/SRC-20 & 21) OP/MAINT
                                                                            QUARTERLY PROJECTIONS
CDP     J NO   CATALOG NO     NEC                      | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
512K    8522   J-201-0866                  ------------|-------------|-------------|-------------|-------------|--------------|
                                           NUMBER OF CONVENINGS|  5 |        |  5 |        |  5 |        |  5 |        |  20 |        |
--- COURSE DATA ---     INITIAL  CHANGE    COURSE CAPACITY     | 60 |        | 60 |        | 60 |        | 60 |        | 240 |        |
                                           UTILIZATION         | 49 |  81.7% | 40 |  66.7% | 29 |  48.3% | 29 |  48.3% | 147 |  61.2% |
ANNUAL CONVENINGS          24      20      NO SHOWS            | 16 |  24.6% | 15 |  27.3% | 11 |  27.5% | 11 |  27.5% |  53 |  26.5% |
COURSE LENGTH WKS         0.2     0.2      BACKLOG-STUDENTS/WKS| 15 |  2 WKS |  0 |  0 WKS |  0 |  0 WKS |  0 |  0 WKS |   0 |  0 WKS |
COURSE CAPACITY            12      12      STUDENT DAYS / AOB  | 49 |   0.5  | 40 |   0.4  | 29 |   0.3  | 29 |   0.3  | 147 |   0.4  |
BUPERS SEATS                0       0                          |    |        |    |        |    |        |    |        |     |        |
                                           TOTAL PASS          | 49 | 100.0% | 40 | 100.0% | 29 | 100.0% | 29 | 100.0% | 147 | 100.0% |
ANNUAL DEMAND     160  CHANGE WEEK    1    TOTAL FAIL          |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
BUPERS DEMAND       0  OFFSET   WKS   0    ACADEMIC  SETBACK   |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
INITIAL BKLOG      40  BACKLOG WKS    7    NON-ACADEM DISENROLL|  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
                                           ---------------------------------------------------------------------------------------


RADIO TRANSCIEVERS (AN/SRC-20 & 21) OP/MAINT
                                                                            QUARTERLY PROJECTIONS
CDP     J NO   CATALOG NO     NEC                      | 1 QTR FY 75 | 2 QTR FY 75 | 3 QTR FY 75 | 4 QTR FY 75 | ANNUAL TOTAL |
512K    8522   J-201-0866                  ------------|-------------|-------------|-------------|-------------|--------------|
                                           NUMBER OF CONVENINGS|  4 |        |  4 |        |  4 |        |  4 |        |  16 |        |
--- COURSE DATA ---     INITIAL  CHANGE    COURSE CAPACITY     | 48 |        | 48 |        | 48 |        | 48 |        | 192 |        |
                                           UTILIZATION         | 39 |  81.3% | 39 |  81.3% | 38 |  79.2% | 32 |  66.7% | 148 |  77.1% |
ANNUAL CONVENINGS          24      16      NO SHOWS            | 13 |  25.0% | 13 |  25.0% | 14 |  26.9% | 12 |  27.3% |  52 |  26.0% |
COURSE LENGTH WKS         0.2     0.2      BACKLOG-STUDENTS/WKS| 28 |  4 WKS | 16 |  2 WKS |  4 |  0 WKS |  0 |  0 WKS |   0 |  0 WKS |
COURSE CAPACITY            12      12      STUDENT DAYS / AOB  | 39 |   0.4  | 39 |   0.4  | 38 |   0.4  | 32 |   0.4  | 148 |   0.4  |
BUPERS SEATS                0       0                          |    |        |    |        |    |        |    |        |     |        |
                                           TOTAL PASS          | 39 | 100.0% | 39 | 100.0% | 38 | 100.0% | 32 | 100.0% | 148 | 100.0% |
ANNUAL DEMAND     160  CHANGE WEEK    1    TOTAL FAIL          |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
BUPERS DEMAND       0  OFFSET   WKS   0    ACADEMIC  SETBACK   |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
INITIAL BKLOG      40  BACKLOG WKS    7    NON-ACADEM DISENROLL|  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |  0 |   0.0% |   0 |   0.0% |
                                           ---------------------------------------------------------------------------------------
```

FIGURE IV-12 SCENARIO - ALIGN CAPACITY TO DEMAND-REDUCE CONVENING FREQUENCY TO IMPROVE UTILIZATION PERCENTAGE

(THIS PAGE INTENTIONALLY LEFT BLANK.)

