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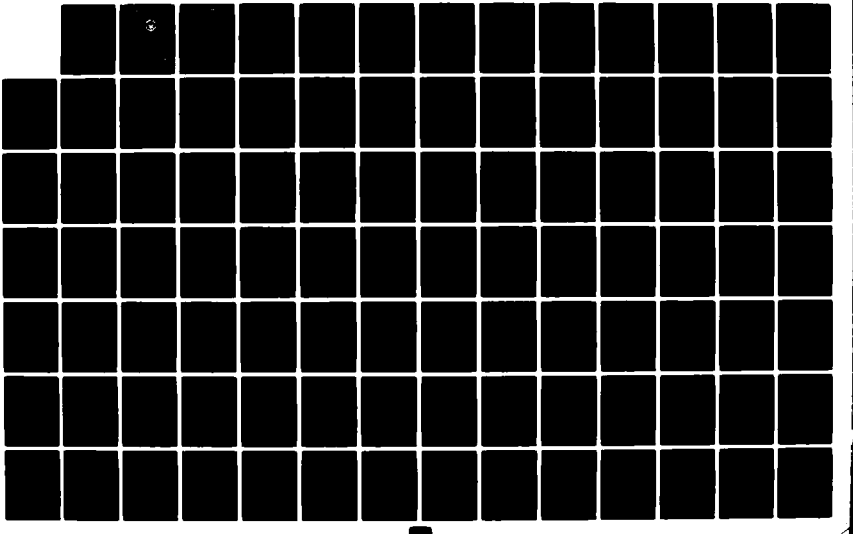

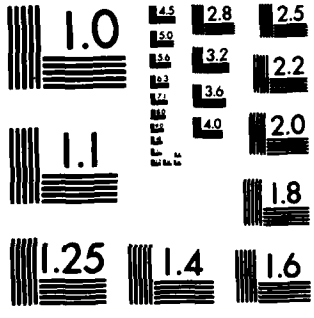

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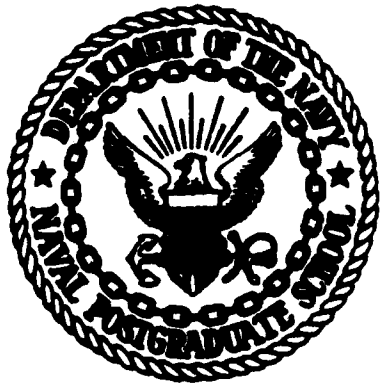

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A SIMULATION MODEL DEPICTING FLEET EXPANSION EFFECTS ON THE FIRE CONTROL TECHNICIANS TRAINING PIPELINE

by

Larry W. Nelms

and

Jeffrey T. Smith

June 1982

Advisor: R. S. Elster

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This thesis is a study of the training pipelines for the Navy's fire control technician ratings during projected fleet expansion to 600-plus ships by 1990. Yearly manning requirements for the FTM, FTG, and FTG(SS) ratings were identified. FTG and FTM transition flow matrices based upon 1983 POM retention goals were formed to derive rating end strengths. Rand Model forecasts for mental categories I, II, and IIIA annual accessions were used

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A Simulation Model Depicting Fleet Expansion Effects on the Fire Control Technicians Training Pipeline

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ABSTRACT

This thesis is a study of the training pipelines for the Navy's fire control technician ratings during projected fleet expansion to 600-plus ships by 1990. Yearly manning requirements for the FTM, FTG, and FTG(SS) ratings were identified. FTG and FTM transition flow matrices based upon 1983 POM retention goals were formed to derive rating end strengths. Rand Model forecasts for mental categories I, II, and IIIA annual accessions were used with predicted end strengths to project manpower supplies. Comparison of supply and demand projections indicated future manning shortfalls in the FT ratings. A FORTRAN-based computer language, designated SLAM, was used to construct a simulation model of the training pipelines. The model was employed to examine the impact of manpower procurement policy modifications upon Service schools' queue durations and stay times. An alternative manning policy was developed to overcome the forecasted manpower deficits without disrupting the schooling time requirements.

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I. INTRODUCTION

The ability of the Navy to train and retrain a sufficient number of qualified men and women in the 1980's represents a major manpower issue. Since the service will depend more heavily on the highly skilled and technically proficient manpower pools in the future years, the impact of growth in the Navy is of utmost importance. An assessment of the implications for a specific rating as the Navy grows in size from about 450 ships to an envisioned 600-plus ships is the purpose of this thesis. Therefore, we have undertaken the task of seeing what impact this expansion will have on the Fire Control Technician ratings (FT's).

Why have we chosen the FT ratings for analysis? Primarily for four reasons: (1) they are critical ratings considered necessary for the manning of surface ships and submarines in support of sophisticated weapon systems currently onboard, (2) they require the higher mental categories, mental group I, II, and IIIA personnel, to be recruited to ensure accessions qualify for the more advanced schools, (3) they have one of the largest growth potentials of all ratings because of their highly technical skills and the current Navy policy to refit battleships which require large numbers of FT's, and (4) there is a high possibility that the ratings will run into manning difficulties in the future. In addition to the above basic reasons, we have chosen the FT ratings because they afford

us the opportunity to examine a variety of training pipeline structures.

Most will agree that training, its objectives, policies, and practices, is a very critical aspect of military preparedness. How it is conducted and the means by which it is carried out will have far reaching effects upon the Navy in the future. Our objective in this thesis is to relate the capabilities of the Navy's training schools to the proposed fleet expansion required for the anticipated naval operations of the next nine years. We do not discuss specific training methodologies, but direct our major emphasis to the analysis of training flows and the optimization of alternatives to the pipelines. The means by which this is carried out is through a computer simulation language called SLAM (Simulation Language for Alternative Modeling). This particular computer language has been chosen because it allows us to view the training pipeline from process, event, and state-variable perspectives. By using a simulation language, we are able to investigate various alternatives to the FT training pipeline and determine what effects changing these variables will have. We have endeavored to design a simulation system to meet these needs in a cost-effective manner.

The factors affecting the direct student output within the training structure are the topic of the first part of the thesis. Chapter II is directed primarily at describing the significant impacts the dwindling supplies of manpower through

1990 will have on the increasing demands of an expanded Navy. A detailed analysis of the methodologies used in determining the supply and demand projections is also presented. The augmented demand of the 1980's may cause costly bottlenecks to occur in the processing of students and jeopardize the training command's ability to produce adequate numbers of technicians. Therefore, in the second half of Chapter II, we outline the Fire Control Technicians' path through the training command, highlighting major branch and decision points the students encounter throughout their formal training. Hopefully, this will give the reader an insight into the complexities which the Navy Military Personnel Command is faced with every day in connection with the management of Service schools.

Chapter III deals exclusively with SLAM programing techniques. It presents the reasoning why we have chosen this specific simulation language and gives a detailed breakdown of the methods used in modeling the FT pipeline. The ability to construct this model in a manner which allows interactions between each event greatly enhances our modeling ability. The later sections of Chapter III are designed to give a step-by-step explanation of the programming involved. These discussions are also aimed at assisting the novice to expand and develop his or her own training pipeline model.

Chapter IV analyzes the results of policy options investigated with SLAM programming, dramatically illustrating the impact the proposed growth of the Navy will have on the FT

training pipeline. Based on our supply-demand projections, alternative means to solve the vivid manpower shortfalls are proposed. The policies are viewed in a broad sense, but they demonstrate quite adequately the flexibilities allowed by our modeling process. It is a means to show the potential cost effective ability simulation modeling can have.

Chapter V evaluates the findings of Chapters II, III, and IV. As a result of this analysis, a few recommendations are proposed to solve some of the foreseeable problems the training command will be faced with if the Navy does in fact grow to its envisioned size of 600-plus ships. The impacts projected may be even worse if newly developed, more sophisticated weapon systems are introduced during this building process.

A great deal was learned about the training command during the investigative and writing phases of the thesis. It is our hope that this knowledge can be used by others as a stepping sone for future learning.

II. NATURE OF THE PROBLEM

A. INTRODUCTION

Can the Navy retain the numbers of personnel required to sustain force strength objectives through the growth period to 1990? As the Navy increases to its projected size of 600-plus ships by 1990, the impact this expansion will have on a particular rating must be examined.

The purpose of this chapter is to study the supply and demand issues of military manpower and to examine some of the impacts of the Navy's planned growth. The Navy training command will be analyzed to see the implications resulting from additional manning requirements for the Fire Control Technician ratings.

B. DEMAND

As the Navy expands in pursuit of its stated goal of a fifteen battle group force by 1990, sustained fleet effectiveness will necessitate a corresponding growth in the Service's manpower figures. Higher annual end strengths will be reflected not only in the obvious additions in sea and squadron billets, but also in the augmented manning of the shore-based supply, maintenance, and administrative facilities required to support the force build-up. These escalations will be accompanied by increased numbers of sailors being categorized under the personnel status of Transients, Patients,

and Prisoners (TP&P). Further impact upon the force manpower planning will be experienced in the training command as the Navy schools respond to the demands for technicians created by the new fleet assets. In readying the school facilities for this expected growth, training command managers will focus attention upon proposed shipbuilding and aircraft purchasing schedules, anticipated lead times for schooling, and the Navy's success in retaining the skilled personnel who have previously completed the Service's courses of instruction. Although simplified by the elimination of aircraft driven manpower demands, development of the Fire Control Technician rating requirements through the 1980's will illustrate our methodology for projecting the manpower demand to be used in training command policy analysis.

1. Ship Driven Demand

Our analysis is based on the figures for billets authorized (BA) extracted from Enlisted Distribution and Verification Reports (EDVR's) of representative ships of planned fleet assets. The billets authorized, determined by proportioning the Congressionally approved Navy manpower end strength among the Service's organizational units, are the measures used by enlisted personnel managers for the peacetime distribution of servicemen, and are thus considered more appropriate for our study than the wartime assignments contained in Ship Manning Documents (SMD's). Multiplication of billets authorized and projected inventories of fleet assets through the 1980's produces the number of fire control

technicians annually needed to fulfill sea duty assignments. This straightforward mathematical procedure results in well-defined requirements, but incorporates several assumptions beyond those inherent in the forecasting of yearly fleet assets. To minimize annual fluctuations in our projections caused by these preliminary simplifications, we have concentrated our analysis of the FT's manpower demands on the trends indicated by the years 1982, 1986, and 1990.

The assumptions introduced in our evaluations of ship manning requirements are three-fold. Most importantly, our approach disregards possible installation of advanced technology aboard present fleet platforms, and therefore views future manning authorizations for today's ships as duplications of current distributions. Secondly, since promotional pipelines of the FTG and FTM ratings join at the E-8 paygrade to form the FTCS rate (E-8), and progress to the combined FTCM rate (E-9), distinction between the growth increases of these ratings is difficult in the two most senior enlisted paygrades. To provide continuity to our example, we have arbitrarily divided the two senior rates into source rating groupings. In so doing, we have considered the known 1981 population of FT E-8's and E-9's to have been derived from equal inputs from each of the contributing ratings. We have also distributed the senior billets according to our professional estimates of which rating possesses the best qualifications for each job specification. The breakdown of combined E-8 and E-9 billet authorizations in the projected years for each rating is

based upon the assumed-constant 1981 paygrade proportions. Finally, in instances in which billet authorization data are not available, such as for the CG-47 class AEGIS cruisers, we have relied upon proposed manning information provided by FTG and FTM enlisted personnel detailers to complete our projections.

Tables 1 and 2 present the ship inventory and personnel manning matrices used in the determination of sea billet requirements. Yearly forecasts of ship-type assets through the 1980's, as indicated in Table 1, were developed from a study conducted at the Naval Postgraduate School, Monterey, California [NPS, 1981]. The study's total proposed growth in operating assets leads to a final 1990 inventory of 611 ships. Of this envisioned fleet, 289 ships will have FT personnel in their crews. Table 2 shows paygrade billet authorizations for the FTG and FTM ratings in those ship classifications requiring fire control technician manning. Paygrades E-1 through E-3 are summed and presented as a single manning demand (listed under E-3) in accordance with current Navy manning policies and with the paygrade specifications employed in the EDVR's. Manning characteristics of the fleet ballistic missile submarines have been doubled to compensate for the simultaneous assignment of two crews (blue and gold) to these assets. Table 3 is formed by multiplying the elements of Tables 1 and 2, and then totaling the yearly paygrade demands for the three base years of our study.

TABLE 1

Estimated Ship Inventory Matrix

SHIP CLASS	NUMBER OF SHIPS IN CLASS								
	1982	1983	1984	1985	1986	1987	1988	1989	1990
AD-14	5	5	5	5	5	5	5	5	5
AD-37	2	2	2	2	2	2	2	2	2
AOE-1	4	4	4	4	4	4	4	4	4
BB-62	1	1	2	2	2	3	4	4	4
CG-16	9	9	9	9	9	9	9	9	9
CG-29	9	9	9	9	9	9	9	9	9
CG-47	1	2	3	4	8	11	14	17	20
CGN-9	1	1	1	1	1	1	1	1	0
CGN-25	1	1	1	1	1	1	1	0	0
CGN-35	1	1	1	1	1	1	1	1	1
CGN-36	2	2	2	2	2	2	2	2	2
CGN-38	2	2	2	2	2	2	2	2	2
CV-61	10	10	10	10	10	10	10	10	10
CVN-65	4	4	4	4	4	4	4	4	4
DD-948	12	12	12	12	12	12	12	12	12
DD-963	30	31	31	31	31	31	31	31	31
DDG-2	23	23	23	23	23	23	23	23	23
DDG-31	4	4	4	4	2	0	0	0	0
DDG-37	10	10	10	10	10	10	10	10	10
DDG-994	4	4	4	4	4	6	8	10	10
FF-1037	2	2	2	2	2	2	2	2	2
FF-1040	10	10	10	10	10	10	10	10	10
FF-1052/1078	42	40	38	38	34	34	34	34	34
FFG-1	6	6	6	6	6	6	6	6	6
FFG-7	19	27	35	40	44	49	54	61	61
LHA-1	5	5	5	5	5	5	5	5	5
LPH-2	7	7	7	7	7	7	7	7	7
SSBN-6 16 (Pois)	19	19	19	19	19	19	19	19	19
SSBN-6 16 (Trid)	12	12	12	12	12	12	12	12	12
SSBN-726	1	2	3	4	4	5	6	7	8
SSN-575	1	1	0	0	0	0	0	0	0
SSN-578	4	4	3	2	1	0	0	0	0
SSN-585	5	5	5	5	5	5	5	5	5
SSN-594	13	13	13	13	13	13	13	13	13
SSN-597	1	1	1	1	1	1	1	1	1
SSN-598	3	3	3	2	0	0	0	0	0
SSN-608	5	5	5	5	5	5	5	5	5
SSN-637	37	37	37	37	37	37	37	37	37
SSN-671	1	1	1	1	1	1	1	1	1
SSN-685	1	1	1	1	1	1	1	1	1
SSN-688	16	19	24	28	31	34	37	40	40

Source: Naval Postgraduate School Study

TABLE 2

Estimated Personnel Inventory Matrix

SHIP CLASS	FTG MANNING							FTM MANNING						
	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-3	E-4	E-5	E-6	E-7	E-8	E-9
AD-14	1	3	3	4	1	2	0	0	0	0	0	0	0	0
AD-37	0	0	2	2	1	0	1	0	0	4	0	2	0	0
AOE-1	0	0	0	0	0	0	0	3	4	2	1	1	0	0
BB-62	23	41	33	9	3	1	1	0	0	0	1	1	0	0
CG-16	0	3	1	1	0	0	1	0	13	9	5	2	0	0
CG-29	1	4	4	3	1	1	0	1	7	6	3	3	0	1
CG-47	1	2	4	3	2	0	0	4	8	10	7	3	1	1
CGN-9	2	4	2	2	1	0	0	2	9	5	4	1	0	1
CGN-25	2	4	2	2	1	0	0	2	9	5	4	1	0	1
CGN-35	2	4	2	2	1	0	0	2	9	5	4	1	0	1
CGN-36	3	2	1	1	1	0	0	1	11	3	5	2	0	1
CGN-38	1	2	2	1	1	0	1	1	4	7	4	1	0	0
CV-61	0	0	0	0	0	0	1	1	7	4	4	1	1	0
CVN-65	0	3	3	1	0	1	0	0	0	0	0	0	0	0
DD-948	2	5	4	3	1	0	0	0	0	0	0	0	0	0
DD-963	0	3	1	0	1	0	0	3	2	3	1	0	0	0
DDG-2	1	3	2	2	1	0	0	0	12	4	4	1	1	0
DDG-31	0	1	2	2	1	0	0	0	7	7	4	1	1	0
DDG-37	0	1	2	4	3	1	0	3	12	5	4	2	0	1
DDG-994	0	5	2	2	1	0	0	1	3	6	5	0	0	1
FF-1037	1	1	1	0	1	0	0	0	0	0	0	0	0	0
FF-1040	1	1	2	2	0	0	0	0	0	0	0	0	0	0
FF-1052/1078	1	2	2	1	1	0	0	0	2	1	1	0	0	0
FFG-1	1	1	2	1	0	1	0	0	5	3	3	1	0	0
FFG-7	0	0	0	0	0	0	0	0	3	4	3	1	0	0
LHA-1	1	3	2	1	1	0	0	2	3	2	1	1	0	0
LPH-2	0	0	0	0	0	0	0	1	4	1	2	1	0	0
SSBN-6 16 (Pois)	0	2	0	2	0	0	0	0	0	0	0	0	0	0
SSBN-6 16 (Trid)	0	0	2	2	2	0	0	0	0	0	0	0	0	0
SSBN-726	0	0	2	2	2	0	0	0	0	0	0	0	0	0
SSN-575	0	0	1	1	1	0	0	0	0	0	0	0	0	0
SSN-578	0	1	1	1	1	0	0	0	0	0	0	0	0	0
SSN-585	0	1	1	1	0	1	0	0	0	0	0	0	0	0
SSN-594	0	1	1	1	1	0	1	0	0	0	0	0	0	0
SSN-597	0	1	1	1	1	0	0	0	0	0	0	0	0	0
SSN-598	0	1	1	0	1	0	0	0	0	0	0	0	0	0
SSN-608	0	1	1	1	1	0	0	0	0	0	0	0	0	0
SSN-637	0	1	1	1	1	0	1	0	0	0	0	0	0	0
SSN-671	0	1	1	1	1	0	0	0	0	0	0	0	0	0
SSN-685	0	1	0	1	0	0	0	0	0	0	0	0	0	0
SSN-688	0	1	1	0	1	0	0	0	0	0	0	0	0	0

Source: Authors

TABLE 3

Estimated Ship Demand Manning Requirements

	1982		1986		1990	
RATE	FTG	FTM	FTG	FTM	FTG	FTM
E1-E3	166	192	188	223	242	273
E-4	651	1077	700	1180	834	1313
E-5	529	703	585	854	719	1054
E-6	431	508	451	618	516	769
E-7	289	166	311	211	359	262
E-8	45	38	46	43	48	53
E-9	76	29	77	36	79	52
TOTAL DEMAND	2187	2713	2358	3165	2797	3776

Source: Authors

2. Support Driven Demand

Current Department of Defense plans outline the ship-building programs for the remainder of the 1980's considered essential in countering the presence of Soviet naval power upon the world's oceans. However, while defense managers have recognized that added ship production will burden the established support installations and shore-based personnel community, studies addressing the impact of fleet expansion on shore facility capabilities and manning have lagged ship development reports, and policy proposals for the upgrading of shore bases therefore remain undefined. Apparently, Navy leaders are confident that the existing facilities are equipped sufficiently to support the projected ship additions, at least in the early stages of growth, and have not announced immediate building plans for shore-based assets. Despite the absence of planned construction, Navy leaders have achkowledged that today's support manpower strengths must be bolstered to meet the increased administrative, material, maintenance, and recreational demands imposed by a 600-plus ship Navy on current base establishments. Determination of the degree to which the support driven manning requirements are to be altered thus becomes fundamental in discussions of anticipated end strengths for the upcoming years.

The calculation of appropriate support manning levels is complicated by a variety of issues, such as substitution of civilian labor force for military personnel policies, and decisions specifying the range of services to be provided by

the shore facilities. Because of these variables, an explicit, universally applied method for estimating shore-based manning requirements has not been developed in Navy research projects. The most common technique used for past projections has been based on promulgated sea-shore rotation factors for the various skill ratings. In this methodology, the mathematical product of the sea billet requirements and a specified rotation factor expresses the additional shore facility assignments needed to provide a desired career pattern for the rating's sailors. Unfortunately, this popular approach entails several unfavorable characteristics for our evaluations. Analytically, the utilization of the sea-shore rotation factor divorces shore base distributions from the actual demand of the support workload. Furthermore, the rotation factor is an influential variable in retention policy management and, as such, should not be unnecessarily constrained in our model by ties to shore billet estimations.

In view of the limitations of the sea-shore rotation factor technique, we have opted to estimate support driven manning requirements through the application of a ship tonnage model. As suggested by Dr. Rolf Clark in his comparison of fleet resource allocations from 1962 to 1977, total fleet tonnage acts as a predictor of modifications in force levels and as a linkage in measuring logistic support expenditures [Clark, 1980]. The 1981 Naval Postgraduate School study of the proposed 600-plus ship Navy also notes a relationship between projected overall shore billet requirements and

forecasted tonnage totals. Using these research projects as examples, we have extended the logic of the fleet tonnage model to the specifics of the shore billet manning of fire control technicians.

In our model for determining the FTG and FTM support demands, we assume that the fundamental relationship between shore billets and tonnage totals remains constant. Equation 1 is used to calculate this fixed value, or tonnage factor, for each rating.

$$\frac{\text{1981 Shore Billets for Rating}}{\left[\text{1981 Total Tonnage of Ships}_{\text{Distributed Billets for Rating}}\right]} = \text{Tonnage Factor} \qquad \text{(Eq. 1)}$$

Source: Authors

Under our assumption, the 1981 base-year tonnage factors, .00025 for FTG's and .00026 for FTM's, can be substituted into Equation 2 to figure total shore billets required for the ratings in each of the studied years.

$$\left[\text{Tonnage Factor}\right] \times \left[\text{Yearly Total Tonnage}\right] = \left[\text{Total Shore Billets for Rating in Year}\right] \qquad \text{(Eq. 2)}$$

Source: Authors

The annual projections of total tonnage for a rating (yearly total tonnage) are developed by summing the full displacement tonnages for all proposed ships with crews having billets designated for manning by the rating.

For our estimations of support driven demands to be compatible with ship driven projections and to be useful in the analysis of billet distributions, the yearly shore billet totals must be broken into rate requirements. In the partitioning of the annual sums, we again assume a constant relationship among components and use 1981 figures to forecast specific rate demands through the 1980's. Combining the E-1 through E-3 rates into one group, seven rate factors, which total to 1.0, are figured for each rating using Equation 3.

$$\frac{\text{1981 Shore Billets for Rate}}{\text{1981 Shore Billets for Rating}} = \text{Rate Support Factor} \qquad \text{(Eq. 3)}$$

Source: Authors

As shown in Equation 4, our expression for the support driven demand model, the annual shore-based requirement for each rate is determined by multiplying the total shore billets for the source rating by the rate support factor.

$$[\text{Shore Billets for Rating in Year}] \times [\text{Rate Support Factor}] = [\text{Shore Billets for Rate in Year}] \qquad \text{(Eq. 4)}$$

Support Demand Model

Source: Authors

Table 4 presents these support driven demands of each rate for our three representative years.

TABLE 4

Estimated Shore Demand Manning Requirements

	1982		1986		1990	
RATE	FTG	FTM	FTG	FTM	FTG	FTM
E1-E3	27	9	29	10	33	11
E-4	9	19	10	20	11	23
E-5	117	75	127	81	142	90
E-6	352	383	382	416	425	463
E-7	163	196	176	213	196	237
E-8	154	168	167	187	185	203
E-9	81	84	88	91	98	102
TOTAL DEMAND	903	934	979	1014	1090	1129
SHIP-SHORE TOTAL	3090	3647	3337	4179	3887	4905

Source: Authors

3. TP&P Driven Demands

On any given day, a fractional component of the Navy's manpower will be classed as medical patients, prisoners, or transients (personnel on leave or on travel orders between duty stations). Slight variations exist between skill ratings, but approximately ten percent of a rating's total strength normally falls into this TP&P category [OPNAVINST 1500.8J, 1979]. Although it can be argued that significant policy changes may serve to reduce this daily loss in the manpower force, long-standing disciplinary and morale standards have stabilized the size of this component. As a result, accurate depictions of the Navy's manpower posture must include additional billet allowances for this substantial TP&P classification.

Using the Navy Enlisted Distribution Statistical Summary Report for calendar year 1981, we have formulated characteristic rating factors for projecting FTG and FTM TP&P requirements through 1990. The TP&P constants (.096 for FTG's and .110 for FTM's) are derived by substituting the 1981 data for each rating into Equation 5.

$$\frac{\text{1981 TP\&P Billet Allowance for Rating}}{[\text{1981 Sea Billets for Rating}] + [\text{1981 Shore Billets for Rating}]} = [\text{TP\&P Factor for Rating}] \qquad \text{(Eq. 5)}$$

Source: Authors

This determined TP&P factor is then inserted into Equation 6 to forecast the total Transients, Patients, and Prisoners attributable to the individual ratings in each evaluated year.

$$\left[\begin{matrix}\text{TP\&P}\\ \text{Rating}\\ \text{Factor}\end{matrix}\right] \times \left\{\left[\begin{matrix}\text{Projected}\\ \text{Sea Billets}\\ \text{for Rating}\\ \text{in Year}\end{matrix}\right] + \left[\begin{matrix}\text{Projected}\\ \text{Shore Billets}\\ \text{for Rating}\\ \text{in Year}\end{matrix}\right]\right\} = \left[\begin{matrix}\text{Projected TP\&P}\\ \text{Allowances}\\ \text{for Rating}\\ \text{in Year}\end{matrix}\right] \qquad \text{(Eq. 6)}$$

Source: Authors

As in the determinations of support driven demands, the yearly TP&P rating forecasts must be separated into rate requirements. The fractional component of the total rating forecast distributed to each rate is calculated by employing Equation 7 and the baseline data from calendar year 1981.

$$\frac{\text{1981 Rate TP\&P Billet Allowances}}{\text{1981 Rating Billet Allowances}} = \begin{matrix}\text{RATE TP\&P}\\ \text{Factor}\end{matrix} \qquad \text{(Eq. 7)}$$

Source: Authors

The predicted TP&P requirements for each rate, given in Table 5, are obtained by substituting the rate TP&P factor derived in Equation 7 into the TP&P Model depicted by Equation 8.

$$\left[\begin{matrix}\text{Rate TP\&P}\\ \text{Factor}\end{matrix}\right] \times \left[\begin{matrix}\text{Projected}\\ \text{TP\&P Rating}\\ \text{Allowances}\\ \text{in Year}\end{matrix}\right] = \left[\begin{matrix}\text{Projected}\\ \text{TP\&P Rate}\\ \text{Requirements}\\ \text{in Year}\end{matrix}\right] \qquad \text{(Eq. 8)}$$

TP&P Model

Source: Authors

4. Total Manpower Demands

Summation of a rate's sea duty billets, support driven requirements, and TP&P allowances determines the annual billet authorizations for a specific paygrade within a rating.

