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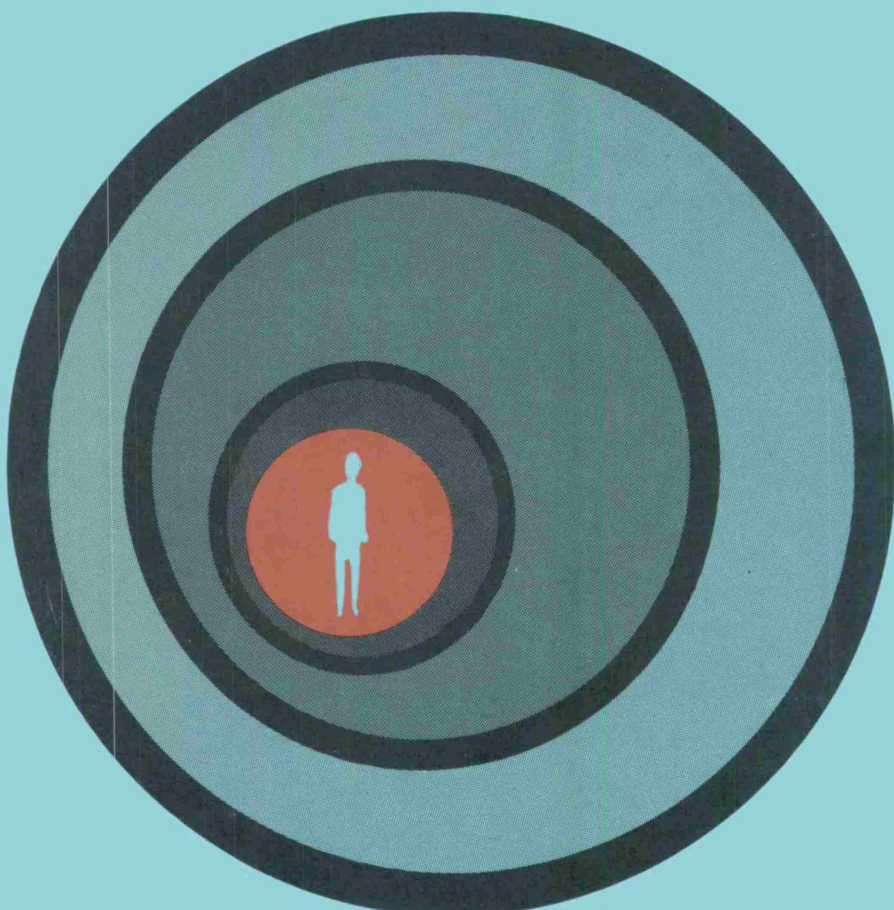
TAEG REPORT
NO. 11-2

APPLICATION OF SIMULATION TO INDIVIDUALIZED SELF-PACED TRAINING



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SEPTEMBER 1974

TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO, FLORIDA 32813

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Application of Simulation to Individualized Self-Paced Training

ABSTRACT

Computer simulation is recognized as a valuable systems analysis research tool which enables the detailed examination, evaluation, and manipulation, under stated conditions, of a system without direct action on the system. This technique provides management with quantitative data on system performance and capabilities which can be used to compare proposed methods, concepts, or designs. The planning of a new Navy technical school provided the opportunity to demonstrate the feasibility and value of simulation as applied to training systems. The school was being programmed to use individualized self-paced instruction and, therefore, was considered to be representative of future instructional systems in the Navy. Not only would the replication of the system prove the feasibility of the application of simulation, but it would provide the training planners with the capability of assessing their particular conceptual system and of checking the validity of their assumptions.

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Computer simulation is recognized as a valuable systems analysis research tool which enables the detailed examination, evaluation, and manipulation, under stated conditions, of a system without direct action on the system. This technique provides management with quantitative data on system performance and capabilities which can be used to compare proposed methods, concepts, or designs. The planning of a new Navy technical school provided the opportunity to demonstrate the feasibility and value of simulation as applied to training systems. The school was being programmed to use individualized self-paced instruction and, therefore, was considered to be representative of future instructional systems in the Navy. Not only would the replication of the system prove the feasibility of the application of simulation, but it would provide the training planners with the capability of assessing their particular conceptual system and of checking the validity of their assumptions.

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WILLIAM H. LINDAHL
JAMES H. GARDNER

TRAINING ANALYSIS AND EVALUATION GROUP

SEPTEMBER 1974

H. C. OKRASKI, Acting Director
Training Analysis and Evaluation Group

B. G. STONE, CAPT, USN
Director, Education and Training Research and Program Development, Chief of Naval Education and Training

FOREWORD

This report is the second in a series concerned with the Training Analysis and Evaluation Group's (TAEG's) effort undertaken in partial fulfillment of the requirements of the Technical Development Plan (TDP) P43-03X, Part 01A, "Design of Training Systems."

A summary of the application of simulation to a training system is presented. The purpose of the report is to describe the goals of this effort and to outline the problem, approach, and results to date.

The report was prepared by Mr. J. Gardner, Operations Research Analyst, Naval Training Equipment Center (NAVTRAEQUIPCEN) and Mr. W. Lindahl, Operations Research Analyst, Training Analysis and Evaluation Group, Orlando, Florida.

Appreciation is expressed to the members of the TAEG Electronic Warfare Project Team who provided guidance in the conceptualization of the training system and to Mr. L. Erhlich and Mr. R. Yanko, both of the IBM Corporation, for their assistance with the GPSS programming effort.

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SECTION I

INTRODUCTION

PURPOSE

This study was performed under the aegis of the Technical Development Plan (TDP) P43-03X, Part 01A, "Design of Training Systems." The purpose of the study was to examine the feasibility of the application of computer simulation to an individualized self-paced training system. Computer simulation is recognized as a valuable systems analysis research tool which enables the detailed examination, evaluation, and manipulation, under stated conditions, of a system without direct action on the system. Since the optimal assignment of personnel and the maximum usage of equipment resources in training are of paramount importance to the Navy, the demonstration of the feasibility of the application of simulation to the solution of scheduling problems is a contribution to the systematic management of instruction. While use of simulation is not unique in the area of system analysis, the application of simulation to a training system is unique. No documented simulation of a training system with individualized self-paced training could be found.

BACKGROUND

The Design of Training Systems (DOTS) Project Team determined that an in-house effort to demonstrate the feasibility and usefulness of simulation to managers concerned with training was needed. The concurrent planning by another Training Analysis and Evaluation Group (TAEG) team for a new Electronic Warfare (EW) School provided the vehicle for the demonstration of a simulation technique. Since the EW School was being programmed to employ the latest techniques in training and education, it was considered an appropriate area of concentration. The simulation product(s) could then be generalized and applied to other specific applications by minor modifications.

The area chosen to demonstrate simulation capabilities was the instruction to be provided to the EW operator personnel at Corry Station, Pensacola, Florida.

The problem confronting the EW School planners is to provide individualized, self-paced instruction with the resources available and with a required output. In an individualized, self-paced instructional system, each student type proceeds through a prescribed course of instruction at his own pace. The prescribed course of instruction is composed of discrete instructional elements, or learning modules. The individual nature of the learning module prescriptions dictates that all students do not take all learning modules but travel through a track of modules tailored to their specific instructional needs. Figure 1 depicts the notion of individual tracks through common modules.

The problem of scheduling, planning, controlling, and forecasting for a system composed of learning modules is not merely a function of the students' learning rates in each module. Each module requires some form of training support media; e.g., programmed instruction, procedures trainers, or sound/slide (Figure 2).

The manager's problem is one of attempting to reduce student waiting times associated with learning modules by providing adequate numbers of modules and corresponding media for the modules. Given a required student output by type and number, the manager must determine the required input, the scheduling of the input, and the quantity and types of training media required to preclude bottlenecks in throughput rates, in order to meet the output requirements.

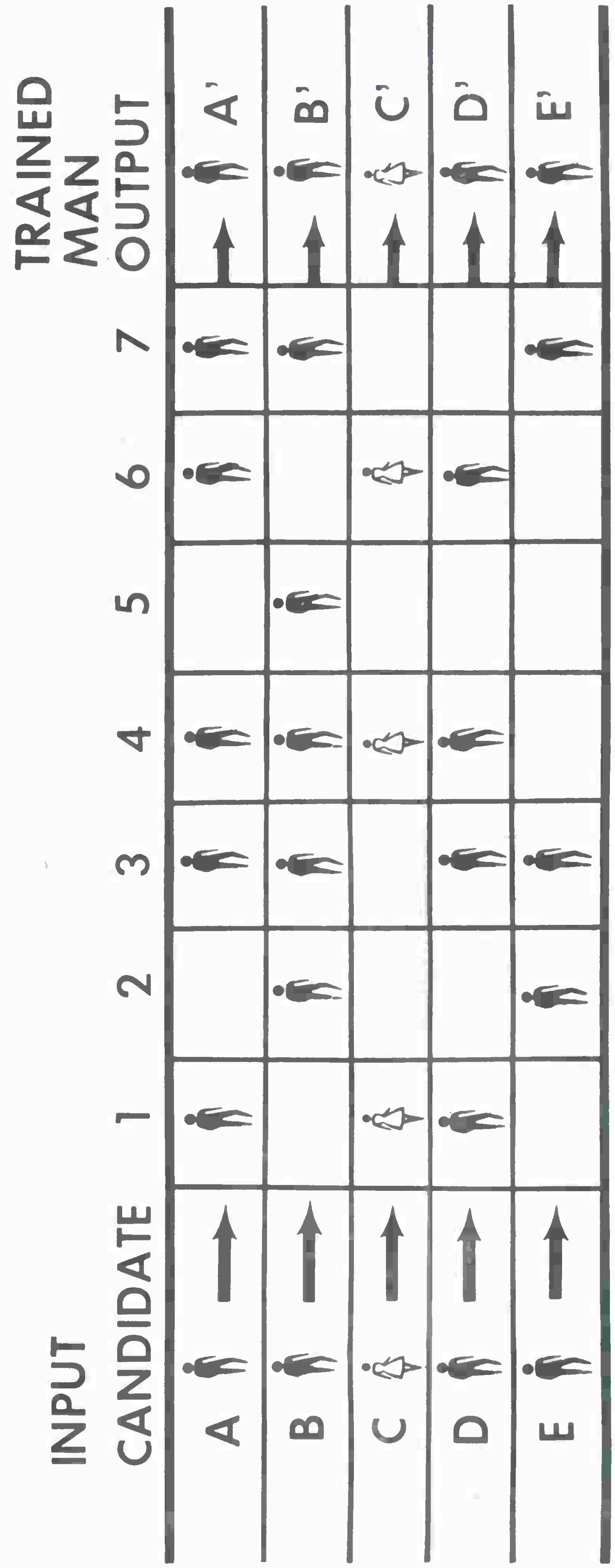


Figure 1. Individual Tracks Through Common Modules

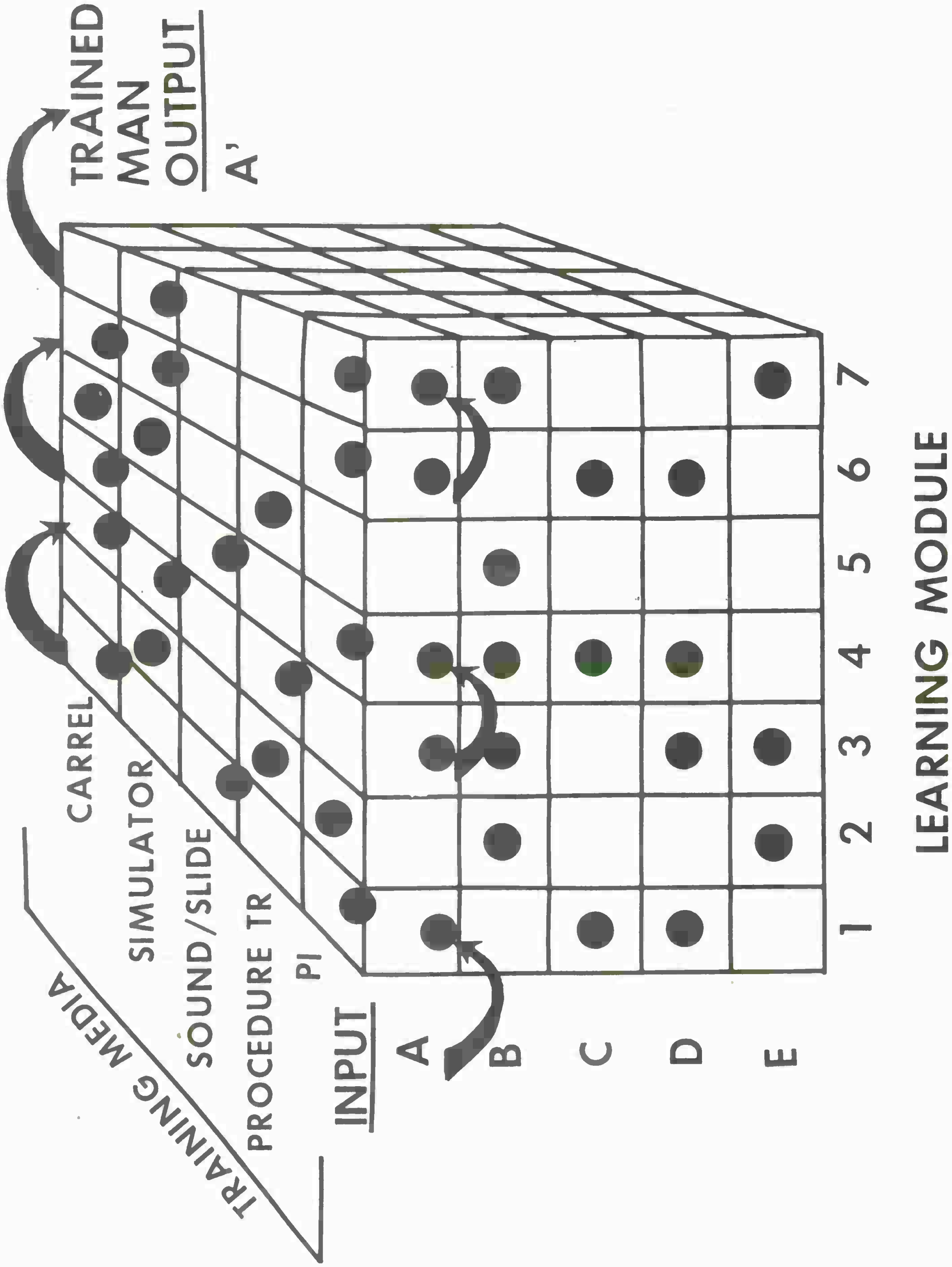


Figure 2. Time-shared Dimension of Training Media

SECTION II

METHOD

The feasibility study of applying simulation to EW operator training systems was structured to include the following: the selection of a representative training system, the selection of a simulation language, the development of a computer program to simulate the system, the manipulation of the simulated system to ask "what if" questions, the analysis of the output data, and a report documenting the study and recommendations. The EW Operator Training System was selected as an appropriate "test-bed" as it was considered to be representative of the approach to instruction to be employed in the Navy training system of the 1980's. In addition, the relative convenience with which system-specific data could be obtained from the TAEG's EW team made this selection doubly desirable.

The computer language selected for the simulation programming was General Purpose Simulation System (GPSS), developed by the IBM Corporation. This high-order computer language handles discrete-event models as network flow models. The selection of this language was due primarily to the possession of in-house programming capabilities utilizing GPSS and the accessibility of an IBM 360/40 computer with GPSS V capability.

The major steps involved in the simulation program developed in this study are the following:

a. Define and constrain the system

b. Develop a program and execute

c. Manipulate variables and analyze outputs

A description of each of these steps and their application in the development of the EW Operator Training System simulation are presented in detail in the remainder of this section.

DEFINE AND CONSTRAIN THE SYSTEM

The EW Operator Training System was defined by the EW TAEG team with the aid of EW planners. The conceptualized system is represented in Figure 3. There are seven types of students which flow through a total of 21 different learning modules. The system will be/is constrained by requirements promulgated by Chief of Naval Operations (CNO), Bureau of Naval Personnel (BUPERS), Chief of Naval Education and Training (CNET) and any other agency that can control the input or specify the output of the system either in personnel requirements and/or dollars. The system is further constrained by the fact that each learning module will have lesson plans that will be completed either in a multi-media carrel, an operational trainer, or in a special procedures trainer (aircraft). A multi-media carrel is an individual study booth equipped with a slide projector, tape deck, synchronizing system for sound/slide programs, and an 8mm sound motion picture projector supported with programmed instruction and texts. An operational trainer is a training device in which trainee stations provide generalized representation of the functional capabilities of present and projected EW equipment. The system features student self-pacing through curriculum elements, active learning, immediate feedback, and defined remedial instructions. The special procedures trainers are two support aircraft with 20 student stations per aircraft for physiological student training purposes.

Thus the training environment is composed of the carrels, operational trainers, and support aircraft. The dynamic entities are associated with the student flow through the prescribed courses of instruction (see Figure 3). The data were initially developed by the EW planners using all available data and experience to date. As the system is installed and exercised, these data will be validated and revised accordingly.

LEARNING MODULE

STUDENT INPUT →	SCHL INTRO/PRE-EXAM	MATHEMATICS	BASIC ELECTRONICS	ELEC TRANS & RECEPT	RADAR SYSTEM	PHYSIOLOGICAL & PSYC EVAL	EW FUNCT ORG PROCED	INTRO TO DEFENSE SYSTEMS	SIGNAL RECOG CONCEPTS	EW CONCEPTS	FUNDAMENTAL ESM	ADVANCED ESM	FUNDAMENTAL ESM SIM	ADVANCED ESM SIM	FUNDAMENTAL ECM	FUNDAMENTAL ECM SIM	ADVANCED ECM SIM	EC CM	ADVANCED MISSION OPNS	ADVANCED SYSTEMS	CAREER INFO	TRAINED OUTPUT →
SQUADRON EW TRAINING OFFICER	X				X		X	X	X	X	X	X	X		X	X		X		X	X	SQUADRON EW TRAINING OFFICER
SURFACE EWO	X			X	X		X	X		X	X	X	X		X			X		X	X	SURFACE EWO
MARINES	X	*	*	X	X	*	X	X	X	X	X	X	X	X	X	X		X	X	X	X	MARINES
CTT (ELINT)	X	*	*	X	X		X	X	X	X	X	X	X	X	X			X		X	X	CTT (ELINT)
NFO	X	X	X	X	X	*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NFO
EW	X	*	*	X	X	*	X	X	X	X	X	X	X	X	X	X		X		X	X	EW
PROSPECTIVE CO'S, OPS/CIC OFFICERS	X						X	X		X		X	X		X			X	X		X	PROSPECTIVE CO'S, OPS/CIC OFFICERS

*REQUIRED IF NOT PREVIOUSLY OBTAINED OR IF PRE-EXAM INDICATES NEED

Figure 3. Proposed Student/Learning Module Matrix for EW Operator Training

DEVELOP A PROGRAM AND EXECUTE

Each transaction in the EW operator training simulation program represents a student. Each student has certain characteristics which were described by the 13 possible characteristics listed in Figure 4. Subroutines in the main program represent two student scheduling procedures: (1) lesson plan, either in carrel or trainer, or (2) carrel, followed by trainer and back to carrel again.

Two smaller programs control time elements of the overall program. The first one controls the time of day or hours per training period and the other controls the number of days to be simulated. An exponential distribution function with different mean rates controls the student input rate. The type of student entering is determined by a discrete numerical function.