SECTION V

MODEL TEST APPLICATIONS SCENARIOS

CONDITIONS FOR MODEL APPLICATION

The three DOTS models can only be useful when applied to a training system which is changing or which can be changed. If the training system remains structurally the same and responds to new demands, either by absorbing them in excess system capacity or by refusing to accept new requirements, the models are useful only to the extent that their bookkeeping capabilities can be used.

Demands placed on the system can originate from a variety of sources, but can be classified roughly into two categories: quantitative demands and qualitative demands. Quantitative demands are those which require system output to change numerically. The system is required to produce trained personnel of the same kind and in the same way as in the past, but the numbers trained in different courses are changed.

Qualitative demands are those which require the system to produce different kinds of trained people, or people trained by different methods. Qualitative demands can originate external to the system (e.g., new equipment training) or internal to the system (e.g., introduction of new instructional methodology). Regardless of type, qualitative demands require the system to be changed in some way other than rearrangement of existing courses and resources. Figure V-1 shows the basic response to qualitative and quantitative change.

PROBABLE APPLICATIONS OF DOTS MODELS

Before discussing the most probable applications of the DOTS models in different system environments, the basic purpose of each of the three models should be re-stated:

a. SCRR model - determines optimum arrangements of course convenings, instructor, and other resources to produce a particular quantitative system output.

b. TPF model - given convening schedules and course types, the TPF model predicts true system output based on a qualitative description of the students entering the system.

c. ETE model - given available resources and course configuration, the ETE model predicts course throughput and resource utilization when individualized learning techniques are employed.

From these model objectives, some general rules concerning model application can be inferred. The SCRR and TPF models complement each other and will be equally applicable to a particular problem. The only exception to this is that the TPF model has bookkeeping capabilities useful in producing training system status reports, and so will find some application regardless of training system operation.

The ETE model, because it deals specifically with the use of individualized learning techniques, is less general than the SCRR or TPF models. Also, because it can function either as a design tool or in monitoring an existing system, the ETE model will be applied at different times in the training requirement-to-implementation cycle than the other models.

TYPE OF CHANGE	PROBABLE TRAINING SYSTEM RESPONSE
QUANTITATIVE CHANGE	● REVAMP COURSE SCHEDULES, INCREASE CONVENING FREQUENCIES AND CAPACITIES FOR SOME COURSES, DECREASE OTHERS.
QUALITATIVE CHANGE	● DESIGN AND IMPLEMENT NEW COURSES, ADJUST SYSTEM RESOURCES TO ACCOMMODATE. ● REDESIGN EXISTING COURSES TO APPLY DIFFERENT INSTRUCTIONAL METHODS. ● RESTRUCTURE SYSTEM. COMBINE COURSES, SHIFT EMPHASIS, MOVE TRAINING TO SHIPBOARD OR VICE VERSA.

FIGURE V-1 TRAINING SYSTEM RESPONSES TO GENERAL DEMANDS

Figure V-2 shows the probable level of application of each of the three models in response to seven different system demand-response combinations. Four of these combinations, and the corresponding application of the three models, will be discussed in the following scenarios. The demand-response combinations to be discussed are:

a. System As Is. Study to improve operation, but no change in instruction methods.

b. Course Offerings Unchanged But Move to ILS Methods.

c. New Equipment Requires New Courses.

d. NEOCS Type Structural Change.

STUDY TO IMPROVE EXISTING SYSTEM. As Figure V-2 indicates, the ETE model is not applicable in this situation. This is because the number of ILS courses is so low at the present time.

The first step in applying the models to this type of study is to determine possible strategies for improving system throughput without increasing system resources. Next, each of these strategies is reviewed to determine the degree to which it can be carried out. Because the strategies can be tested without disturbing the real system, it is reasonable to postulate both an ideal situation, in which the strategy can be stated without regard to real world constraints, and other "most likely" situations, in which the analyst attempts to include known conditions in estimating how far a strategy can reasonably be carried.