TABLE 5

Estimated TP&P Requirements

	1982		1986		1990	
RATE	FTG	FTM	FTG	FTM	FTG	FTM
E1-E3	37	36	40	41	46	48
E-4	104	154	113	170	131	199
E-5	97	163	105	180	122	211
E-6	52	65	56	72	64	84
E-7	37	42	40	46	46	54
E-8	1	1	1	2	2	2
E-9	1	1	1	2	2	2
TOTAL	329	451	356	513	414	600

Based on 1981 data.

Source: Authors

Further addition of the E-1/3 through E-9 rate authorizations provides the total manpower demands for the rating in a particular year. Table 6 is formed by totaling the elements of Tables 3, 4, and 5, and therefore summarizes the forecasted demands for FTG and FTM technicians in the Navy through 1990. These projections indicate growth rates of 26 percent for FTG's and 35 percent for FTM's during this nine year period.

The rapid increase in the number of fire control technicians necessary to operate the envisioned 600-plus ship Navy of 1990 suggests that the recruiting and training commands will have difficult tasks in responding to future manpower demands. However, yearly accessions and technical schooling requirements can be eased substantially by improved Navy success in retaining enlisted personnel. Although influenced by an unstable economic picture throughout the nation, early fiscal year 1982 retention statistics indicate encouraging trends in the Service's ability to upgrade its retention performance. The Basic Manpower Transition Model depicted in Equation 9 demonstrates the potential impact of retention performance upon manpower accession demands by expressing the relationship between personnel inventories, a transition matrix encompassing yearly retention statistics, and annual accessions.

$$\begin{bmatrix}\text{End Strengths}\\ \text{at End}\\ \text{of Year}\end{bmatrix} = \begin{bmatrix}\text{Personnel}\\ \text{Inventories}\\ \text{at Beginning}\\ \text{of Year}\end{bmatrix} \times \begin{bmatrix}\text{Transition}\\ \text{Matrix}\end{bmatrix} + \begin{bmatrix}\text{Total}\\ \text{Accessions}\\ \text{for Year}\end{bmatrix} \quad \text{(Eq. 9)}$$

Basic Manpower Transition Model

Source: Authors

TABLE 6

Estimated Total Manning Requirements

	1982		1986		1990	
RATE	FTG	FTM	FTG	FTM	FTG	FTM
E1-E3	230	237	257	274	321	332
E-4	764	1246	823	1370	976	1535
E-5	743	937	817	1115	983	1355
E-6	835	955	889	1106	1006	1316
E-7	489	402	527	470	601	553
E-8	200	207	214	228	235	258
E-9	158	114	166	129	179	156
TOTAL	3419	4098	3693	4692	4301	5505

Source: Authors

Manpower managers must strive to match yearly end strengths with total billet authorization demands through the manipulation of programs and policies affecting the transition matrix and through the annual enlistment of qualified sailors.

C. PERSONNEL TRANSITION MATRICES

The transition matrix component of Equation 9 is the mathematical tool for ascertaining the make-up of a manpower force following a specified period of system operation. This flow matrix describes the movement of individuals through a rank-order organization by detailing the percentage of personnel advancing, not changing, or moving back in the system structure during each period. In so doing, the matrix encompasses both the statistics of promotion and of retention within the organization. Multiplication of the beginning personnel inventories, classed according to the rank structure of the system, by the transition matrix forecasts the organization's total ending inventory, partitioned into appropriately sized rank groupings.

In our analysis, we have utilized several transition models to predict annual FT end strengths through the 1980's. Comparison of these personnel stocks with our forecasts of the billet demands for the expanding fleet results in estimates of the yearly accessions necessary to sustain fleet performance. The breakdown of the projected manpower strengths by rate also enables us to identify and examine specific shortfalls in the fire control technician manning levels. Our calculations of

FT end strengths and projections of manning deficits will be presented in detail in the discussions following the description of the transitional flow methodology.

1. 1981 Transition Matrices for FTG's and FTM's

Tables 7 and 8 present the two transition matrices underlying our projections of the fire control technician ratings' end strengths in the next nine years. The matrices are based upon data, provided by Defense Manpower Data Center, Monterey, California, describing the flow of FTG's (Table 7) and FTM's (Table 8) through the Navy enlisted rates during fiscal year 1981. Statistics for the E-1 through E-3 rates are grouped to conform with our previous forecasting procedures. Since information on the FTCS (E-8) and FTCM (E-9) rates was not available, we have assumed the flow statistics for these senior rates to be equal within the FTG and FTM ratings, and have estimated the percentages given in the tables. The elements of these tables indicate the fraction of the beginning rate inventory, identified in the left column, that is located at the end of 1981 in the rank designated in the column headings. For example, Table 7 specifies that 46.9 percent of the FTG's classed as E-4's at the start of 1981 remained in this rate at the year's closing, while 33.7 percent were advanced to FTG2 (paygrade E-5). In addition, the matrix shows that 3.6 percent of the E-4's were reduced in rate and placed in the ending E-1/3 inventory. The right hand column in each table, entitled LOSS, lists the proportion of the beginning inventory departing the personnel system during the year.

TABLE 7

1981 Personnel Transition Matrix for FTG's

		End of Year							
		E-1/3	E-4	E-5	E-6	E-7	E-8	E-9	LOSS
Beginning of Year	E-1/3	.336	.447	.008	0	0	0	0	.21
	E-4	.036	.469	.337	0	0	0	0	.157
	E-5	.002	.011	.597	.147	0	0	0	.242
	E-6	0	0	.002	.701	.138	0	0	.159
	E-7	0	0	0	0	.814	.068	0	.118
	E-8	0	0	0	0	0	.750	.05	.2
	E-9	0	0	0	0	0	0	.75	.25

Re-enlistment Rates

FIRST TERM	SECOND TERM	CAREER
29%	58%	86%

Source: Authors

TABLE 8

1981 Personnel Transition Matrix for FTM's

		End of Year							
		E-1/3	E-4	E-5	E-6	E-7	E-8	E-9	LOSS
Beginning of Year	E-1/3	.284	.478	.003	0	0	0	0	.235
	E-4	.031	.506	.287	0	0	0	0	.176
	E-5	0	.01	.581	.153	0	0	0	.257
	E-6	0	.003	.003	.722	.148	0	0	.124
	E-7	0	0	0	0	.845	.073	0	.083
	E-8	0	0	0	0	0	.75	.05	.2
	E-9	0	0	0	0	0	0	.75	.25

Re-enlistment Rates

FIRST TERM	SECOND TERM	CAREER
24%	61%	93.5%

Source: Authors

In the E-4 example of Table 7, 15.7 percent of the FTG3's were discharged in the year. These listed loss rates total all personnel departures, including retirees, administrative and disciplinary discharges, and end of service obligation losses.

2. Development of 1983 POM Projections Flow Matrices

The 1981 personnel transition matrices record the most recent annual accounts of the movement of FTG's and FTM's through the Navy's rate structure. Forecasts founded upon these historical performances assume that the career behavioral patterns of servicemen will remain fundamentally constant. However, Navy leaders have recently pursued increased budget allocations for personnel recruiting, training, and quality-of-life programs in hopes of attracting higher quality recruits and of motivating sailors toward continued military careers. This added emphasis on manpower management, coupled with a high nation-wide youth unemployment rate, has imparted an optimistic outlook among Navy leaders toward the achievement of greater retention success. As a result, the Navy has established, in the fiscal year 1983 Program Objectives Memorandum (POM), increased retention goals for first-term, second-term, and career-designated re-enlistments of 47, 67, and 98 percent.

Recognizing the importance of retention characteristics in determining transition rates, the substantial growth in retention statistics planned by the Navy, and the impact of

transition flows upon the analysis of future manpower supply and demand trade-offs, we have augmented our research with FTG and FTM flow matrices developed from the 1983 POM goals. In formulating the FTG and FTM 1983 models, we have first evaluated the actual 1981 stock flows and, using equations representing first-term, second-term, and career-designated enlistment loss rates, have factored out the departures attributable to these three categories for both the FTG's and FTM's. After having extracted these numbers from the 1981 models, we have employed the loss rate equations to define the losses that occur in a hypothetical system operating under the 1983 POM retention goal statistics and have then inserted these departure figures into the amended 1981 stock flows. The resulting theorized manning levels have been converted into projected FTG and FTM transition matrices for application to analyzing manpower issues of the expanding Navy. Although this matrix logic assumes that the promotional policies of the Navy are fixed throughout the 1980's, and that the 1983 POM goals are typical of the remaining years of our study, the application of 1983 POM goal-oriented matrices provides a means of assessing the implications of improved retention efforts.

In extracting the loss figures of each re-enlistment group (first-term, second-term, and career) from the 1981 personnel stocks of the E-1/3 through E-9 rates, we must first calculate a technician's expected time in ·ate (TIR).

These averages enable us to determine in which rates enlistment decision points occur and the proportion of each rate's stocks that encounter career choices in a particular year. Manipulation of the 1981 transition matrices provides the most current estimates of these times in service. The diagonal elements in the inverse of a matrix formed by subtracting the 1981 transition matrix from an identity matrix represent the average TIR's. Table 9 presents these results for the FTG and FTM ratings.

TABLE 9

Time in Rate for FTG and FTM Ratings

	TIME IN RATE (IN YEARS)						
RATING	E-1/3	E-4	E-5	E-6	E-7	E-8	E-9
FTG	1.58	2.01	2.54	3.35	5.38	4.00	4.00
FTM	1.46	2.15	2.44	3.62	6.45	4.00	4.00

Source: Authors

The average TIR's for FTG's and FTM's indicate that most first-term FT's, either four year or six year obligators, reach enlistment decisions prior to advancing to paygrade E-6. Under these circumstances, we can calculate first-term losses of fire control technicians with the general expression given in Equation 10.

1st Term Loss Rate = (Eq. 10)

$$\frac{\text{(Loss of Eligible E-3's)+(E-4 Loss)+(E-5 1st Term Loss)}}{\text{(Elig E-3)} + (.5)\text{(E-4)(\% 4YO)} + \left[\frac{(1)}{\text{TIR E5}}\text{(\% 4YO)} + \frac{(1)}{\text{TIR E5}}\text{(\% 6YO)}\right]\text{(E-5)}}$$

where:

E5 1st Term Loss = Total E5 Loss - E5 2nd Term Loss

= Total E-5 Loss

$$- \frac{(1)}{\text{TIR E-5}}(.4)\text{(E-5)(\% 4YO)(\% 2YR-RENL)}$$

and,

Loss of Eligible E-3's = (.4)(Loss of Elig E-3's)

= (.4) (.05)(E-3's)

% 4YO = percent of total enlistees that are 4 year obligators,

% 6YO = percent of total enlistees that are 6 year obligators,

% 2YR-RENL = percent of re-enlistees that sign two year contracts

Source: Authors

This formula adheres to the terminology of FT personnel managers in which loss percentages are based solely on career

decisions of eligible personnel and thus disregard administrative, disciplinary, and unqualified personnel losses. Because Navy regulations severely restrict the numbers of E-1 through E-3's qualified for continued service, our model considers only five percent of this group eligible for re-enlistment. The statistics from 1981 substantiate this approximation and depict a relatively low first-term loss rate of 40 percent within this cohort, apparently stemming from the imposed requirements. Since the FT ratings are manned with high quality accessions and the transition matrices of Tables 7 and 8 display only minimal rate reduction trends after advancement to paygrade E-4, we have overlooked possible punitive discharges in the upper five rates and have considered the entire populations in these rates as eligible for re-enlistment.

In the development of Equation 10 we have used a professional judgment to align our model with observations of actual re-enlistment practices of E-4's. Although Table 9 indicates that the average technician advances to the E-5 paygrade in 3 years 7 months, we consider 50 percent of the E-4 four year obligator population eligible for the first-term re-enlistment decision. This addition to the equation compensates for both slow advancers and for manpower policies that currently permit top performers in the training pipeline to progress to the E-4 rate in a one year period. This accelerated pace significantly reduces the average E-1/3 TIR and thus the typical paygrade status of four year obligators upon re-enlistment.

The advancement timetables depicted in Table 9 also imply that, in the determination of first-term and second-term loss rates, the total personnel departures in the E-5 rate during 1981 be distributed among the two loss categories. This distinction is necessary to account for personnel entering the Navy as four year obligators and subsequently re-enlisting for only two years, thus being classed as second-term re-enlistees for career decisions at the six year point of service. Derivation of the 1981 E-5 first-term losses used in Equation 10 serves as an example of the method of proportionment enployed throughout our development of the 1983 POM-goal matrices. The first-term losses are calculated by subtracting from the known 1981 Service departures of E-5 personnel the number of those FT's assumed to be leaving the Service in their second enlistments. Second-term losses are specified as a fraction of the eligible E-5 group. The cohort size of the eligible second-term E-5 population is defined as the product of the total number of E-5's, the inverse of the E-5 TIR (specifying the fraction of E-5's reaching a career decision point during a one year period), and the proportion of FT's classed as four year first-term obligators who sign two-year second-term contracts. Multiplying this cohort size by an assumed second-term loss rate of 40 percent results in the number of second-term E-5 losses to be withdrawn from the total E-5 losses when calculating the first-term loss rate. This assumed loss percentage closely corresponds with the recorded statistics of 1981 and the proposed goals for 1983.

In our application of Equation 10 to the 1981 FTG and FTM manning matrices, we have proportioned 25 percent of the first-term ratees as four year obligators and 75 percent as six year enlistees in accordance with current accession statistics. Additionally, we have assumed that 75 percent of those personnel continuing enlistments beyond their initial terms sign two year contracts, while the remaining re-enlistees agree to four years of obligated service. These percentages are also employed in later determinations of second-term and career loss rates. Using these behavioral characteristics and the assumptions for the E-1/3, E-4, and E-5 cohorts described above, we have substituted 1981 personnel stock data into Equation 10 and have determined the first-term loss rates for FTG's and FTM's to be 71 and 76 percent, respectively. These projections closely approximate the recorded statistics for the year.

Second-term loss percentages are extracted from the 1981 transition matrices using Equation 11.

$$\text{2nd Term Loss Rate} = \frac{\text{E-5 2nd Term Loss} + \text{E-6 2nd Term Loss}}{(\text{E-5's}) \frac{(1)}{\text{TIR E-5}} (\%\ \text{4-YO})(\%\ \text{2YR RENL}) + \text{Eligible E-6's}} \qquad \text{(Eq. 11)}$$

where:

$$\text{Eligible E-6's} = (.2)(\%\ 4\text{-YO})(\%\ 2\text{YR RENL})(\text{E-6's})$$

$$+ \frac{(1)}{\text{TIR E-6}}(\%\ 4\text{-YO})(\%\ 4\text{YR RENL})(\text{E-6's})$$

$$+ \frac{(1)}{\text{TIR E-6}}(\%\ 6\text{-YO})(\%\ 2\text{YR RENL})(\text{E-6's})$$

$$+ (.1)(\%\ 6\text{YO})(\%\ 4\text{YR RENL})(\text{E-6's})$$

and,

$$\text{E-6 2nd Term Loss} = \text{Total E-6 Loss} - \text{E-6 Career Loss}$$

$$= \text{Total} - \frac{(1)}{\text{TIR E-6}}(\%\ 4\text{-YO})(\%\ 2\text{YR RENL})(\text{E-6's})(.2)$$

$$- \frac{(1)}{\text{TIR E-6}}(\%\ 6\text{-YO})(\%\ 2\text{YR RENL})(\text{E-6's})(.2)$$

Source: Authors

Similar to the concepts underlying first-term loss rate determinations, this expression divides the totaled E-5 and E-6 second-term personnel departures by the eligible FT population for the second-term re-enlistment category. Delineation of the E-6 second-term population is complicated by the variety of enlistment contract combinations possible within a length of service period of ten years. In this population cohort we have included the E-6 personnel who originally serve four year contracts and then re-enlist for four years (4 by 4 obligators), and the FT's who fulfill initial six year tours prior to signing two-year contracts (6 by 2 obligators). Additionally, although Table 9 shows that the average E-6 FT

is not classed as a 4 by 2 or 6 by 4 obligator, we have considered portions of these groupings as accelerated promotees and slow advancers, and therefore as inputs to the eligible E-6 population for second-term statistics. In figuring E-6 second-term losses, we have assumed an 80 percent career retention rate for E-6's and have thus subtracted twenty percent of the predicted eligible E-6 career population from the total losses of this cohort. Applying the 1981 FT data to Equation 11 results in loss rates of 42 percent for FTG's and 39 percent for FTM's. These predictions are within one percent of the reported 1981 retention statistics and thus act to substantiate the underriding assumptions of our modeling.

Navy manpower planners view personnel departing the Service after twenty years of duty as retirees and do not include them in compilation of loss rate statistics. Equation 12, our expression for the career loss rate, encompasses this definition while also adhering to the principles employed in Equations 10 and 11.

Career Loss Rate = (Eq. 12)

$$\frac{\text{E-6 Career Loss + E-7 Non-Retirees Loss}}{\text{Elig E-6's + Elig E-7's + Elig E-8's + Elig E-9's}}$$

where:

$$\text{Elig E-6's} = \frac{(1)}{\text{TIR E-6}}(\%\ \text{4YO})(\%\ \text{2YR 1st RENL})(\%\ \text{2YR 2nd RENL})(\text{E-6})$$

$$+ (.2)(\%\ \text{4YO})(\%\ \text{2YR 1st RENL})(\%\ \text{2YR 2nd RENL})(\text{E-6's})$$

$$+ (.2)(\%\ \text{6YO})(\%\ \text{2YR 1st RENL})(\%\ \text{2YR 2nd RENL})(\text{E-6's})$$

and,

Eligible E-7's = (.5)(E-7's)

Eligible E-8's = (.2)(E-8's)

Eligible E-9's = (.1)(E-9's)

E-7 Non-retirees Loss = (.2)(Total E-7 Loss)

Source: Authors

Because of the extended TIR's for E-7's shown in Table 9 and the Navy's tendency to negotiate re-enlistment contracts of two to four year duration, we have estimated that half of the E-7 population of FTG's and FTM's will encounter re-enlistment decisions each year. Of those E-7's opting to leave the Service at these decision points, we have assumed that twenty percent have served less than 20 years in the Navy and thus become inputs to the loss rate figures. We have further simplified our calculations by assuming that all E-8 and E-9 departures are attributable to 20-year retirees and thus do not affect loss percentages. Only small fractions of the E-8 and E-9 populations have been adjudged eligible for re-enlistment since servicemen within these rates are usually close to or have passed the 20-year service standard for retirement and are less likely to sustain additional military obligations. Following these assumptions in the application of Equation 12 to the 1981 personnel stocks of FT's results in career loss

percentages of 14 and 6.5 percent for the FTG's and FTM's, respectively.

After having first formulated the loss rate equations and derived the percentages associated with the 1981 transition matrices, we can examine the effect of replacing the 1981 personnel loss statistics with 1983 POM goals for loss rates. Equation 13 provides the fundamental relationship required for this study.

$$\text{Loss Rate} = 1 - \text{Retention} = \frac{\text{Losses}}{\text{Elig Population}} \qquad \text{(Eq. 13)}$$

where, eligible population, for each case, is defined as the denominators of the Equations 10, 11, and 12.

Source: Authors

Substituting the 1983 retention goals into this expression gives the following loss rate objectives:

$$\text{1st Term Loss Rate} = 1 - .47 = .53$$

$$\text{2nd Term Loss Rate} = 1 - .67 = .33$$

$$\text{Career Loss Rate} = 1 - .98 = .02$$

Solving for Losses in Equation 13 determines the total number of losses required in the 1981 personnel stock figures to produce matrices satisfying the 1983 POM goals for retention.

Once the theorized losses for the 1983 POM matrices have been calculated, a means for distributing these departures among the beginning inventories of each rate is required.

We have utilized the following guidelines in making this proportionment:

1. For first-term loss rates, E-3 losses are assumed to be constant, and the remaining losses are distributed between E-4's and E-5's in the same proportions as in the 1981 matrices.
2. For second-term loss rates, the determined losses are distributed between E-5's and E-6's in the same proportions as in the 1981 matrices.
3. For career loss rates, the determined losses are distributed between E-6's and E-7's in the same proportions as in the 1981 matrices.

Subtracting the resulting distributed losses from each rate's actual 1981 loss rate figures gives the number of personnel that must be added to the 1981 matrices to produce transition flows based on the 1983 POM goals.

To complete our development of the 1983 POM goal-oriented matrices, the projected gains to be added within each 1981 rate's beginning inventory must be partitioned into appropriate cohorts of the ending inventories. In accomplishing this division, we have assumed that all additions occur in either the cohort representing those personnel remaining in the rate throughout the year or in the cohort of those technicians advancing to the next rate by year's end. The projected gains have been distributed to these two groups according to 1981 proportions. The new transition matrices are then calculated by dividing the determined cohort sizes

by the total number of personnel within each rate. Tables 10 and 11 display the resulting 1983 POM projections personnel transition matrices for the FTG's and FTM's.

D. SUPPLY

In the 1980's the United States will experience a significant decline in the sizes of the population cohorts initially entering the full time work force. Given this problem, we have examined enlisted supply projections by using a mathematical model. This section presents the supply issues that need to be examined to see if there will be enough personnel available to meet the demands for new enlistees.

The primary means used to determine this supply through 1990 is a model commonly referred to as the Rand Model. This model is a result of Fernandez' work in "Forecasting Enlisted Supply: Projections for 1979-1990" [Fernandez, 1979]. In his study, Fernandez develops an enlistment supply model for Navy non-prior service (NPS) male high school diploma graduates (HSDG). The model is developed for mental categories I, II, IIIA, and IIIB. This is extremely relevant, since the only mental categories recruited for the Fire Control Technician ratings are mental groups I, II, and IIIA.

1. Enlistment Supply Model

For the supply-limited mental groups, the number of voluntary enlistments into the service in a given month, relative to the available youth population pool, is postulated to depend upon the ratio of military to civilian wages,

TABLE 10

1983 POM Projections Personnel Transition Matrix for FTG's

		End of Year							
		E-1/3	E-4	E-5	E-6	E-7	E-8	E-9	LOSS
Beginning of Year	E-1/3	.336	.447	.008	0	0	0	0	.209
	E-4	.036	.493	.354	0	0	0	0	.117
	E-5	.002	.011	.646	.158	0	0	0	.183
	E-6	0	0	.002	.753	.148	0	0	.097
	E-7	0	0	0	0	.831	.071	0	.098
	E-8	0	0	0	0	0	.750	.05	.2
	E-9	0	0	0	0	0	0	.75	.25

Projected Re-enlistments

FIRST TERM	SECOND TERM	CAREER
47%	67%	98%

Source: Authors

TABLE 11

1983 POM Projections Personnel Transition Matrix for FTM's

		End of Year							
		E-1/3	E-4	E-5	E-6	E-7	E-8	E-9	LOSS
Beginning of Year	E-1/3	.284	.478	.003	0	0	0	0	.235
	E-4	.031	.542	.306	0	0	0	0	.121
	E-5	0	.01	.642	.168	0	0	0	.18
	E-6	0	.003	.003	.763	.156	0	0	.075
	E-7	0	0	0	0	.855	.073	0	.072
	E-8	0	0	0	0	0	.750	.05	.2
	E-9	0	0	0	0	0	0	.75	.25

Source: Authors

on the number of recruiters in production for the service in that month, on values of the youth unemployment rate, and upon certain seasonal factors. This is expressed in Equation (14), the basic form of the Rand Model used for our estimation of mental groups I, II, and IIIA.

$$E_t/POOL_t = a_0 + \sum_{i=1}^{11} a_i \, MDUM_{i,t} + b(MP_t/CP_t)$$

$$+ c \, RECR_t + \sum_{j=0}^{11} d_j \, U_{t-j} + \varepsilon_t \qquad \text{(Eq. 14)}$$

where:

E_t = voluntary enlistments in period t

$POOL_t$ = weighted average of NPS male civilians aged 17 to 21 at time t, the weights being the proportions of total DoD enlistments of each age in the post-draft years; in thousands

$MDUM_{i,t}$ = indicator variables for month 1 (January) through 11 (November), taking on the value 1 if period t falls on month i, and zero otherwise

MP_t = average first year regular military compensation at time t for enlistees with less than two years of service

CP_t = average weekly earnings in the total private economy at time t, seasonally adjusted

$RECR_t$ = number of production recruiters for the particular service at time t

U_t = unemployment rate for males, aged 16 to 19, at time t, seasonally adjusted

ε_t = random disturbance term at time t, assumed independent and identically distributed normal random variables with mean zero

a_0 is a constant and a_i, b, c, and d_j are regression derived weights.

Source: Fernandez, 1979

A more complete description of variables, including sources, are contained in Appendix B of "Forecasting Enlisted Supply; Projections for 1979-1990," by Richard Fernandez. For our calculations, Fernandez' input parameters have been updated to set military yearly pay equal to 11,300 dollars, establish civilian wages of 261 dollars and 85 cents per week, and assign a recruiting force strength of 3540 in 1982 with an increase of 50 recruiters each year thereafter. Projected youth unemployment rates through the 1980's, obtained from the Bureau of Labor Statistics, have also been used in our analysis to describe the nation's economy for the next nine years. Our resulting enlistment supply estimates are probably somewhat high since we have considered the military to civilian pay ratio to be constant even though servicemen's pay has historically lagged advances in nation-wide wages. Applying Equation (14) to the updated variables, we have obtained the results contained in Table 12. These totals are highlighted for years 1982, 1986, and 1990 in Table 13.

TABLE 12

Navy Enlisted Supply Projections

NPS Males

Year	Mental Groups I and II	Mental Group IIIA
1982	30585	20470
1983	27746	18734
1984	25404	17404
1985	24153	16722
1986	22956	16087
1987	22372	15854
1988	22094	15836
1989	22045	15931
1990	22473	15645

Source: RAND Model by Richard Fernandez

TABLE 13

Fire Control Technician Supply Projections
with 1981 Re-Enlistment Rates

(Total Supply of Mental Groups I, II, and IIIA)

1982		1986		1990	
I and II	IIIA	I and II	IIIA	I and II	IIIA
30585	20470	22956	16087	21473	15645

Expected (FT) Accessions Based on 1981 Data
(4.25% Groups I and II, 1.1% Group IIIA)

Based on 1981 Re-enlistment Rates for FT's

First Term	Second Term	Career
28%	66%	90%

Resulting Stocks Through 1990

	1982		1986		1990	
Rate	FTG	FTM	FTG	FTM	FTG	FTM
E1/E3	310	292	287	258	264	237
E-4	1085	1156	1116	1193	1021	1090
E-5	723	689	944	834	900	785
E-6	438	505	427	448	449	448
E-7	399	370	349	406	337	418
E-8	85	78	96	103	94	115
E-9	18	19	18	18	19	21

Source: Authors

Based on 1981 statistics obtained from the recruiting command, only 4.26 percent of mental groups I and II, and 1.1 percent of mental group IIIA were recruited for the Fire Control Technician ratings. By applying these percentages to the supply figures indicated in Table 12, we obtain the results presented in Tables 13 and 14. As indicated in Table 13, there will be a decreasing supply in the 17 to 21 year old population available to meet the increasing demand required by expanding the fleet to the 600-plus ship level.