The cumulative exponential or Poisson distribution function which describes student arrivals is illustrated in Figure 5. A Poisson or exponential distribution states that the probability of k arrivals in time t is $e^{-t/m} (t/m)^{k}/k!$ where m is the mean interarrival time. The probability that the next arrival will occur within t time units is $1-e^{-t/m}$. In Figure 5 the probability value appears along the horizontal axis and t/m along the vertical axis. The interarrival time is obtained by multiplying the function value by m. The function gives results which are accurate to within 0.1 percent for $45 < m \leq 250$ and 1.0 percent for $m \leq 45$.

The type of student, or student mix, entering the school is determined by a discrete numerical function. The student input population or percentage mix of student types was specified by the EW planners. Figure 6 graphically depicts the student mix. By using the GPSS function argument, RN 1, the following results are obtained: Squadron EW Training Officer if $0 \leq$ RN1 $\leq .0376$, Surface EWO if $.0367 <$ RN1 $\leq .0827$, and so forth.

In the main program each transaction equals a student with 13 possible characteristics as follows:

Student M1, P1, P2, ...P12
(Transaction)

Where:

M1 - The Standard Numerical Attribute (SNA) for the transit time of the student currently being processed.

P1 - Student Type - There are presently seven possible student types: (1) Squadron EW Training Officer, (2) Surface EWO, (3) Marines, (4) CTT(ELINT), (5) NFO, (6) EW, (7) Prospective CO's and OPS/CIC Officers.

P2 - Facilities Counter - Locates which one of 90 possible trainers is unoccupied.

P3 - Number Counter - Determines which class schedule (learning track) to put student through for the first nine classes or learning modules.

P4 - Learning Module Number - Student is placed in a particular module (26 possible) according to his prescribed learning track.

P5 - Lesson Plan Number - Used for first nine modules and is a function of the particular learning module.

P6 - Average time for lesson plan within module.

P7 - Time deviate for each lesson plan.

P8 - Special Number Counter for particular Lesson Plan Groups (carrel vs. operational trainer) within module. Basically, same as P3, except this counter is peculiar to modules 10 through 26.

P9 - Lesson Plan Number - used for modules 10 through 26; concerns both carrel and operational trainer.

P10 - Not used (available for other desirable attributes).

P11 - Time student enters school.

P12 - Subroutine transfer counter.

Figure 4. Student Characteristics

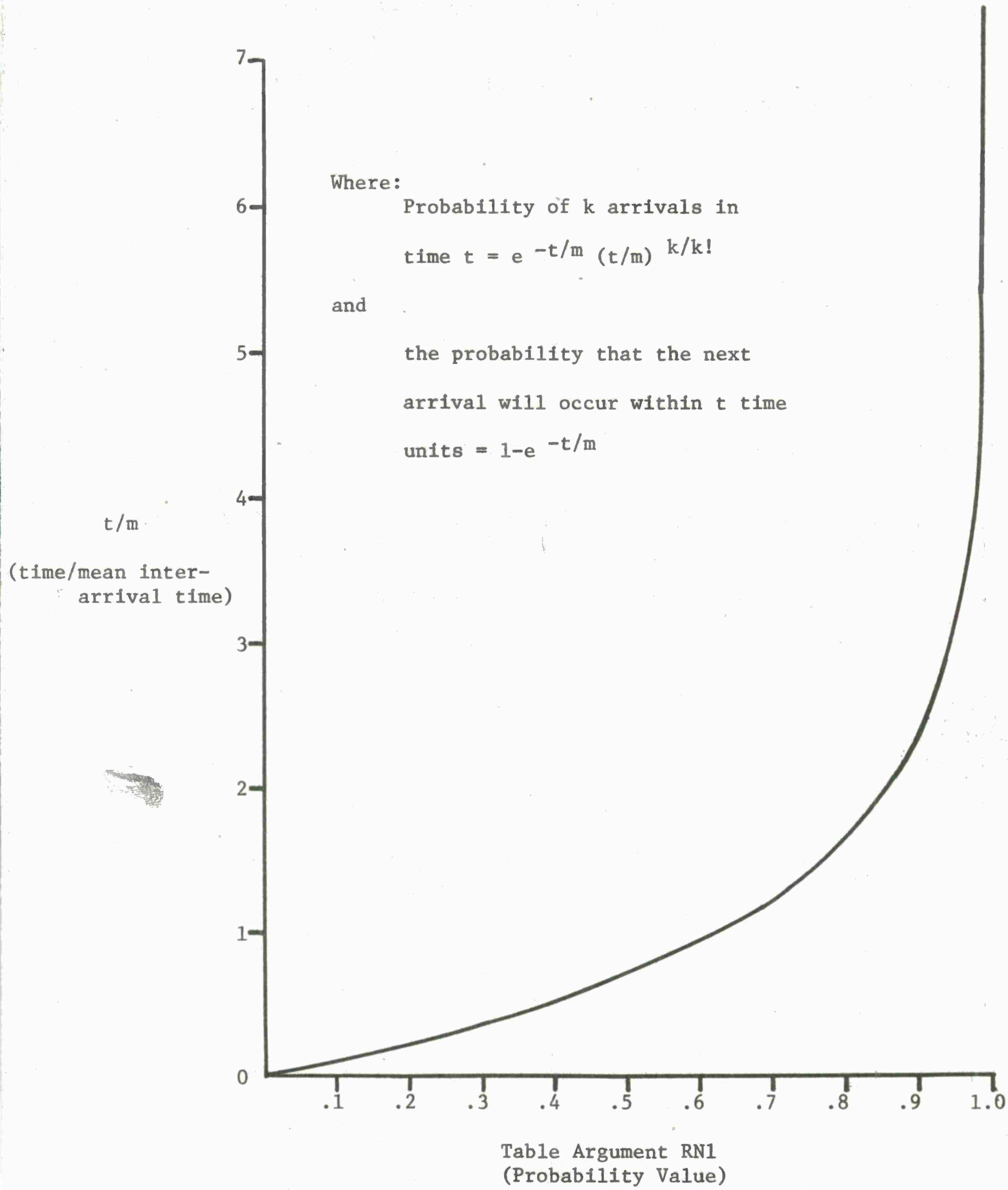
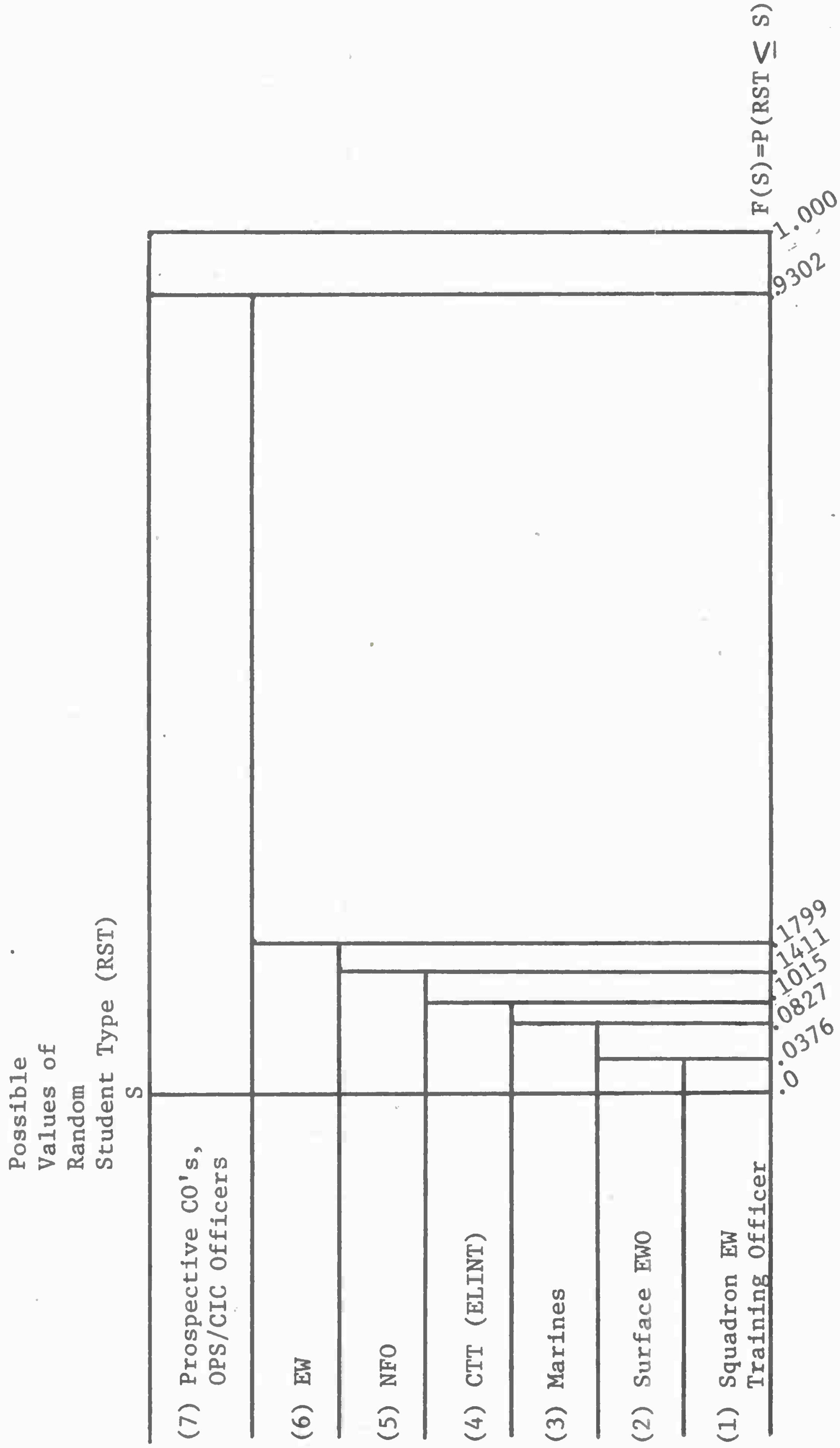


Figure 5. Cumulative Exponential or Poisson Distribution Function to Describe Student Arrivals



RN1 (Random Number 1) = Cumulative Probability

Example: If .1411 < RN1 ≤ .1799, student type is (5) NFO

Figure 6. Student Mix

Each type of student has an individual track set up by one of two student schedule subroutines, which uses a list numerical function to pick the classes or modules, the number of lesson plans, and the mean times as well as deviations about that time in the lesson plan. Boolean variable entities are used at key decision blocks to determine individual student paths through the network.

The overall concept of the simulation program for this particular application can be better understood by referring to Figure 7 which gives a Macro view of the model. Basically, there are three phases of the student flow which are of concern in the program: an initiation phase, an execution phase, and a completion phase. The student arrival and type are determined as described above. The specific network track is specified by the conceptual system shown in Figure 3. As the student progresses, he is assigned to the proper module and is processed through that module according to a normative distribution of lesson plan times. If the module is occupied, he waits in a queue until it is available. Intrinsic in this scheduling is the consideration of length of the school day. If the student is currently in a module he will complete that particular lesson before leaving. This process is iterative in nature until the prescribed network path is completed. Statistical data are compiled for all phases of his progress.

MANIPULATE VARIABLES AND ANALYZE OUTPUTS

The manipulation of variables and the resultant analysis of outputs is an ongoing task. Initially, the system was run with certain inputs. The outputs were then observed to determine adequacy with the specified requirements. Figure 8 illustrates the inputs/outputs/constraints of the system. By manipulating the variables under his control, the manager can determine

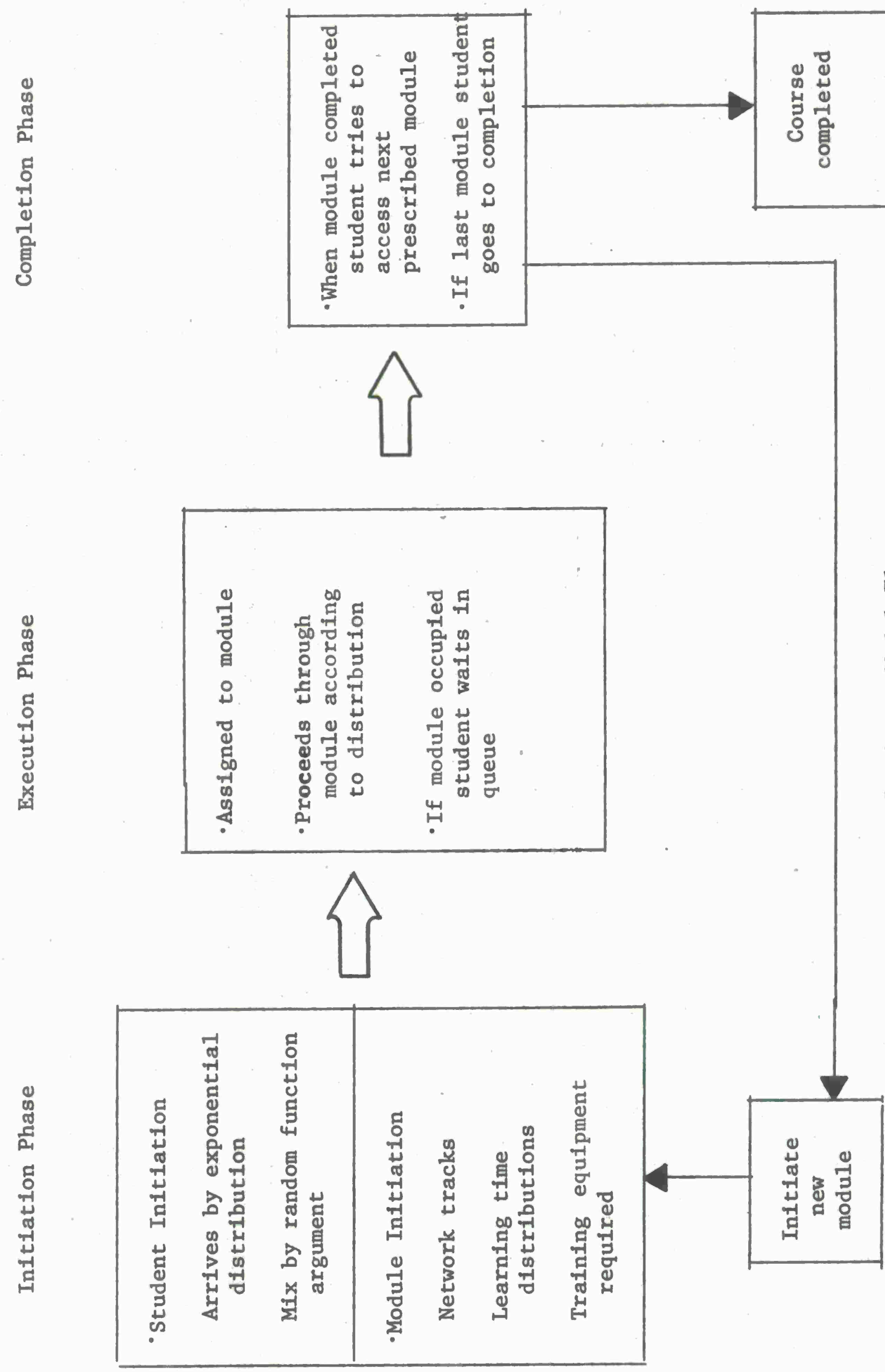


Figure 7. Macro Model Flow

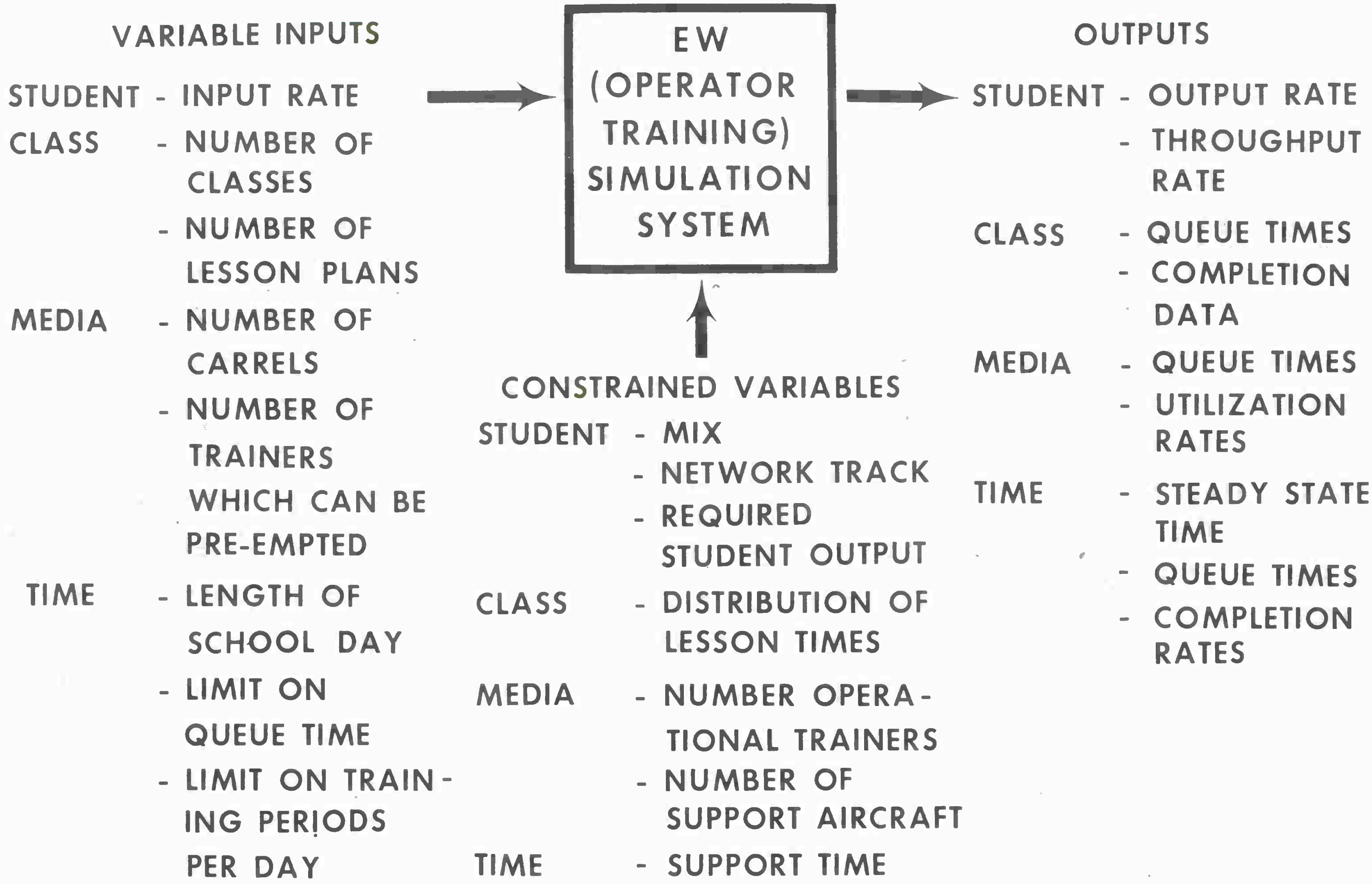


Figure 8. Input/Output/Constraint Diagram

what effect this will have on the output. To date, the input variables have been held constant except for student input rate in order to examine the capacities of the conceptualized system. The results of this exercise are presented in Section III.

SECTION III

RESULTS

Since the requirement for trained EW operators by number and type was exogenous to their system (specified by CNO), this was considered to be the driving force of the system. This coupled with an austere budget, yet relatively free to determine, or at least suggest, how that budgeted money would be expended on training media, the planners needed to insure that the conceptualized system would meet the required output within the dollar constraints. The range of items under consideration is shown in Figure 8.