CONDITIONS FOR APPLICATION	SCRR	TPF	ETE
1) SYSTEM AS IS. NO CHANGE DESIRED OR REQUIRED.	NO	LOW	NO
2) SYSTEM AS IS. STUDY TO IMPROVE OPERATION BUT NO CHANGE IN INSTRUCTION METHODS	HIGH	HIGH	NO
3) COURSE OFFERINGS UNCHANGED BUT MOVE TO NEW (E.G., ILS) METHODS	HIGH	HIGH	HIGH
4) NEW EQUIPMENT REQUIRES NEW COURSES (OTHERWISE, NO CHANGE)	MODERATE	MODERATE	MODERATE
5) UNANTICIPATED DEMAND CHANGE BUT SYSTEM STRUCTURE UNCHANGED	MODERATE	MODERATE	LOW
6) DEMAND OUTSIDE CURRENT SYSTEM SCOPE, SYSTEM STRUCTURE IS CHANGED.	HIGH	HIGH	HIGH
7) NEOCS TYPE STRUCTURAL CHANGE	HIGH	HIGH	HIGH

LEGEND:
NO - NO MODEL APPLICATION
LOW - MODELS USEFUL BUT NOT ESSENTIAL
MODERATE - MODELS USED BUT IMPROVEMENT IS PRIMARILY IN SPEED OF RESPONSE
HIGH - MODELS ESSENTIAL TO SUCCESSFUL RESPONSE

FIGURE V-2 DOTS MODEL APPLICABILITY UNDER DIFFERENT TYPES OF DEMAND

Each of these strategies is then tested using the SCRR model and the TPF model. The analyst then determines the best combination of feasibility and benefit and translates these results into recommendations for change within the system, or into requests for change in operations external to the system.

Figure V-3 is a detailed flow of the use of this method for a training system such as FLETRACEN, NORVA. For purposes of this illustration, it was assumed that the first resource to be studied was the instructor staff. The first strategy listed represents an ideal situation in which all instructors can teach all courses, so that an optimum class schedule can be derived without being constrained by the availability of a particular type of instructor. The second strategy is a "most likely" case of the instructor pooling strategy, and the third is a different strategy for providing limited instructor pooling.

IMPLEMENTATION OF ILS METHODS. Unlike the previous example, the strategy here is known; i.e., to implement ILS techniques for a set of existing courses. The ETE model would come into play at two different stages in this situation. First, it would be used to derive the desired ILS course configurations and to assess the resources required to support the courses converted to ILS.

Second, with these desired ILS course specifications as the starting point, it would be used to assess the impact on the training system of these ILS courses, and assure that the system will perform satisfactorily and that the resources exist to support ILS operation.

The steps in this sequence are illustrated in Figure V-4. Each feedback loop shown can represent several iterations of the process. The SCRR and TPF models, again, act in complementary fashion, with the SCRR model determining optimum resource allocation and the TPF model testing system throughput.

NEW EQUIPMENT REQUIRING NEW COURSES. Figure V-2 shows this situation providing only a moderate level of use for the three models. The moderate usage level is projected based on the assumption that only a limited number of new courses will result from the introduction of a single new piece of equipment. The introduction of one or two courses could be accomplished without the aid of the models.

The primary purpose of this scenario is to show the time differential in model application for certain kinds of courses. Where courses deal with specific pieces of equipment, it is usually not practical to employ ILS techniques early in the life of the equipment, when frequent engineering changes are being made. For this scenario, it is assumed that the original course material is supplied, in conventional classroom form, by the equipment vendor.

Figure V-5 shows the timeline application of the models. When the ILS version of these equipment courses is developed, the steps followed will be the same as those described in the previous scenario.