By using the 1981 re-enlistment rates for the FT's and inserting the predicted accessions into the resulting transition matrix of the basic manpower transition flow model, as presented earlier, the stocks of FT's, as shown in Table 13, are calculated. The number of FT's available in 1990 will be reduced substantially from present stocks. Even by using the POM 1983 projected re-enlistment rates of 47 percent for first term, 67 percent second term and 98 percent for career personnel, the resulting numbers of FT's still do not increase dramatically through 1990 (see Table 14 for specific results).

2. Demand-Supply Comparison

When the results obtained in our demand analysis are compared with the manpower supply projections, possible shortfalls are indicated. Table 15 compares the ship and shore demand with the supply stocks based on the increase re-enlistment rates in the 1983 POM. This table combines the FTG and FTM ratings. As shown, there is an excess of E-1 through E-5

TABLE 14

Fire Control Technician Supply Projections
with 1983 POM Re-Enlistment Rates

First Term	Second Term	Career
47%	67%	98%

Resulting Increase in Stock for All Rates

	1982		1986		1990	
Rate	FTG	FTM	FTG	FTM	FTG	FTM
E1/E3	310	292	291	262	268	242
E-4	1111	1198	1174	1293	1079	1191
E-5	813	803	1145	1078	1132	1065
E-6	506	579	597	642	691	725
E-7	426	390	446	505	509	613
E-8	88	78	112	114	127	147
E-9	19	19	20	19	22	24

Source: Authors

TABLE 15

Combined Ship/Shore Demand Versus Supply Through 1990

Increased Re-Enlistment Rates (POM '83)

	FIRST TERM			SECOND TERM			CAREER		
	47%			67%			98%		
	1982			1986			1990		
RATE	DEMAND	SUPPLY	DIFF	DEMAND	SUPPLY	DIFF	DEMAND	SUPPLY	DIFF
E1-E3	467	602	+ 135	531	553	+ 22	653	510	- 143
E-4	2010	2309	+ 299	2193	2467	+ 274	2511	2270	- 241
E-5	1680	1616	- 64	1932	2221	+ 289	2338	2197	- 141
E-6	1790	1085	- 705	1995	1239	- 756	2322	1416	- 906
E-7	891	816	- 75	997	951	- 46	1154	1122	- 32
E-8	407	166	- 241	442	226	- 216	493	274	- 219
E-9	272	38	- 234	295	39	- 256	335	46	- 289
TOTAL	7517	6632	- 885	8385	7696	- 689	9806	7835	-1971
E1-E5 DIFF	--		+ 370	--		+ 585	--		- 525
E6-E9 DIFF	--		-1255	--		-1274	--		-1446

Source: Authors

personnel up to, and including, 1986. However, starting in 1987 and continuing through 1990, there are major shortfalls realized in all rates. For the more senior enlistees, the E-6 through E-9 paygrades, the shortages exist today and the situation in manning for skilled technicians never improves. The figures, which show increasing demands on a yearly basis and reducing annual supplies, indicate that the manning projections for the future look rather grim.

Although the enhanced retention objectives of the 1983 POM will lessen the loss of trained technicians, the planned increases in the career force will not totally alleviate the discouraging manning outlook presented by our supply and demand forecasts. Given we could achieve 100 percent manning in 1982, and using the 1983 POM projected re-enlistment rates, we can see from Table 16 that the manning shortfalls would still exist in all rates, except E-7. Therefore, the Navy's manpower managers, working with limited accessions, must not only solve the problems in compensating for past deficits, but also respond to growth requirements stemming from the expanding fleet. Our approach to this perplexing problem is to examine the FT training pipeline in an attempt to determine the impact increased demand will have on the training command and to try to determine methods for eliminating the FT billet shortfalls.

E. TRAINING PIPELINES

The Navy training system is a complex interrelationship of people, equipment, materials, and facilities designed to

TABLE 16

Demand Versus Supply with Zerobased 1982* Demand and POM 1983 Re-Enlistment Rates

RATE	1982 DEMAND	1982 SUPPLY	1982 DIFF	1986 DEMAND	1986 SUPPLY	1986 DIFF	1990 DEMAND	1990 SUPPLY	1990 DIFF
E1-E3	467	467	0	531	554	+ 23	653	510	- 143
E-4	2010	2010	0	2193	2483	+ 290	2511	2293	- 218
E-5	1680	1680	0	1932	2276	+ 344	2338	2223	- 115
E-6	1790	1790	0	1995	1468	- 527	2322	1501	- 821
E-7	891	891	0	997	1243	+ 246	1154	1344	+ 190
E-8	407	407	0	442	343	- 99	493	365	- 128
E-9	272	272	0	295	118	- 177	335	89	- 246
TOTAL	7517	7517	0	8385	8485	+ 100	9806	8325	-1481
E1-E5 DIFF	--		0	--		+657	--		- 476
E6-E9 DIFF	--		0	00		-557	--		-1005

*Assuming all demand requirements are made in 1982.

Source: Authors

maintain an effective military capability. The added burden on the training command created by the increased demands for personnel in the envisioned 600-plus ship fleet will be dramatic. In addition to meeting growth requirements of the expanded Navy, personnel must be supplied to the training pipeline to replace the shortfalls now existing in the E-6 through E-9 categories. The augmented demand for technicians may overload present school facilities and result in lengthy time requirements for training.

Pipeline managers derive student loading requirements for the Service schools from the needs to replace personnel losses and to satisfy forecasted growth in billet assignments. In the preceeding discussions, losses have been projected by employing the personnel transition matrices. Additionally, gains in billet authorizations for FT's have been predicted through the use of mathematical models based on the anticipated ship-mix of the fleet during the 1980's. The deficit between these needs and the projected end strengths describes a demand for an output of trained personnel from the Navy's schools.

Training command managers must schedule and coordinate the pipeline training so that technicians are available at the proper time to replace the personnel losses and to fill the new billets. Computer simulation models can aid in finding solutions to these management problems. Overviews of the general training requirements of the Navy and of the specifics of the FT schooling process are presented below

and form the basis for the subsequent descriptions of the simulation modeling techniques used in our analysis of the future fire control technician training process.

1. General Training Flow

The typical enlistee enters the Navy at any one of three Recruit Training Centers (RTC's), located at Great Lakes, Illinois, Orlando, Florida, or San Diego, California. After completing seven weeks of Basic Military Training (BMT), the recruits are processed to initial assignments, either ashore or afloat. If the individuals are qualified and selected, they will proceed to advanced training courses. These schools usually involve Class A school for fundamental training in a specific area, followed by Class C school for the more technical subject matter to be covered. Depending on the type of training selected, the enlistee could possibly not reach his or her first command for a year and one-half, or more.

2. Training Pipeline for Fire Control Technicians

Figure 1 is provided as a rudimentary guide to the Fire Control Technician flow through the training pipeline. The FT is recruited as a four year (4 YO) or as a six year (6 YO) obligator. The distinction between the two will be highlighted later as the pipeline is examined in greater detail. The attrition figures shown in Figure 1 and the statistics on rollback graduates presented in the following discussions are based on 1981 data and have been provided by managers of the various Service schools.

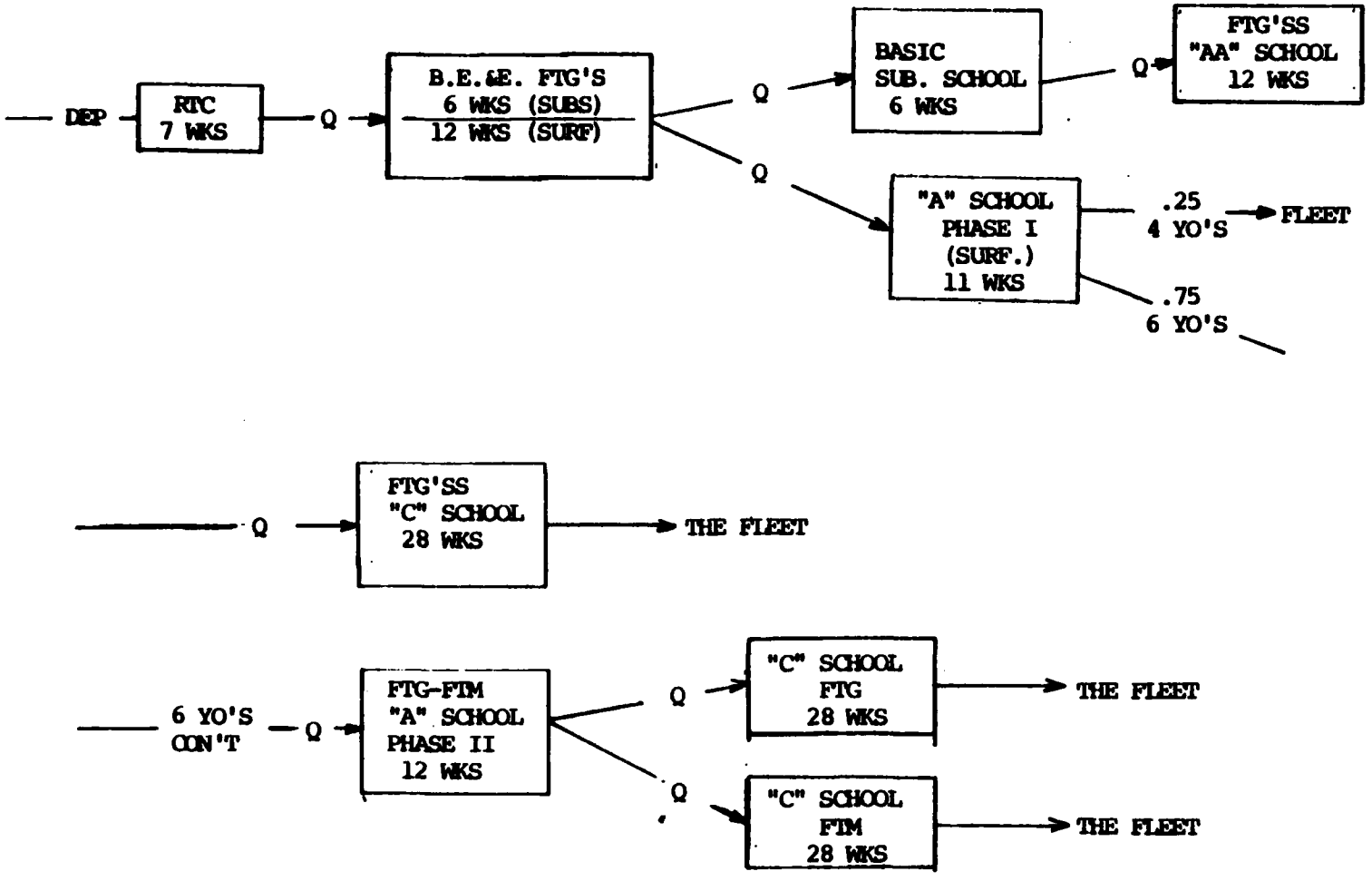


FIGURE 1. Fire Control Technician Training Pipeline Diagram

TOTAL LENGTH OF SCHOOLING (FTG-FTM SURF.)
FOR 6 YO'S 68 WKS (1 YEAR AND 4 MONTHS)

TOTAL ATTRITION THROUGH "C" SCHOOL

FTG (SURFACE)

RTC	B.E.&E.	"A"	"C"
5%	24%	3%	4%

FTG (SUBSURFACE)

RTC	B.E.&.E.	"SUB"	"A"	"C"
5%	22%	9%	8%	8%

FTM (ONLY SURFACE)

RTC	B.E.&.E.	"A"	"C"
5%	28%	3%	4%

Source: Authors

FIGURE 1. (Continued)

Once an individual is recruited and enlists for the FT rating, several choices must be made. Does the enlistee want to be a Fire Control Technician Missile (FTM) or a Fire Control Technician Gunnery (FTG)? The differentiation between the two is simple, the missile tech FTM works and maintains particular missile systems, while the FTG controls primarily gunfire support systems. Also, the decision must be made whether to go to the surface community or to the subsurface community and serve in submarines. Whichever choice is made, the training is identical until Basic Electricity and Electronics (BE&E) is reached.

The enlistee also has the option to delay entry into the Navy. This program, the Delayed Entry Program (DEP), can influence the student loading on the training command. Depending upon the individual, he can wait up to one year after signing up to enter the Recruit Training Center (RTC). The advantage with the DEP is that the individual can choose the time he enters the Navy, thus dispersing the heavy recruitment flows into the RTC's throughout the year. Whether an enlistee enters through the DEP or not, he begins his first phase of training at the RTC. Basic training of the recruit is concerned with transforming a civilian into a potential member of the Navy. In the space of a few short weeks, the recruit learns primarily how to adapt to military life. This training is very general in character because of the wide variety of programs open to all individuals after they finish basic

training. As shown in Figure 1, the attrition rate for FT's through the RTC is relatively low at five percent. If a recruit is having academic or physical difficulties through RTC, he can be rolled back or delayed in graduation for approximately two weeks. This figure is also low, and is about five percent.

At the conclusion of the basic training, the FT recruit is sent to BE&E School. The overall objective of this school is to provide the basic technical knowledge and skills in electrical and electronics theory and application which are prerequisites for additional training at Class A Schools. The course employs a computer managed, individualized multimedia instructional system, wherein each student proceeds at his best learning pace, allowing the individual student to proceed at a reasonable speed through the curriculum.

Several important activities transpire at this particular phase of training for the FT. First, they are subdivided into their specific communities. The FTG (subsurface) personnel spend approximately six weeks here before proceeding on to Basic Submarine School. The FTG/FTM (surface) seamen, on the other hand, stay in BE&E School for about 12 weeks. These times will vary, of course, because it is a self-paced type learning experience and the more proficient individuals finish earlier, with the less adept taking somewhat longer. Second, as attested to by the high attrition rates for the FTG (subsurface) students, 22 percent, and for the FTG/FTM (surface) trainees, 28 percent, a weeding out process takes

place. This is a very necessary step because the individuals who cannot handle the educational and mental demands placed on them at BE&E School would certainly not be able to make it further in the training cycle as the courses of instruction become more difficult. Those who attrite from BE&E School are sent back to the fleet for reassignment, with some being allowed to apply for a different rating.

Upon completion of the BE&E training, the FTG(SS) trainees go to basic Submarine School. The course of instruction is six weeks in length and is designed to provide fundamental knowledge of submarine duty and escape procedures. The attrition rate is nine percent, with the sailors attriting returning to the surface community for reassignment. As with the RTC, the school has a rollback rate of about 15 percent, which allows the willing but somewhat less capable students to delay approximately one week before proceeding on to the next phase of training.

Once they have completed basic Submarine School, the FTG(SS) trainees go to Underwater Fire Control Technician Class A School. The main purpose of this school is to provide the personnel with a basic knowledge of the fundamentals of electronics, fire control electromechanical devices, and analog and digital computers. It also provides them with the prerequisites for further advanced electronic equipment or system training in the submarine community. The FTG(SS) A School is 12 weeks in length with an attrition rate of eight percent. The attriters are sent back to the surface community

for reassignment and redesignation. This school has a 16 percent rollback rate.

Contrarily, the FTG/FTM (surface) sailors proceed from BE&E School to Fire Control Technician Phase I A School. The main purpose here is to provide E-1 through E-3 personnel a basic knowledge of the fundamentals of electronics, fire control, electromechanical devices, and general purpose test equipment. Also, the course covers material on electrical safety, basic electronics (solid state RF/AF theory), motors and generators, computers and fire control problems. The students are in Phase I A School 11 weeks before going to Phase II of A School. The attrition rate is approximately three percent with a 15 percent rollback feature. One note of importance at this point, not all FTG/FTM trainees go to Phase II of A School. Approximately 25 percent of the students are four year obligators and, instead of continuing to more advanced schooling at Phase II and C School, are assigned directly to fleet or shore commands. Only six year obligators continue to advanced training at Phase II and C Schools. Additionally, the lower one-third of the class in Phase I is not permitted to continue to higher levels of training and are reassigned, terminating their training. In other words, only six year obligators in the top two-thirds of the class complete Phase I of A School and continue to Phase II.

Phase II of A School is designed to prepare trainees for advanced equipment or systems courses. It covers radar principles, analog and digital computer fundamentals, and

combat weapons systems concepts. This school is 12 weeks in length and has a very small attrition rate of only three percent. As with the other schools in the training pipeline, an approximate 16 percent rollback feature is incorporated.

At this point the system becomes rather intricate because the FTG(SS), FTM (surface), and FTG (surface) communities split into different directions. The FTG(SS) trainees, having already been separated, divide again into different and unique Underwater Fire Control Technician Class C Schools. Each school is classified according to the specific weapons system the individual is being trained to operate and maintain.

All FTG(SS) C Schools are designed to provide technicians with knowledge of weapon systems theory of functional operation, and practical experience in both equipment operating procedures and organizational maintenance. The training courses use multi-media, group-paced instructional techniques which include a hands-on, specialized training approach to learning. Once the FTG(SS) trainees complete their course of study at the designated C School, they are assigned a specific Navy Enlisted Classification Code (NEC). This code designates the individual as a specialist in a particular combat system.

Unlike the FTG(SS) community, the FTG and FTG surface trainees have stayed together throughout the pipeline until this point. Once they complete A School Phase II they separate and are assigned to various Fire Control Technician Class C Schools. The specific C Schools vary in length,

like the FTG(SS) community, from a minimum of eight weeks to a maximum of 42 weeks. Not everybody attends just one C School. The majority of students attend between three and seven schools. Therefore, like the FTG(SS) sailors, the average time spent in the C School area is approximately 28 weeks. This holds true for both FTG and FTM students. The C Schools are designed along the same lines for the FTG/FTM's as with the FTG(SS) community. They provide the more advanced training for functional operation and practical experience for equipment performance and maintenance.

Upon completion of the C School phase, again the individual is assigned a specific NEC which classifies him as specialist in the weapon system his training was centered around. The overall attrition rate for the FTG and FTM surface community is four percent, which is somewhat lower than that of the FTG(SS) sailors. No specific reason is given for this attrition anomaly. The FTG or FTM trainee is now ready for assignment to a shore or fleet command, as determined by the needs of the Navy.

As presented, the training flow of the FT's is rather complex. Each school through the pipeline has its own unique qualities, which include varying attrition, student loading, lengths, and rollback rates. By summing just the nominal lengths for the various schools through the FTG surface pipeline, we can see that the total time expected in the training cycle is 68 weeks (one year and four months). This leads to some interesting problem areas and implications.

For example, little or nothing has been mentioned of the delays due to travel time, or wait time for the school to begin. Not all schools begin the day the student arrives. Many times the student must wait several days or weeks to start the school assigned. Rollback or setback rates can certainly affect the completion times and also affect the student loading factor of the different classes. All these factors contribute to the length of stay in the FT pipeline.

In the first part of this chapter, certain requirements or demands were given for the fleet and shore commands. Since these demands are on an annual time table, the lag time required to train the students has a dramatic effect on the overall manning of the Navy today. Pipeline managers need to recognize this required lead time, including queue times and external factors, which affects the flow of students.

As stated before, the overall objective of the training pipeline is to maintain an effective military capability. The growth of the Navy to 600-plus ships will have a major effect on the training command's ability to perform this task. Requirements for increased class sizes and the needs for additional instructors, materials, and facilities will be important considerations in mapping the Service's response to the manning problems we have forecasted. Examination of the FT training pipeline demonstrates the extent to which the training command will be affected by the projected growth of the fleet. The predicted FT schooling requirements are complex, but form only a small input to the overall training

and manpower problems that will be encountered by the Navy in fulfilling needs for a multitude of ratings.

III. SIMULATION MODELING METHODOLOGY

A. INTRODUCTION

OPNAV Instruction 1500.8J, in detailing the Navy's training planning process in support of systems developments, recognizes that "affordable and cost effective training must derive from trade-off analyses of manpower, personnel, and training resources." Congressional constraints on enlistee qualifications and manpower authorizations establish recruiting goals and impact upon the academic potential of the enlisted force. Decisions within the Navy Military Personnel Command influencing the retention of skilled servicemen or the promotional opportunities of sailors are directly reflected in the demands placed upon the training command and in the number of accessions required each year. Similarly, training school objectives dictating factors such as course durations, student-instructor ratios, or grading standards affect recruiting command quotas and the availability of trained personnel for billet assignment. Responsible policy development within one of the three sectors of the Navy's total manning posture must therefore consider the forecasted effects upon the other resources.

Our analysis of supply and demand figures for the FTG and FTM ratings suggests that modifications in the Navy's manpower and personnel policies will be required during the 1980's in response to changing demographics and the proposed fleet expansion. These policy shifts will undoubtedly

necessitate adjustments within the fire control technician training process as the Navy's schools react to varying inputs and increasing numbers of senior technician billets. However, our projections are predicated upon a series of assumptions imposed to simplify the economic, social, technological, and political environments for the next nine years. Small variations in any of the factors influencing these anticipated environments can substantially alter the forecasts. For example, Dr. Rolf Clark, noting expected reactions in the Navy's proposed growth to fiscal restrictions and market pricing, estimates that a reduction of one percent in procurement dollars will induce a ten percent decrease in force size in the 1990's [Clark, 1980]. This degree of sensitivity, coupled with the obvious difficulties in correctly depicting all of the input variables throughout the 1980's, renders the accuracy of our forecasts, particularly in the long-range supply determinations, conditional upon nation-wide trends and global developments. For this reason, proposed training command policies derived from these forecasts must be annotated to describe the underlying assumptions.

In view of these complexities in prediction and of the wide range of environmental conditions possible from changes in the multitude of input parameters, a method for studying policy options under alternative climates is needed by the managers of the Navy's training command. A viable technique will enable manpower planners to assess proposals arising from unexpected shifts within the economic, social,

technological, and political arenas. Accordingly, we have designed a simulation model of the fire control technician training pipeline and, using the SLAM programming language, adapted this representation for computer analysis. Our subsequent study illustrates the usefulness of this modeling approach for timely and cost-effective policy evaluation.

B. SIMULATION MODELS

Researchers have often been confronted with the problem of predicting the performance of a collection of interacting objects which, when grouped as a whole, identify a system. From studies of this nature, investigators have developed methods for constructing conceptual models that demonstrate the functioning of the system and facilitate understanding the influence of component factors. The degree of detail and the size of these models are characterized by the scope of interest of the examiners. Thus, the perceptual framework may limit the study to only a segment of a larger, encompassing system.

Simulation problem-solving techniques can be traced hundreds of years in history and include the early development of navigational tables. However the widespread application of the methodology began after World War II and has paralleled the advancements in computer hardware and software. Until this boom in technology, research was restricted to analytical studies that were generally expensive and time-consuming, even in simplified forms. With the rapid progress

in computers during the 1950's and 1960's, the cost of multiple computations was substantially lowered and step-by-step manipulations of complicated, dynamic systems became economically feasible. The enhanced computer capabilities gave analysts the freedom to build complex mathematical models that could be translated into machine programs for relatively quick experimentation. These computer-applied mathematical representations of systems have become known as simulation models.

The related process of simulation modeling can therefore be defined as "the representation of the dynamic behavior of the system by moving it from state to state in accordance with well-defined operating rules" [Pritsker and Pegden, 1979]. The description of the system is accomplished through equations indicating the values of a set of variables throughout a period of time. As these variables assume specific attributes, the conditions of the entire system at any particular time are defined. Manipulations of the initial variable setpoints or of the mathematical rules delineating movements over time permit the investigations of alternative system arrangements.

The universal application of simulation modeling for systems problem-solving has established the method of analysis as a leading operations research technique within both the private and public sectors of the economy. Initial interests in this approach focused on efforts in the 1950's by military leaders to produce superior, yet affordable air

defense weapons systems and by civilian engineers intent on optimizing solutions to large scale problems, such as river basin water control [Forrester, 1968]. Then, with the improvements in digital electronic computers in the early 1960's, the business world began utilizing simulation in the study of market trends. Dr. J.W. Forrester of the Massachusetts Institute of Technology further intensified the technique's employment in management science during the late 1960's with his explanations in the field of industrial dynamics. The growth of simulation modeling continued through the 1970's and the methodology is now applied to a long listing of management topics, including maintenance scheduling, information system design, consumer behavior prediction, and inventory control models.

In addition to their broad applicability, simulation models are beneficial in reducing the cost, risk, and time required to analyze systems. For example, computerized simulations can represent the operations of proposed systems and identify poor design features prior to construction expenditures. Functions of existing programs can also be modeled and studied without disturbing the status quo or unnecessarily lowering productivity. Furthermore, the technique permits the safe testing for the functional limits of a system's components. These advantages are augmented by the time savings created by the processing speeds of today's computers.

The popularity of simulation modeling has stimulated the output of a variety of computer-based languages designed

specifically for this type of experimentation. Some of the most widely used computer adaptations are the continuous-system simulation languages DYNAMO and CSMP-III, and the discrete modeling languages GPSS, SIMSCRIPT, and SIMULA. The continuous simulation models illustrate systems in which the rates of change in the values of variables are a function of time and are therefore expressed as algebraic, difference, or differential equations. In contrast, the discrete representations describe operations where variable attributes change instantaneously at precise times.

Each of the commercially available simulation languages offers some advantages over its competitors. DYNAMO, which originated at MIT to supplement work in industrial dynamics, is easy to learn and, despite an unsophisticated integration methodology, is often employed by social scientists to evaluate information feedback systems. Continuous System Modeling Program III (CSMP-III) is a FORTRAN-based language with excellent output capabilities and diagnostics, although its usage is relatively expensive. Of the discrete modeling languages, SIMSCRIPT is the most machine-independent and encompasses outstanding data collection features. However, SIMSCRIPT programs are sometimes hampered by noncomprehensive diagnostics, which lead to poor debugging, and by low error detection warnings. The latest version (V) of General Purpose Simulation System (GPSS) provides improved debugging capabilities, but is limited in its application to basic

queueing and inventory problems. SIMULA, popular in European scientific and administrative research, is a complex extension of the ALGOL language that enhances programming of special experimental models [Jacoby and Kowalik, 1980]. Table 17 compares the features of the three prominent discrete simulation languages.

C. SLAM

Although many of the available simulation languages are capable of satisfying our immediate experimentation with the Navy's training command processing of FT's,we have selected the recently introduced program entitled Simulation Language for Alternative Modeling (SLAM). Developed in 1979 by Claude Dennis Pegden and A. Alan B. Pritsker, this processing package contains the flexibility to model network-oriented, discrete-event, and continuous systems, or a combination of these structures. This unique feature overcomes major drawbacks in other languages and provides the framework for potential extensions to the current research. Additionally, SLAM is written in compliance with 1966 ANSI FORTRAN standard to ease implementation on a large number of computer installations. Also important from a Navy standpoint, a SLAM processor is presently utilized by the Department of the Navy Training Analysis and Evaluation Group located in Orlando, Florida.