In order to perform comparative analyses of system capabilities or to compare alternative system strategies, certain input variables should remain constant together with the constrained variables, while other key controllable input variables are manipulated.

The conceptual system as described in Figure 3 was analyzed by the EW planners in TAEG to determine the mix of media for each module which would satisfy the overall training requirements within the dollar constraints. Initially, the number of multi-media carrels was set at 220, the number of operational trainers was set at 90, and the number of support aircraft was set at 2 with 30 student positions per aircraft. By keeping variables such as the number of classes, lesson plans per class, and the distributions of time for each lesson plan constant and varying the student input rate, the planners were able to get an idea of the capacity and limits of the conceptualized system.

Once the conceptual system was adequately defined and constrained, the simulation was reduced to the iterative process of execution, manipulation, and analysis of the outputs for the program. Three student input rates were simulated and compared. The input rates were four, six, and eight students per day, with the arrival times and appropriate mix determined by the methods described in Section II.

A brief discussion of the results for each of the three input rates is presented below. Details of the simulation program, i.e., program listing, flow charts, and sample output, are contained in Appendices A, B and C respectively. Standard GPSS output provides a great amount of tabulated statistical data on the system being simulated. In this particular application much of these data were not relevant to the problems under consideration. However, in the future, much of these data may prove useful for the "fine tuning" of the system once it becomes operational.

a. Four Students Per Day

At an input rate of four students per day the most significant output of the simulation was the fact that no queues were observed. Students proceeded through the system without any delays caused by the unavailability of media. Under these conditions the observed completion times are considered to be optimal. The completion times for an input rate of four students per day are summarized in Table 1.

TABLE 1. COMPLETION TIMES FOR AN INPUT RATE OF FOUR STUDENTS PER DAY

	Completion Time (in days)			Standard
Type Student	Maximum	Minimum	Mean	Deviation
Squadron EW Training Officer	38	36	36.67	0.707
Surface EWO	39	34	36.71	1.601
Marines	53	52	52.33	0.577
CTT (ELINT)	48	41	43.82	2.085
NFO	53	51	51.71	0.915
EW	54	41	47.17	2.855
Prospective CO's, OPS/CIC Officers	25	21	22.82	1.128

These figures not only represent the expected average completion time for each type of student in the system defined but give support to the efficacy of employing individualized, self-paced instruction. These average completion times represent a reduction in instruction time over the traditional lock-step type of instruction of approximately 30 percent. For example, a representative EW traditional lock-step form of instruction would require approximately 65 hours, whereas in our example the time required is approximately 47 hours, or a reduction in time of about 28 percent.

b. Six Students Per Day

When the input rate is increased from four to six students per day, queues begin to develop. However, the queues have a negligible effect on the completion times associated with each student type. The reason for this is that the queues affect an insignificant number of students. This is shown by the following output data:

Type of facility	Average length of queue	Percent students affected
Carrel	44.58 minutes	1.10
Operational Trainer	41.97 minutes	0.60

This means that 98.9 percent of the students in the system experienced no queuing associated with carrels and 99.4 percent had no queues with operational trainer usage. While the net effect on average completion times for all students, expressed in days, was not significant, any queue over 30 minutes was arbitrarily considered serious from a student motivational standpoint. Detailed analysis of the system output data associated with each queue could remedy this situation by the addition of, or the manipulation of, media associated with the queue. Since the average completion times were considered to be more significant indicators of system performance, and the minor fluctuations observed in these times were attributed more to the errors associated with the GPSS random number arguments and distribution times than to the queues, efforts to reduce the queues were deemed unnecessary.

c. Eight Students Per Day

The training system continued to perform as prescribed when the input rate was increased to eight students per day, with the average completion rates remaining stable. The queues began to become significant at this input rate--approaching three hours for the carrels and one hour for operational trainers. However, the percent of students experiencing queues was still relatively low; i.e., 5.6 percent for carrels and 4.7 percent for operational trainers. Even though the queues appear excessive, the time compression resulting from the use of individualized self-paced instruction versus traditional instruction would indicate that these queues may be tolerable. If a 30 percent reduction in instruction time is anticipated, then a queue of three hours 5.6 percent of the time does not seem significant. Before any adjustments are made to reduce the queues, tradeoffs should be considered between the cost of adding media, the disadvantages of a student waiting for the media, the overall effect on the student's completion rate, and so on.

Simulation runs utilizing input rates greater than eight students/day were not attempted since the computational limits of the processing equipment were being approached. With an input rate of eight students/day there were approximately 500 students in the system which had to be monitored and the computer processing time became prohibitive. Most applications of simulation to training systems should not be as complex as the system examined in this study and, therefore, should not present this problem. If it does prove prohibitive, larger processing equipment should be obtained to conduct the simulation.

The results of these simulation runs indicate that the conceptual EW Operator Training System as defined and constrained will have the capability to meet the specified system requirements. As shown in Table 2, the average completion times are fairly constant over the input rates chosen. While queues develop for the six and eight students per day input rates, the impact on the average completion times is not readily discernible. The queues do impact the output of the system since more people are maintained in the system as the input rate and the queues increase. Table 3 represents an extrapolated summary of expected annual output for the system. With an input rate of four students per day, 187 students occupy the system once steady-state conditions are reached. For six and eight students per day, the number of students in the system increases to 314 and 438 respectively. There appears to be no need to increase quantities of training media to reduce the queues associated with higher input rates since the lower rates will satisfy the specified output requirements. Once the conceptual system becomes operational, however, some manipulation or addition of media for certain modules may prove desirable as experience is gained. A more accurate emulation of the system will be possible after real world systems data are available and the assumptions and estimates reflecting system performance are verified.

TABLE 2. AVERAGE COMPLETION TIMES (IN DAYS)

Type Student	Input Rate (Students Per Day)		
	4	6	8
Squadron EW Training Officer	36.6	37.4	37.3
Surface EWO	36.7	36.6	37.5
Marines	52.3	49.2	51.7
CTT (ELINT)	43.8	44.0	44.3
NFO	51.7	53.4	52.6
EW	47.2	47.4	47.6
Prospective CO's, OPS/CIC Officers	22.8	22.2	23.0

TABLE 3. EXPECTED ANNUAL EW OPERATOR TRAINING SYSTEM OUTPUT

Type Student	Input Rate (Students Per Day)		
	4	6	8
Squadron EW Training Officer	32	47	58
Squadron EWO	38	56	70
Marines	16	23	29
CTT (ELINT)	34	50	61
NFO	33	48	59
EW	640	935	1157
Prospective CO's, OPS/CIC Officers	60	87	108
Totals	853	1246	1542

SECTION IV

CONCLUSIONS

Simulation of a training system by computer can provide useful analytical capability which enhances the manager's ability to assess requirements and capacities while formulating various alternatives to a problem.

The simulation technique described and applied in this report provides a powerful analytical capability for EW planners. Changes in student input rates can be examined systematically to assess the effect of achieving personnel and resources in steady state of the system. In addition, the effects of changing learning modules, lesson plans, and training support equipment on the training system can be determined. The queuing effects expected at the carrels or trainers can also be examined as a function of changes in student mix, input rates or as other pertinent variables are changed. The training manager can get a reasonable idea of the different student throughput rates and how the throughput rates are affected by changes in the input variables. The list of system entities and how they can be analyzed is extensive. The particular problem facing the manager dictates the area of analysis. The simulation described here provides the vehicle for such analysis. During the system definition, the manager is forced to analyze his system. This forced system analysis provides training management perspectives heretofore unavailable.

It should be noted that simulation models do not yield absolute solutions to problems. This generic type of model only replicates the system described to the level of detail it is designed. It does, however, provide an invaluable tool for management to assess the validity or consequences of assumptions, thus enabling a more systematic and realistic solution to a planning problem. The ultimate decision-making responsibility still rests with the manager; simulation and other analytical techniques are only tools for increasing the effectiveness of the manager.

SECTION V

RECOMMENDATIONS

The power of simulation as a planning tool for training system consideration has been demonstrated in this study. However, before continued effort is expended either on this specific application, i.e., EW operator training, or on the modification of the simulation programs to a generalized individualized self-paced instructional system, detailed analysis of assumptions made and the relevance of particular outputs is needed. Specific problems, which are suited to analysis by simulation of the system, must be examined on their individual merits. This case-by-case assessment would allow the formatting of output data to satisfy the problem needs and allow rapid assessment and possible solutions.

Training plans, and the formulation of training plans, should include simulation as well as other analytical techniques, as applicable. "As applicable" implies that the analysis warrants the potential benefits or cost savings accrued from the application of the technique. Training plans, especially for conceptual systems, need more accurate ways of determining the capacities and requirements of proposed training systems.

In addition to providing real quantifiable data for comparison in planning for training, simulation can provide realistic data for budget considerations. These data, for example, would provide timely inputs to the Program Objective Memorandum (POM).

The ability and requirement "to do" simulations should be undertaken by staff groups, either military or civilian, which have programming and system analysis capabilities.

The use of simulation for other specific applications should be addressed as the need arises. The installation of individualized self-paced instructional systems in the Navy is still in the beginning stages. As these instructional systems become prominent in the Navy, the need for employing analytic tools, such as simulation in the design for and control of training, is clear and it is urgent.

BIBLIOGRAPHY

Andrew, Gary M. and Moir, Ronald E. Information-Decision Systems in Education. Itasca, Illinois: F. E. Peacock. 1970.

Electronic Warfare Training Analysis. TAEG Report 4. 1972. Naval Training Equipment Center. Orlando, Florida.

General Purpose Simulation System V User's Manual. SH 20-0851-1. August 1971. IBM Corporation, Technical Publications Department. White Plains, New York.

Greenberg, Stanley. GPSS Primer. New York: Wiley - Interscience. 1972.

Hammond, John S. "Do's and Don'ts of Computer Models for Planning." Harvard Business Review. March-April 1974, pages 110-123.

Hammond, John S. "The Role of the Manager and Management Scientist in Successful Implementation." Sloan Management Review. Winter 1974.

Pearson, Ted E.; MacKeraghan, Lysle R.; Stubbs, Willard B.; and Moore, Jr., Edward O. Electronic Warfare Maintenance Training Analysis, Executive Summary. TAEG Report No. 9-1. 1974. Naval Training Equipment Center. Orlando, Florida.

Pearson, Ted E.; MacKeraghan, Lysle R.; Stubbs, Willard B.; and Moore, Jr., Edward O. Electronic Warfare Maintenance Training Analysis. TAEG Report No. 9-2. 1974. Naval Training Equipment Center. Orlando, Florida.

Richmond, Samuel B. Operations Research for Management Decisions. New York: The Ronald Press Company, 1968.

APPENDIX A

CONTROL CARDS

This program was run on an IBM 360/40 using GPSS V with the following control cards:

```
//NAVY JOB TIME=600
//EXECS  EXEC   PGM=DAG01V,PARM=B,TIME=600
//DOUTPUT   DD     SYSOUT=A
//DINTERO   DD    UNIT=SYSDA,SPACE=(TRK,(10,10))
//DSYMTAB   DD    UNIT=SYSDA,SPACE=(TRK,10,10))
//DREPTGEN  DD    UNIT=SYSDA,SPACE=(TRK,(10,10))
//DINTWORK  DD    UNIT=(SYSDA,SEP=(DINTERO)),SPACE=(TRK,(10,10))
//DRDSAVEO  DD UNIT=2400,VOL=SER=NEWTAP,LABEL=(,NL),DISP=(OLD,PASS)
//DRDSAVEI  DD UNIT=2400,VOL=SER=OLDTAP,LABEL=(,NL),DISP=(OLD,PASS)
//DXREFDS   DD      UNIT=SYSDA,SPACE=(TRK,(1,1))
//DINPUT1   DD   *
       REALLOCATE VAR,11,FSV,20,HSV,20,CHA,15,BLO,250,FAC,100
       REALLOCATE STO,10,QUE,30,LOG,10,TAB,10,FUN,20,GRP,0,BVR,24
       REALLOCATE COM,56868
```

BOOLEAN VARIABLES

```
 1 BVARIABLE  ((P1'E'3)+(P1'E'4)+(P1'E'6))*(P4'E'1)
 2 BVARIABLE  ((P1'E'3)+(P1'E'4)+(P1'E'6))*(P4'E'2)
 3 BVARIABLE  ((P1'E'3)+(P1'E'5)+(P1'E'6))*(P4'E'5)
 4 BVARIABLE  ((P1'E'7)*(P4'E'25))+(P4'E'26)
 5 BVARIABLE  FNI61+FNI62+FNI63+FNI64+FNI65+FNI66+FNI67+FNI68+FNI69
 6 BVARIABLE  FNI70+FNI71+FNI72+FNI73+FNI74+FNI75+FNI76+FNI77+FNI78
 7 BVARIABLE  FNI79+FNI80+FNI81+FNI82+FNI83+FNI84+FNI85+FNI86+FNI87
 8 BVARIABLE  FNI88+FNI89+FNI90
 9 BVARIABLE  BV5+BV6+BV7+BV8
10 BVARIABLE  (P1'NE'7)*((P8'E'19)+(P8'E'23))+BV11+(BV12*BV13)+BV14
11 BVARIABLE  ((P1'L'3)*(P8'E'32))
12 BVARIABLE  ((P1'E'3)+(P1'E'4)+(P1'E'5)+(P1'E'6))
13 BVARIABLE  ((P8'E'26)+(P8'E'35))
14 BVARIABLE  (P1'E'7)*((P8'E'4)+(P8'E'13))
15 BVARIABLE  ((P1'E'1)*(P8'E'39))+BV18+BV16+BV17
16 BVARIABLE  ((P1'E'3)+(P1'E'5)+(P1'E'6))*(P8'E'42)
17 BVARIABLE  ((P1'E'7)*(P8'E'18))+BV23
18 BVARIABLE  (P1'E'2)*(P8'E'37)
19 BVARIABLE  (P1'NE'7)*((P8'E'18)+(P8'E'22))+BV20+(BV12*BV21)+BV22
20 BVARIABLE  (P1'L'3)*(P8'E'31)
21 BVARIABLE  ((P8'E'25)+(P8'E'34))
22 BVARIABLE  (P1'E'7)*((P8'E'3)+(P8'E'12))
23 BVARIABLE  ((P1'E'4)*(P8'E'40))
```

VARIABLES, MATRIX, STORAGE

```
 1 VARIABLE    15-F1-F2-F3-F4-F5-F6-F7-F8-F9-F10-F11-F12-F13-F14-F15
 2 VARIABLE    12-F16-F17-F18-F19-F20-F21-F22-F23-F24-F25-F26-F27
 3 VARIABLE    12-F30-F31-F32-F33-F34-F35-F36-F37-F38-F39-F40-F41
 4 VARIABLE    12-F43-F44-F45-F46-F47-F48-F49-F50-F51-F52-F53-F54
 5 VARIABLE    12-F56-F57-F58-F59-F60-F61-F62-F63-F64-F65-F66-F67
 6 VARIABLE    12-F69-F70-F71-F72-F73-F74-F75-F76-F77-F78-F79-F80
 7 VARIABLE    09-F82-F83-F84-F85-F86-F87-F88-F89-F90
 8 VARIABLE    V1+V2+V3+V4+V5+V6+V7+V10
 9 FVARIABLE   MP11/48
10 VARIABLE    06-F29-F42-F55-F68-F81-F28

1   MATRIX     H,28,7
2   MATRIX     H,1,7
3   MATRIX     H,1,1

    INITIAL    LS1

    STORAGE    S1,220/S2,90/S3,50
```

FUNCTIONS

```
SETO    FUNCTION    P3,L18      SQDN EW TRNG OFFICER SCHEDUAL
,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,17/,18/,19/,20/,21/,22/,25/,26

SEWO    FUNCTION    P3,L16      SURFACE EWO TRAINING SCHEDUAL
,3/,4/,6/,7/,9/,10/,11/,12/,13/,14/,17/,18/,21/,22/,25/,26

CTTE    FUNCTION    P3,L21      CTT(ELINT) TRAINING SCHEDUAL
,1/,2/,3/,4/,6/,7/,8/,9/,10/,11/,12/,13/,14/,15/,16/,17/,18/,21/,22
,25/,26

PROCO   FUNCTION    P3,L13      PROSPECTIVE CO'S
,6/,7/,9/,12/,13/,14/,17/,18/,21/,22/,23/,24/,25

CLASS   FUNCTION    P4,L26      TIMING FOR EACH CLASS
,8/,4/,4/,4/,17/,4/,5/,2/,3/,4/,6/,2/,5/,16/,5/,7/,5/,5
,4/,6/,6/,5/,7/,5/,8/,3

TIME    FUNCTION    P4,L26      DEVIATE
,2/,2/,2/,1/,3/,2/,2/,1/,1/,1/,2/,1/,1/,1/,1/,2/,1/,1/,1/,1/,1/,1/,2
,1/,2/,1

LOOP    FUNCTION    P4,L9      LOOPING WITHIN THE FIRST 9 CLASSES
,1/,22/,17/,9/,1/,4/,3/,18/,13

GETIT   FUNCTION    P8,L46     LOOPING LESSON PLANS FOR MARINES,NFO,EW
,5/,2/,2/,1/,1/,2/,1/,1/,2/,1/,1/,1/,2/,1/,3/,1/,1/,2/,2/,21/,4/,1/,1/
,3/,4/,1/,4/,1/,1/,2/,2/,2/,1/,2/,2/,4/,4/,3/,5/,1/,4/,2/,2/,5/,3/,3

PCOX    FUNCTION    P8,L22     LOOPING LESSON PLAN FOR CO'S
,21/,4/,1/,1/,4/,1/,1/,2/,2/,2/,1/,2/,2/,3/,5/,1/,4/,2/,2/,5/,3/,3

SQEW    FUNCTION    P8,L41     LOOPING LESSON PLAN FOR SQDN EW TRNG OFFICER
,5/,2/,2/,1/,1/,2/,1/,1/,2/,1/,1/,1/,2/,1/,3/,1/,1/,2/,2/,21/,4/,1/,1/
,4/,1/,1/,2/,2/,2/,1/,2/,2/,4/,4/,3/,5/,1/,4/,2/,3/,3

SUEWO   FUNCTION    P8,L39     LOOPING LESSON PLAN FOR SURFACE EWO
,5/,2/,2/,1/,1/,2/,1/,1/,2/,2/,1/,1/,2/,1/,3/,1/,1/,2/,2/,21/,4/,1/,1
,4/,1/,1/,2/,2/,2/,1/,2/,2/,3/,5/,1/,4/,2/,3/,3

ELINT   FUNCTION    P8,L42
,5/,2/,2/,1/,1/,2/,1/,1/,2/,1/,1/,1/,2/,1/,3/,1/,1/,2/,2/,21/,4/,1/,1/
,3/,4/,1/,4/,1/,1/,2/,2/,2/,1/,2/,2/,3/,5/,1/,4/,2/,3/,3


 2      FUNCTION    RN2,D7
.0376,1/.0827,2/.1015,3/.1411,4/.1799,5/.9302,6/1.,7

EXPON   FUNCTION    RN1,C24      EXPONENTIAL PROBABILITY DISTRIBUTION
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38/
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2/
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9997,8
```

SUBROUTINES

CARRL

```
CARRL  ASSIGN     12+,1
 WON   GATE LS    KAY,ZIPE
       QUEUE      P4
       QUEUE      27
       ENTER      1
       DEPART     P4
       DEPART     27
       ADVANCE    P6,P7
       LEAVE      1
       LOOP       9,WON
       TRANSFER   ,P12
ZIPE   LINK       HEME,FIFO,GON
 GON   GATE LS    KAY
       ADVANCE    2,FN$EXPON
       TRANSFER   ,WON
```