NEOCS TYPE STRUCTURAL CHANGE. Some of the recommendations contained in the Naval Enlisted Occupational Classification Study (NEOCS) could result in major changes to the structure and role of training systems such as FLETRACEN NORVA. It is impractical, lacking information on the strategies to be used in accomplishing the goals set forth in the NEOCS report, to attempt to define all the ways in which the DOTS models could be applied to so fundamental a restructuring of the training system. A single objective and its implications will be considered

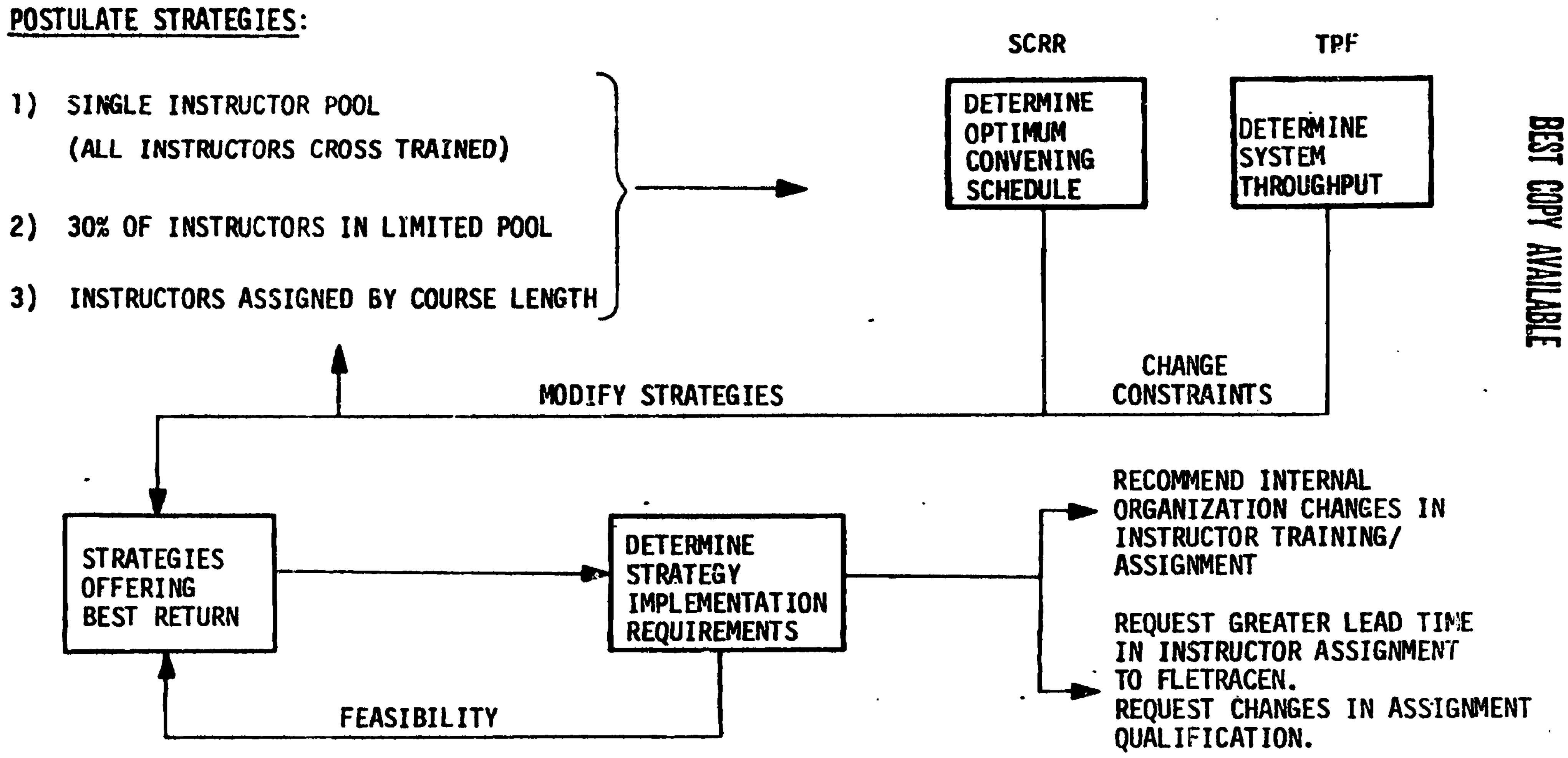


FIGURE V-3 APPLICATION OF MODELS TO EXISTING SYSTEM

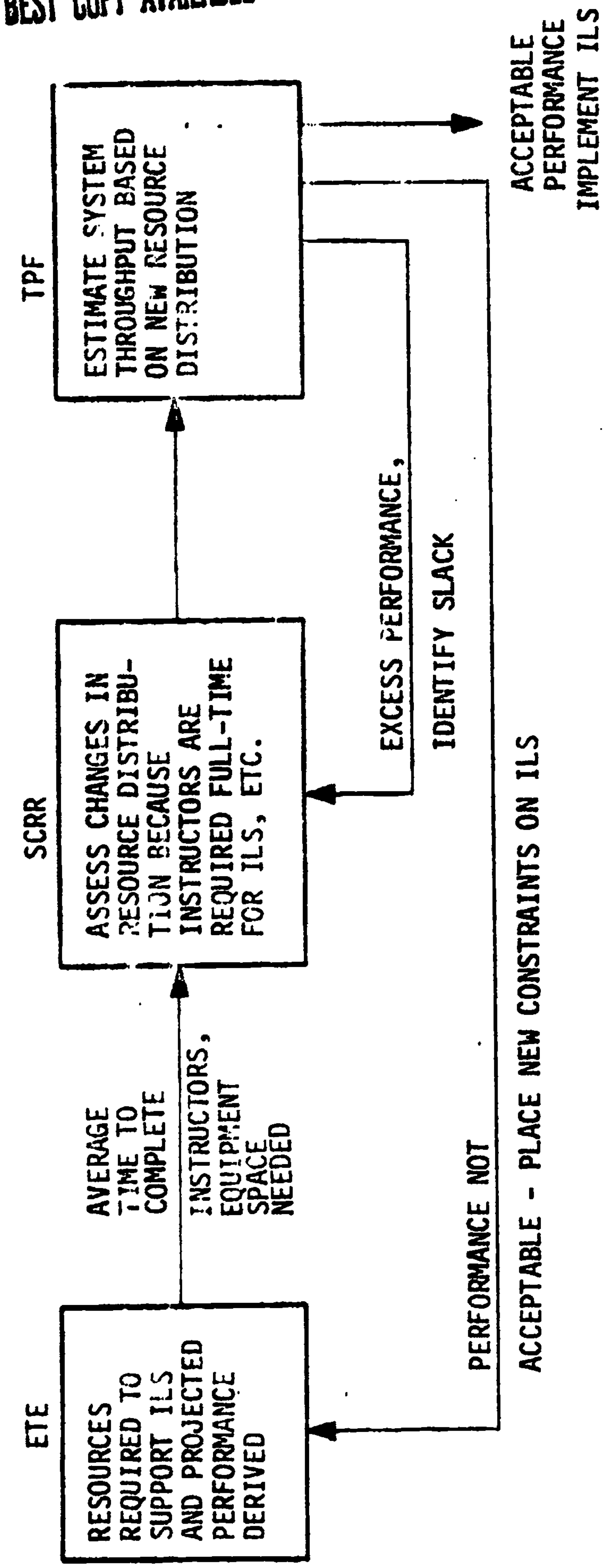


FIGURE V-4 MODEL APPLICATION TO ILS IMPLEMENTATION