The unified framework of SLAM, which enables the interface of network, event, and continuous segments of systems, significantly enhances the modeling powers of the user.

TABLE 17

Discrete Simulation Languages' Features

FEATURE	GPSS	SIMULA	SIMSCRIPT
Versatility	Restricted	General	General
Computational facilities	Poor	Good	Good
General-purpose programming facilities	No	Yes	Yes
Ease of use	Easy	For advanced users	For advanced users
Computational efficiency	Low	High	High
Data collection facilities	Adequate	Good	Excellent
Input-Output facilities	Inflexible	Good	Good
Compiler availability	Good	Restricted (in USA)	Very good

Source: Jacoby and Kowalik (1980)

Analysts can minimize modeling efforts by employing the convenient network-orientation (or process orientation) capabilities for sizeable portions of sophisticated systems, while turning to the flexibility, but complexity of the discrete event orientation when needed. Under the continuous system approach, the programmer may specify that the values of the state, or continuous, variables be computed using either a fixed step function or a variable step size determined by the Runge-Kutta-Fehlberg numerical integration algorithm [Pegden and Pritsker, 1980]. The following interactive features are possible through combinations of these three orientations:

1. Entities in the network model can initiate the occurrence of discrete events.
2. Events can alter the flow of entities in the network model.
3. Entities in the network model can cause instantaneous changes to values of the state variables.
4. When state variables reach prescribed threshold values, they can initiate entities in the network model.
5. Events can cause instantaneous changes in the values of state variables.
6. When state variables reach prescribed threshold values, they can initiate events.

[Pegden and Pritsker, 1980]

The compatibility of the three approaches permits the evolutionary construction of models and frees the researcher from the restrictions imparted when the initial orientation must govern the entire analysis. Furthermore, SLAM modeling eliminates the requirement to program events in chronological order. Although we have focused our analysis exclusively upon a network model, a fundamental description of the three modeling views is presented below to facilitate discussions of future studies.

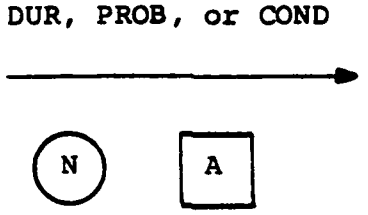
1. Process Orientation (Networks)

The basis for many simulations entails the sequencing of system elements in a predetermined pattern. For these models SLAM utilizes the process orientation to establish network structures and to route entities through a series of elements, such as queues, servers, and decision points, that represent the system of interest. The programmed network is formed by the use of specialized SLAM symbols for nodes, which designate functions to be performed, and branches (or activities), which specify the movement of items between the nodes. The flows of entities through the system structure are thus directed by decision-logic characteristics of each node and branch. To aid in the collection of data on the dynamic behavior of the system, SLAM incorporates notation to differentiate the entities through the assignment of attributes. The effectiveness of this simulation is dependent upon the analyst's ability to create a pictorial representation of the network operation and to transcribe the model

into program statements acceptable for translation by the SLAM processor.

As entities, representing trainees in our system, are routed across branches of the SLAM network model, several characteristic functions can be specified. A primary utilization of the branch symbology is the inputting of explicit time delays into the model with the designation of an activity duration. The delay can be depicted as a constant value, a random sample from a probability distribution, or a specified attribute of the arriving entity. Using an activity-scanning feature, SLAM programs can also make the timing of activities dependent upon the release time of a prescribed node. Another prominent usage of the branch terminology is the assignment of a probability or a condition necessary for an entity to follow a particular path in the model. Additionally, for branches representing services for the routed entity (the activities frollowing QUEUE and SELECT nodes), the number of parallel servers may be indicated. Finally, the programmer may obtain statistical data for an activity's utilization by assigning an activity number. Figure 2 gives the SLAM symbology for diagramming activities.

Distinct system functions are introduced in SLAM network models by the use of nodes. The fifteen available node types are shown in Table 18. These functions further delineate the flow of items through the model and amplify the user's options in describing system performance. Adding a defined



The symbol for a branch representing an activity in which:

N	is the number of parallel servers if the activity represents servers
A	is an activity number (an integer)
DUR	is the duration specified for the activity
PROB	is the probability of selecting the activity
COND	is a conditional expression for selecting the activity if the activity is a nonserver.

Source: Pegden & Pritsker (1979)

FIGURE 2. SLAM Symbology for Diagramming Activities

TABLE 18

Types of Network Nodes in SLAM

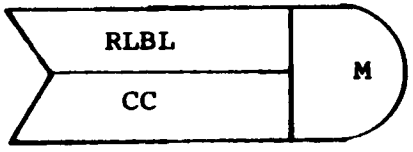
Name	Symbol/Statement	Function
ACCUM		The ACCUM node combines entities by specifying a release mechanism consisting of the number of arrivals required for subsequent releases (SR), and the attribute-holding criterion (SAVE). The latter prescribes the rule for assigning attributes to the entities released from the node based on the attributes of the arriving entities.
	ACCUM,FR,SR,SAVE,M;	
ALTER		The ALTER node changes the capacity of the resource RLBL by CC units.
	ALTER,RLBL/CC,M;	

TABLE 18 (Continued)

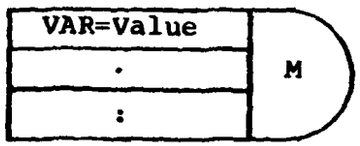
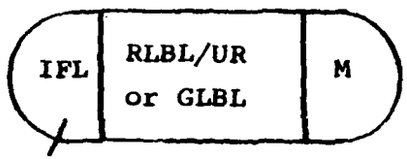
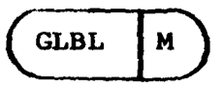
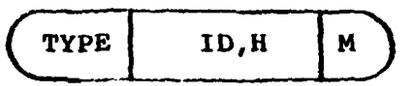
Name	Symbol/Statement	Function
ASSIGN		The ASSIGN node assigns values to entity attributes and to global variables at each arrival at the node
	ASSIGN,VAR=Value,repeats---,M;	
AWAIT		The AWAIT node delays entities in file IFL based on the availability of UR units of resource RLBL or the status of a gate GLBL.
	AWAIT(IFL),RLBL/UR or GLBL,M;	
CLOSE		The CLOSE node changes the status of gate GLBL to closed.
	CLOSE,GLBL,M;	
COLCT		The COLCT node collects statistics on and histograms of SLAM variables at each arrival at the node. TYPE specifies the variable or type of statistics to be recorded, ID specifies the identifier used for labeling output reports, and H specifies parameters to be used in preparing histograms.
	COLCT,TYPE,ID,H,M;	

TABLE 18 (Continued)

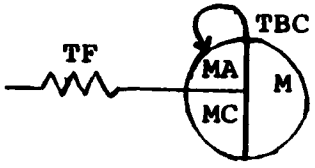
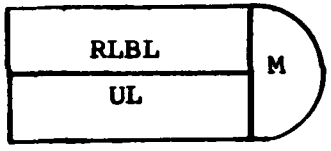
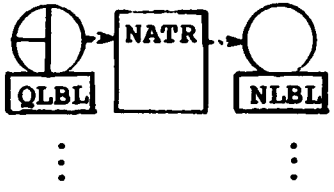
Name	Symbol/Statement	Function
CREATE	 CREATE,TBC,TF,MA,MC,M;	The CREATE node generates entities with the first release at time TF and thereafter according to the time between creations TBC up to a maximum of MC releases. The time of creation is stored in attribute MA of the entity.
FREE	 FREE,RLBL/UF,M;	The FREE node releases UF units of resource RLBL. The freed units are made available to entities waiting at PREEMPT and AWAIT nodes.
GOON	GOON,M;	The GOON (go on) node provides a continuation node in which every entering entity passes directly through the node.
MATCH		The MATCH node delays the movement of entities by keeping them in QUEUE nodes until entities with the same value of attribute NATR are resident in every QUEUE node preceding the MATCH node. When a match on attribute NATR occurs each matching entity is

TABLE 18 (Continued)

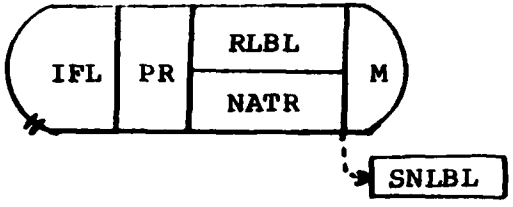
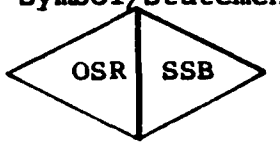
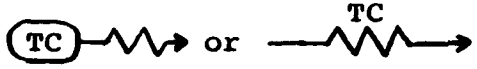
Name	Symbol/Statement	Function
MATCH (Continued)	MATCH,NATR,QLBL/NLBL, repeats--;	routed from its QUEUE node (labeled QLBL) to the node labeled NLBL.
OPEN		The OPEN node changes the status of gate GLBL to open
	OPEN,GLBL,M;	
PREEMPT		The PREEMPT node preempts resources seized by entities at AWAIT nodes. The PREEMPT node can also be employed in a priority mode which allows preempting entities with a given level of priority to be preempted by entities with higher priority (PR). The remaining activity time is stored in attribute NATR and the preempted entity is routed to the node labeled SNLBL.
	PREMPT(IFL)/PR,RLBL,SNLBL,NATR,M;	
QUEUE		The QUEUE node delays entities in file IFL until a server becomes available. The QUEUE node initially contains IQ entities and has a capacity of QC entities. For multiple queues, SLBL specifies the label of the associated SELECT node.
	QUEUE(IFL),IQ,QC,BLOCK or BALK,SLBL;	

TABLE 18 (Continued)

Name	Symbol/Statement	Function
SELECT	 SELECT,QSR,SSR,BLOCK or BALK,QLBL's;	The SELECT node selects among multiple queues (QLBL's) and available servers based on the queue selection rule (QSR) and the server selection rule (SSR).
TERM	 TERM,TC;	The TERM node destroys entities and terminates the simulation. The arrival of the TCth entity causes the simulation run to be terminated.

Source: Pegden & Pritsker, 1979

maximum number of branches to be taken when departing a node (indicated by the M values in Table 18) to the probability and conditional characteristics of branches completes the entity routing specifications. Processing stations encompassing delays experienced while entities receive services according to inputted selection and priority criteria are symbolized with the QUEUE, SELECT, and MATCH nodes. Simulation of resources, or commodities, required by entities prior to continued movement in the system is achieved through the application of AWAIT, FREE, PREEMPT, and ALTER nodes. Similarly, OPEN and CLOSE nodes control the positioning of gates located within the model to temporarily halt the flow of items. The COLCT node enables the analyst to generate statistical outputs and histograms of system behavior.

2. Discrete Event Orientation

In discrete event modeling, dynamic changes to a system's status are specified according to the logical consequences or events as they occur in a time-ordered sequence. SLAM programs of discrete models utilize events to initiate and complete activities. Thus, entities arriving at or departing from activities trigger modifications to the system's variables and to the attributes of the entities. The user prescribes the mathematical relationships of these changes in FORTRAN-coded subroutines. Construction of discrete models is simplified by SLAM-provided subroutines of commonly used functions. Table 19 displays a set of these subprograms satisfying approximately ninety percent of discrete event modeling requirements [Pegden and Pritsker, 1980].

TABLE 19

SLAM Subroutines for Commonly Used Functions in Discrete Modeling

Subprogram	Description
Subroutine COLCT(XVAL,ICLCT)	Records XVAL as one observation for statistics on variable number ICLCT.
Subroutine COPY(NRANK,IFILE,A)	Copies the attributes of the entity with rank NRANK in file IFILE into buffer array A, without removing the entry from the file.
Subroutine FILEM(IFILE,A)	Files the entry defined by the attributes in buffer array A into file IFILE.
Function NFIND(NRANK,IFILE,NATR,MCODE,X,TOL)	Searches file IFILE beginning with the entry with rank NRANK for an entity whose attribute number NATR bears a relationship specified by MCODE to the value X within a tolerance TOL.
Subroutine RMOVE(NRANK,IFILE,A)	Removes the entry with a rank NRANK from file IFILE and copies the entry's attributes into buffer array A.
Subroutine SCHDL(JEVNT,DT,A)	Schedules an event with event code JEVNT to occur at current time plus DT time units with attributes specified by the buffer array A.
Random sample functions	Generates random samples from the commonly encountered probability distributions.

Source: Pegden & Pritsker (1979)

The basic organization of SLAM modeling for discrete events is shown in Figure 3. In general, the user must develop the main program initialization steps and the subroutine EVENT(I) which establishes the sequencing of the program's events. The initialization subroutine (INTLC) is an optional input used when conditions other than the initial designations of the main program are added. The output subroutine (OTPUT) is also optional and allows the analyst to extract data in amplification of the normal reports. Aided by the subroutines and functions of SLAM, the modeler builds the event routines to describe the consequences from the accomplishment of the calendar of events set forth in subroutine EVENT(I).

3. Continuous Modeling

The third approach within the SLAM language to simulation systems is continuous modeling. In this technique, the performance of the system is represented with a set of equations describing the changing status of the model's variables as time progresses. These determining characteristics, called state variables, and their required derivatives are updated throughout the simulation process in accordance with user-identified step sizes. When the state variables cross defined thresholds in a specified direction, events which instantaneously alter the status of the entire system are instigated. Time-histories of the state variables are produced by the SLAM program to supplement evaluation of the system's behavior during the testing period.

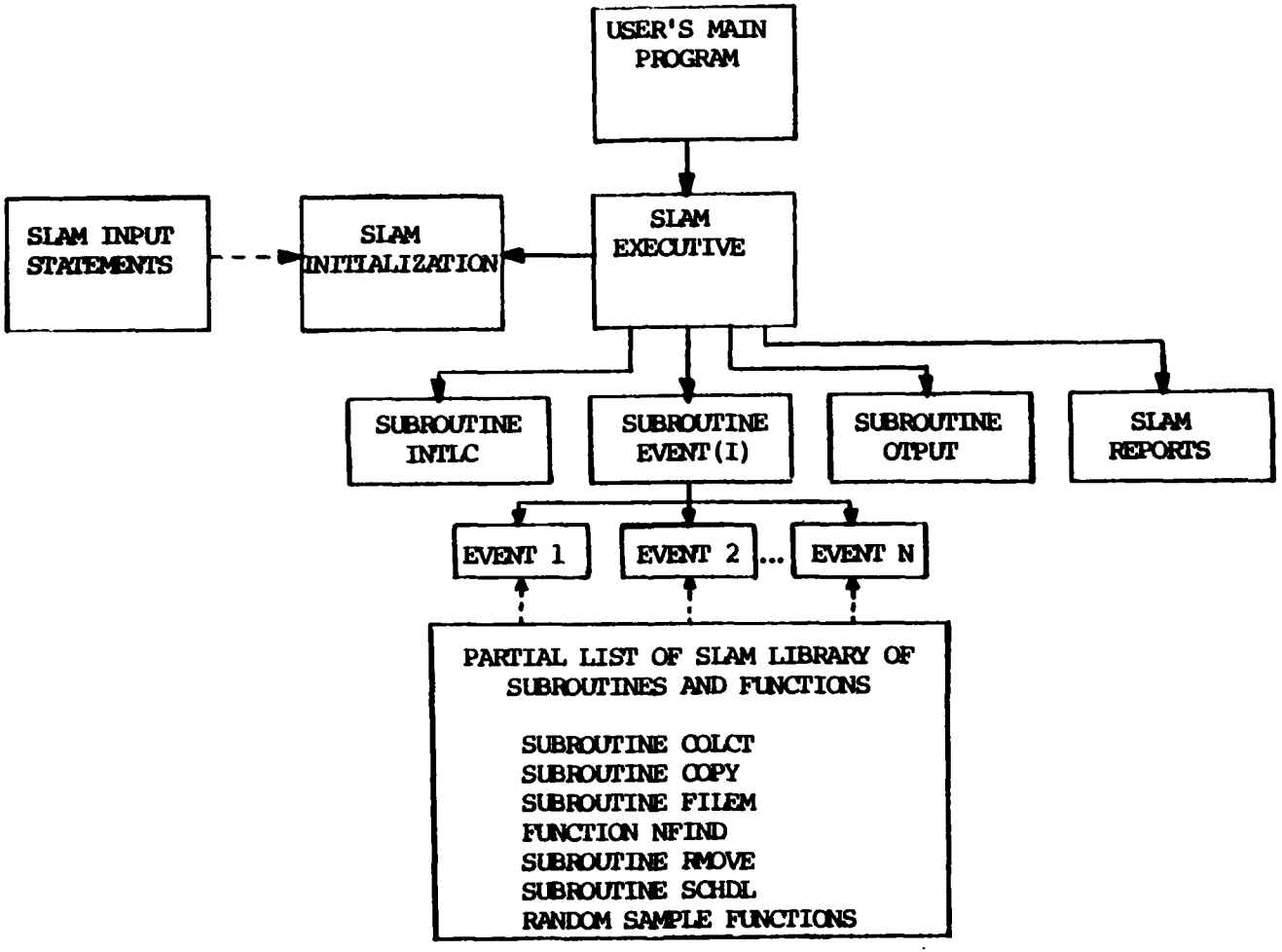
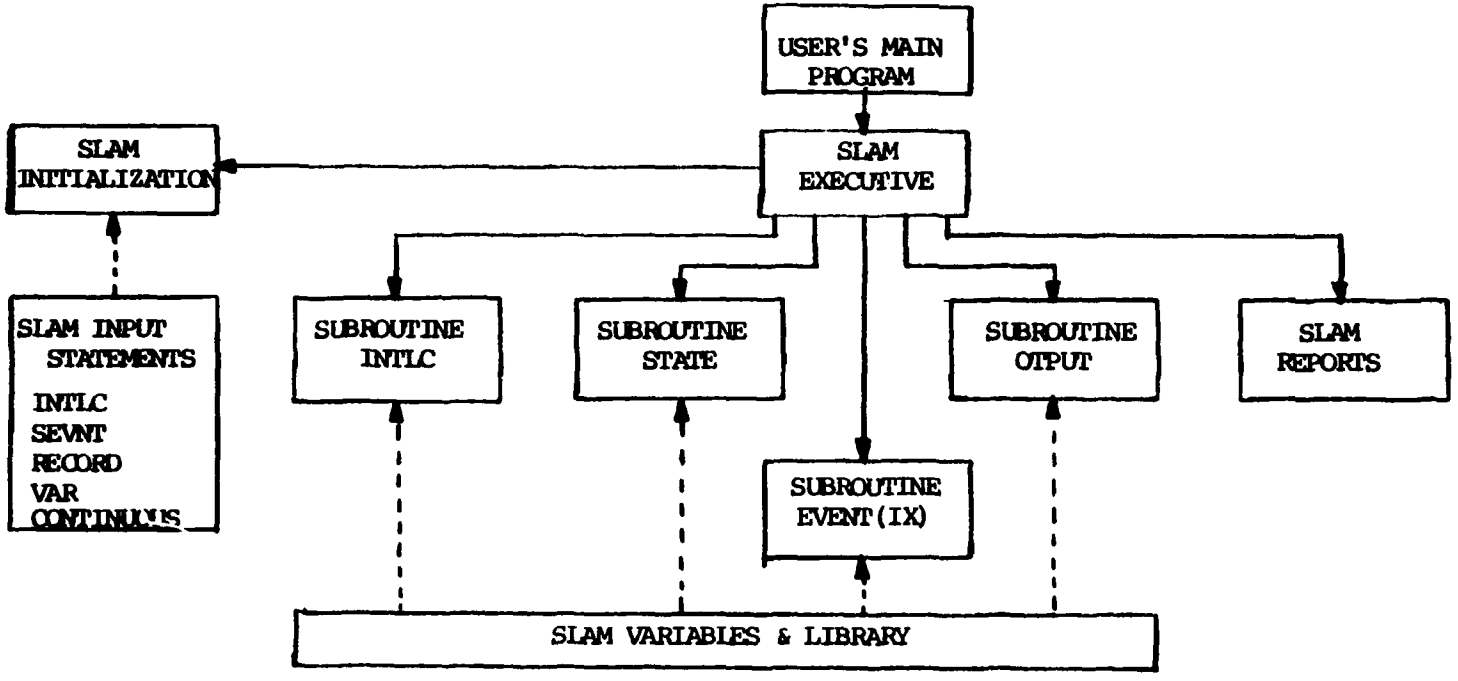


FIGURE 3. SLAM Organization for Discrete-Event Modeling
Source: Pegden & Pritsker (1979)

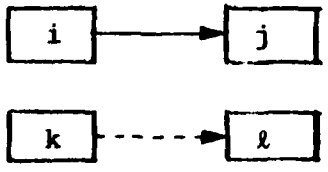
Modeling strategies for continuous and discrete event systems in SLAM are closely related and thus lessen the adjustments required for analysis under combined orientations. Figure 4 charts the continuous system organization of SLAM. As in the discrete event processing, the user exercises options in writing subroutines INTLC and OTPUT, and delineates the consequences of the occurrence of state event I in the subroutine EVENT(I). However, the continuous system modeler is also responsible for developing a subroutine STATE that introduces the equations identifying the state variables. Additional specifications must also be inputted in the SLAM initialization steps. The state-event (SEVNT) statement determines the conditions of threshold crossings necessary to initiate system status changes. Step sizes used in the computation of difference or differential equations of the state variables are indicated in the CONTINUOUS input statement. Time-history documentation requirements of the simulation are placed in the RECORD input, prescribing the interval of output reports, and in the variable (VAR) statement that lists the dependent variables to be studied for each independent variable.

4. Combined Modeling

Each independent orientation employed by the SLAM language offers attractive modeling features to the analyst. Moreover, the accumulation of the three approaches within one processor package is both convenient and cost-effective.



LEGEND



SUBROUTINE i CALLS j

SUBROUTINE k ACCESSIBLE TO ℓ

FIGURE 4. SLAM Organization for Continuous Modeling
Source: Pegden & Pritsker (1979)

However, the most significant characteristic of the SLAM program, and the one that distinguishes it from other computer simulation languages, is the combined modeling capability. SLAM establishes this united concept with the addition of several simple node functions that govern the operations conducted at orientation interface points. As an example, entities transgressing a network and arriving at the special EVENT node cause a designated discrete event to be performed. Similarly, a network DETECT node will detain an entity until a continuous system state variable reaches a setpoint value and thus releases the entity. Interactions of the discrete event and continuous models are provided in the use of the previously described SEVNT statement. An informative synopsis of SLAM techniques for combined modeling is presented by Pegden and Pritsker (1979).

5. SLAM Summary Report

The primary output for analysis from SLAM programming is the Summary Report. This compilation of statistics for a system's operations is routinely produced at the end of a simulation, but may be requested at periodic intervals throughout the system trial. Beginning with a general, descriptive section, the Summary Report is partitioned into seven categories of information. In addition to the initial identification data, statistics are displayed for variables based on observations, time-persistent variables, files of queues, regular activities (stemming from nodes other than QUEUE and SELECT), service activities, and resources. In

AD-A122 434 A SIMULATION MODEL DEPICTING FLEET EXPANSION EFFECTS ON 2/3
THE FIRE CONTROL TECHNICIANS TRAINING PIPELINE(U) NAVAL
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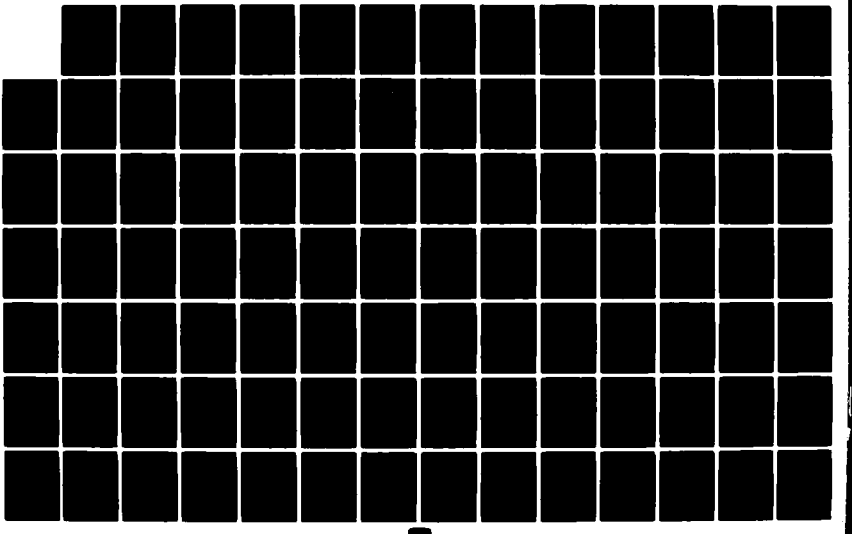

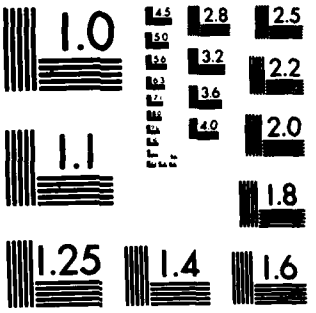

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amplification of these comprehensive figures, the network orientation allows the display of histograms depicting the variations in the duration of selected components within the total system process. The continuous model organization also provides detailed plotting of collected data for in-depth analysis.

D. FIRE CONTROL TECHNICIAN TRAINING PIPELINE SIMULATION

Simulation modeling has proven to be a cost-effective method of studying administrative and policy decisions in a wide variety of management situations and has been adopted by many military operations research organizations. Further application of the analytical tools incorporated in this methodology can potentially aid in the mapping of managerial strategies within the Navy training command. Rising personnel payrolls, advancing technology, and increasing force requirements throughout the 1980's will demand maximized efficiency in the operations of Navy schools. Anticipated budgets will be unable to absorb manpower productivity losses resulting from delays within the schools commands as students await available classrooms and convening dates. School capacities must therefore be planned to sustain technical expertise while minimizing operating, maintenance, new construction, and overhead expenditures. Varying student entry points into the pipeline and scheduling modifications may affect the speed at which technicians are trained and thus may be valuable options in responding to short notice or

unforeseen manning developments. These, and other policy alternatives, are especially suited for simulation analysis and can be conveniently modeled with network orientation procedures. As a demonstration of the strengths of this technique, a SLAM simulation, to be used in the assessment of policy options for filling existing and projected fleet manning shortages, has been developed for the fire control technician training pipeline.

Our modeling of the FT training pipeline is founded upon the concepts diagrammed in Figure 1 and follows the general guidelines for SLAM network processing. The model is divided into sections representing the five phases of the normal training progression: Recruit Training Command (RTC), Basic Electricity and Electronics School (BE&E), A School Phase I, A School Phase II, and C School. The capacity of the SLAM language to process systems programmed without chronological order simplifies the initial modeling and permits the additional splitting of the network into individual FTG and FTM C Schools, and into a separate FTG(SS) pipeline that entails a Submarine School phase. Although in some cases service veterans and fleet personnel sources of manpower inputs are not presently utilized, we have included provisions for introducing these prospective trainees to the system so as to provide a broader latitude in policy analysis. We did not find it necessary to venture beyond network structuring in our methodology, but the basic model can easily be expanded for future research of a specialized or complex nature by

interfacing with discrete event and continuous systems terminology. The complete SLAM program for the FT training pipeline is listed in Appendix A.