SUBROUTINES

CAREL

```
CAREL  ASSIGN       12+,1
 NOW   GATE LS      KAY,ZIPER
       QUEUE        P4
       QUEUE        27
       ENTER        1
       DEPART       P4
       DEPART       27
       ADVANCE      P6,P7
       LEAVE        1
       LOOP         5,NOW
       MSAVEVALUE   1+,P4,P1,1,H
       TRANSFER     ,P12
ZIPER  LINK         HOME,FIFO,GONE
 GONE  GATE LS      KAY
       ADVANCE      2,FN$EXPON
       TRANSFER     ,NOW
```

SUBROUTINES

OTSTA

```
OTSTA ASSIGN      12+,1
GOTO  GATE LS     KAY,NONER
      QUEUE       P4
      QUEUE       28
      TEST NE     V8,0
      ENTER       2
      DEPART      P4
      DEPART      28
JAMES ASSIGN      2+,1
      GATE NU     P2,FIND
      SEIZE       P2
      ADVANCE     P6,P7
      RELEASE     P2
      LEAVE       2
      TEST L      P2,90,INIAT
  ZIP LOOP        9,GOTO
      TRANSFER    ,P12
NONER LINK        INTO,FIFO,SUE
  SUE GATE LS     KAY
      ADVANCE     2,FN$EXPON
      TRANSFER    ,GOTO
INIAT ASSIGN      2-,90
      TRANSFER    ,ZIP
 FIND TEST L      P2,90,ZEROO
      TRANSFER    ,JAMES
ZEROO ASSIGN      2-,90
      TRANSFER    ,JAMES
```

SUBROUTINES

```
ASIGN
ASIGN   ASSIGN      3+,1
        TEST E      P1,1,*+3
        ASSIGN      4,FN$SETO
        TRANSFER    ,*+19
        TEST E      P1,2,*+3
        ASSIGN      4,FN$SEWO
        TRANSFER    ,*+16
        TEST E      P1,3,*+3
        ASSIGN      4,P3
        TRANSFER    ,*+13
        TEST E      P1,4,*+3
        ASSIGN      4,FN$CTTE
        TRANSFER    ,*+10
        TEST E      P1,5,*+3
        ASSIGN      4,P3
        TRANSFER    ,*+7
        TEST E      P1,6,*+5
        TEST E      P3,23,*+2
        ASSIGN      3+,2
        ASSIGN      4,P3
        TRANSFER    ,*+2
        ASSIGN      4,FN$PROCO
        ASSIGN      6,FN$CLASS
        ASSIGN      7,FN$TIME
        TRANSFER    P,12,1
```

<u>HOWRD</u>

SUBROUTINES

```
HOWRD  ASSIGN     8+,1
       TEST E     P1,1,*+3
       ASSIGN     9,FN$SOEW
       TRANSFER   ,RON
       TEST E     P1,2,*+3
       ASSIGN     9,FN$SUEWO
       TRANSFER   ,RON
       TEST E     P1,3,*+3
       ASSIGN     9,FN$GETIT
       TRANSFER   ,RON
       TEST E     P1,4,*+3
       ASSIGN     9,FN$ELINT
       TRANSFER   ,RON
       TEST E     P1,5,*+3
       ASSIGN     9,FN$GETIT
       TRANSFER   ,RON
       TEST E     P1,6,*+3
       ASSIGN     9,FN$GETIT
       TRANSFER   ,*+2
       ASSIGN     9,FN$PCOX
RON    TRANSFER   P,12,1
```

TIME-ORIENTED PROGRAMS

```
      GENERATE    ,,,1
NXDAY ADVANCE     16
      LOGIC I     KAY
      ADVANCE     32
      TRANSFER    SBR,UNLKH,12
      TRANSFER    ,NXDAY

UNLKH LOGIC I     KAY
      UNLINK      HOME,GONE,ALL
      UNLINK      HEME,GON,ALL
      UNLINK      BETA,INFO,ALL
      UNLINK      INTO,SUE,ALL
      UNLINK      TWO,GOLF,ALL
      TRANSFER    P,12,1


      GENERATE    16
      TERMINATE   1             DESTROY ABOVE XACT;DECRIMIT RUN TERM, COUNT
```

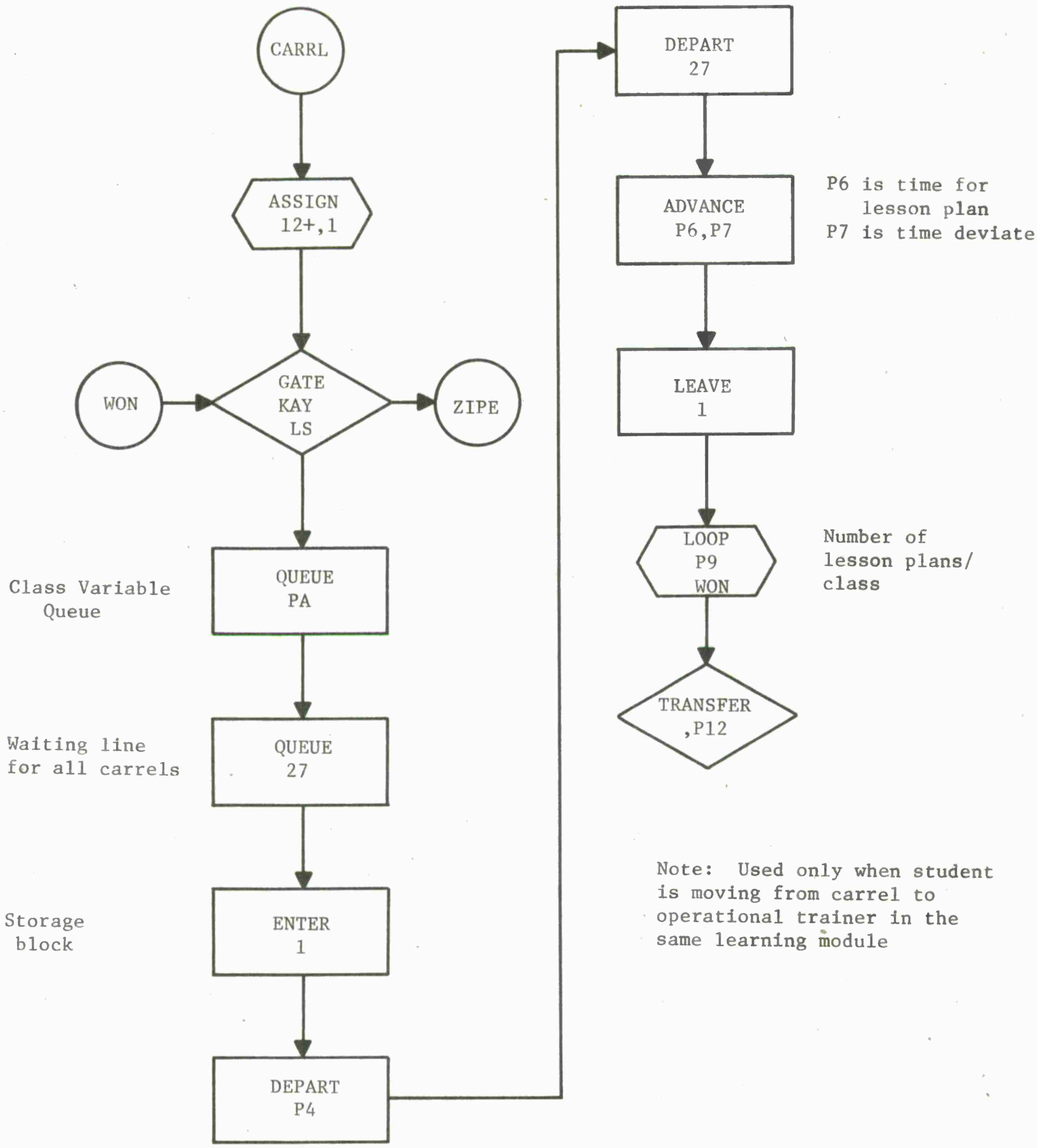
MAIN PROGRAM

```
STT    GENERATE    12,FN$EXPON
       ASSIGN      1,FN2
       MARK        11
       MSAVEVALUE  2+,1,P1,1,H
 EVON  TRANSFER    SBR,ASIGN,12
       ASSIGN      5,FN$LOOP
       TEST E      BV1,1,MOON
       TRANSFER    .455,EVON,WHITE
 MOON  TEST E      BV2,1,STAR
       TRANSFER    .556,EVON,WHITE
 STAR  TEST E      BV3,1,WHITE
       TRANSFER    .700,EVON,WINN       GO TO PHYSIOL AND PSYCHOL. ROUTINE
WHITE  TRANSFER    SBR,CAREL,12
       TEST E      P4,9,EVON
TEPEE  TRANSFER    SBR,ASIGN,12
       TRANSFER    SBR,HOWRD,12
       TRANSFER    SBR,CARRL,12
       TEST E      BV15,0,THINK
       TEST E      BV10,1,IBM
       MSAVEVALUE  1+,P4,P1,1,H
       ASSIGN      3+,1
       TRANSFER    ,TEPEE
  IBM  TEST E      P4,12,IBMM
       MSAVEVALUE  1+,P4,P1,1,H
       TRANSFER    ,TEPEE
 IBMM  TRANSFER    SBR,ASIGN,12
       TRANSFER    SBR,HOWRD,12
       TRANSFER    SBR,OTSTA,12
       TEST E      P4,20,*+3
       MSAVEVALUE  1+,P4,P1,1,H
       MSAVEVALUE  1+,19,P1,1,H
       TEST NE     P4,20,TEPEE
       TEST E      BV19,1,HIT
       MSAVEVALUE  1+,P4,P1,1,H
  HIT  ASSIGN      3-,2
       TRANSFER    ,TEPEE
THINK  MSAVEVALUE  1+,P4,P1,1,H
       TEST E      P4,21,*+2
       MSAVEVALUE  1+,22,P1,1,H
       ASSIGN      3+,1
       TRANSFER    SBR,ASIGN,12
       TRANSFER    SBR,HOWRD,12
       TRANSFER    SBR,CARRL,12
       MSAVEVALUE  1+,P4,P1,1,H
       TEST L      P4,25,JUNE
       TRANSFER    SBR,ASIGN,12
       TRANSFER    SBR,HOWRD,12
  INN  GATE LS     KAY,WING
       QUEUE       P4                    ADVANCED MISSION OPERATIONS OT
       QUEUE       28
       TEST E      BV9,1
TNOW   ASSIGN      2,61
MONEY  GATE NI     P2,LOOK
       PREEMPT     P2
       DEPART      P4
       DEPART      28
       ADVANCE     P6,P7
       RETURN      P2
```

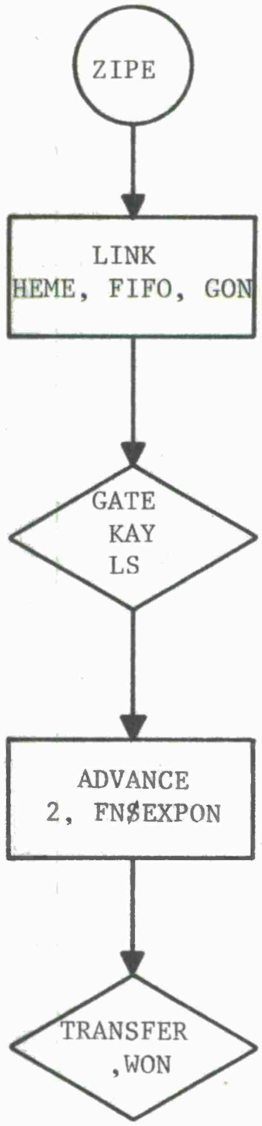
MAIN PROGRAM (CONT'D)

```
        LOOP         9,INN
        MSAVEVALUE   1+,P4,P1,1,H
        TRANSFER     ,GIRL
WING    LINK         BETA,FIFO,INFO
 INFO   GATE LS      KAY
        ADVANCE      2,FN$EXPON
        TRANSFER     ,INN
 LOOK   ASSIGN       2+,1
        TEST E       P2,91,MONEY
        TRANSFER     ,TNOW
WINN    GATE LS      KAY,GOOF
        QUEUE        P4                      PHYSIOLOGICAL AND PSYCHOLOGICAL
        GATE SNF     3
        ENTER        3
        DEPART       P4
        ADVANCE      P6,P7
        LEAVE        3
CROWN   MSAVEVALUE   1+,P4,P1,1,H
        TRANSFER     ,EVON
GOOF    LINK         TWO,FIFO,GOLF          PSYCHOLOGICAL ROUTINE
 GOLF   GATE LS      KAY
        ADVANCE      2,FN$EXPON
        TRANSFER     ,WINN
JUNE    TRANSFER     SBR,ASIGN,12
        TRANSFER     SBR,HOWRD,12
        TRANSFER     SBR,CARRL,12
        MSAVEVALUE   1+,P4,P1,1,H
 GIRL   TEST E       BV4,0,TAB
        TRANSFER     SBR,ASIGN,12
        TRANSFER     SBR,HOWRD,12
        TRANSFER     SBR,CARRL,12
        MSAVEVALUE   1+,P4,P1,1,H
        TRANFER      ,GIRL
TAB     SAVEVALUE    P1,V9
        TABULATE     P1
        TERMINATE
      1 TABLE        X1,30,1,100
      2 TABLE        X2,30,1,100
      3 TABLE        X3,30,1,100
      4 TABLE        X4,30,1,100
      5 TABLE        X5,30,1,100
      6 TABLE        X6,30,1,100
      7 TABLE        X7,20,1,100
        START        225,,10
        SAVE
        END
```

APPENDIX B

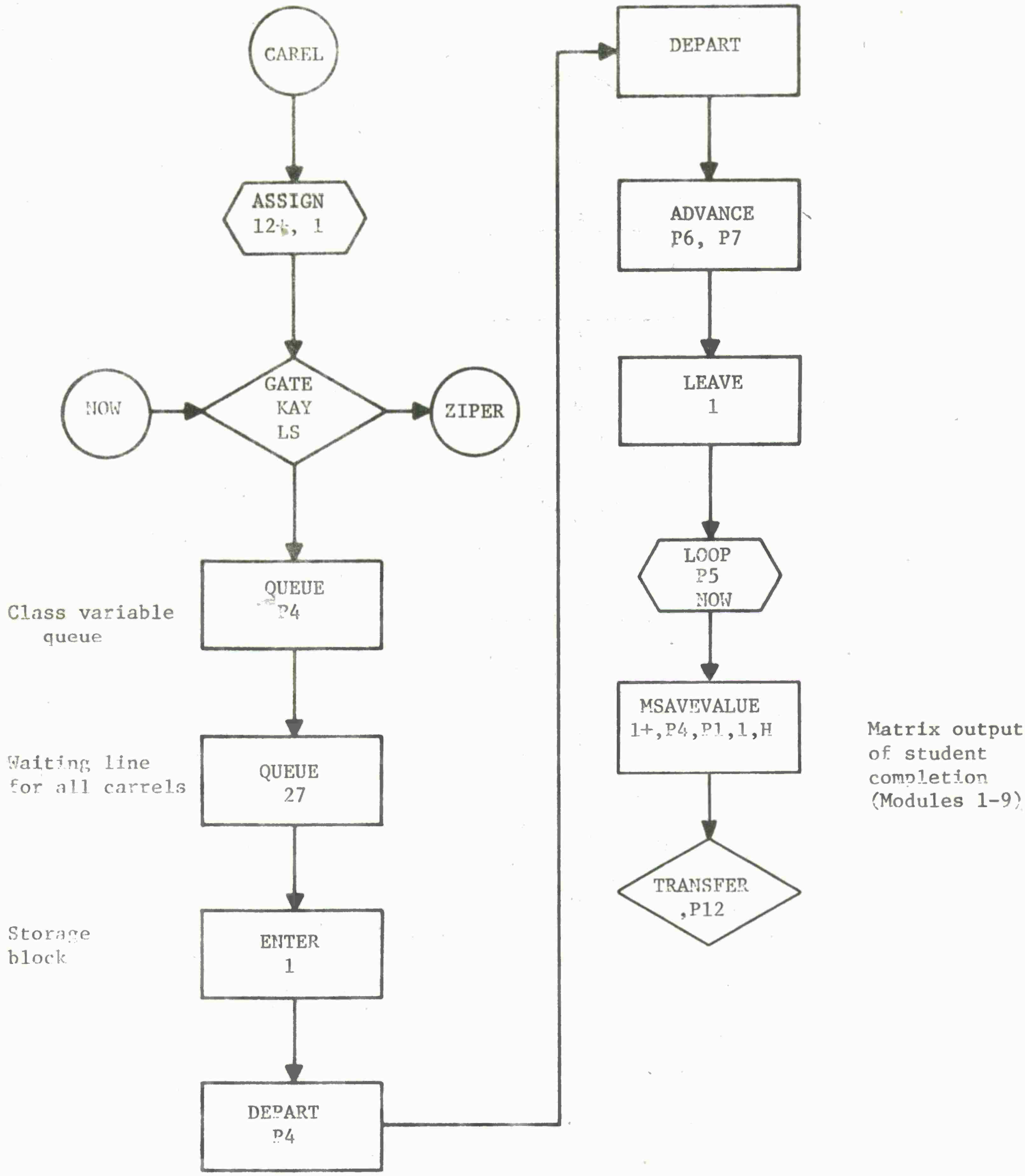

CARRL
ASSIGN 12+,1
WON
GATE KAY LS
ZIPE
Class Variable Queue
QUEUE PA
Waiting line for all carrels
QUEUE 27
Storage block
ENTER 1
DEPART P4
DEPART 27
ADVANCE P6,P7
P6 is time for lesson plan
P7 is time deviate
LEAVE 1
LOOP P9 WON
Number of lesson plans/ class
TRANSFER ,P12
Note: Used only when student is moving from carrel to operational trainer in the same learning module

CARRL (Part 1)

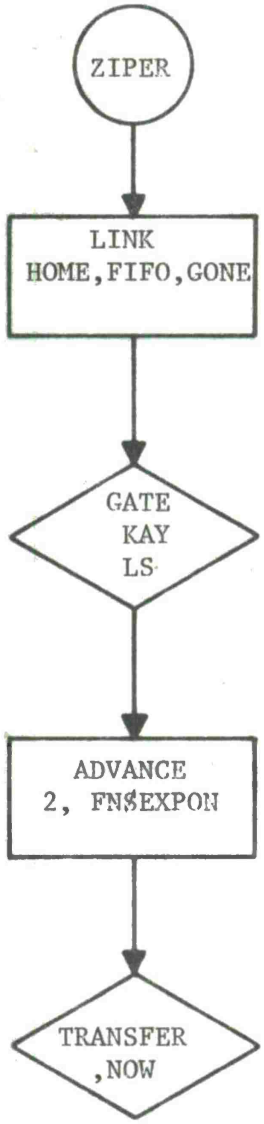


Note: Sends student home at the end of an 8-hour day and returns him to school the next day.