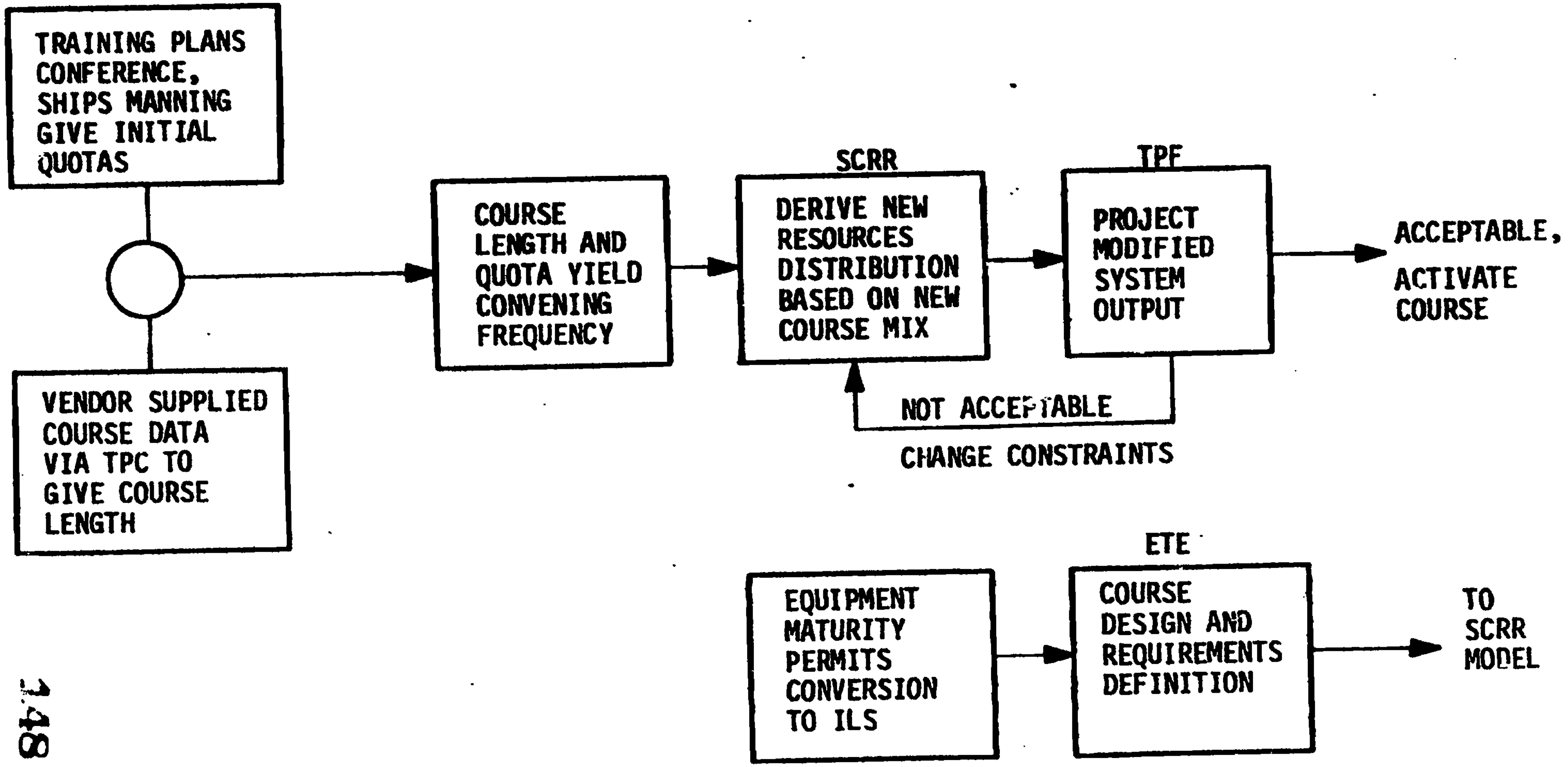


FIGURE V-5 MODEL APPLICATION TO INTRODUCTION OF NEW EQUIPMENT here. Table V-1 lists some of the implications of the NEOCS objective to postpone heavy technical training until the second tour, and to increase fleet and type training early in the first tour.

Since the Fleet Training Centers represent the on-shore training establishment of the fleets, they are reasonable candidates to control the allocation of shore-based and OBT to satisfy the requirement for increased fleet and type training. OBT represents an excellent candidate for individualized instructional techniques. In fact, if a significant portion of any increase in fleet and type training could employ individualized methods, the same instructional matter could be employed both ashore and on-board.

Therefore, for this scenario, it is assumed that COMTRALANT/PAC and their respective FLETRACEN's have been tasked with the establishment and control of fleet/type training to be conducted jointly on-board and at the training centers. Further, it is assumed that, where possible, this training will be individualized and transferable between shipboard and the FLETRACEN.

Although all the possible impacts of a task of this type cannot be foreseen, some of the more basic steps are diagrammed in Figure V-6. The scenario is based on a task approach in which all possible FLETRACEN and COMTRALANT/PAC resources are applied on a maximum priority basis.