Although we have exercised freedom while imposing simplifying assumptions for our pipeline model, we have also inserted a large number of variables for policy experimentation. Class convening dates are programmed at constant intervals that do not consider holidays or possible adjustments caused by equipment casualties. Furthermore, annual leave time earned by the trainees is not added to the network. It is reasoned that these authorized off-duty periods will be granted to servicemen awaiting class start dates, thereby reducing the effects of lengthy queues within the pipeline. Difficulty in modeling the many possible paths and time requirements of the complicated C School phase is overcome by representing the training as a single course with a duration determined by a normal distribution function. Lines three through eight of the SLAM program are initialization statements delineating thirty-one input parameters that can be varied in the study of policy alternatives. Table 20 identifies these XX(I) variables. In addition to these variable inputs, many other parameters, such as travel times, class sizes, personnel input frequencies, and length of schools, can be easily modified to enhance alternative analysis. The range of these potential changes can be drawn from the explanations of each phase in our SLAM program presented below. The modeling

TABLE 20

SLAM Program Variables for Pipeline Simulation

Variable	Description
XX(1)	Percent of recruits that are 4 year obligators.
XX(2)	Percent of recruits completing RTC on-time.
XX(3)	Percent of BE&E trainees that graduate.
XX(4)	Percent of surface A School Phase I trainees that graduate on-time.
XX(5)	Percent of surface A School Phase I trainees that graduate, includes on-time and rollback finishers.
XX(6)	Percent of surface A School Phase I 4 year obligator graduates that extend to 6 year obligators.
XX(7)	Percent of surface A School Phase II trainees that graduate on-time.
XX(8)	Percent of surface A School Phase II trainees that graduate, includes on-time and rollback finishers.
XX(9)	Percent of surface FTG C School trainees that graduate on-time.
XX(10)	Percent of surface FTG C School trainees that graduate, includes on-time and rollback finishers.
XX(11)	Percent of surface school service veteran inputs that are FTG's.
XX(12)	Percent of FTM C School trainees that graduate on-time.
XX(13)	Percent of FTM C School trainees that graduate, includes on-time and rollback finishers.
XX(14)	Percent of BE&E School surface fleet personnel inputs that are 6 year obligators.
XX(15)	Percent of A School Phase I surface fleet personnel inputs that are 6 year obligators.
XX(16)	Percent of A School Phase II surface fleet personnel inputs that are 6 year obligators.

TABLE 20 (Continued)

Variable	Description
XX(17)	Percent of recruits completing RTC, includes on-time and rollback finishers.
XX(18)	Percent of fleet personnel inputs to surface school that are FTG's.
XX(19)	Percent of fleet personnel FTG Subsurface inputs to BE&E School that are 6 year obligators.
XX(20)	Percent of FTG fleet personnel inputs to Submarine School that are 6 year obligators.
XX(21)	Percent of Submarine School trainees that graduate on-time.
XX(22)	Percent of Submarine School trainees that graduate, includes on-time and rollback finishers.
XX(23)	Percent of fleet personnel inputs to FTG Subsurface A School that are 6 year obligators.
XX(24)	Percent of FTG Subsurface A School trainees that graduate on-time.
XX(25)	Percent of FTG Subsurface A School trainees that graduate, includes on-time and rollback finishers.
XX(26)	Percent of FTG Subsurface C School trainees that graduate on-time.
XX(27)	Percent of FTG Subsurface C School trainees that graduate, includes on-time and roll-back finishers.
XX(28)	Percent of 4 year obligators assigned as FTG's.
XX(29)	Percent of 6 year obligators assigned as FTG (surface).
XX(30)	Percent of 6 year obligators assigned as either FTG (surface) or FTM.
XX(31)	Percent of 6 year obligators converted to 4 year obligators at completion of surface A School Phase I.

Source: Authors

techniques incorporated in the construction of the Recruit Training Command and BE&E phases of the training pipeline illustrate the concepts employed throughout our system structure and will be developed in detail. Brief descriptions of the subsequent phases, including explanations of unique characteristics, will augment diagrams depicting the specific flow of each segment of the network.

1. Initialization

The first fourteen lines of the FT training pipeline program (see Appendix A) are introductory statements establishing initial conditions for the network. Following the initialization of the thirty-one parameters are statements, lines 10-14, prescribing the use of BE&E School quotas by both the surface trainees and the subsurface participants. The maximum number of surface designated quotas, 360, and subsurface designated resources, 40, available at any one time are based on calculations from the 1981 data of trainees processed by the three BE&E schools contributing to the FT pipeline. The start (STRT) and begin (BGN) gates programmed in lines 12 and 14 are employed to schedule students' commencements of the BE&E School on weekdays only. Lines 11 and 13 demonstrate the SLAM language capability to annotate input terminology with descriptive comments directly following the ending semicolon of the statement. This attractive feature is utilized throughout the program listed in Appendix A.

2. Recruit Training Command Phase

Direct translation of our pipeline model into SLAM input statements begins with the RTC phase of the network. Figure 5 presents the SLAM diagram of this structure. The introduction of recruited FT's is accomplished with a CREATE node specifying the rate at which accessions enter the training process. Recognizing that Navy recruiting success is governed by seasonal fluctuations in the numbers and enlistment desires of the available population and therefore varies substantially during the course of a year, the programmed model allows the user to modify the accession rate every calendar quarter for each of the nine years examined in this study. These quarterly rates result from the application of the percentages of total 1981 accessions recruited in each three month period to the Rand Model projections for Navy enlistments of male, non-prior service, mental category I, II, and IIIA individuals in each of the investigated years. In addition, the model is initially simulated for a three year period, at a constant 1981 accession rate, allowing the designed system parameters to stabilize and thereby eliminating unwarranted biasing caused by inaccurate assignment of starting values. At the completion of this run-in period, the SLAM program clears the statistical data files and begins compilation of the figures outputted in the SLAM Summary Report.

The recruits introduced at the CREATE node enter the system and immediately arrive at a decision point, represented in the model by the GOON node labeled RECR. A

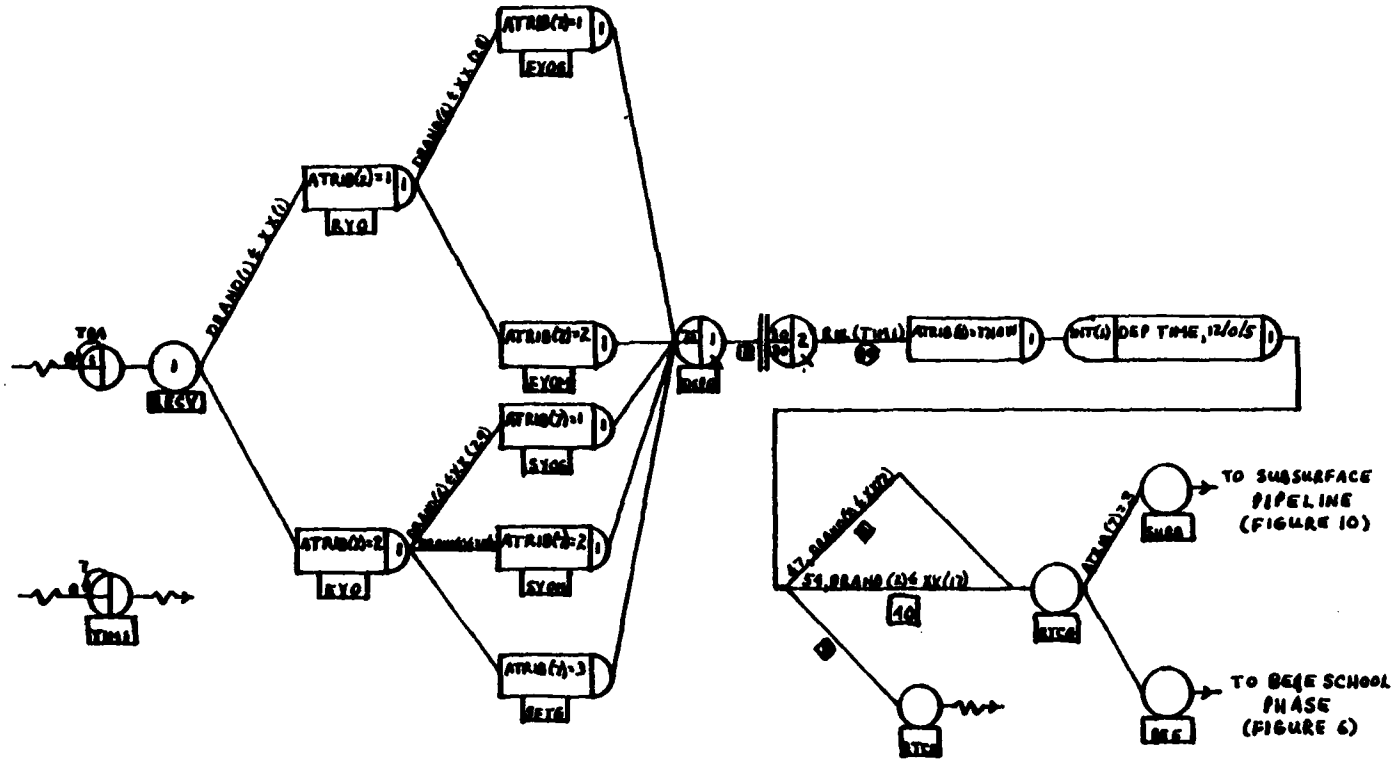


Figure 5. SLAM Model for Recruit Training Command Phase of Training Pipeline

specified percentage of the accessions are routed to the RYO ASSIGN node and are designated as four year obligators, while the remainder of the entities travel to the EYO ASSIGN node for designation as six year obligators. Since current Navy policy does not permit four year obligators to enter the subsurface training pipeline, all accessions following this path of the model are assigned either to the FTG (surface) or FTM training cycles. This differentiation is accomplished through the two branches, or activities, emanating from the RYO ASSIGN node and leading to the FYOG and FYOM ASSIGN nodes. Six year obligators entering the FT training pipeline can be assigned to one of three possible career paths: FTG (surface), FTG (subsurface), or FTM. The three branches of the model originating at the EYO ASSIGN node are used to specify the proportions of accessions programmed into these career patterns.

In SLAM branch programming, the conditional routing characteristics of grouped activities are prioritized according to the order of input. The breakdown of the six year obligators into service ratings serves as an excellent example of this methodology. In lines 106-108 of the program, the SLAM variables XX(29) and XX(30) are employed to distinguish the entities routed to each of the three career categories. SLAM variable XX(29), the governing factor in the first condition listed, represents the fraction of six year obligators entering the FTG surface training courses. Arriving entities are directed along this path of the model to the SYOG

ASSIGN node when a generated random number between zero and 1.0 is less than or equal to the percentage assigned to variable XX(29). The second routing condition prescribed at the EYO ASSIGN node grouping is based on variable XX(30), the total percentage of six year obligators participating in training for surface duty assignments. Since the FTG (surface) accessions have previously been processed to the FYOG ASSIGN node by the first branch, only the FTM trainees are programmed for rating designation at the ASSIGN node labeled SYOM. All entities passing through the EYO ASSIGN node and not fulfilling the specifications of either of the two initial conditional characteristics are defaulted to the third network branch. These entities are designated as FTG (subsurface) accessions (attribute 7 set equal to 3) at the SFTG ASSIGN node. This technique of categorizing flow through the network is common throughout our model.

After designation of service obligation times and ratings, the entities in the network are re-united at the QUEUE node labeled DEPQ. This stoppage in the system flow symbolizes the delayed entry pool currently managed by the Navy to align enlistees' entry into the service with available RTC and training school openings. Although the model's logic gears the commencement of RTC to class capacities, no attempts have been made to parallel the Navy's PRIDE program in coordinating service entry dates with schools' availability and the individual desires of the recruits for starting dates. After having reached the DEPQ node, the entities await the

opportunity to continue movement symoblic of RTC training. However, a delay is imposed in the model with the insertion of a blocking QUEUE (QUEUE 2) that restricts the number of FT's in a RTC class to thirty. This class capacity is determined by delegating a representative percentage (5%) of the total capacities of the Navy's centers in Great Lakes, San Diego, and Orlando to the FT ratings. The modeling of the system as one RTC, instead of the actual three, reduces the computer time and eases the programming requirements without degrading the accuracy of the desired outputs.

The use of another CREATE node, entitled TIM1, programs the RTC classes to start once a week. This node initiates an entity that serves to release the entities stored in QUEUE (2) every seven program days. The released items travel to an ASSIGN node where they receive an attribute value corresponding to the current simulation time and representing the start of RTC. From here the entities are routed to the RTC QUE COLCT node which determines the waiting time experienced by each entity prior to the start of RTC and which generates a descriptive histogram of this aspect of the system's behavior. In departing the RTC QUE node, entities can be directed along one of three paths symbolizing performance in RTC training. The first two conditional routes specify the length of training incurred by normal, or on-time, graduates and by finishers who require repeat schooling (rollbacks). The final branch stemming from the RTC QUE node encompasses

the individuals dropped from the system because of performance deficiencies in RTC training.

The two activities simulating on-time and rollback graduates of RTC training input into a GOON node for further routing. The only difference associated with these paths is the length of training distributed to the entities. The normal trainees are programmed for forty-seven days of training and the rollback students for fifty-four days at RTC. The routing GOON node can be conveniently changed to a COLCT node for compilation of statistics and histograms for the simulation output. However, the capacity of the SLAM Summary Report is limited to twenty-five COLCT nodes and we have therefore opted to by-pass this statistical result. Network flow beyond this GOON node is divided by an activity condition based upon the attribute denoting the entity's career rating. FTG (subsurface) entities enter the submarine school pipeline beginning at GOON node SUBB, whereas the surface FTG and FTM entities continue to the GOON node BEE.

3. Basic Electricity and Electronics School (Surface) Phase

In many aspects the structuring of the BE&E School (surface) phase duplicates the methodology of the RTC segment of the network. However, Figure 6 shows that this portion is made considerably more complex by three source inputs and by the inclusion of resource and gate modeling. The addition of both fleet personnel and service veterans is intended to provide flexibility in experimenting with management options

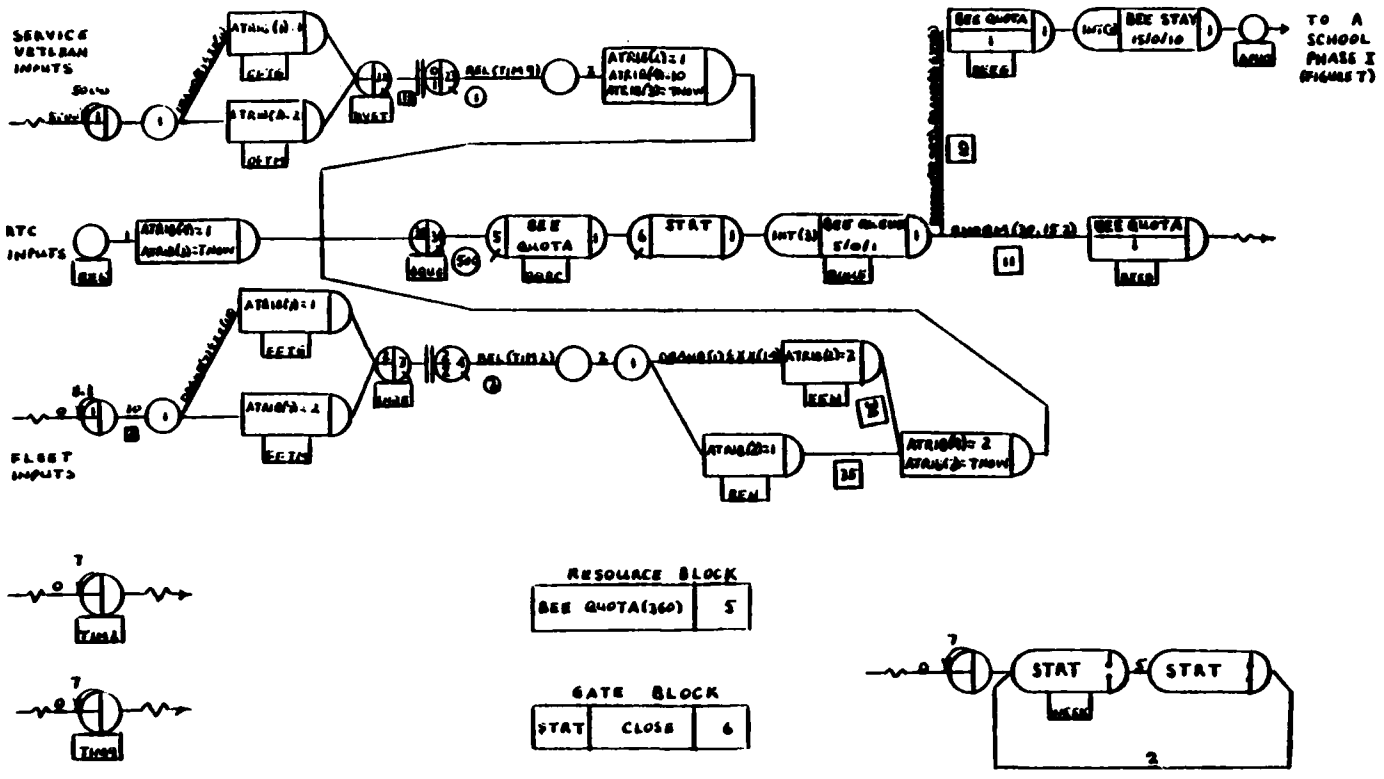


Figure 6. SLAM Model for Basic Electricity and Electronics School (Surface) Phase of Training Pipelines

for enhancing the training command productivity. Utilization of the resource and gate terminology is necessary for the simulation of the self-paced course of instruction at BE&E School.

Of the contributing sources to the BE&E phase, the RTC input is the most easily programmed. Entity flow from the preceeding RTC phase passes through the GOON node BEE and across a one-day activity representative of a sailor's travel time to Basic Electricity and Electronics School. Since BE&E and RTC facilities are housed in adjacent locations, this estimation of average travel time appears justifiable. The system flow is next routed into an ASSIGN node in which the arrival time of the entity at BE&E School is inputted as an identifying attribute to be used in the calculation of stay times. Also at this node, the source of input is coded into attribute (4). This designation facilitates the tracking of entities and thus substantially improves the analysis of various policy alternatives. Continuing along this network path, the entities are directed to the QUEUE node labeled BQUO which, in addition to specifying the initial number of participants in the schooling system, serves as a joining point for the three source inputs of this phase.

The second input source to the BE&E phase stems from fleet sailors qualifying for the FT training program. A CREATE node originates the new pipeline participants at a specified rate of entry (1 every 8.3 days in Figure 6). Upon creation, these entities begin a thirty-day activity

symbolizing the delay incurred while awaiting orders to a BE&E School. This figure is a professional estimate of the time required for the processing of applications and the promulgation of official orders. After this lengthy activity the entities, using the SLAM random number generator and activity condition procedures, are divided and designated as either FTG's, at the FFTG ASSIGN node, or FTM's, at the FFTM ASSIGN node. The two groups are then united at the INBE QUEUE node which, in combination with the blocking QUEUE (4) and the activity release time programmed by the TIM2 CREATE node, limit the fleet input to a maximum of two per week. Following release from QUEUE (4) the activities cross the two-day branch that models a typical travel time from fleet and shore-based units to BE&E School. Continuing through a GOON node, the fleet inputs are again split and identified as four and six year obligators at the REN and EEN ASSIGN nodes. The entities are re-united at another ASSIGN node where values are given to attributes specifying the arrival time at the school and the input source of the participants. From here the network routes the items into the joining QUEUE labeled BQUO.

Although service veteran inputs are not normally associated with BE&E School training, we have constructed the training pipeline model to include this potential population pool for accessions. As is shown in Figure 6, while evaluating policies that do not consider these additions, this arm of the network can be essentially blocked by programming the

function of the CREATE node to occur only far in the future (5000 days in the network diagram) and at a slow rate of input (1 every 5000 days). Service veterans are assumed to be immediately available for entry into the training system and thus are not subject to a delay caused by the processing of official orders. Additionally, all veterans re-enlisting and joining the pipeline are considered to be four year obligators. With these two exceptions, the flow of service veterans into the EQUO QUEUE node parallels that of the fleet personnel input source.

The self-paced, computerized mode of instruction utilized in the BE&E Schools necessitates a modeling approach different from the techniques employed in representing the class structure of RTC. Trainees enter the BE&E Schools individually and progress through the course at a pace commensurate with their own learning skills. This leads to a wide range of stay times at the schools while eliminating the need to program rollbacks within this segment of training. Also, the capacity of the BE&E Schools restricts the number of servicemen that can be undergoing instruction at any given time. The SLAM programming of these special characteristics begins following the interweaving of the three input sources at the BQUO QUEUE node.

Entities flowing through the BQUO node are routed into an AWAIT node, designated BQRC, which controls the distribution of BE&E School seats, or openings, through the utilization of the SLAM resource BEE QUOTA. If the entity arrives at

this node and the school capacity if not maximized, a quota is assigned and the participant continues through the system. However, when all school seats (360 in our model) are being used, the arriving entity is placed in a queue until another participant completes the course and a quota is made available. Upon receipt of a seat assignment, the entity is directed to a second AWAIT node that is controlled by the SLAM GATE labeled STRT. Flow through the AWAIT node is permitted only while the GATE is in the open position. The GATE closure, modeled at the bottom of Figure 6, is timed to occur for a two day period every week and thus can be used to represent weekends. As a result, the network simulates a pattern in which the BE&E School self-paced instruction can be initiated only between Mondays and Fridays of each week. From the second AWAIT node, the entities travel to the BQUE COLCT node where statistical data is compiled on the BE&E School queuing process.

The distinction between BE&E School graduates and drop-outs is modeled by the two network paths emanating from the BQUE COLCT node. Entities identified as graduates, through the comparison of a generated random number with SLAM variable XX(3), are routed along an activity whose duration is specified by a random distribution function having a mean of 82 days and a standard deviation of 28 days. These numerical inputs represent the performance figures for 1981 of FT's in the BE&E School located at Great Lakes Navy Training Center. Trainees failing to complete the BE&E phase retain a quota assignment for a time period described by the random distribution

function about a mean of 30 days and having a standard deviation of 15 days. The two school performance activities terminate at FREE nodes, labeled BEEG and BEED, where the processed entities relinguish possession of school seat quotas, thereby enabling a participant in the BQRC AWAIT node queue, if any, to continue network flow. BE&E School drop-outs then depart the training pipeline, while graduates advance to a COLCT node for computation of BE&E stay-time statistics. The simulated graduates then progress to the A School Phase I network structure by passing through the linking GOON node designated APHO.

4. A School Phase I (Surface)

Network modeling of the A School Phase I training process for surface ratings follows the program logic of the previous segments. The structuring of the input source arms of the system is identical to that of the BE&E phase and the flow through the training course representation adheres to the concepts of the RTC portion of our model. However, requirements for the detailed tracking of Phase I trainees significantly increases the number of alternative network paths available to entities passing through the A School symbology. This added complexity is imposed to distinguish which entities continue into subsequent pipeline training and to assign the advancing entities differentiating characteristics.

Figure 7 maps the network orientation of Phase I of A School. Attribute (6), introduced in ASSIGN nodes POAG and

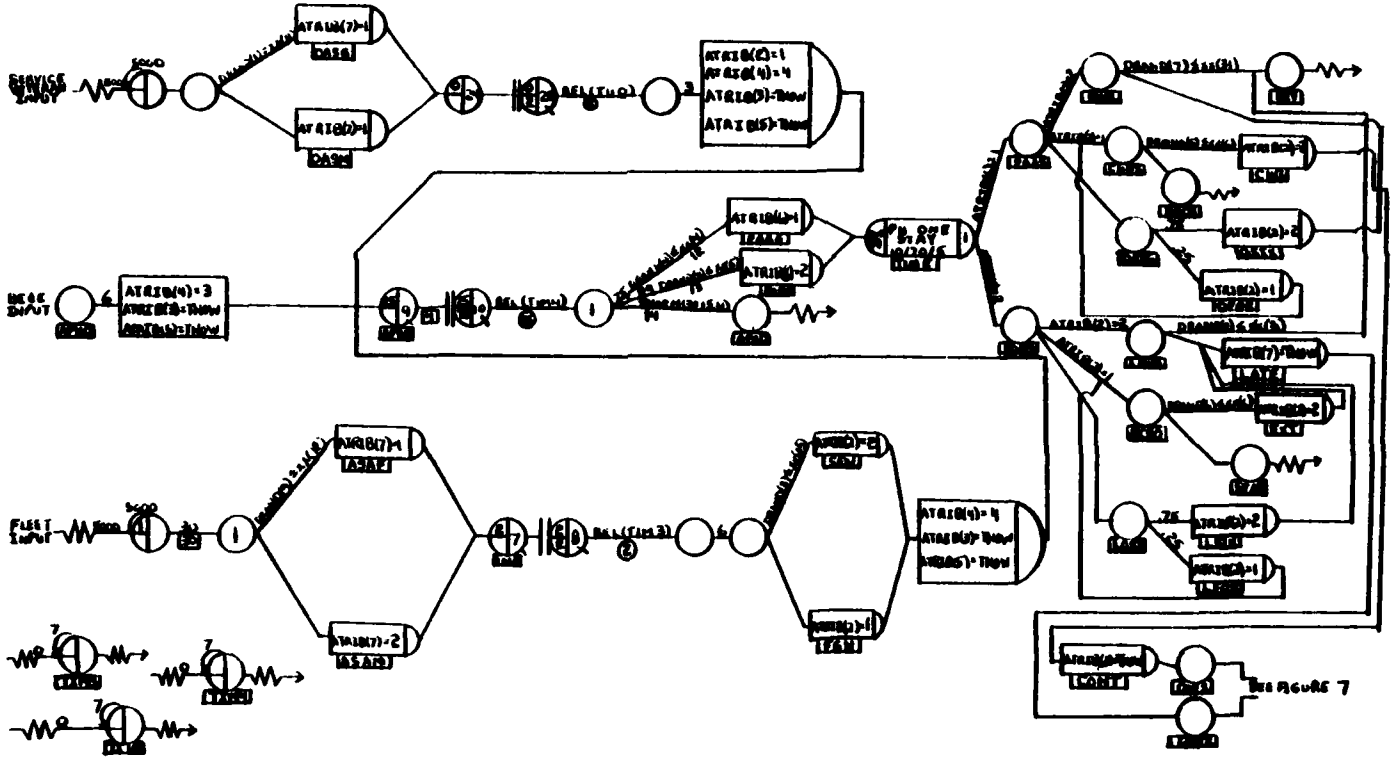


Figure 7. SLAM Model for A School Phase I (Surface) Segment of Training Pipeline

POBG, separates the on-time graduates and rollback graduates, and serves as a basis for the system's branching following the COLCT node labeled TIME. The distinction among graduates is relevant to the timing of system flow in the second phase of A School and will be amplified in the discussions below. The alternative paths available to the on-time graduates, those activities stemming from GOON node POAS, are mirrored by the potential process branches encountered at GOON node POBS by the rollback graduates. GOON nodes CHOS and BCHO symbolize the decision points at which qualifying four year obligators may extend their enlistment contracts. This option is critical since our model parallels the current Navy policy of advancing only six year obligators beyond A School Phase I of the pipeline. The training command also presently siphons out the lower performing six year obligators in Phase I, converts these trainees to four year obligators, and terminates their schooling upon completion of this phase. This management policy is programmed at the QUAL and LQUA GOON nodes where an activity condition specified in variable XX(31) is utilized in determining the number of entities possessing an attribute value of two that are to be released from the network. The decision logic included in the program at GOON nodes ORIG and LORI proportions those entities inserted into intermediary stations of the network at system start-up into groups of four and six year obligators. Addition of the ORIG and LORI node branching aids in the evaluation

of alternative policies in which prioritization for entity routing creates lengthy stay times in the system.