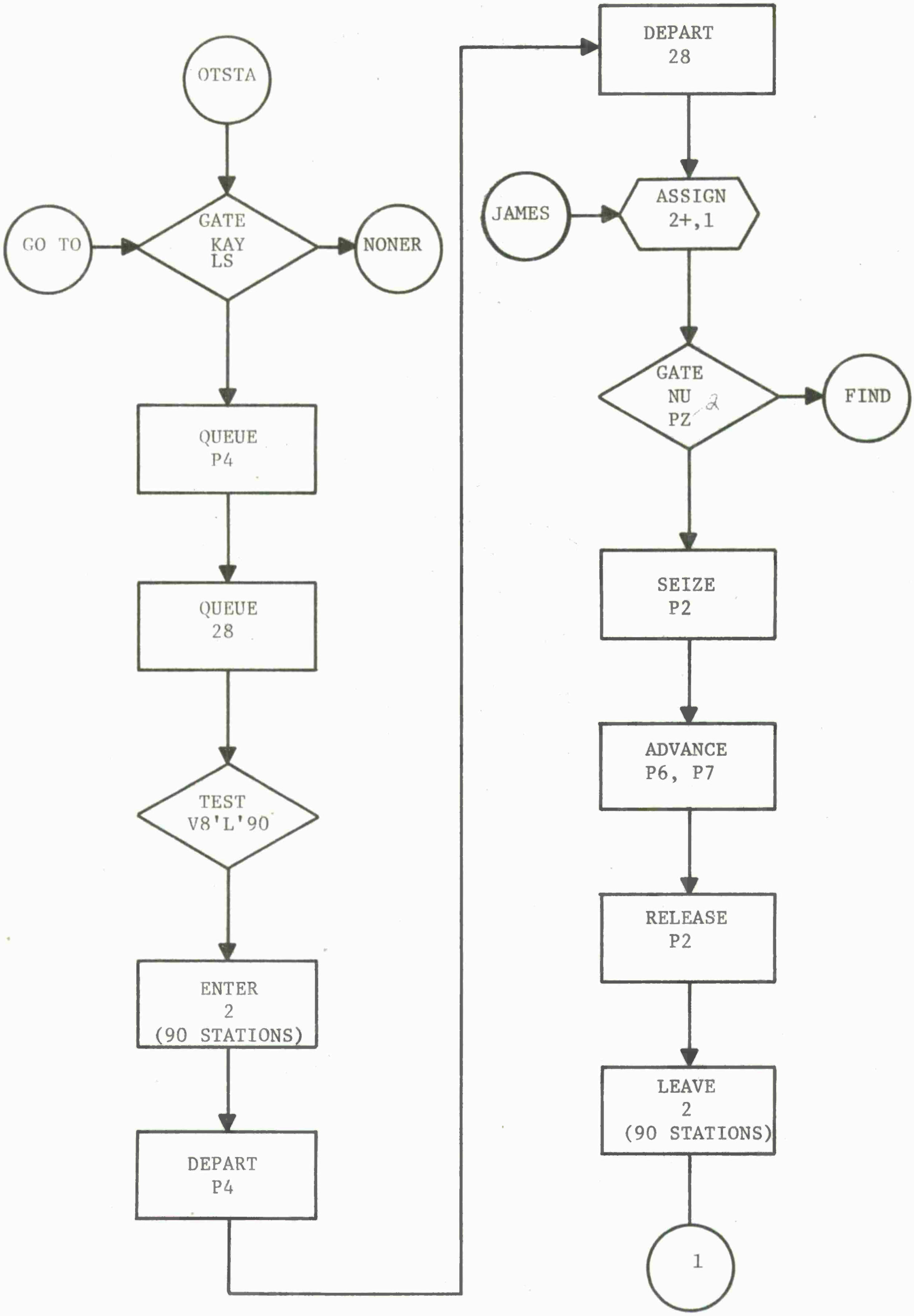
CARRL (Part 2)


CAREL
ASSIGN
12+, 1
NOW
GATE
KAY
LS
ZIPER
Class variable
queue
QUEUE
P4
Waiting line
for all carrels
QUEUE
27
Storage
block
ENTER
1
DEPART
P4
DEPART
ADVANCE
P6, P7
LEAVE
1
LOOP
P5
NOW
MSAVEVALUE
1+,P4,P1,1,H
Matrix output
of student
completion
(Modules 1-9)
TRANSFER
,P12

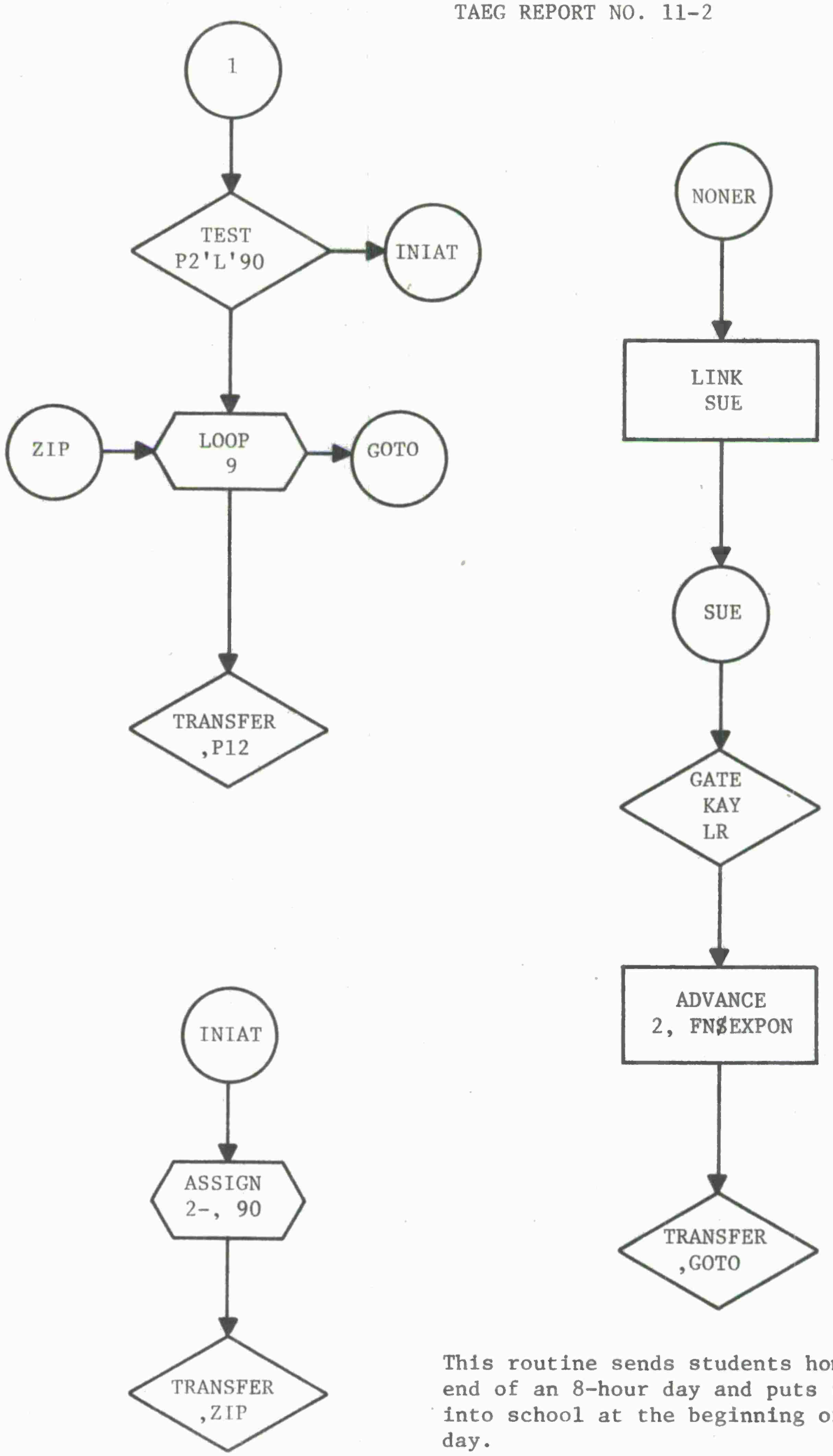
CAREL (Part 1)


ZIPER
LINK
HOME,FIFO,GONE
GATE
KAY
LS
ADVANCE
2, FN$EXPON
TRANSFER
,NOW

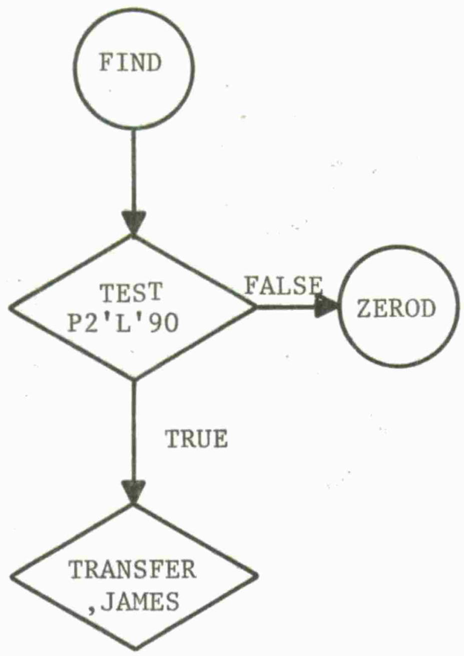
CAREL (PART 2)

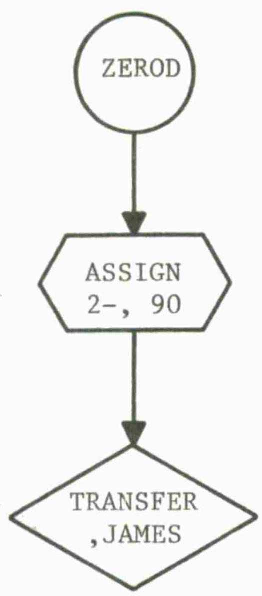


OTSTA (OPERATIONAL TRAINER STATION)
(PART 1)

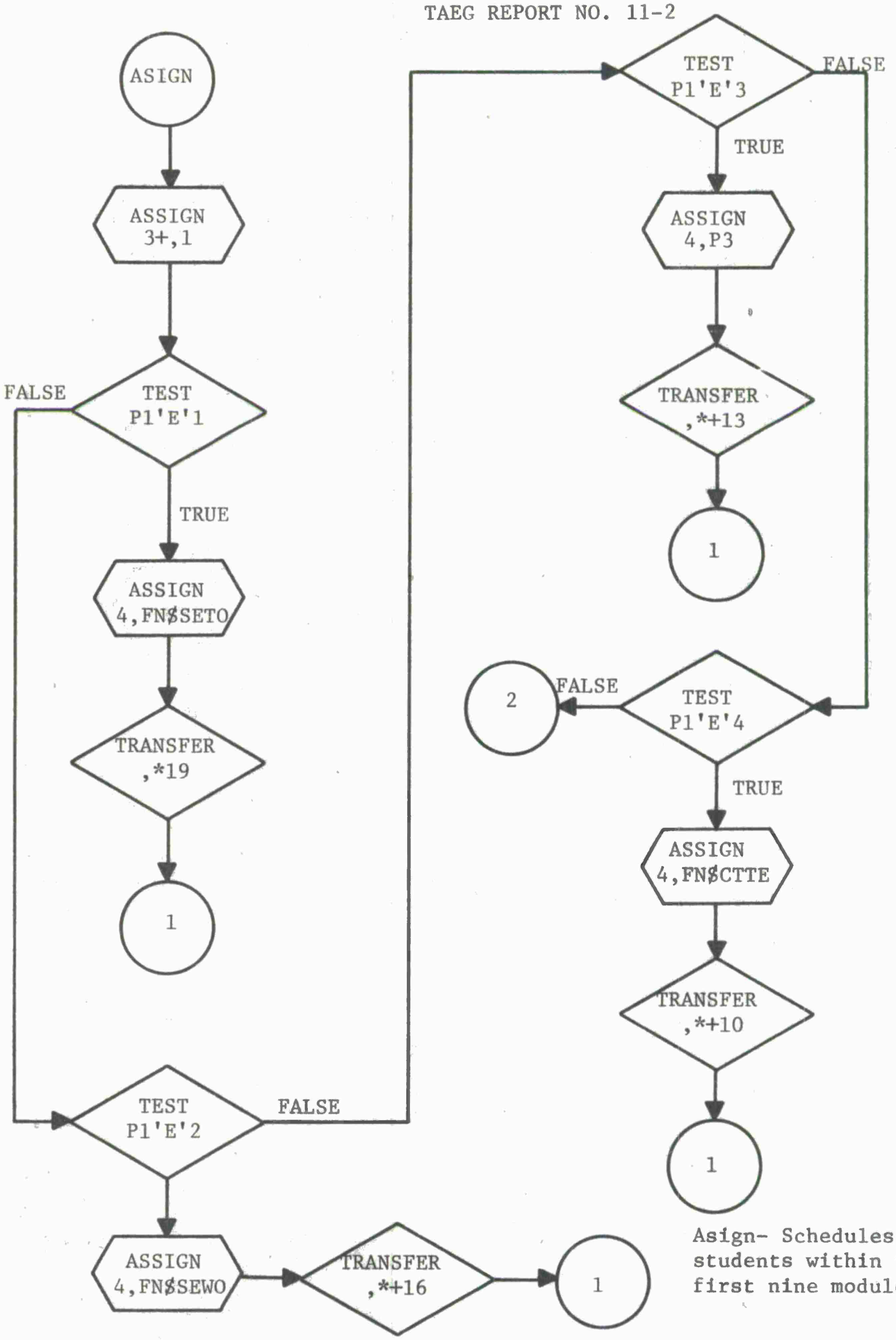


This routine sends students home at the end of an 8-hour day and puts them back into school at the beginning of the next day.


FIND
TEST
P2'L'90
FALSE
ZEROD
TRUE
TRANSFER
,JAMES

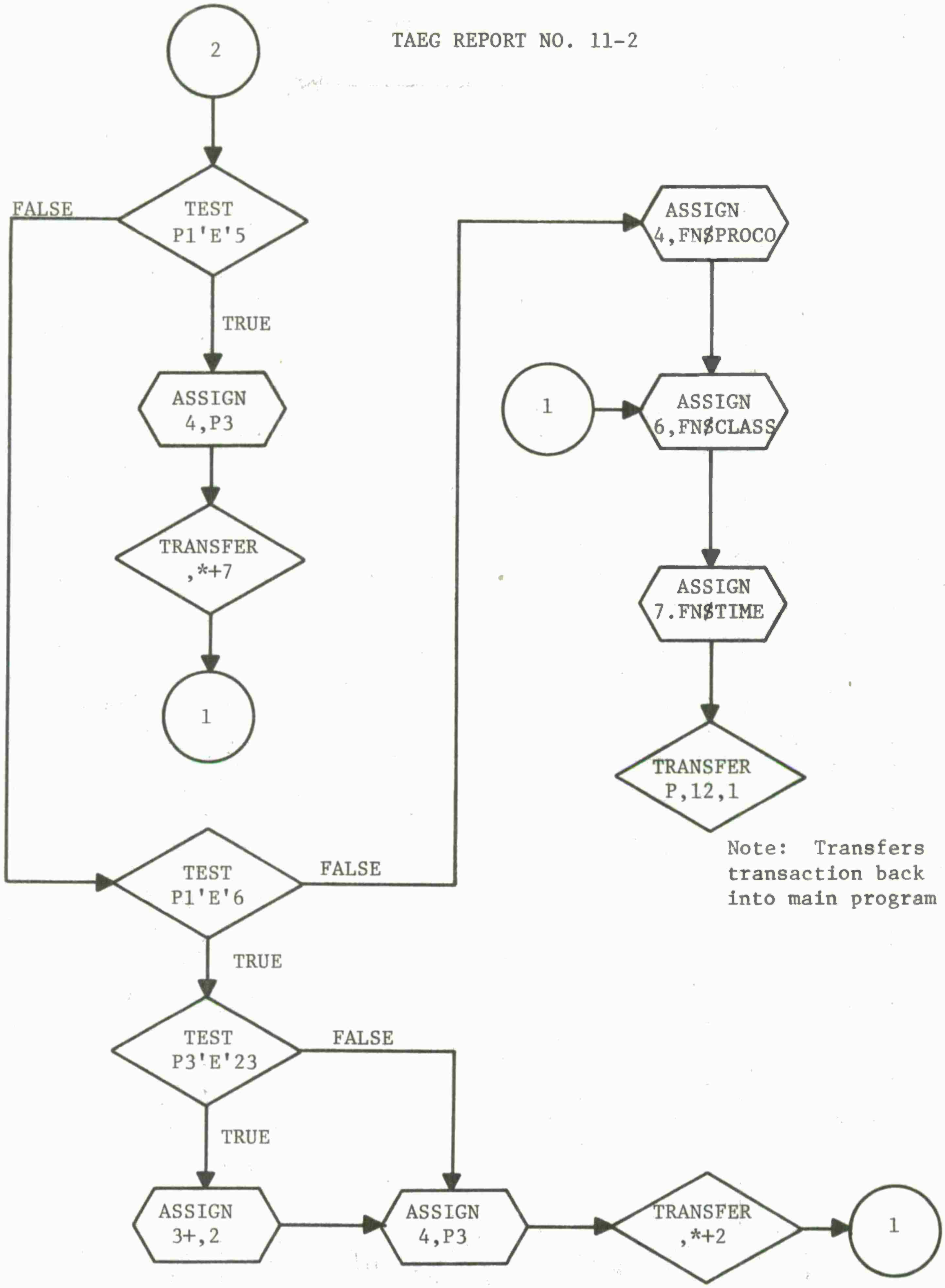

ZEROD
ASSIGN
2-, 90
TRANSFER
,JAMES

OTSTA (PART 3)

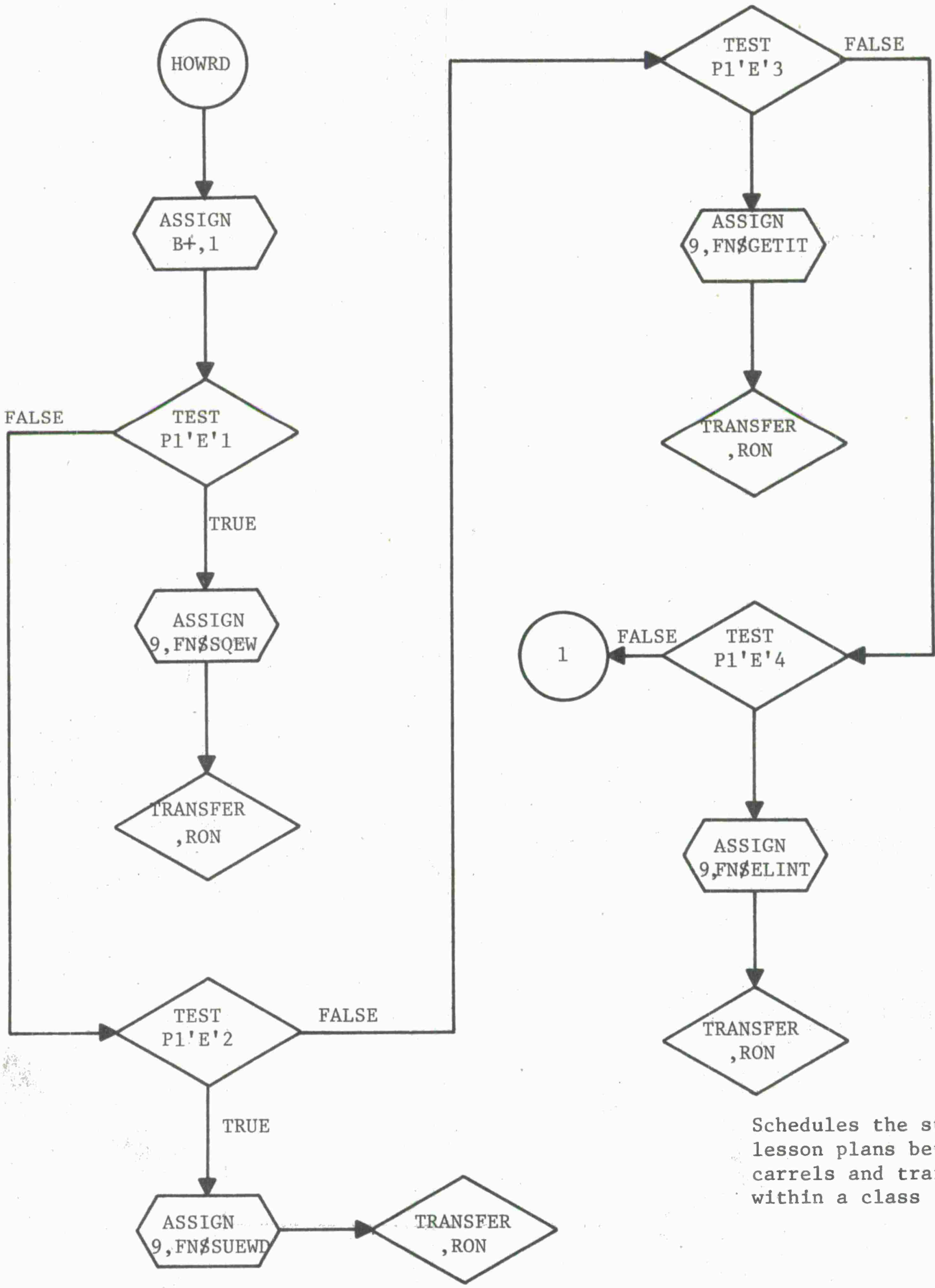


Asign- Schedules students within the first nine modules

ASIGN (PART 1)