POSTPONE HEAVY TECHNICAL TRAINING

- CHANGE IN PROFILE OF STUDENTS ENTERING "C" SCHOOL AND ESTABLISHMENT OF "E" SCHOOLS
- INCREASED EMPHASIS ON OBT FOR FIRST TOUR

INCREASED FLEET AND TYPE TRAINING

- SOME COULD BE CARRIED OUT ON BOARD
- INCREASED LOAD ON FLETRACEN'S FOR NEW, GENERAL COURSES

TABLE V-1 IMPLICATIONS OF PROPOSED CHANGES IN TRAINING OCCURRENCES

BEST COPY AVAILABLE

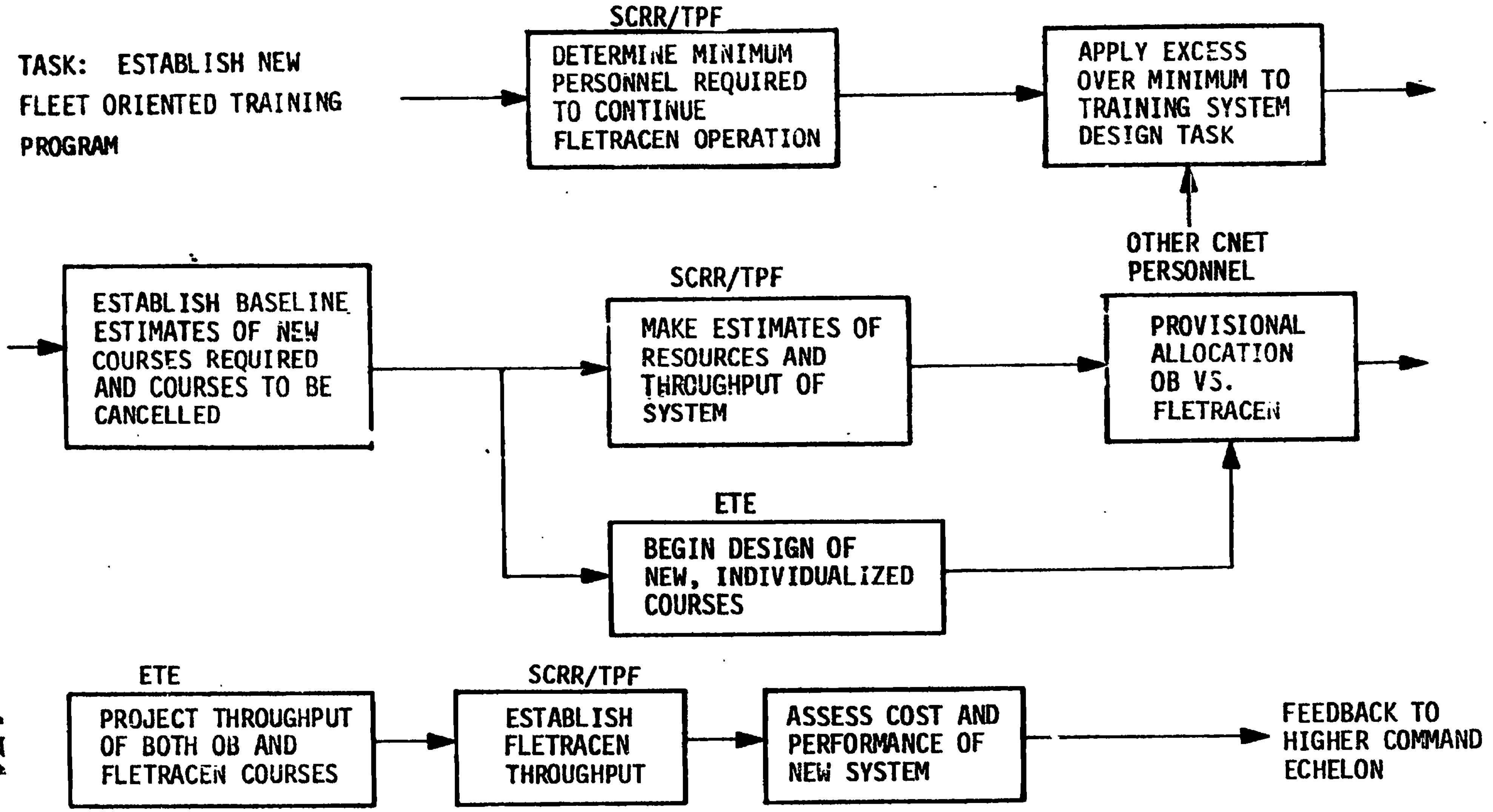


FIGURE V-6 MODEL APPLICATION FOR CHANGE TO SYSTEM STRUCTURE