5. A School Phase II (Surface)

A SLAM technique for ranking the order of network flow is depicted in Figure 8, the model diagram of Phase II of A School training. Once again the modeling of inputs from fleet personnel and service veterans adheres to the logic employed in the BE&E phase. However, in this segment these two arms of the network lead into holding queues QUE 5 and QUE 6. Combined with the two queues associated with the graduates from Phase I, QUE 1 (on-time graduates) and QUE 2 (roll-backs), these nodes collect the system entities awaiting assignment to Phase II classes. The SELECT node, labeled SEL1, withdraws entities from the four contributing queues in accordance with programmed specifications. Thus, by altering the SELECT statement characteristics, experiments in policy modifications are quickly accomplished. Processing of entities departing SELECT node SEL1 initially corresponds to the basic sequencing of class-structured courses introduced in the RTC model. As in previous phases, following the accumulation of statistics for the waiting queue, entities flow through branches symbolizing course performance. Subsequently, the entities progress through two additional COLCT nodes, designated APTG and COMB, where data for Phase II and total A School stay-times are compiled. Nested between the APTG and COMB nodes is a grouping of activities that function to

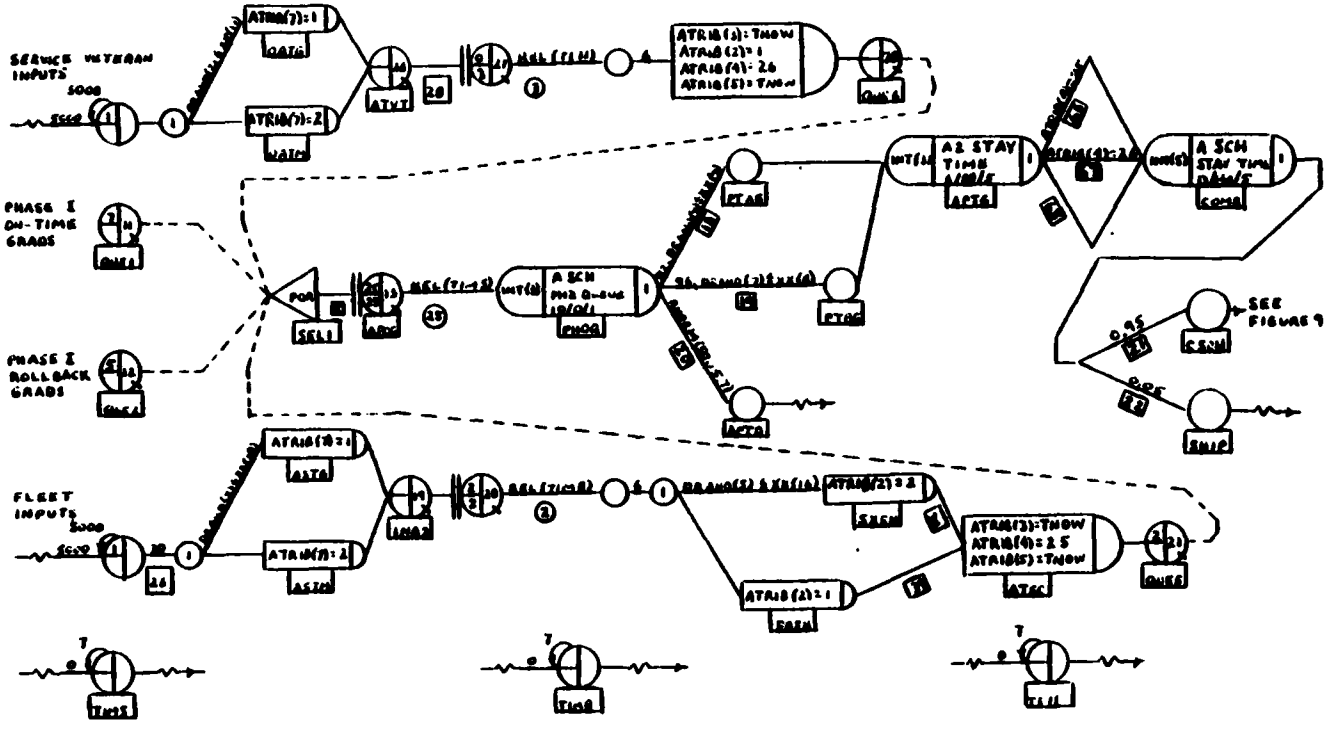


Figure 8. SLAM Model for A School Phase II (Surface) Segment of Training Pipeline

count the number of fleet personnel, service veterans, and pipeline source inputs completing Phase II. Finally, five percent of the Phase II graduates are released from the network following the COMB COLCT node. This out-flow is representative of the reports from Navy school managers of the actual trainee losses within the pipeline at this juncture.

6. C School (Surface) Phase

Figure 9 diagrams our model for the C School (surface) phase of the FT training pipeline. The structure can be viewed as two identically sequenced sub-sections branching from the ASSIGN node labeled PHTI, with the upper network symbolizing the FTG schools and the lower network depicting the FTM training facilities. Because the myriad of possible paths through the individual specialization courses of the FT C School pipeline introduces enormous programming complexities, in our system design we have represented the training as a singular class. Although this approach prevents the analysis of the affects created by changes in specific Navy Enlisted Classification (NEC's) requirements, the degree of detail in the model's output is sufficient for our broad pipeline evaluation and justifies this simplification. Using information provided by FT pipeline managers and the promulgated lengths of the various courses, we have modeled the C School duration as a random distribution function having a mean of 200 days and a standard deviation of 77 days. For entities simulating rollback graduates, an extra two weeks is

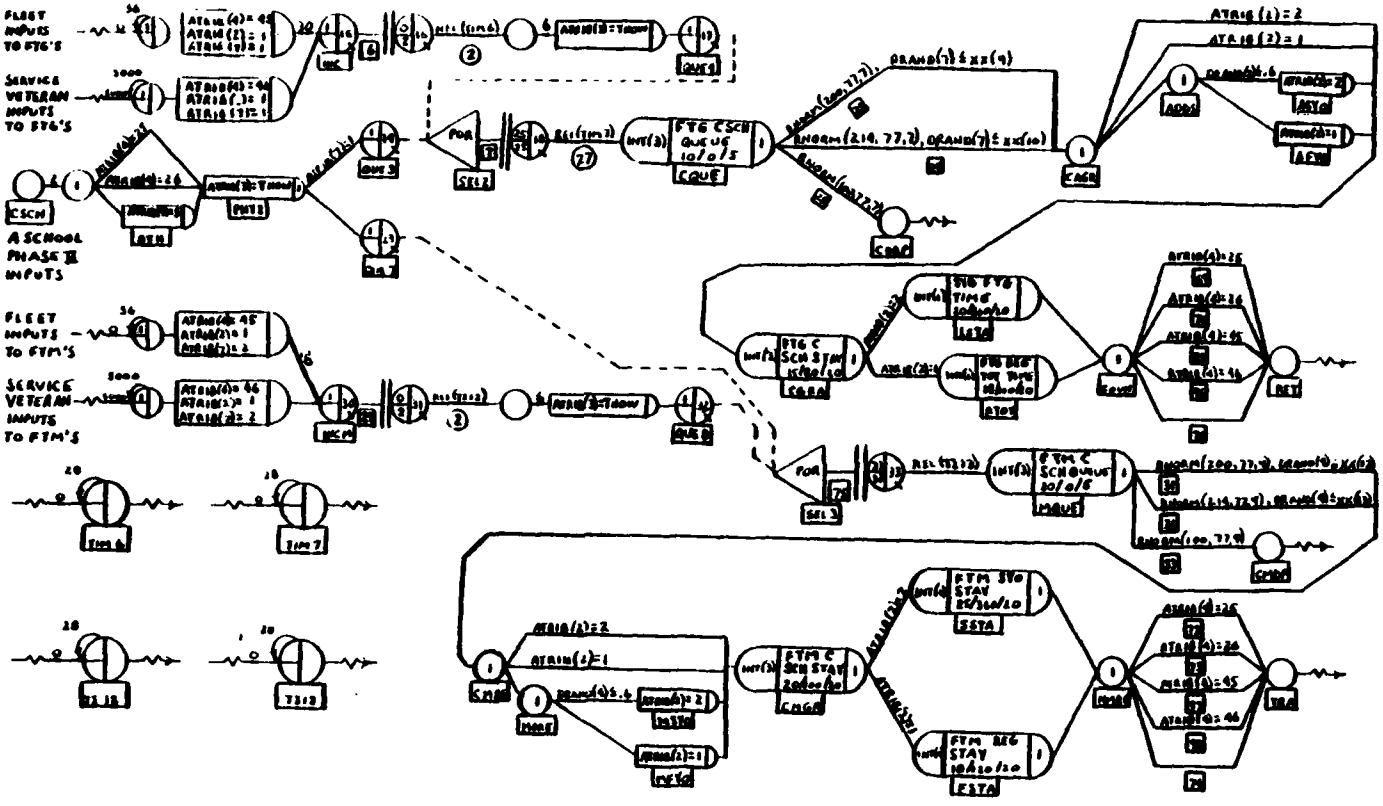


Figure 9. SLAM Model for C School (Surface) Phase of Training Pipeline

added to the mean. Class capacities of twenty-five for the FTG course and thirty-three for the FTM instruction are based upon 1981 data for C School graduates.

The sequencing of each segment of Figure 9 is similar to that of the foregoing phases. SELECT node terminology is employed to establish a priority in the acceptance of source inputs for the C School classes. The flows through GOON nodes ADDS and MORE ensure that those entities within the network upon simulation initialization are categorized as either four or six year obligators. Branching activities emanating from GOON nodes COUN and NMBS calculate the entities attributable to A School Phase II and C School source inputs, and are therefore helpful aids in policy experimentation. The termination nodes labeled RET and TRA symbolize the completion of the surface ratings' training pipelines.

7. FTG Subsurface Pipeline

Simulated FTG (subsurface) entities are separated from the surface ratings in the RTC phase of our model and are routed through a series of modeled subsurface schools. Figures 10 through 13 present the flow pattern of participants in the four phases of this pipeline component. The network sequences an abbreviated BE&E course, a Submarine School, the single-phased A School, and the specialized C School. As in the surface ratings' pipelines, the class capacities and frequency of scheduled courses are derived from 1981 training command statistics. Again the difficulties in

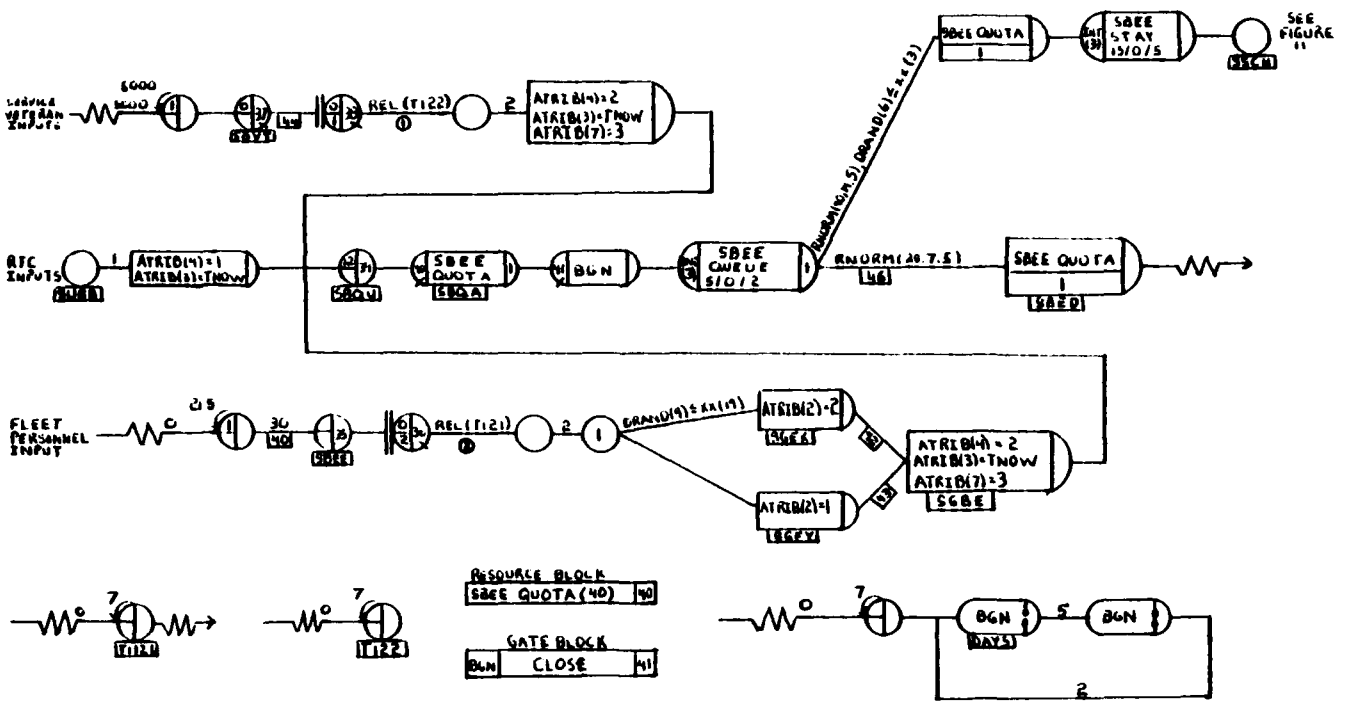


Figure 10. SLAM Model for Basic Electricity and Electronics School (Subsurface) Phase of Training Pipeline

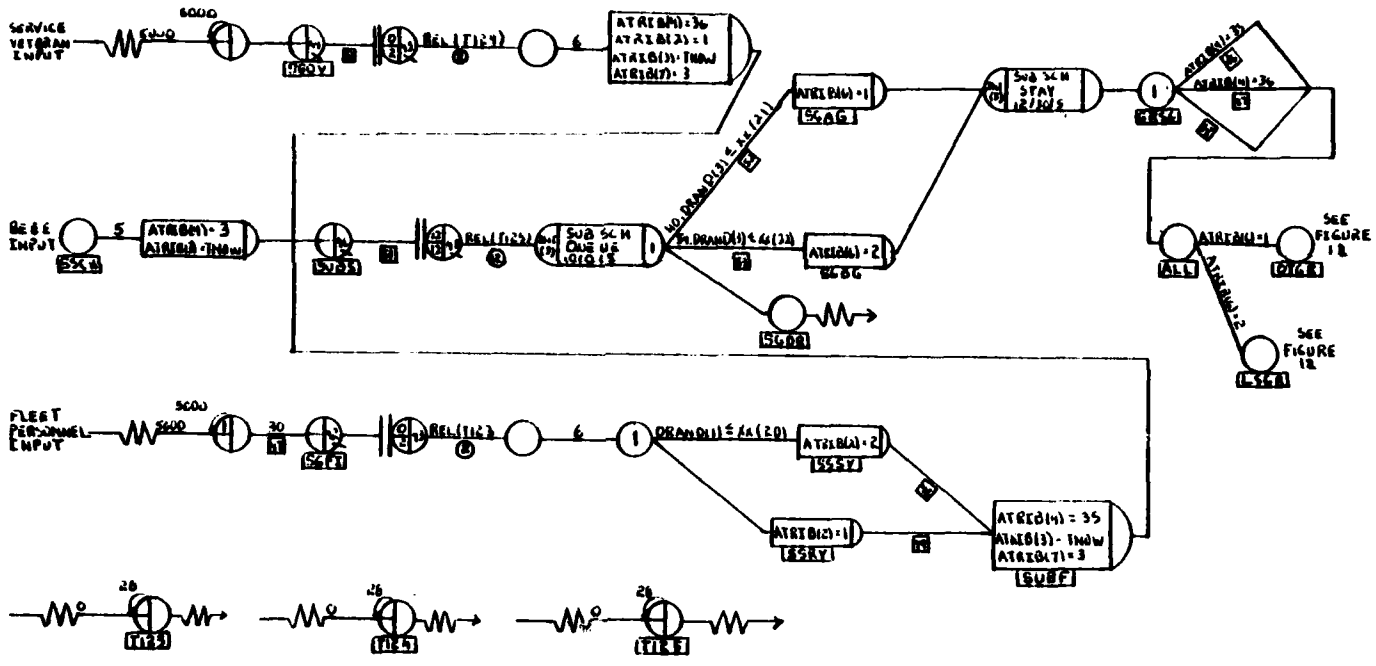


Figure 11. SLAM Model for Submarine School Phase of Training Pipeline

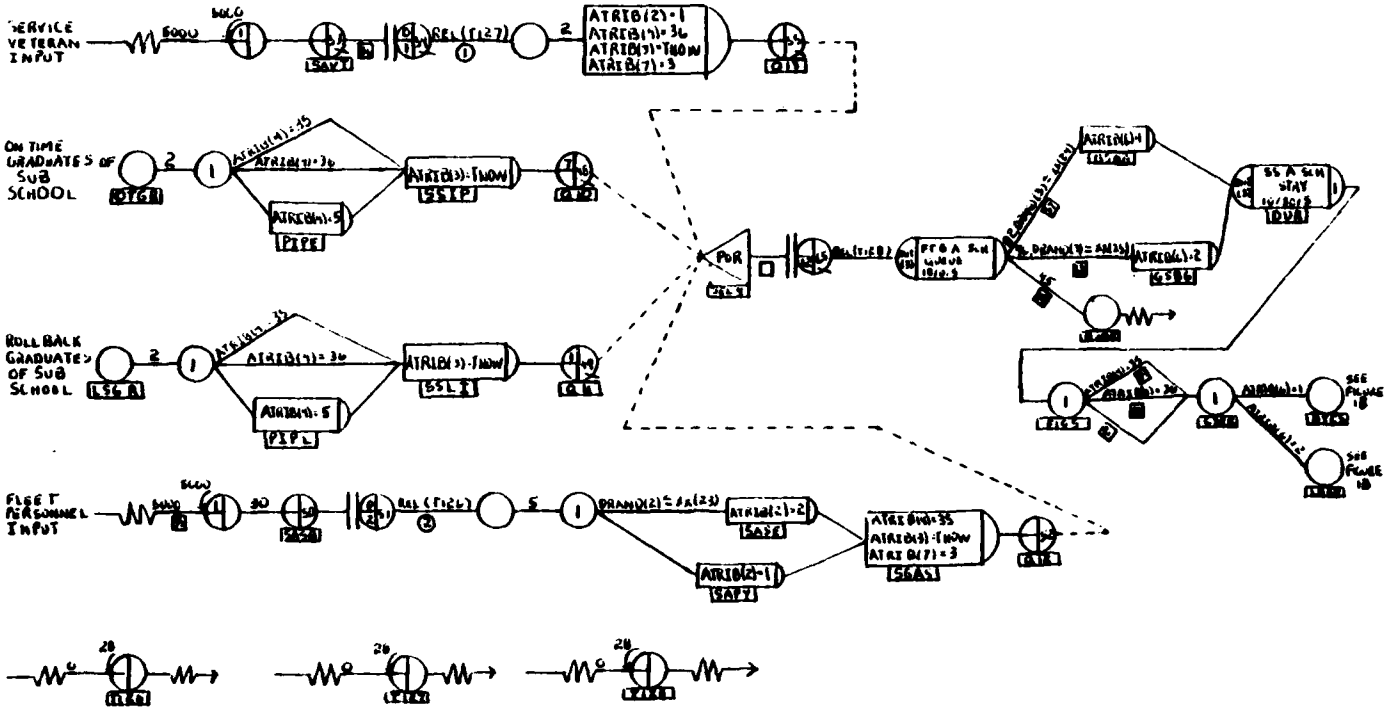


Figure 12. SLAM Model for A School (Subsurface) Phase of Training Pipeline

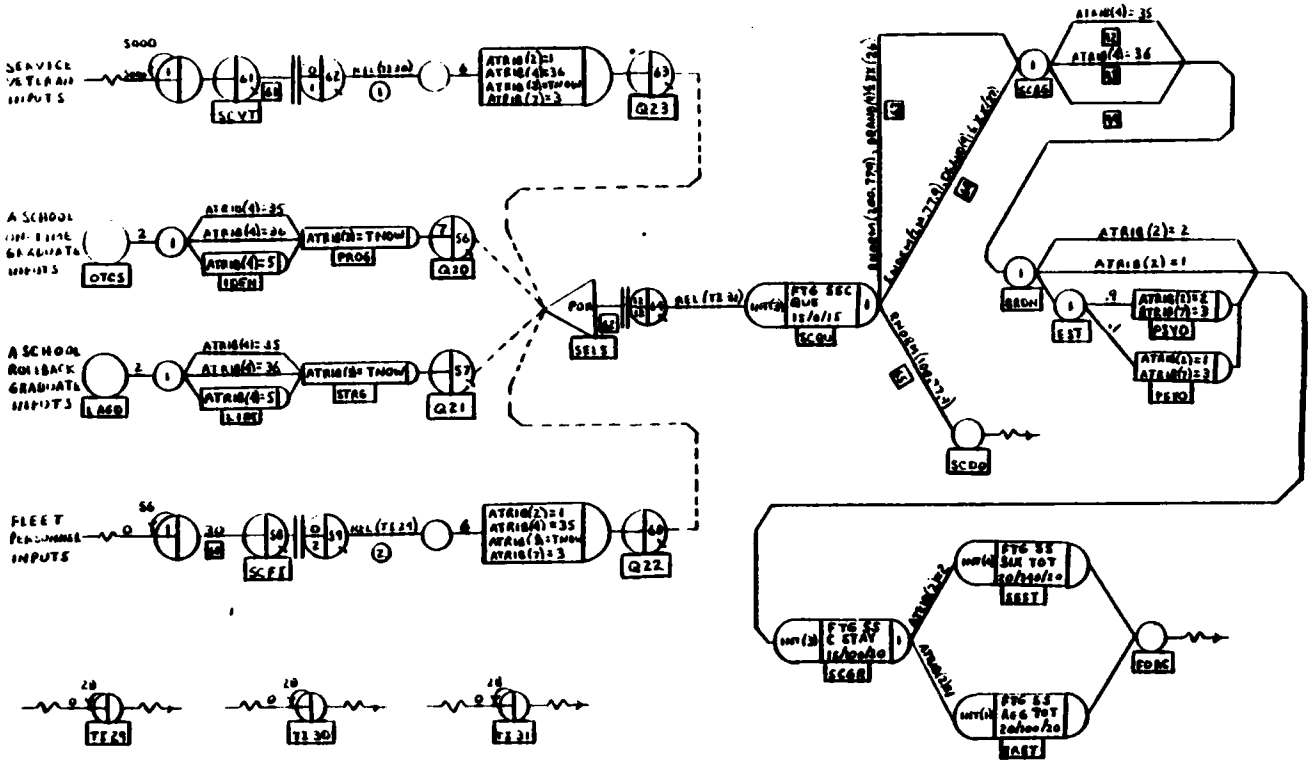


Figure 13. SLAM Model for C School (Subsurface) Phase of Training Pipeline

constructing the C School phase model are alleviated by symbolizing the various course combinations leading to NEC assignments as a solitary class with a random distribution function describing the length of the training.

The program logic of most segments of the FTG(SS) pipeline duplicates the concepts utilized in modeling the surface community schools. Because the continuity of system flow is not interrupted by activity groupings which distinguish between FTG and FTM entities Figures 10, 12, and 13 are somewhat less complicated than the surface pipeline counterparts. However, with this one exception, the pipeline models are identical for the BE&E phases (Figures 6 and 10). Similarly, the subsurface A School structure (Figure 12) follows the flow in the Phase II portion of A School training for both the surface FTG's and the FTM's. Furthermore, the programming of subsurface C School (Figure 13) combines the surface pipeline modeling logic for the four source inputs to A School Phase II with the fundamental sequencing of surface C School nodes.

The sole unique feature of the FTG(SS) pipeline is the insertion of a Submarine School phase between the BE&E and A School components. This training is managed in a locked-step format and therefore conforms to the modeling techniques for class-structured progression first employed in the RTC phase of our program. The network branching at GOON node GRSG categorizes the simulated graduates by input source and is used to supplement policy analysis. Prior to departing this

phase, the entities are again separated at GOON node ALL so that on-time and rollback graduates' advancement through the A School segment can be prioritized. The SLAM terminology for the service veteran and fleet personnel input arms of this phase also replicates the examples of previous network discussions.

8. Summary of Training Pipeline

The addition of Submarine School to the normal cycle of RTC, BE&E, A School, and C School components completes the subsurface training requirements. Joining this sequence of courses with the surface FTG and FTM network paths defines the fire control technician schooling process aimed at preparing today's sailors for the demands imposed by the technology of modern weapon systems. When viewed in aggregate, Figures 5 through 13 depict our SLAM model of this total FT training pipeline.

IV. DISCUSSION OF RESULTS

A. INTRODUCTION

Experimentation with the SLAM representation of the fire control technician training pipeline presented in Chapter III enables us to assess the impact of Navy policy actions upon service schools' performance capabilities. Simulations of this training process lead to the development of preferred methods for accessing technicians and to refinements in the management of manpower assets for the years ahead. In creating the basic policy alternatives used in our computer model evaluations, we have imposed several assumptions concerning the operations of the FT training schools through the 1980's. Our program is capable of investigating changes in the physical size of training facilities; but, since plans for future shore-based construction and for increases in instructor assignments are undeveloped, we have narrowed our study to only those policies modifying procedures within the existing schools structure. We have also viewed currently employed instructional techniques and technologies to be constant throughout the nine years of our project. Finally, we have assumed that improvements to today's weapon systems and maintenance programs will not require added training time.