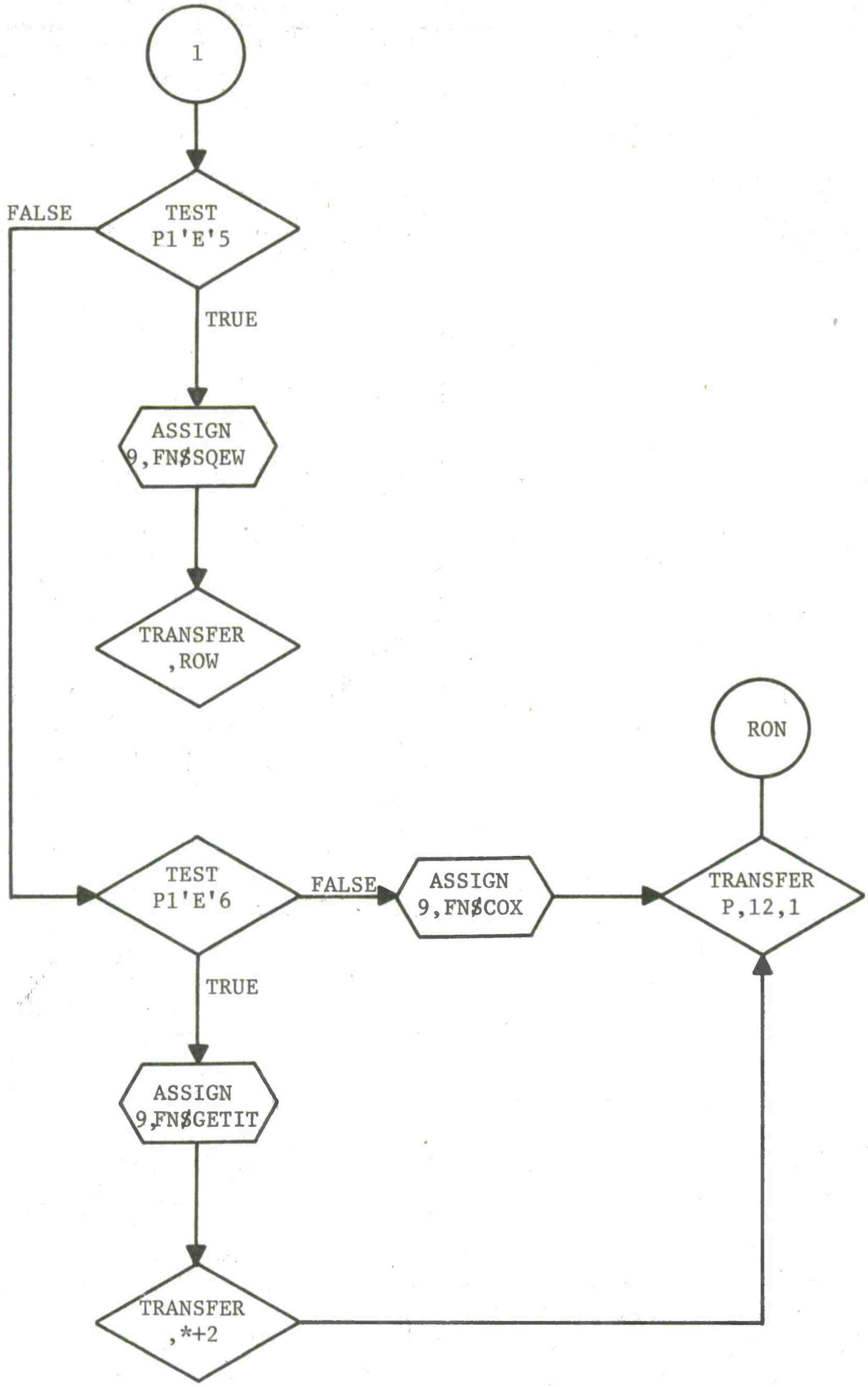

2
TEST
P1'E'5
FALSE
TRUE
ASSIGN
4,P3
TRANSFER
,*+7
1
TEST
P1'E'6
FALSE
TRUE
TEST
P3'E'23
FALSE
TRUE
ASSIGN
3+,2
ASSIGN
4,P3
TRANSFER
,*+2
1
ASSIGN
4,FN$PROCO
1
ASSIGN
6,FN$CLASS
ASSIGN
7.FN$TIME
TRANSFER
P,12,1
Note: Transfers
transaction back
into main program

ASIGN (PART 2)



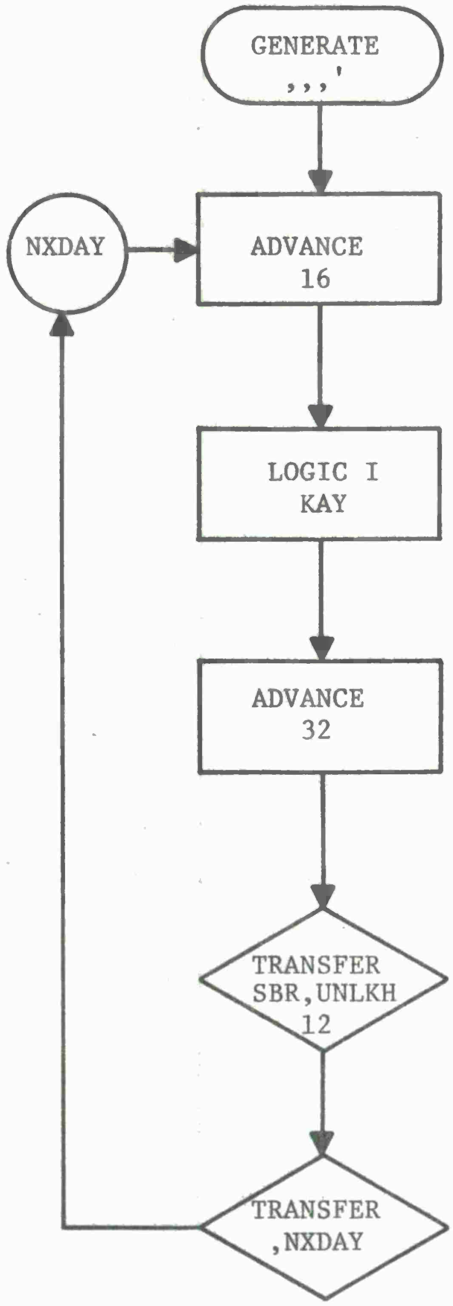
Schedules the student lesson plans between carrels and trainers within a class

HOWRD

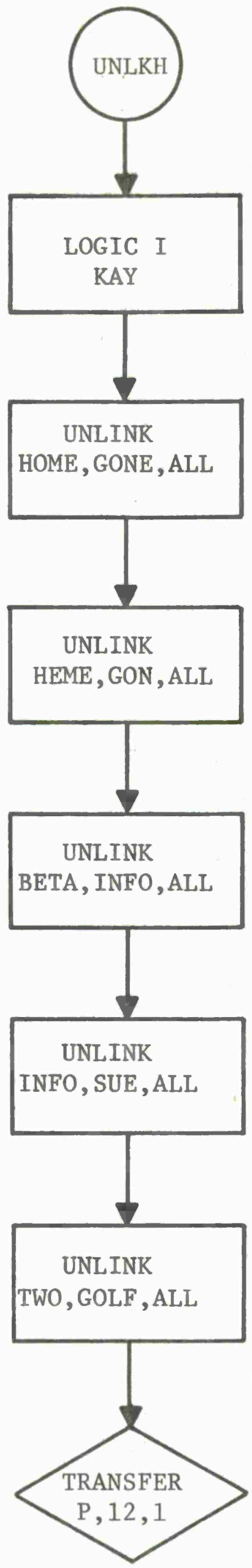

1
FALSE
TEST
P1'E'5
TRUE
ASSIGN
9,FN$SQEW
TRANSFER
,ROW
RON
TEST
P1'E'6
FALSE
ASSIGN
9,FN$COX
TRANSFER
P,12,1
TRUE
ASSIGN
9,FN$GETIT
TRANSFER
,*+2

HOWRD (PART 2)

TIME-ORIENTED PROGRAMS

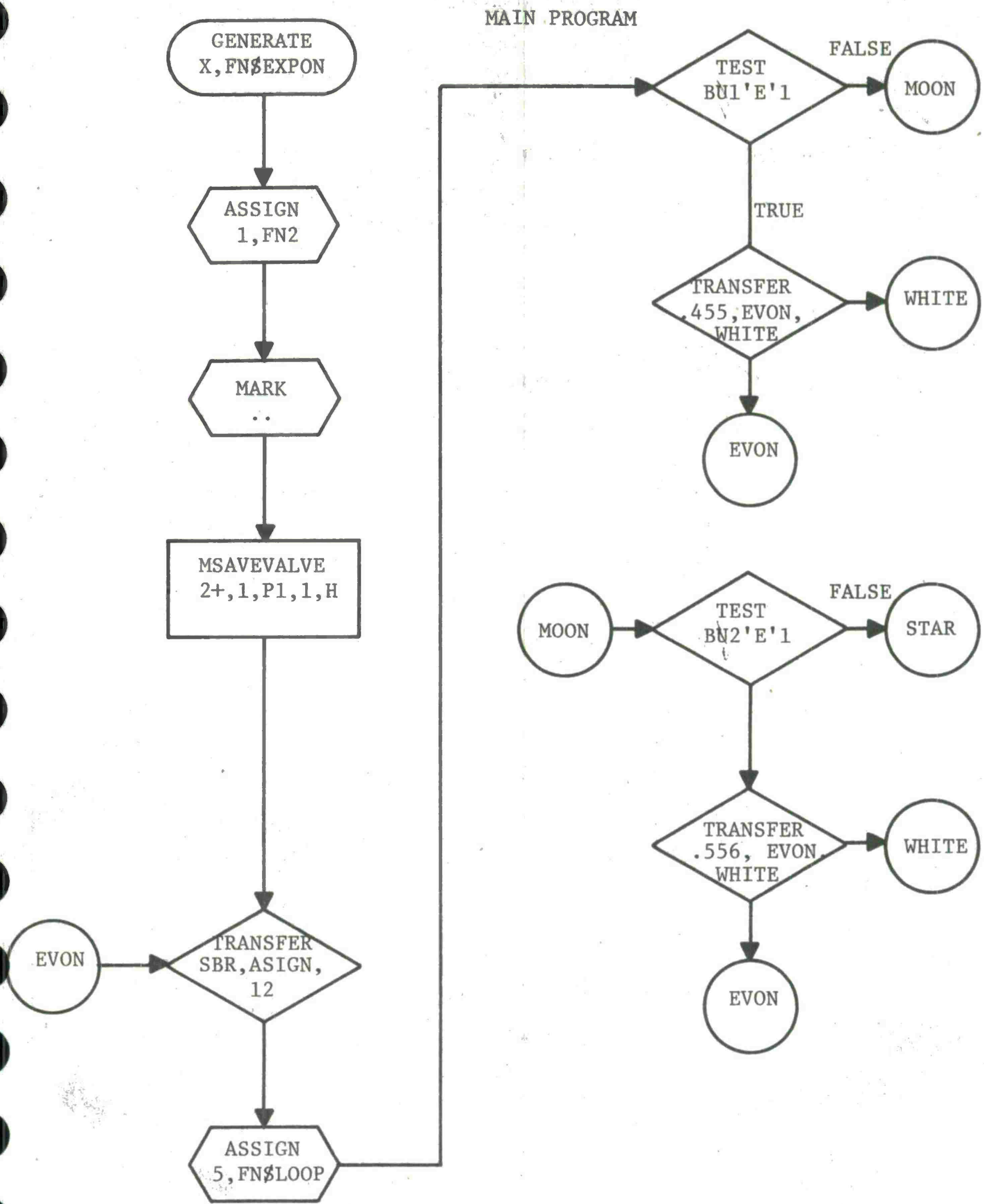


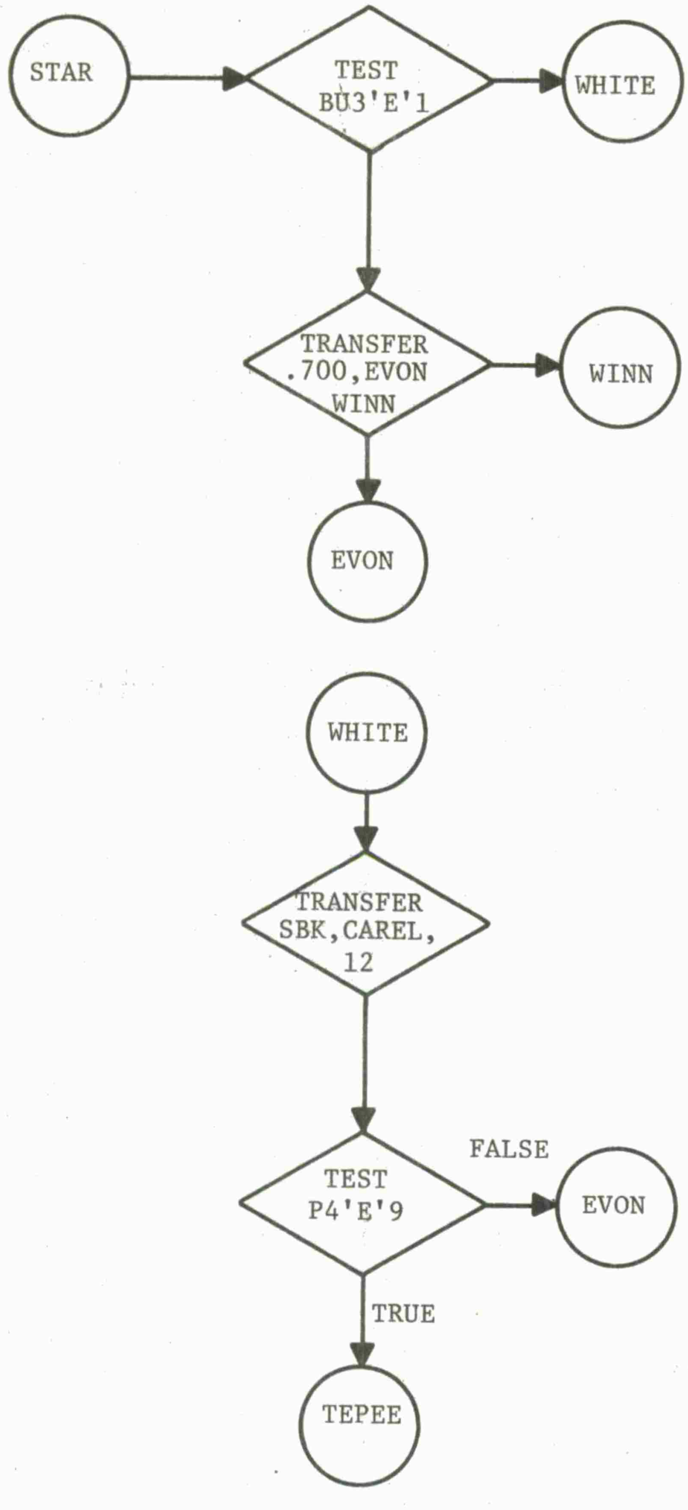
Note: Controls the number of hours for a school day, presently set at 8 hours