Bounded by these criteria, we have tested various Navy-wide and training command management options, and, by integrating the most beneficial alternatives, constructed a

feasible solution to the FT training pipeline's problems generated by an increasing fleet size. Although we do not have rating-specific data, Navy officials estimate that, on a typical day, approximately 5000 servicemen are temporarily assigned duties while awaiting commencement of training classes. This uncomplimentary statistic, coupled with rapid advances in manpower costs, highlights the impact of training upon the Navy's fiscal budget and has served to focus our analysis upon the implications of training requirements on system queue times and on the overall time necessary to process a trainee through the pipeline. The supply and demand forecasts set forth in Chapter II have provided us two approaches for viewing these pipelines characteristics and for evaluating proposed policies using a SLAM simulation model. Table 21 summarizes the accessions into the training pipeline used for these two approaches by describing the manpower inputs for the supply-driven or baseline case and our proposed alternative input scenario designed to meet the projected demand for FT's in the 1980's. The impact of each manning posture on the training command is detailed in the following discussions. A sample output from the SLAM Summary Report, which supplied the statistics for our analysis, is presented in Appendix B. The output provides the data for an entire simulated year of training pipeline operation.

B. SUPPLY-DRIVEN RESULTS (BASELINE)

We will first consider the performance behavior of the FT training pipeline in a scenario based upon the Rand Model

TABLE 21

Annual Manpower Accessions

Pipeline Entry Point	Baseline Case	Alternative Inputs		
	E-1/3 Inputs	E-1/3 Inputs	Fleet Inputs	Service Veterans
RTC	*	**	--	--
BE&E (Sfc)	--	--	44	--
A Sch Ph II	--	--	--	167
FTG C Sch	--	--	7	20
FTM C Sch	--	--	7	20
BE&E (SS)	--	--	15	--
FTG (SS) A Sch	--	--	--	5
FTG (SS) C Sch	--	--	2	--

* Rand Model yearly forecasts, partitioned by calendar quarters.

** Rand Model yearly forecasts augmented by 250 in years 1987-1990, partitioned by calendar quarters.

Source: Authors

projections for accessions through 1990 and upon the 1983 transition matrices determined in Chapter II. In developing this hypothetical environment, we have pictured the nation's economic conditions in the upcoming years as extensions of current trends and have forecasted the economy in accordance with the figures for youth unemployment promulgated by the Bureau of Labor Statistics. We have also abstained from altering Navy recruiting policies or resources beyond the minor growth in the population of production recruiters presented in our earlier discussions of the Rand Model. The resulting annual inputs to the FT training pipeline, consisting of non-prior service recruits, parallels the decline in the nation-wide pool of eligible 17 to 21 year-old males expected throughout the 1980's. This supply-driven viewpoint establishes a baseline condition from which to compare subsequent performance descriptions derived from varying system models.

As previously indicated in Table 13, the Rand Model forecasts of mental categories I, II, and IIIA accessions distributed to the FT ratings are maximized for our study in 1982. During the next eight years these anticipated annual accessions fall thirty percent from the initial estimate of 1530 recruits. This substantial decline suggests that, if the training command is adequately equipped to receive the student inputs in the first year and can thus avoid early disruptions from system backloads, the most significant time delays caused by facility overloading will be realized in the

beginning period. The results for the various pre-school queue times encountered throughout the pipeline during our baseline simulation, as shown in Table 22, generally support this assessment of the training system.

The pipeline delays incurred in the baseline scenario, as depicted in Table 22, are not excessive and therefore are regarded as manageable, particularly in the surface school segments. Although the 1982 Delayed Entry Pool (DEP) mean length of 39.1 days appears relatively large, this figure is well within the present program's guidelines that allow recruits to postpone service entry as long as one year. Moreover, since recruits do not earn military pay during the DEP period, some degree of freedom in the pre-service queue is beneficial to the manpower managers' scheduling of optimum pipeline commencement dates. The surface-designated FTG's and FTM's progress through the training cycle without appreciable blockages until reaching the C School phase. At this point, on the average a 17-18 day wait arises because the A School completion and C School commencement dates are not synchronized. Fortunately, the C School queue is positioned approximately one year into the training sequence and thus provides pipeline managers the opportunity to circumvent unproductive man-days by granting accumulated leave time to the trainees. Furthermore, the maximum expected C School queue lengths of 35 days are closely aligned to the yearly 30 day leave authorizations earned by servicemen.

TABLE 22

School Queue Times: Baseline Case

Queue	School Queue Times								
	Number Processed			Mean Value (Days)			Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
DEP	1560	6708	11097	39.1	14.9	10.4	54.0	54.0	54.0
BE&E (Surface)	1432	6202	10222	1.0	1.0	1.0	1.0	1.0	1.0
A Sch PH II	580	2479	4150	2.0	2.0	2.0	2.0	2.0	2.0
FTG C School	224	971	1639	17.8	17.8	17.8	35.0	35.0	35.0
FTM C School	325	1456	2413	17.9	18.0	17.9	35.0	35.0	35.0
BE&E (Subs)	184	865	1466	0.9	0.9	0.9	1.0	1.0	1.0
Sub School	131	618	1074	14.9	19.5	18.3	31.0	53.0	53.0
FTG (SS) A Sch	131	611	1059	16.7	16.3	16.2	42.0	42.0	42.0
FTG (SS) C Sch	132	615	1050	26.6	26.3	26.3	28.0	28.0	28.0

Source: Authors

Although the subsurface pipeline delays for the supply-driven results are also deemed manageable, the wait times are more pronounced than the surface school characteristics, and therefore necessitate enhanced supervision. The increases from 1982 to 1986 in the mean and maximum values of the Submarine School queue times imply that the blockage is a function of both the scheduling of the school's start dates and the school's classroom capacity. Apparently, the student loading during the early years of the study creates a temporary backlog of trainees awaiting class assignments. Figure 14, the 1986 histogram of the queue times encountered prior to the commencement of Submarine School, illustrates this backlog by showing that nine percent of the subsurface trainees experience delays greater than 30 days even though the school is scheduled to begin every 28 days in our program. However, the stabilization of these Submarine School queue figures by the year 1990 indicates that the subsurface training facility recovers from this initial capacity constraint and is adequately equipped for the reduced demands of the later years of our project. The mean values for each of the queues associated with Submarine, FTG(SS) A and FTG(SS) C Schools are considerably less than the programmed intervals of 28 days between class commencements, but the total of these times surpasses the 30 day leave annual authorizations and requires managerial attention. Closer alignment than our program's depiction of school start and completion dates can minimize these projected delays, especially when the model is amplified

Queue Time (Days)	Freq	Freq	Percent of Submarine School Graduates (618 Students Processed) 0 10 20 30 40 50 60 70 80 90 100
0-5	0.11	0.11	*****
6-10	0.13	0.24	****** C
11-15	0.14	0.38	****** C
16-20	0.14	0.52	****** C
21-25	0.18	0.70	******** C
26-30	0.13	0.83	***** C
31-35	0.08	0.91	**** C
36-40	0.04	0.95	** C
41-45	0.03	0.98	** C
46-50	0.02	0.99	* C
INF	0.01	1.00	* C

C denotes cumulative frequency

* denotes relative frequency of Queue Time grouping

Source: Authors

FIGURE 14. 1986 Submarine School Queue Time Histogram: Baseline Case

to include the commencement dates for all of the numerous C Schools actually offered.

By combining the anticipated queue times with the programmed course durations, the expected stay times at particular service schools are determined. Table 23 presents these predicted mean values for the three emphasized years of our study. The time statistics are derived by tracking simulated trainees through the pipeline representation and therefore reflect the inputted rollback and probability distribution of course lengths features incorporated in our model. The consistency of the figures throughout the nine years indicates that, with adherence to sound management principles and to the scheduling requirements discussed above, the processing of the majority of trainees through the pipeline is routinely accomplished in the baseline scenario. However, Table 23 also displays the maximum course durations experienced by students during our simulations and suggests that some individuals encounter lengthy stay times either because of academic difficulties or because of the SLAM program's specifications for selecting individuals for classes from among the trainees waiting in the school graduate, fleet personnel, and service veteran queues. Careful pipeline management, employing frequent monitoring of trainee progress in the system and case-by-case adjustments to class selection standards, will avoid these excessive stay times and will thus minimize expensive man-day losses and the underutilization of school capacities.

TABLE 23

School Stay Times: Baseline Case

School	School Stay Times								
	Number Graduated			Mean Value (Days)			Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
BE&E (Surface)	1053	4608	7606	88.7	88.5	88.1	165.1	179.6	196.5
A School (Sfc)	560	2497	4157	167.0	166.9	166.8	193.0	194.4	194.4
FTG C School	212	1005	1667	225.6	226.0	225.4	435.6	461.7	461.7
FTM C School	351	1523	2511	241.6	227.2	225.9	492.6	492.6	492.6
BE&E (Subs)	136	622	1078	41.5	40.6	40.9	78.3	79.1	88.9
Sub School	131	612	1069	56.9	60.8	59.8	81.9	106.6	106.6
FTG (SS) A Sch	131	614	1053	100.3	100.2	100.0	124.0	138.0	138.0
FTG (SS) C Sch	143	648	1073	227.5	228.7	229.6	404.1	447.8	447.8

Source: Authors

The expected overall time required for an enlistee to pass through the entire baseline scenario's FT training pipeline is displayed in Table 24. As in the determination of school stay times, the figures are obtained by recording the advancement times of each simulated trainee through the system to the completion of the C School phase. The statistics for surface-designated FTG and FTM four year obligators represent only the small number of fleet inputs into C School, since all other four year obligators depart the training pipeline at the conclusion of A School Phase I. Similarly, because the subsurface schools do not currently accept four year obligators, the FTG(SS) results are limited to six-year obligators. The figures of Table 24 depict typical six year obligator training cycle durations of approximately 19 months for surface-designated technicians and 17 months for subsurface FT's. Figures 15, 16, and 17 graph the distributions of these expected pipeline durations for the six year enlistees. Again, the predicted maximum values for stay times (reaching a high of 29 months for FTM's) indicate that excessive processing times arise when students experience academic problems or class selection standards are rigidly enforced. Manpower managers must be alert to these isolated cases and ready to intervene with corrective scheduling.

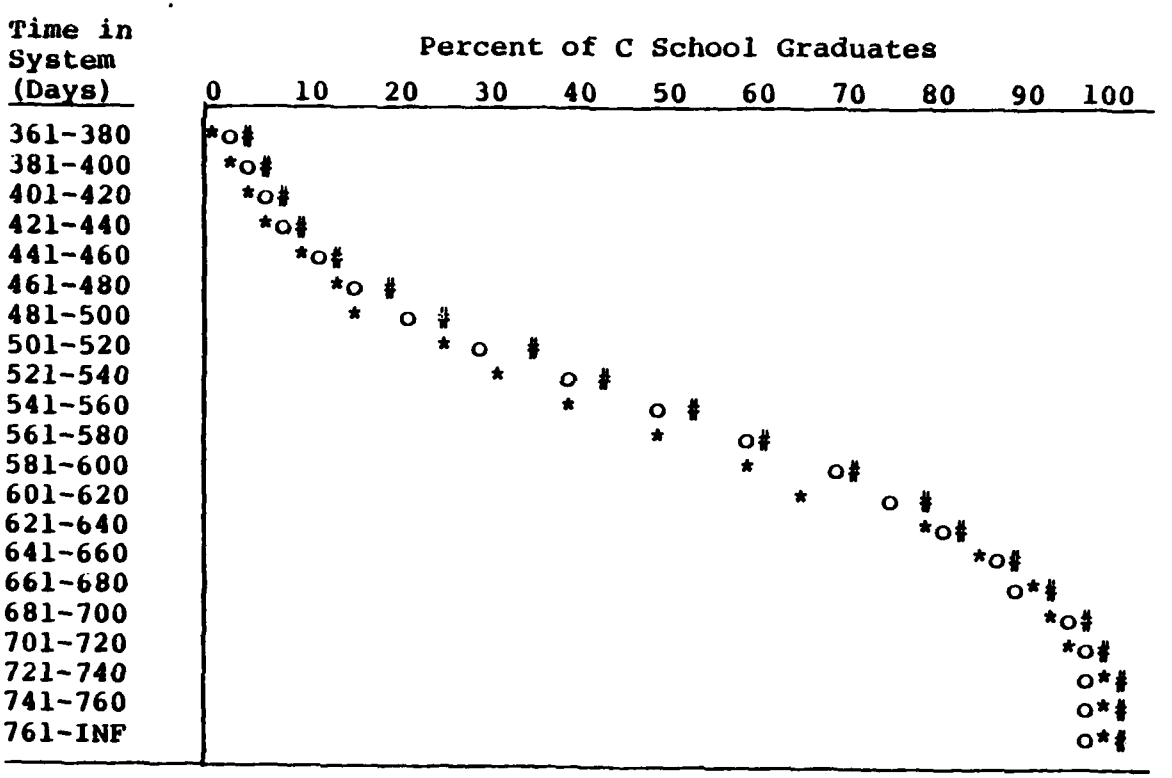
From a training manager's perspective, our results in the baseline scenario simulation are encouraging. Substantial interruptions in the schooling process can be successfully

TABLE 24

Time-in-System Projections: Baseline Case

Obligators	Number Processed			Time-in-System Projections: Mean Value (Days)			Time-in-System Projections: Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
FTG 4-YO	6	31	58	278.8	292.5	288.5	318.4	418.2	418.2
FTG 6-YO	206	974	1609	568.9	558.2	549.4	830.8	839.9	839.9
FTM 4-YO	8	32	60	280.3	284.6	290.5	410.3	466.2	518.3
FTM 6-YO	343	1491	2451	585.8	558.2	547.9	869.8	869.8	869.8
FTG (SS) 6-YO	143	648	1073	526.5	511.4	501.8	718.9	745.6	745.6

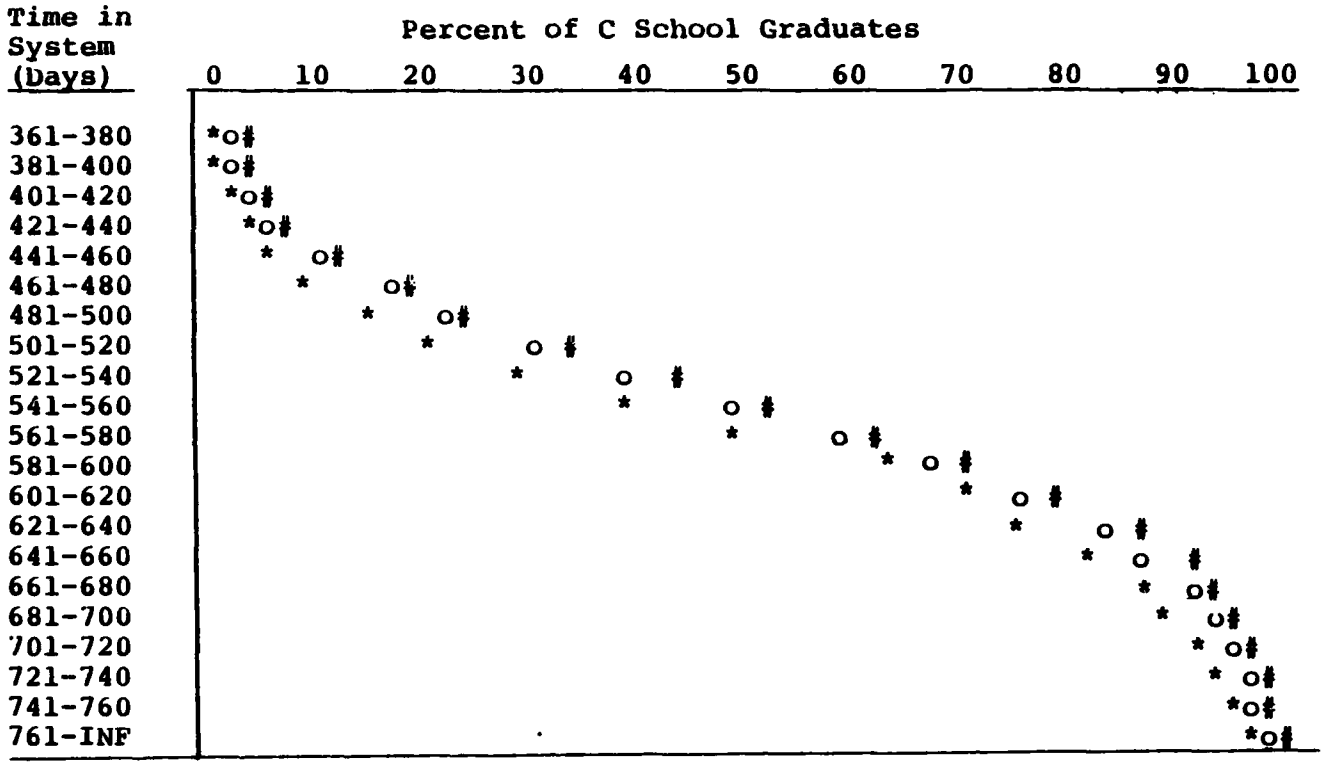
Source: Authors



* denotes 1982 statistics (206 students processed)
o denotes 1986 statistics (974 students processed)
# denotes 1990 statistics (1609 students processed)

Source: Authors

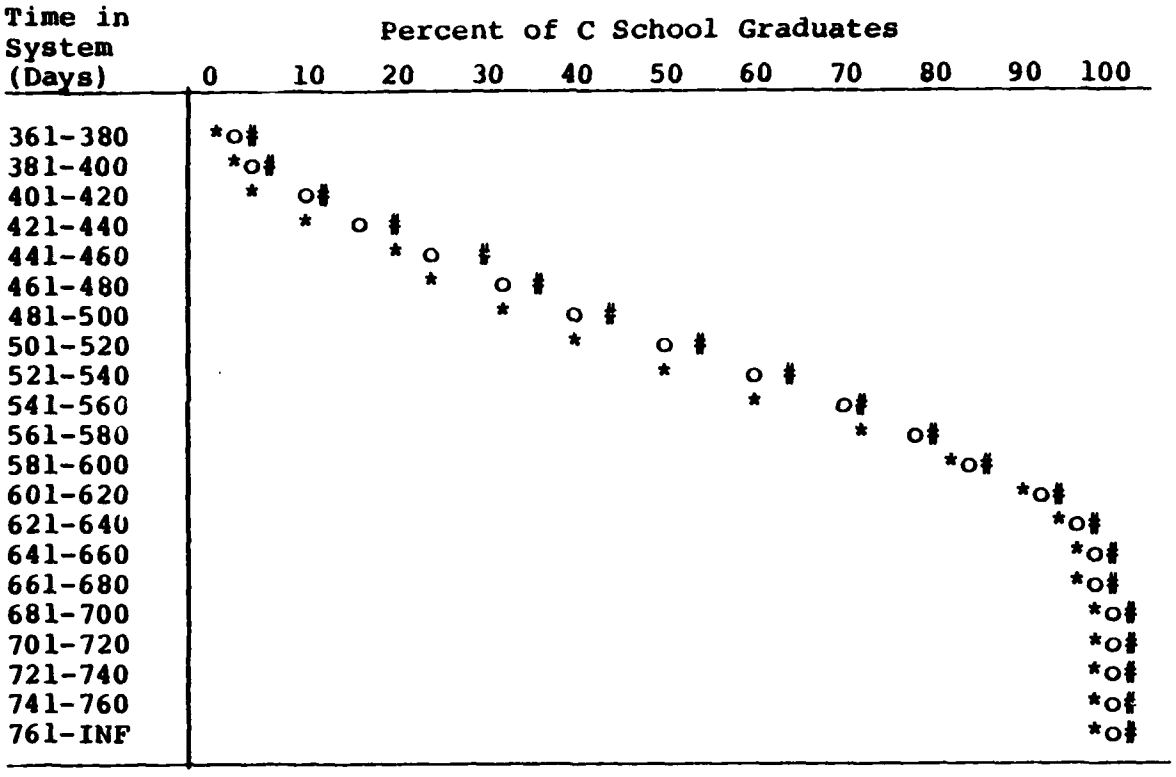
FIGURE 15. FTG 6 YO Time-in-System Histogram: Baseline Case



* denotes 1982 statistics (343 students processed)
o denotes 1986 statistics (1491 students processed)
# denotes 1990 statistics (2451 students processed)

Source: Authors

FIGURE 16. FTM 6 YO Time-in-System Histogram: Baseline Case



* denotes 1982 statistics (143 students processed)
o denotes 1986 statistics (648 students processed)
# denotes 1990 statistics (1073 students processed)

Source: Authors

FIGURE 17. FTG(SS) 6 YO Time-in-System Histogram: Baseline Case

avoided and, since school queue times are relatively constant throughout the nine years, the school capacities are apparently capable of handling the forecasted student loading. However, as previously demonstrated in Tables 15 and 16, manpower supply projections developed from the 1983 POM transition matrices and the annual accession figures for FT's fail to fulfill the billet requirements demanded by an expanding fleet. This shortfall will force the Navy either to intensify recruiting efforts in the 17 to 21 year-old population, e.g., enlist more lower mental group personnel, or to tap alternate manpower pools for the acquisition of the necessary numbers of technicians. Consequently, the supply-driven simulation results cannot be viewed as definitive statements of the training command's future performance capabilities. Instead, the baseline scenario forecasts become measuring blocks for evaluating policy decisions designed to support the projected Navy-wide growth.

C. DEMAND-DRIVEN RESULTS (ALTERNATIVE INPUTS)

A realistic and meaningful assessment of the Navy training command's potential to function efficiently throughout the 1980's must examine student loads that reflect the increasing demands for technicians in the envisioned 600-plus ship fleet. The inability of our supply-driven projections to meet this demand underscores the critical need to modify the Service's current recruiting and personnel policies. From a manpower procurement standpoint, the many additional sources that can

be identified for accessing FT's, including college students, the 22 to 30 year-old male civilian labor force, and possibly more women, indicate that attainment of the necessary numbers is feasible. With this assumption, the problem of end strength build-up centers around the augmentation and allocation of recruiting budgets and the alignment of training capabilities to fleet requirements. While seeking a solution to the FT manning dilemma, we have not constrained our policy decisions with considerations of the relative recruiting expenses of these various populations. Instead, we have assumed that the available source pools are sufficiently large to supply the required added inputs, and that recruitment within these sectors is cost-effective. These simplifications enable us to concentrate our analysis upon the affects of program adjustments on the performance of the training pipeline. In this manner, we have constructed a method for increasing the output of FT's while remaining within the limitations of the Navy's present training resources.

Our study is directed toward the evaluation of a training pipeline that will both overcome present manning deficits and respond to projected growth through the next nine years. In proposing policy options for augmented accessions to this pipeline, we are handicapped by the time-in-rate requirements imposed for promotions to the upper enlisted ranks. Many of the senior billets in which shortfalls currently exist and the projected higher positions that will not be filled under

the 1983 POM transition matrix progressions cannot be reached prior to 1990 by recruits entering RTC today. Thus, in addition to causing exorbitant backloads within the training schools, the excessive front-loading of the pipeline with increased E-1 manning will not solve our personnel problems.

However, Tables 15 and 16, the compilations of our supply and demand projections based on the 1983 POM retention goals, also display manpower needs in the E-1/3 through E-5 paygrades in the year 1990. These lower rates are attainable early in sailors' career patterns and therefore shortages can be readily eliminated by accessing increased numbers directly into the beginning stages of the training pipeline. In developing our alternative manning proposal shown in Table 21, we have waited until 1987 before introducing a 250 man E-1/3 augmentation to the Rand Model projections, an augmentation intended to satisfy the expanding requirements for technicians. Because of the decline in the eligible population of 17 to 21 year-olds, this addition will not raise the yearly accessions to the high level of inputs reached in 1982, and thus will not over-tax the class capacities in the introductory schools of the training command. At the same time, the enhanced outputs from the service schools will fill the expected gaps in the junior billet assignments during the final years of our projection. These extra recruits can surface either from the tapping of alternate source pools, the relaxation of mental category standards, or intensified recruiting in the male youth cohort.

The projected senior billet shortfalls of our study necessitate policy modifications that input additional accessions at intermediary stages in the training pipeline. Enlisted personnel managers are currently filling some of these deficits by accepting qualified, top performing sailors from surface and shore commands as direct inputs into advanced schools of the training process. However, this supply of manpower is limited by the low percentage of servicemen who exit RTC possessing the necessary academic potential to perform as fire control technicians and who do not immediately enter another rating's pipeline. Therefore, in our alternative input scenario, we have patterned the yearly additions of fleet personnel into the cycle after the recorded 1981 inputs, in which only 44 sailors were introduced in the BE&E (surface) phase, 15 experienced enlistees entered the subsurface pipeline at the BE&E School, and fleet inputs into the surface C Schools averaged about one every two classes.

Although the specification for inputting accessions midstream in the training sequence lessens the number of eligible civilian source pools from which to choose, several groupings, such as college students capable of validating the theoretical courses, civilian laborers already possessing electronics skills, or high quality ex-servicemen, have been viewed as acceptable augmentations to our proposed accession mix. Despite the potential of each of these population sectors, we have opted to limit our policy changes to billet

openings for service veterans. The selection of this prior-service pool as the target for future recruitment is based on the following favorable factors:

1. Entry of service veterans, in effect, enables the Navy to capitalize on previously conducted training.
2. Veterans are knowledgeable of, and accustomed to, the military lifestyle and service discipline, and are therefore unlikely to leave for these reasons.
3. Recent trends in recruiting statistics indicate that service veterans, influenced by the current economic recession, are returning to the Navy in increased numbers.

Because projections derived from the envisioned ship-mix and manning requirements of Tables 4 and 5 indicate an increase of only 86 billets in the subsurface community, we have concentrated our additional service veteran inputs in the surface pipeline schools. The specifics of our manning proposals are delineated in Table 21.

Comparison of the results from a SLAM program simulation of the FT training pipeline, modified to conform to our alternative input scenario, with the performance statistics of the baseline case enables us to identify possible problem areas attributable to the suggested accession policy and to judge the manageability of the affects projected from our manning proposal. Although the alternative input simulation introduces an additional 998 trainees into the DEP, inputs 2583 service veterans into intermediary stages of the

pipeline, and processes 2522 more technicians through the C Schools during the nine years of the study, the pre-school queue times, presented in Table 25, are remarkably similar to the forecasts in Table 22 for the supply-driven case. For a majority of the queues, the mean values for all corresponding pipeline delays in the two scenarios match within two days.