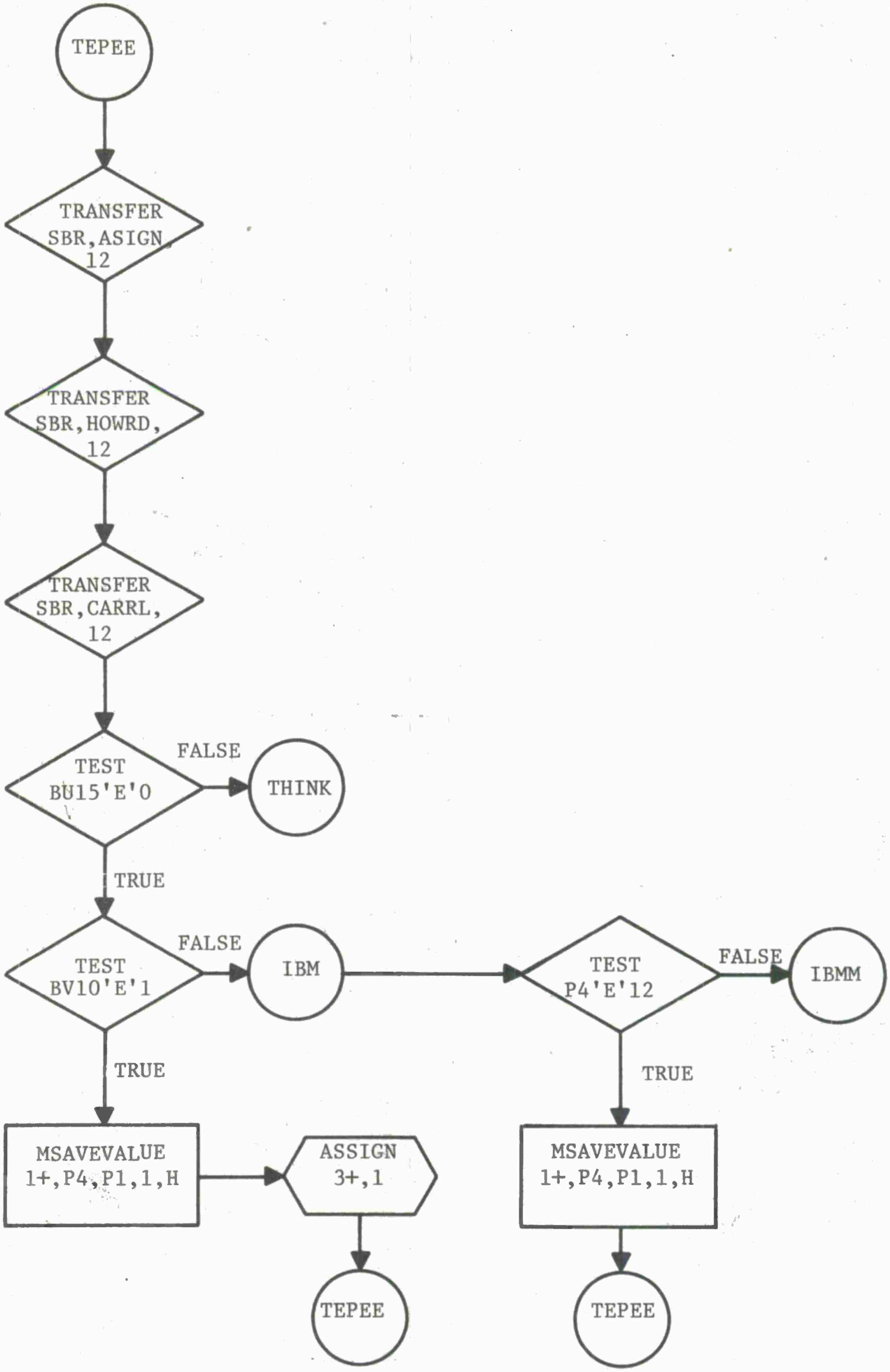


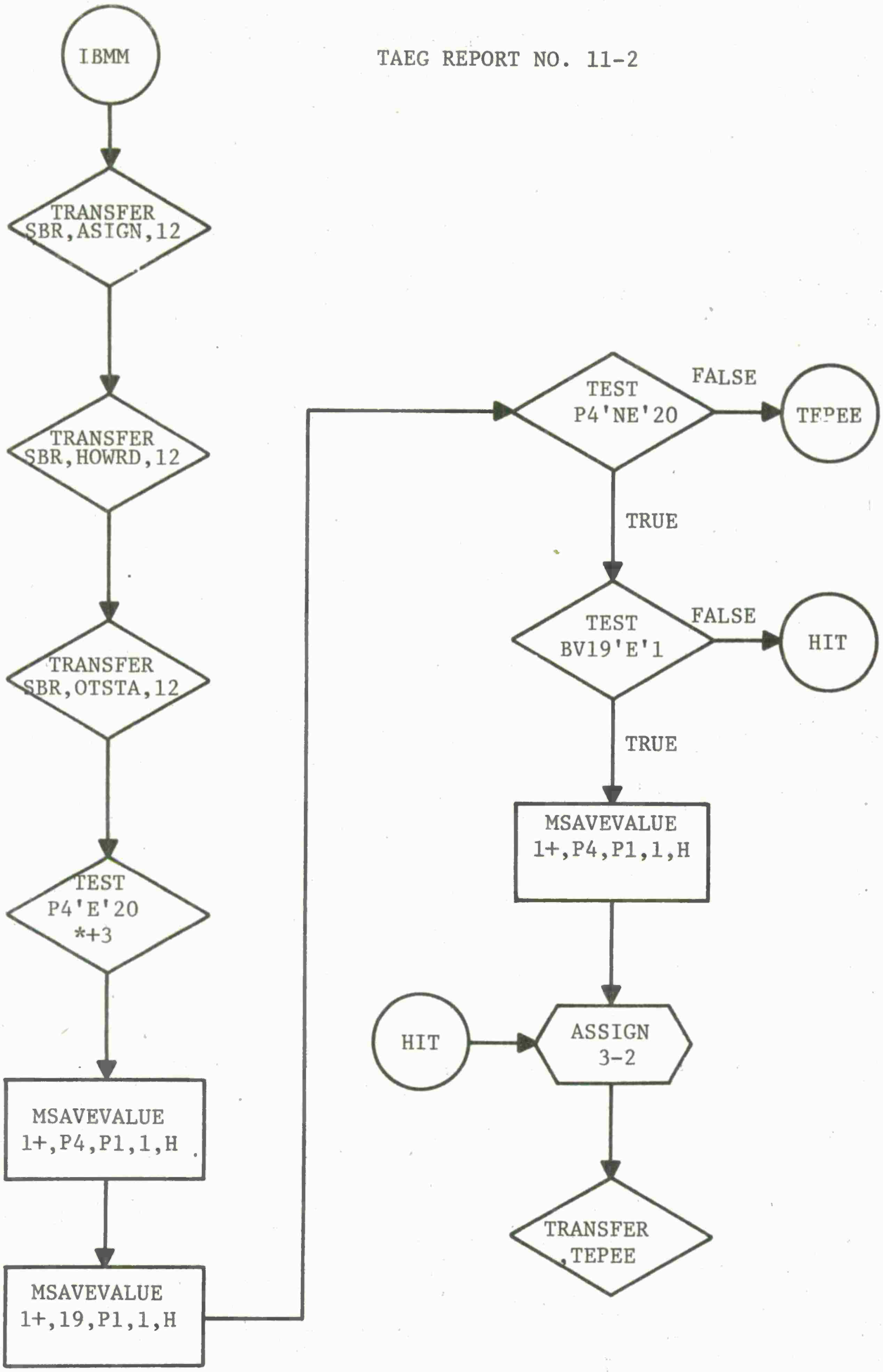
Note: Controls time in training period and number of training periods per day

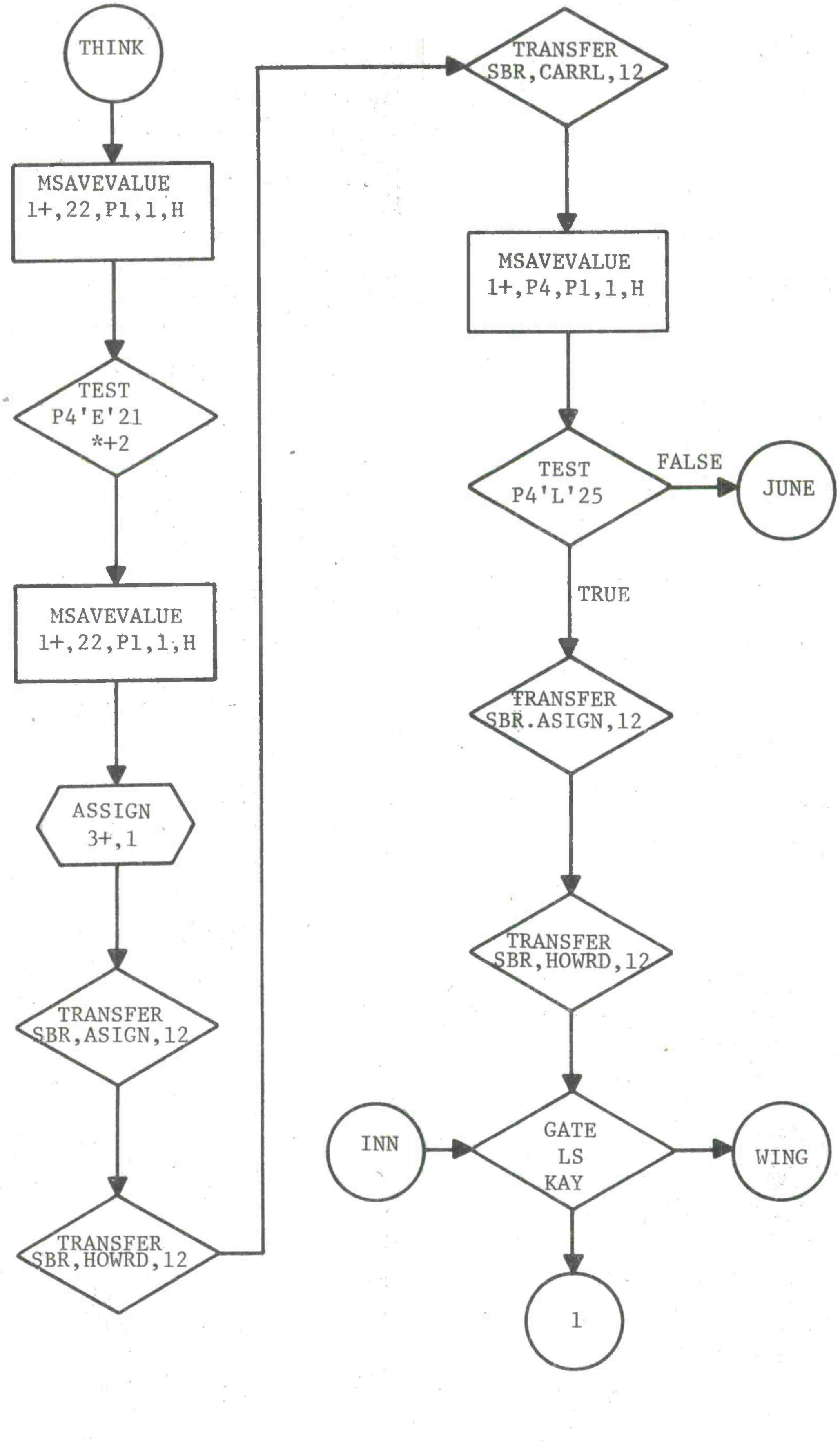
MAIN PROGRAM




STAR
TEST
BU3'E'1
WHITE
TRANSFER
.700,EVON
WINN
WINN
EVON
WHITE
TRANSFER
SBK,CAREL,
12
TEST
P4'E'9
FALSE
EVON
TRUE
TEPEE


TEPEE
TRANSFER SBR,ASIGN, 12
TRANSFER SBR,HOWRD, 12
TRANSFER SBR,CARRL, 12
TEST BU15'E'0
FALSE
THINK
TRUE
TEST BV10'E'1
FALSE
IBM
TEST P4'E'12
FALSE
IBMM
TRUE
TRUE
MSAVEVALUE 1+,P4,P1,1,H
ASSIGN 3+,1
MSAVEVALUE 1+,P4,P1,1,H
TEPEE
TEPEE


IBMM
TRANSFER
SBR,ASIGN,12
TRANSFER
SBR,HOWRD,12
TRANSFER
SBR,OTSTA,12
TEST
P4'E'20
*+3
MSAVEVALUE
1+,P4,P1,1,H
MSAVEVALUE
1+,19,P1,1,H
TEST
P4'NE'20
FALSE
TEPEE
TRUE
TEST
BV19'E'1
FALSE
HIT
TRUE
MSAVEVALUE
1+,P4,P1,1,H
HIT
ASSIGN
3-2
TRANSFER
,TEPEE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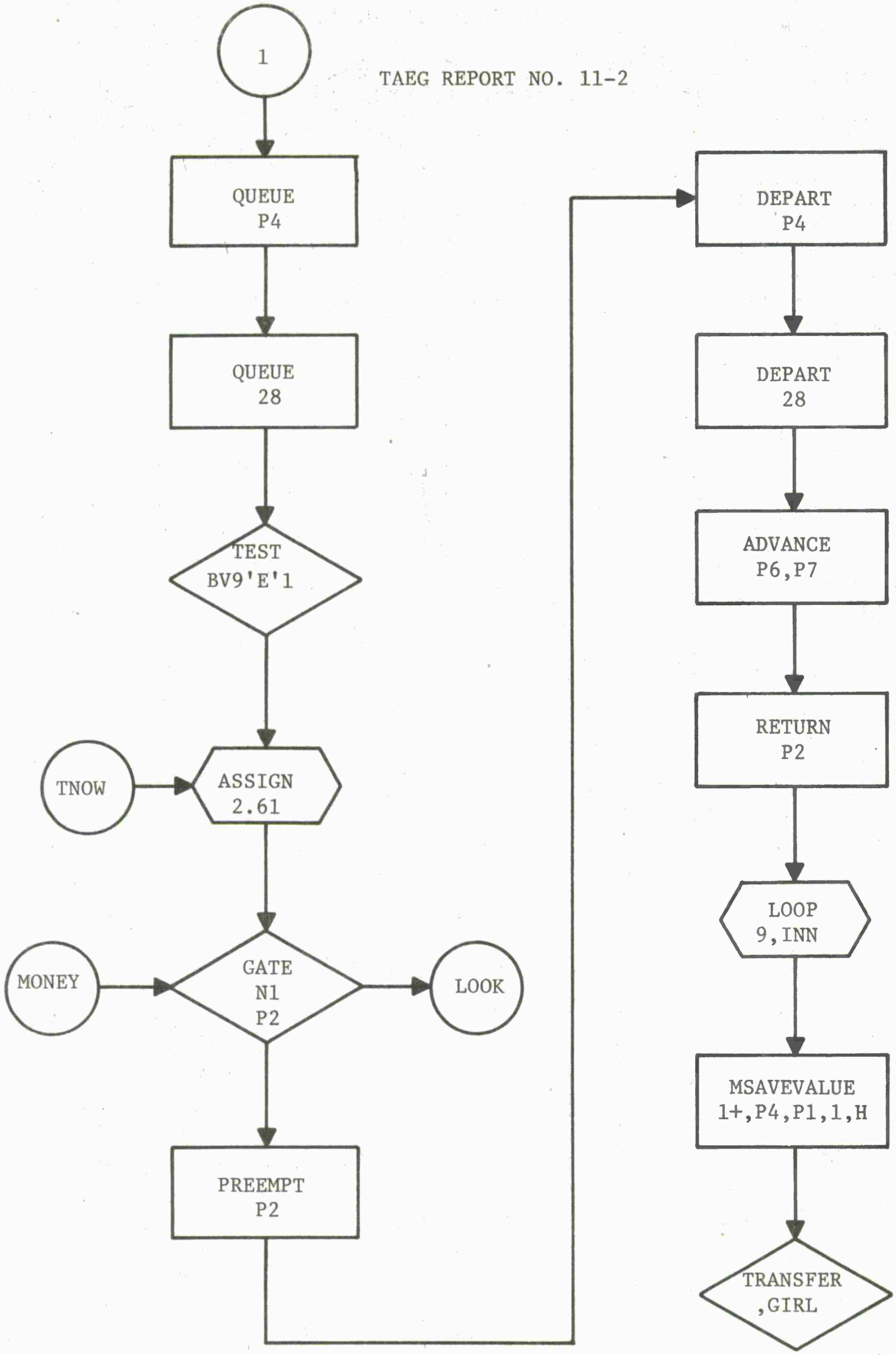
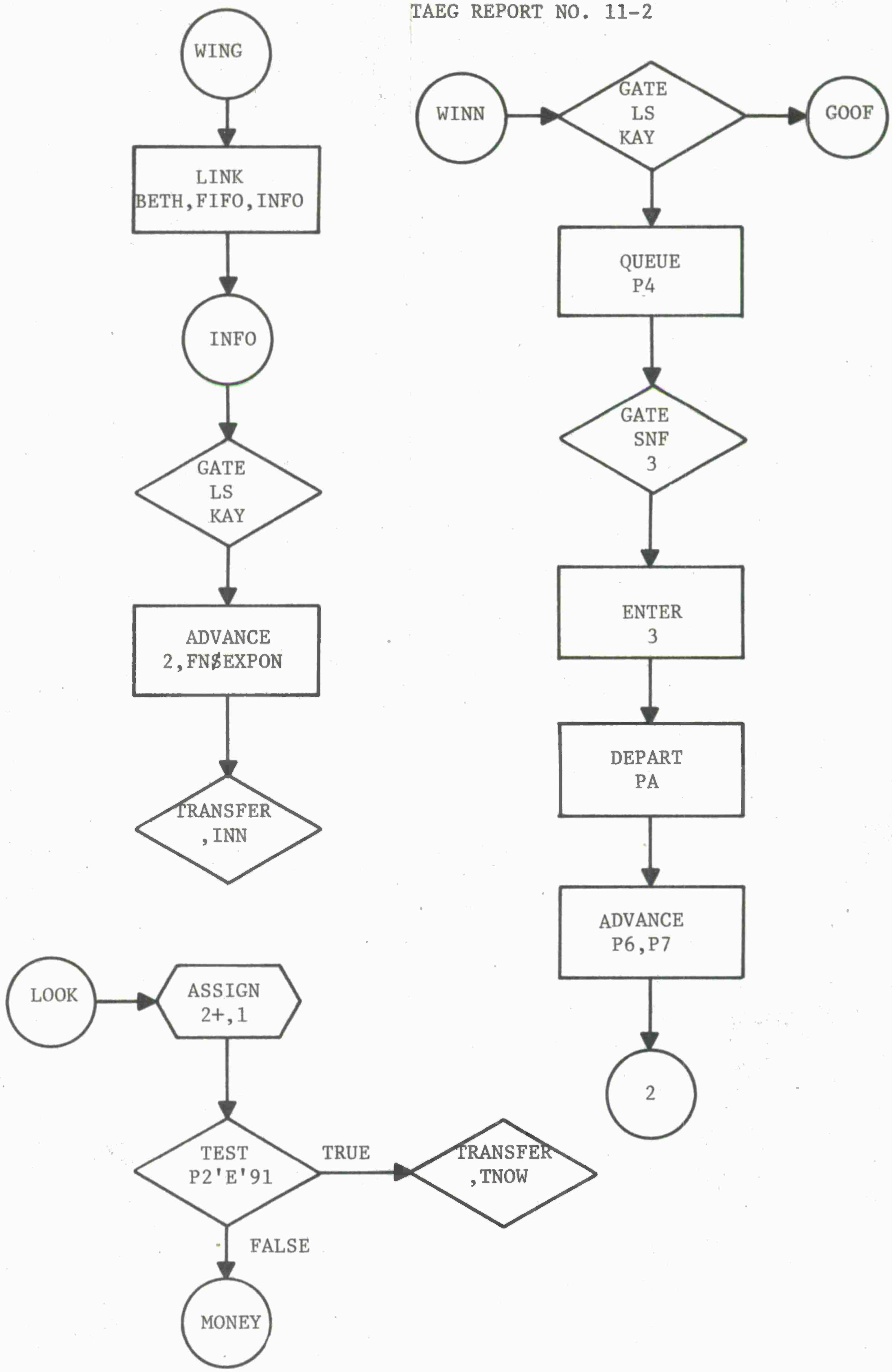
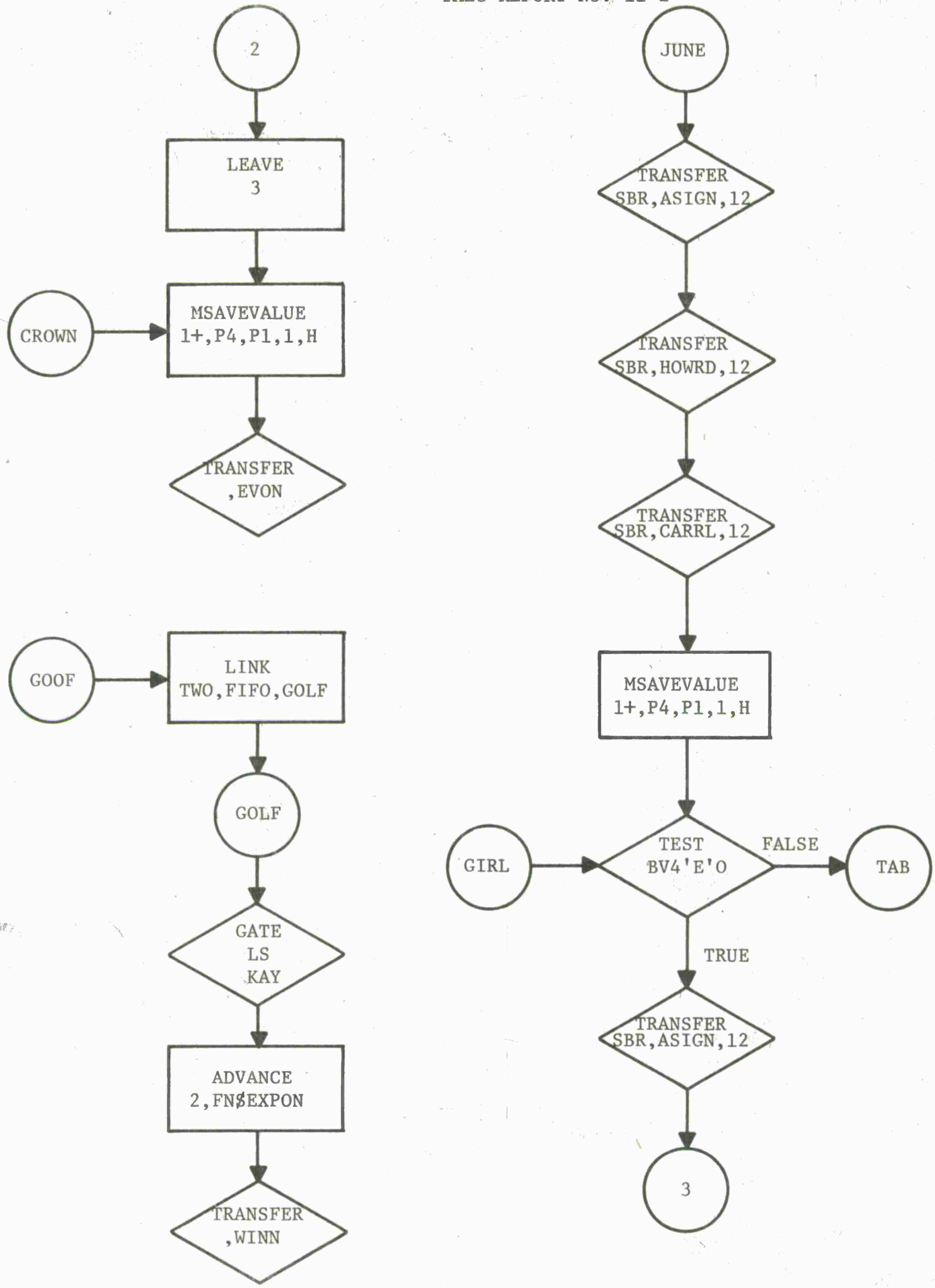
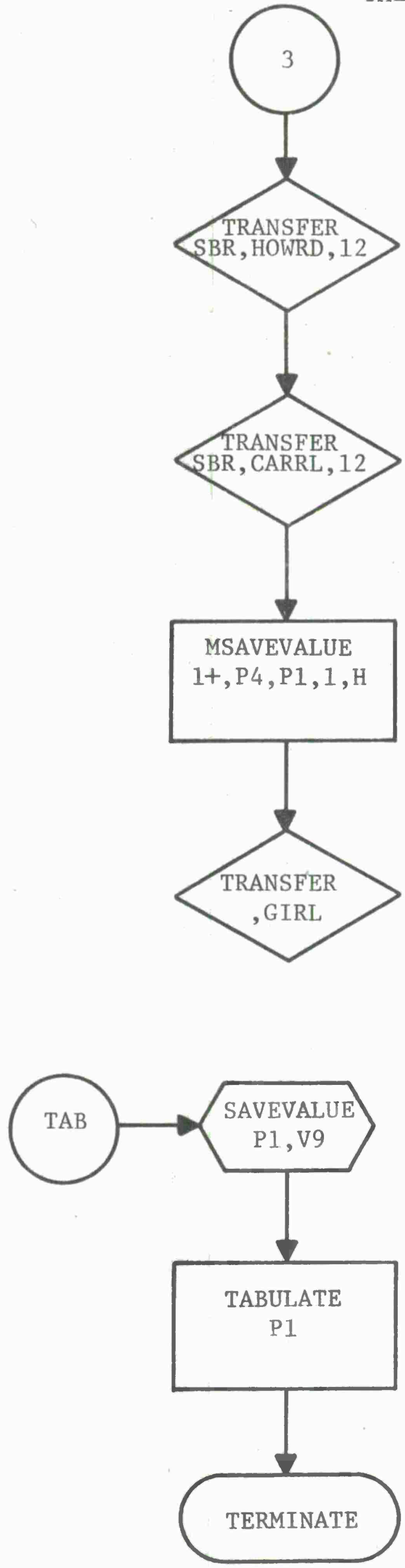
MSAVEVALUE
1+,22,P1,1,H
TEST
P4'E'21
*+2
MSAVEVALUE
1+,22,P1,1,H
ASSIGN
3+,1
TRANSFER
SBR,ASIGN,12
TRANSFER
SBR,HOWRD,12
TRANSFER
SBR,CARRL,12
MSAVEVALUE
1+,P4,P1,1,H
TEST
P4'L'25
FALSE
JUNE
TRUE
TRANSFER
SBR.ASIGN,12
TRANSFER
SBR,HOWRD,12
INN
GATE
LS
KAY
WING
1


1
QUEUE P4
QUEUE 28
TEST BV9'E'1
TNOW
ASSIGN 2.61
MONEY
GATE N1 P2
LOOK
PREEMPT P2
DEPART P4
DEPART 28
ADVANCE P6,P7
RETURN P2
LOOP 9,INN
MSAVEVALUE 1+,P4,P1,1,H
TRANSFER ,GIRL


WING
LINK
BETH,FIFO,INFO
INFO
GATE
LS
KAY
ADVANCE
2,FN$EXPON
TRANSFER
,INN
WINN
GATE
LS
KAY
GOOF
QUEUE
P4
GATE
SNF
3
ENTER
3
DEPART
PA
ADVANCE
P6,P7
2
LOOK
ASSIGN
2+,1
TEST
P2'E'91
TRUE
TRANSFER
,TNOW
FALSE
MONEY


2
LEAVE 3
CROWN
MSAVEVALUE 1+,P4,P1,1,H
TRANSFER ,EVON
GOOF
LINK TWO,FIFO,GOLF
GOLF
GATE LS KAY
ADVANCE 2,FN$EXPON
TRANSFER ,WINN
JUNE
TRANSFER SBR,ASIGN,12
TRANSFER SBR,HOWRD,12
TRANSFER SBR,CARRL,12
MSAVEVALUE 1+,P4,P1,1,H
GIRL
TEST BV4'E'O
FALSE
TAB
TRUE
TRANSFER SBR,ASIGN,12
3


3
TRANSFER
SBR,HOWRD,12
TRANSFER
SBR,CARRL,12
MSAVEVALUE
1+,P4,P1,1,H
TRANSFER
,GIRL
TAB
SAVEVALUE
P1,V9
TABULATE
P1
TERMINATE

APPENDIX C

SAMPLE OUTPUT

INPUT RATE 6 STUDENTS/DAY

FACILITIES

FACILITY	NUMBER ENTRIES	AVERAGE TIME/TRAN	-AVERAGE UTILIZATION DURING- TOTAL TIME	AVAIL. TIME	UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	TRANSACTION NUMBER SEIZING	PREEMPTING
1	224	6.339	.283				100.0	232	
2	226	6.000	.270				100.0	107	
3	212	6.202	.262				100.0	288	
4	225	5.844	.262				100.0	237	
5	208	5.918	.245				100.0	67	
6	205	5.975	.244				100.0	291	
7	211	5.890	.248				100.0		
8	216	5.912	.254				100.0	85	
9	199	5.989	.238				100.0		
10	206	5.645	.232				100.0	86	
11	207	5.816	.240				100.0	102	
12	201	6.039	.242				100.0		
13	202	5.836	.235				100.0	246	
14	205	5.736	.234				100.0	229	
15	201	6.004	.241				100.0		
16	196	5.882	.230				100.0	115	
17	195	6.071	.236				100.0	157	
18	204	5.691	.231				100.0	174	
19	199	6.035	.239				100.0	220	
20	185	6.113	.225				100.0	207	
21	192	5.776	.221				100.0	182	
22	189	5.830	.220				100.0	285	
23	190	6.063	.230				100.0	24	
24	190	5.915	.224				100.0	163	
25	191	5.842	.222				100.0	139	
26	186	5.881	.218				100.0	150	
27	183	5.956	.217				100.0		
28	181	6.348	.229				100.0	42	
29	184	5.668	.208				100.0	87	
30	183	5.972	.218				100.0	131	
31	182	5.846	.212				100.0	99	
32	191	5.900	.225				100.0	93	
33	184	5.929	.217				100.0	22	
34	187	6.155	.229				100.0	178	
35	187	5.898	.220				100.0	281	
36	174	5.965	.207				100.0		
37	179	5.787	.206				100.0		
38	170	6.594	.223				100.0	68	
39	180	6.038	.217				100.0	226	
40	171	6.374	.217				100.0		
41	166	6.433	.213				100.0	284	
42	179	6.312	.225				100.0	204	
43	178	6.264	.222				100.0	236	
44	180	6.061	.217				100.0	196	
45	170	6.205	.210				100.0	64	
46	165	6.042	.199				100.0	239	
47	167	5.892	.196				100.0	141	
48	163	5.981	.194				100.0	179	
49	163	6.368	.207				100.0	156	
50	172	5.982	.205				100.0	46	
51	165	5.830	.192				100.0	305	

STORAGES

STORAGE	CAPACITY	AVERAGE CONTENTS	ENTRIES	AVERAGE TIME/UNIT	-AVERAGE UTILIZATION DURING- TOTAL TIME	AVAIL. TIME	UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	CURRENT CONTENTS	MAXIMUM CONTENTS
1	220	56.066	77401	3.627	.254				100.0	220	220
2	90	18.627	15586	5.985	.206				100.0	72	90
3	50	1.196	356	16.834	.023				100.0	5	7

QUEUES

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
1	1	.002	283	278	98.2	.038	2.199		
2	3	.003	6989	6979	99.8	.002	1.599		
3	4	.003	9742	9729	99.8	.001	1.307		
4	3	.000	5195	5193	99.9	.000	1.500		
5	1	.000	356	356	100.0	.000	.000		
6	2	.000	2408	2405	99.8	.002	1.666		
7	2	.000	1790	1789	99.9	.000	1.000		
8	2	.001	9358	9353	99.9	.000	1.399		
9	5	.002	7458	7448	99.8	.001	1.199		
10	21	.108	9818	9462	96.3	.055	1.519		8
11	7	.015	5885	5827	99.0	.013	1.327		
12	2	.001	10132	10126	99.9	.000	1.166		
13	3	.001	2335	2327	99.6	.003	1.125		
14	2	.000	466	464	99.5	.004	1.000		
15	4	.006	1489	1463	98.2	.022	1.307		
16	2	.000	1472	1471	99.9	.002	3.000		
17	11	.063	4297	4087	95.1	.074	1.514		2
18	5	.003	2974	2960	99.5	.006	1.357		
19	2	.000	1353	1352	99.9	.000	1.000		
20	2	.001	1325	1320	99.6	.006	1.599		
21	7	.037	2313	2185	94.4	.081	1.476		2
22	4	.001	3464	3459	99.8	.002	2.000		
23	1	.000	96	96	100.0	.000	.000		
24	1	.000	235	235	100.0	.000	.000		
25	3	.002	836	825	98.6	.016	1.272		1
26	3	.001	1522	1515	99.5	.004	1.000		
27	37	.238	77414	76612	98.9	.015	1.486		13
28	15	.023	15821	15736	99.4	.007	1.399		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

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*****************************************
*                                       *
*               TABLES                  *
*                                       *
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TABLE 1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
	37.428	1.015	524.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.801	-7.314
31	0	.00	.0	100.0	.828	-6.329
32	0	.00	.0	100.0	.854	-5.345
33	0	.00	.0	100.0	.881	-4.360
34	0	.00	.0	100.0	.908	-3.375
35	0	.00	.0	100.0	.935	-2.391
36	3	21.42	21.4	78.5	.961	-1.406
37	4	28.57	49.9	50.0	.988	-.421
38	5	35.71	85.7	14.2	1.015	.562
39	2	14.28	100.0	.0	1.041	1.547

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
	36.590	1.097	805.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.819	-6.004
31	0	.00	.0	100.0	.847	-5.093
32	0	.00	.0	100.0	.874	-4.182
33	0	.00	.0	100.0	.901	-3.271
34	0	.00	.0	100.0	.929	-2.360
35	4	18.18	18.1	81.8	.956	-1.449
36	6	27.27	45.4	54.5	.983	-.538
37	8	36.36	81.8	18.1	1.011	.372
38	3	13.63	95.4	4.5	1.038	1.283
39	1	4.54	100.0	.0	1.065	2.194

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
	49.166	3.652	295.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.610	-5.247
31	0	.00	.0	100.0	.630	-4.973
32	0	.00	.0	100.0	.650	-4.700
33	0	.00	.0	100.0	.671	-4.426
34	0	.00	.0	100.0	.691	-4.152
35	0	.00	.0	100.0	.711	-3.878
36	0	.00	.0	100.0	.732	-3.604
37	0	.00	.0	100.0	.752	-3.331
38	0	.00	.0	100.0	.772	-3.057
39	0	.00	.0	100.0	.793	-2.783
40	0	.00	.0	100.0	.813	-2.509
41	0	.00	.0	100.0	.833	-2.236
42	0	.00	.0	100.0	.854	-1.962
43	0	.00	.0	100.0	.874	-1.688
44	0	.00	.0	100.0	.894	-1.414
45	1	16.66	16.6	83.3	.915	-1.140
46	1	16.66	33.3	66.6	.935	-.867
47	1	16.66	49.9	50.0	.955	-.593
48	0	.00	49.9	50.0	.976	-.319
49	0	.00	49.9	50.0	.996	-.045
50	0	.00	49.9	50.0	1.016	.228
51	1	16.66	66.6	33.3	1.037	.501
52	1	16.66	83.3	16.6	1.057	.775
53	0	.00	83.3	16.6	1.077	1.049
54	1	16.66	100.0	.0	1.098	1.323

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	NON-WEIGHTED
	44.000	3.613	704.000	

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.681	-3.874
31	0	.00	.0	100.0	.704	-3.597
32	0	.00	.0	100.0	.727	-3.321
33	0	.00	.0	100.0	.750	-3.044
34	0	.00	.0	100.0	.772	-2.767
35	0	.00	.0	100.0	.795	-2.490
36	0	.00	.0	100.0	.818	-2.214
37	0	.00	.0	100.0	.840	-1.937
38	0	.00	.0	100.0	.863	-1.660
39	0	.00	.0	100.0	.886	-1.383
40	3	18.75	18.7	81.2	.909	-1.107
41	1	6.25	25.0	75.0	.931	-.830
42	4	25.00	50.0	50.0	.954	-.553
43	1	6.25	56.2	43.7	.977	-.276
44	1	6.25	62.5	37.5	1.000	-.000
45	1	6.25	68.7	31.2	1.022	.276
46	0	.00	68.7	31.2	1.045	.553
47	1	6.25	75.0	25.0	1.068	.830
48	3	18.75	93.7	6.2	1.090	1.107
49	0	.00	93.7	6.2	1.113	1.383
50	0	.00	93.7	6.2	1.136	1.660
51	0	.00	93.7	6.2	1.159	1.937
52	1	6.25	100.0	.0	1.181	2.214

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 5

ENTRIES IN TABLE		MEAN ARGUMENT		STANDARD DEVIATION	SUM OF ARGUMENTS	
		53.375		1.921	427.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.562	-12.162
31	0	.00	.0	100.0	.580	-11.642
32	0	.00	.0	100.0	.599	-11.121
33	0	.00	.0	100.0	.618	-10.601
34	0	.00	.0	100.0	.637	-10.081
35	0	.00	.0	100.0	.655	-9.560
36	0	.00	.0	100.0	.674	-9.040
37	0	.00	.0	100.0	.693	-8.520
38	0	.00	.0	100.0	.711	-8.000
39	0	.00	.0	100.0	.730	-7.479
40	0	.00	.0	100.0	.749	-6.959
41	0	.00	.0	100.0	.768	-6.439
42	0	.00	.0	100.0	.786	-5.918
43	0	.00	.0	100.0	.805	-5.398
44	0	.00	.0	100.0	.824	-4.878
45	0	.00	.0	100.0	.843	-4.357
46	0	.00	.0	100.0	.861	-3.837
47	0	.00	.0	100.0	.880	-3.317
48	0	.00	.0	100.0	.899	-2.796
49	0	.00	.0	100.0	.918	-2.276
50	0	.00	.0	100.0	.936	-1.756
51	1	12.50	12.5	87.5	.955	-1.235
52	2	25.00	37.5	62.5	.974	-.715
53	2	25.00	62.5	37.5	.992	-.195
54	1	12.50	75.0	25.0	1.011	.325
55	1	12.50	87.5	12.5	1.030	.845
56	0	.00	87.5	12.5	1.049	1.365
57	1	12.50	100.0	.0	1.067	1.886

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 6

ENTRIES IN TABLE | MEAN ARGUMENT 47.438 | STANDARD DEVIATION 3.109 | SUM OF ARGUMENTS 12429.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
30	0	.00	.0	100.0	.632	-5.608
31	0	.00	.0	100.0	.653	-5.286
32	0	.00	.0	100.0	.674	-4.965
33	0	.00	.0	100.0	.695	-4.643
34	0	.00	.0	100.0	.716	-4.322
35	0	.00	.0	100.0	.737	-4.000
36	0	.00	.0	100.0	.758	-3.678
37	0	.00	.0	100.0	.779	-3.357
38	0	.00	.0	100.0	.801	-3.035
39	0	.00	.0	100.0	.822	-2.714
40	0	.00	.0	100.0	.843	-2.392
41	0	.00	.0	100.0	.864	-2.070
42	9	3.43	3.4	96.5	.885	-1.749
43	18	6.87	10.3	89.6	.906	-1.427
44	31	11.83	22.1	77.8	.927	-1.105
45	40	15.26	37.4	62.5	.948	-.784
46	20	7.63	45.0	54.9	.969	-.462
47	11	4.19	49.2	50.7	.990	-.141
48	17	6.48	55.7	44.2	1.011	.180
49	24	9.16	64.8	35.1	1.032	.502
50	36	13.74	78.6	21.3	1.053	.823
51	37	14.12	92.7	7.2	1.075	1.145
52	11	4.19	96.9	3.0	1.096	1.466
53	7	2.67	99.6	.3	1.117	1.788
54	1	.38	100.0	.0	1.138	2.110

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 7

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
	22.161	1.097	687.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
20	1	3.22	3.2	96.7	.902	-1.968
21	9	29.03	32.2	67.7	.947	-1.057
22	8	25.80	58.0	41.9	.992	-.146
23	11	35.48	93.5	6.4	1.037	.764
24	1	3.22	96.7	3.2	1.082	1.675
25	1	3.22	100.0	.0	1.128	2.586

REMAINING FREQUENCIES ARE ALL ZERO

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*************************************
*                                   *
*         HALFWORD MATRICES         *
*                                   *
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HALFWORD MATRIX 1

ROW/COLUMN	1	2	3	4	5	6	7
1	0	0	4	14	21	244	0
2	0	0	7	11	20	267	0
3	0	29	14	22	19	479	0
4	20	29	14	22	19	466	0
5	0	0	7	0	17	327	0
6	20	28	13	22	19	458	38
7	20	28	13	22	18	454	38
8	20	0	12	22	18	443	0
9	18	28	12	21	18	426	37
10	17	26	11	19	14	368	0
11	17	26	11	19	14	370	0
12	17	26	11	18	14	350	37
13	17	24	9	17	14	336	37
14	17	24	9	17	14	338	37
15	0	0	9	17	12	326	0
16	0	0	9	17	12	326	0
17	16	23	8	16	12	304	34
18	16	23	8	16	12	307	34
19	16	0	7	0	11	292	0
20	16	0	7	0	11	292	0
21	15	22	7	16	10	269	31
22	15	22	7	16	10	269	31
23	0	0	7	0	9	0	31
24	0	0	7	0	9	0	31
25	15	22	6	16	9	266	31
26	14	22	6	16	8	262	0

ROWS 27-28, COLUMNS 1-7 ARE ZERO