Table 25 illustrates that, as a result of the increased demand for FTG and FTM students generated in the alternative input case by growth in fire control technician billets fom 1982 to 1990, the surface pipeline C Schools, Submarine School, and FTG(SS) A School all apparently approach capacity limitations and the queue time means for these schools are lengthened approximately three to six days over the baseline figures for the emphasized years. These minor additions to the queue times are most prevalent in the early years of our projection. Since the total increase in queue times in any one of the specific pipelines is less than 12 days, these school queue mean extensions are not considered serious when viewed in the context of an 18 month training process. Furthermore, in the total pipelines for the surface FTG's and FTM's, the school queue means are still comfortably below the allotted 30 days annual leave period of each trainee, and thus manpower productivity losses can be avoided by granting personnel leave to students prior to the commencement of C School. As in the baseline case, the subsurface pipeline queue times extend beyond the yearly authorizations and require monitoring by

TABLE 25

School Queue Times: Alternative Input Case

Queue	School Queue Times								
	Number Processed			Mean Value (Days)			Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
DEP	1560	6708	12095	39.1	14.9	10.4	54.0	54.0	54.0
BE&E (Surface)	1407	6153	11005	1.0	1.0	1.0	1.0	1.0	1.0
A Sch PH II	726	3308	5804	1.8	1.8	1.8	2.0	2.0	2.0
FTG C School	269	1326	2432	21.1	18.7	19.0	42.0	42.0	42.0
FTM C School	402	2034	3496	20.6	22.1	20.5	42.0	49.0	49.0
BE&E (Subs)	202	904	1627	0.9	0.9	0.9	1.0	1.0	1.0
Sub School	146	677	1219	20.8	23.8	21.2	46.0	67.8	67.8
FTG (SS) A Sch	145	693	1252	17.9	21.6	20.6	42.0	42.0	42.0
FTG (SS) C Sch	146	698	1259	27.3	28.0	27.5	50.0	56.0	56.0

Source: Authors

manpower managers. However, the small time additions created by the sizeable accession increases indicate that the juggling of school start dates and the modeling of all C Schools will overcome excessive pipeline delays. The SLAM Summary Report histograms further alleviate apprehensions concerning the demand placed upon the Service schools by showing that small percentages of trainees can be expected to wait in excess of one month for class assignments. Figure 18, the histogram for the 1986 FTM C School queue under the alternative input scenario, is a typical histogram depicting about one-seventh of the students being delayed more than thirty days.

The maximum queue durations experienced in our alternative input case, presented in Table 25, generally parallel the previous forecasts of the baseline simulation. The close similarity between the two scenarios suggests that the delay determinations for the proposed manning policy are dominated by the model's programmed start dates and method for forming classes from the students waiting in the school pipeline, fleet input, and service veteran queues. In most cases, the delays are not the result of system overloads. Only the FTM C, Submarine, and FTG(SS) C Schools display lengthenings of maximum queue times beyond one week when the proposed accessions mix is coupled with the baseline personnel inputs. Although these increases are somewhat disturbing, the SLAM program summaries predict that, except for the FTG(SS) C School, less than six percent of the trainees incur delays within five days of these maximums. For the subsurface C

Queue Time (Days)	Rel Freq	Cum Freq	Percent of Submarine School Graduates (2034 Students Processed) 0 10 20 30 40 50 60 70 80 90 100
0-5	0.00	0.00	
6-10	0.12	0.12	******C
11-15	0.20	0.32	******** C
16-20	0.00	0.32	C
21-25	0.30	0.62	********** C
26-30	0.24	0.85	********* C
31-35	0.10	0.95	**** C
36-40	0.00	0.95	C
41-45	0.05	0.99	** C
46-50	0.00	0.99	C
INF	0.00	1.00	C

C denotes cumulative frequency

* denotes relative frequency for Queue Time grouping

Source: Authors

FIGURE 18. 1986 FTM C School Queue Time Histogram: Alternative Input Case

School, over eighty-six percent of the students are processed through the queue in less than 30 days. Therefore, it seems reasonable to assume that pipeline managers can eliminate prolonged waits for these schools through the occasional manipulation of selection priorities and procedures.

Considering the similar results for anticipated queue times in our two scenarios, and recognizing that the modeling techniques in the SLAM program will produce mathematically consistent estimates of course durations, it is not surprising that the alternative input simulation's approximations for school stay times, shown in Table 26, correlate with the baseline figures in Table 23. The most significant difference in the two tables occurs in the surface A School segments of the pipeline, where a two to three week reduction is noted in the demand-driven mean value statistics. Unfortunately, this lowering of the means does not represent improved processing speeds, but rather reflects the introduction of 167 students each year directly into Phase II of A School. However, it is important that the substantial gain in the number of trained technicians does not impart a system overload and cause subsequent major delays in the pipeline.

Comparison of TAbles 23 and 26 highlights the potential of our suggested manning policy to function within the present capabilities of the Navy's training command. The time a FTG (surface) student can expect to remain at C School is lessened by about a week in the accession-mix scenario. This improvement appears to stem from the frequency of class start

TABLE 26

School Stay Times: Alternative Input Case

School	Number Graduated			School Stay Times: Mean Value (Days)			School Stay Times: Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
BE&E (Surface)	1037	4600	8138	84.5	83.3	83.3	191.8	191.8	193.9
A School (Sfc)	658	3284	5756	153.1	148.6	147.6	193.8	194.3	194.2
FTG C School	224	1293	2389	216.4	217.1	219.9	419.7	450.9	464.9
FTM C School	393	2062	3524	230.0	227.3	224.4	495.1	495.1	495.1
BE&E (Subs)	150	676	1223	40.7	39.8	40.5	75.7	81.0	81.0
Sub School	140	665	1205	61.5	65.4	62.9	91.3	119.1	119.1
FTG (SS) A Sch	144	686	1240	101.6	105.1	104.2	124.0	138.0	138.0
FTG (SS) C Sch	153	718	1259	229.2	228.4	227.3	426.5	447.8	451.1

Source: Authors

dates in our model, and the programmed distribution of the 20 service veterans added annually to this school's enrollment. This also results in an eleven day reduction in the 1982 stay time statistics for the FTM C School, which similarly accesses 20 veterans yearly under the demand-driven pipeline conditions. However, the improvement in FTM student processing is lost during the middle years of our study and the training time requirements for these technicians in the later years parallel the baseline estimates. This variation in the FTM stay time figures substantiates the earlier assessment that the C School is approaching capacity constraints under our increased accession proposal. Summations of the subsurface course durations in Tables 23 and 26, performed as a means of appraising the impact created by augmented accessions into the FTG(SS) pipeline, indicate that the theorized manning policy will have little effect upon the submarine training facilities. The few differences in maximum school stay times experienced during simulations of the two scenarios further support the compatibility of our envisioned accession programs with Service school resources. Thus, efficient management of the enhanced student loading in the individual schools certainly appears to be a realistic and attainable goal.

The expected time-in-system characteristics of the alternative input scenario are presented in Table 27. As in the baseline case previously depicted in Table 24, these statistics are compiled by tracing each student through the

TABLE 27

Time-in-System Projections: Alternative Input Case

Obligators	Number Processed			Time-in-System Projections: Mean Value (Days)			Time-in-System Projections: Maximum Time (Days)		
	1982	1986	1990	1982	1986	1990	1982	1986	1990
FTG 4-YO	20	347	710	243.5	333.8	378.6	368.6	593.1	723.6
FTG 6-YO	204	946	1679	562.1	547.9	541.9	829.1	855.9	855.9
FTM 4-YO	27	491	931	241.0	350.2	384.9	333.5	572.5	697.8
FTM 6-YO	366	1571	2593	573.8	557.0	547.3	850.6	850.6	850.6
FTG (SS) 6-YO	149	689	1201	543.8	522.7	507.7	756.3	756.3	756.3

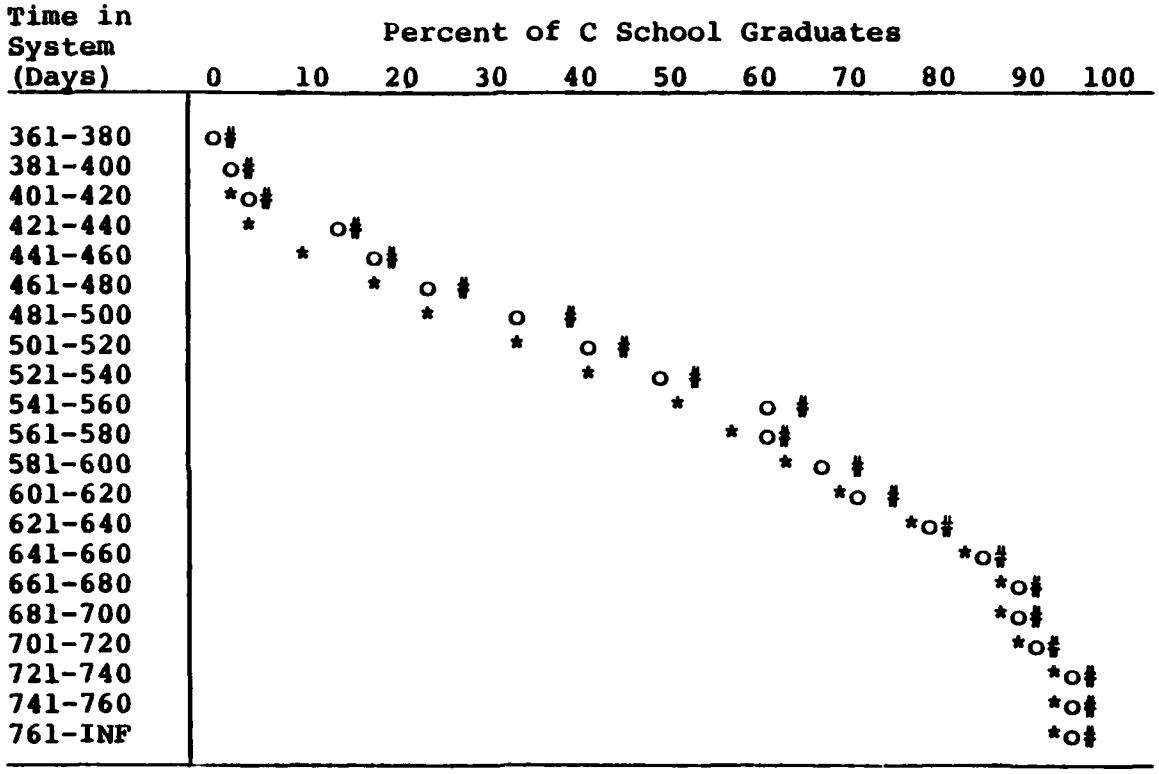
Source: Authors

training cycle and then grouping according to first-term service contract obligations. Since Table 27 is limited to data for C School graduates, the surface-designated four year obligator figures include only those fleet personnel and service veterans inputted at either the beginning of A School Phase II or the start of C School and progressing through the training command. Viewing the results for 1982 in Tables 24 and 27, a pronounced reduction is noted in the time-in-system projections for the two four year obligator categories of the alternative input case. These declines reflect the increase of 27 students in the C School four year obligator accessions (fleet personnel and veterans) during the initial simulation year and the selection criteria of our model which gives class assignment priorities to the intermediary inputs. In contrast to the first year statistics, the 1986 and 1990 system time estimates under the proposed manning environment are significantly greater than the baseline scenario. This reversal in the comparison of the two cases develops when the service veteran trainees, originally introduced into the alternative input scenario at Phase II of A School, conclude C School training. The Phase II veteran accessions, which are unique to this proposed accession-mix simulation, extend the amount of pipeline training conducted and thus the required time in the system. Because the large number of Phase II accessions overshadows the 20 annual veteran inputs to the C Schools, the 1990 mean value statistics in

the demand-driven case essentially summarize the length of time necessary to complete both A School Phase II and C School. However, the matching baseline figures encompass only the C School duration.

The system times projected in Table 27 for six year obligators in a pipeline manned to produce adequate numbers of technicians for the 600-plus ship fleet do not indicate future overcrowding problems within the Service schools. The forecasted mean values for the FTG and FTM six year obligators are less than the corresponding baseline scenario figures previously judged as reasonable estimates of schooling durations. These improvements are apparently attributable to the quickened pace of C School processing. The FTG(SS) statistics differ from the baseline figures by a maximum of 17 days and thus represent a minimum of added managerial difficulties.

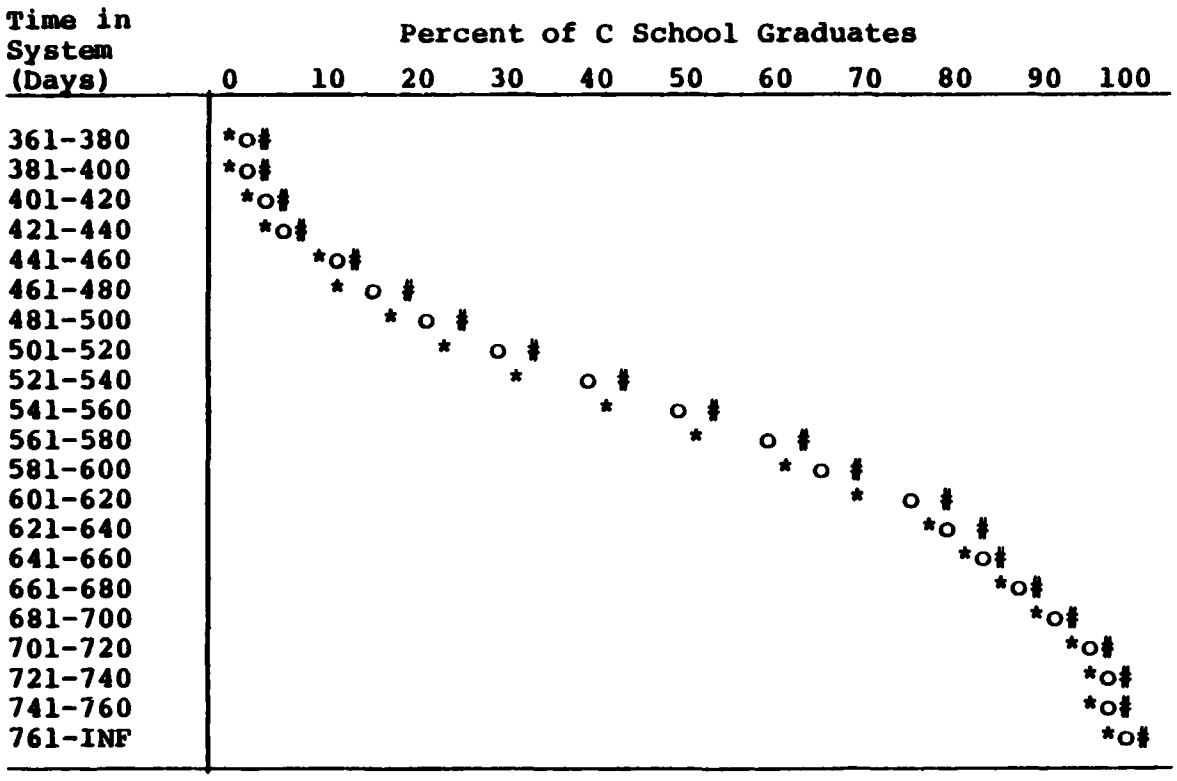
Although some elements of Table 27 indicate greater maximum system stay times than the baseline results of Table 24, the SLAM Report summaries show that these extensions are infrequent occurrences arising from the increased manning demands, Figures 19, 20, and 21 graphically present the breakdown of time-in-system statistics for the FTG, FTM, and FTG(SS) C School graduates committed to six year contracts, and thus supplement the purely mathematical definition provided by the mean and maximum values. The 1986 system time behavior of FTG six year obligators serves as an example of the utilization of these three figures. Whereas the Table 27



* denotes 1982 statistics (204 students processed)
o denotes 1986 statistics (946 students processed)
# denotes 1990 statistics (1679 students processed)

Source: Authors

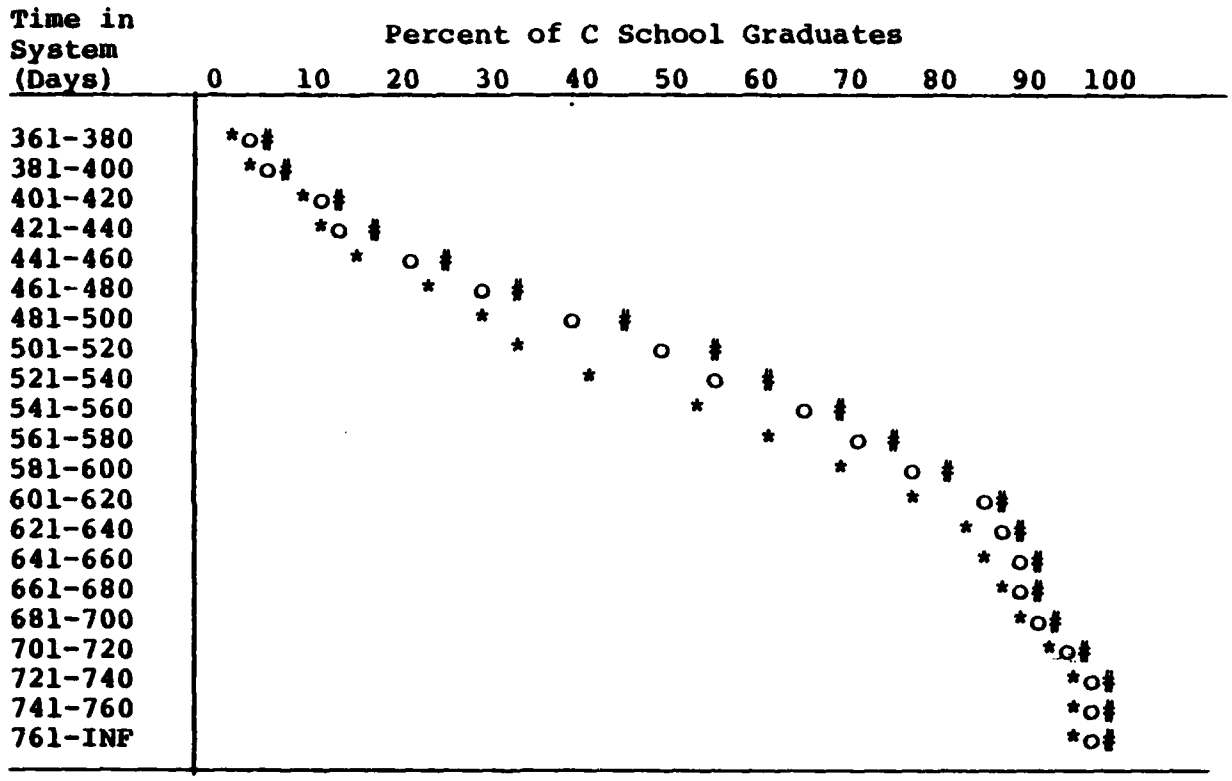
FIGURE 19. FTG 6 YO Time-in-System Histogram: Alternative Input Case



* denotes 1982 statistics (366 students processed)
o denotes 1986 statistics (1571 students processed)
# denotes 1990 statistics (2593 students processed)

Source: Authors

FIGURE 20. FTM 6 YO Time-in-System Histogram: Alternative Input Case



* denotes 1982 statistics (149 students processed)
o denotes 1986 statistics (689 students processed)
# denotes 1990 statistics (1201 students processed)

Source: Authors

FIGURE 21. FTG(SS) 6 YO Time-in-System Histogram: Alternative Input Case

description of this 1986 characteristic is limited to the reporting of a mean value of 547.9 days and a maximum duration of 855.9 days, Figure 19 illustrates that 50 percent of the trainees are processed within 550 days and 90 percent inside of 660 days. The rapid drop-off in the tails of the three curves pictured in each of the figures demonstrates the isolation of the lengthy stay times to small numbers of trainees and suggests that individual scheduling for these students can avoid unusual program delays.

D. SUMMARY

The above discussions detail the significant results from our SLAM program evaluations of the training pipeline operating in a demand-driven environment. Comparison of the pipeline characteristics of this scenario against the patterns of a baseline case have repeatedly demonstrated similarities between the two simulations. The pre-school delays of the training cycle sequence and the school stay times associated with our alternative input scenario approximately duplicate those of the supply-driven projections. Additionally, review of the forecasted time-in-system statistics illustrated in Figures 15, 16, 17, 19, 20, and 21 amplifies the resemblance between the results of the two simulations. If the output of technicians from the alternative input simulation can be shown to fulfill the projected shortfalls in the 1990 FT end strengths, then the commonality in our pipelines' performance behavior will attest to the present-day training command's potential

to adapt to the increasing demands for FTG's and FTM's in an expanding fleet.

The difference in the number of school graduates recorded in the SLAM Summary Reports of our two simulations defines the expected increase in technicians resulting from the proposed accession policy. Table 28 groups, by rate, the yearly growth in FTG and FTM outputs of the training command created by the enhanced manning accessions of the alternative input scenario. In determining these groupings, we have assumed that, of the fleet personnel and service veteran additions, those trainees completing the lengthy pipeline process emerge as E-6 graduates of the C Schools, and those sailors dropping out of the surface schools sequence after Phae I of A School are rated as E-4's. Of the added 250 E-1 accessions introduced annually in years 1987 through 1990, those students processed through C Schools during our simulation are considered to be E-4's, whereas the servicemen returning to the fleet after Phase I of A School are viewed as E-3 inputs. Because the Navy designates trainees as FT's either upon completion of Phase I of A School or upon graudation from FTG(SS) A School, the few students (99 in the nine simulated years) attributable to the extra accessions in the proposed policy who attrite from the most advanced schools of the pipeline are counted as E-4 additions to the FT communities. Table 28 does not include possible inputs from the large number of drop-outs from the RTC, BE&E Schools, Submarine School, and A School Phase I segments of the pipelines and

TABLE 28

Increased Number of Technicians from Alternative Inputs

GAINS OVER BASELINE NUMBERS

	E-6		E-4		E-3	
YEAR	FTG	FTM	FTG	FTM	FTG	FTM
1982	43	50	4	2	-	-
1983	101	130	8	6	-	-
1984	107	130	8	6	-	-
1985	135	138	6	4	-	-
1986	112	132	3	2	-	-
1987	124	126	60	29	-	-
1988	117	123	75	31	23	24
1989	130	130	41	72	75	39
1990	134	126	69	107	44	19

Source: Authors

therefore probably underestimates the added number of technicians to be expected from the suggested manning policy.

Summation of the increased numbers of technicians shown in Table 28 and the annual projections for the enlistment of fire control technicians, derived from the Rand Model's estimates of 17 to 21 year-old male, NPS, mental category I, II, and IIIA personnel, produces the total yearly accessions forecasted under our alternative input scenario. When these enhanced accession numbers, along with the 1983 POM projection transition matrices and the 1981 FT end strengths, are entered into the basic manpower transition model described in Equation 9, the anticipated manning levels for the fire control technicians through the 1980's can be be calculated. Table 29 compares the resulting predictions for the supply of FT's in the years 1982, 1986, and 1990 to the previously determined demand figures.

The supply forecasts depicted in Table 29 indicate that the FT billets required by a 600-plus ship fleet can be filled by 1990 under our proposed accession policy. In fact, sufficient numbers of FT's are produced by 1986 to equal the total manning requirements. However, the breakdown of the 1986 projected end strengths into junior and senior rate groupings (E-1 through E-5 and E-6 through E-9) displays a concentration of the manning totals for the mid-year of our study in the lower rated billets. Despite the substantial input of E-6's by 1986 (1078 FT's) directly into the manpower

TABLE 29

Demand Versus Supply: Alternative Inputs

(Using 1983 POM Projection Transition Matrices)

	1982			1986			1990		
RATE	DEMAND	SUPPLY	DIFF	DEMAND	SUPPLY	DIFF	DEMAND	SUPPLY	DIFF
E1/E3	467	602	+ 135	531	555	+ 24	653	623	- 30
E-4	2010	2316	+ 306	2193	2484	+ 291	2511	2624	+ 113
E-5	1680	1616	- 64	1932	2239	+ 307	2338	2329	- 9
E-6	1790	1178	- 612	1995	1961	- 34	2322	2382	+ 60
E-7	891	816	- 75	997	1147	+ 150	1154	1623	+ 469
E-8	407	166	- 241	442	238	- 204	493	345	- 148
E-9	272	38	- 234	295	39	- 256	335	52	- 283
TOTAL	7517	6732	- 785	8385	8663	+ 278	9806	9978	+ 172
E1-E5 DIFF	--	--	+ 377	--	--	+ 622	--	--	+ 74
E6-E9 DIFF	--	--	-1162	--	--	- 344	--	--	+ 99

Source: Authors

model, the senior billets remain unfulfilled. But by 1990, enough of the additional accessions in our alternative input scenario have progressed through the FT promotion system so that both the junior and senior groupings are fully manned. Although the nine year period of our simulation is too short to enable the transition model to develop adequate numbers of E-8 and E-9 personnel, the surplus of E-7's produced in the simulation overcomes the deficits in the two senior paygrades. This substitution of CPO's for the E-8/E-9 billet demands seems to be a realistic solution to the manpower problem created by the large-scale undermanning of these rates in today's fleet. Other than the E-8 and E-9 paygrades, the projected 1990 manning levels for each rate are considered satisfactory. The minor shortfalls in the E-1/3 and E-5 rates can be filled with the excess E-4's, and probably would be eliminated if a percentage of the school drop-outs from the training pipeline were also inputted into the manpower calculations.

Our proposed manning policy is a simplified accession-mix that will enable manpower planners to fill the multiplying billet requirements of the future without saturating the Service schools' capabilities. Experimentation with a simulation model of the current FT training pipeline has demonstrated that, if recruiting sources can be targeted and utilized, the output of FT's from the Navy's training command can overcome existing manning deficits and satisfy the forecasted growth in the FTG and FTM manpower authorizations.

We recognize that alternative manning postures more responsive to the complex input variables may be developed to satisfy these goals. Our suggested solution is intended to serve as an example for the application of SLAM simulation techniques to the evaluation of these important policy decisions.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

As the size of the fleet expands in the foreseeable future, the overall effects on the FT training pipeline can be projected. The simulation results, do indeed, quantitatively demonstrate the impacts the growth of the Navy will have on the training of FT's. Whether the individual enters the Navy by direct means as a recruit and progresses through the total training syllabus, or enters as a lateral entry candidate in a pre-selected school, each person will create a certain identifiable effect on the particular pipeline. The ramifications such trainees will cause in the training pipeline can be estimated using a simulation model. SLAM has allowed us to measure, analyze, and even forecast which variables will fluctuate, given alternative personnel accession options, within the FT training pipeline. This method of forecasting personnel increases in the training command structure is a beneficial tool for program managers.

Nevertheless, the supply-demand picture must not be overlooked. Chapter II gave graphic evidence, based upon our predictions, that there will be significant shortages in the FT ratings in the years through 1990. If the retention rates improve dramatically, obviously, the effects of this envisioned growth will not be as critical. Conversely, if there is a reversal in the retention trends and a migration or exodus

from these particular ratings occurs, then the ensuing requirements within the training command to replenish the decreasing stocks in personnel will be quite noticeable. As Chapter IV vividly illustrated, there is a method to assimilate increased numbers of personnel to reduce current shortfalls and man the expanded fleet. This can be successfully accomplished without having deleterious effects on the performance of the training pipeline. By using the Manpower Transition Matrix Model to obtain required numbers of personnel in meeting these future requirements, and then incorporating the projected forecasts into the SLAM program, we can estimate what will happen to the training command in the years ahead. Then, an optimum accession policy can be determined.

Establishment of a baseline case is critical when modeling any system. We have applied the 1981 statistics for the distribution of Navy-wide accessions into the FT ratings to the Rand Model's forecasted enlistments of mental category I, II, and IIIA personnel through the 1980's to form a supply-driven model from which to compare demand-driven policy options. Using this supply-driven model as our baseline case, we have derived an alternative that will do two things: 1) solve the existing problem of shortages in the more senior enlisted rates for the FT's, and 2) man the fleet in the future as it grows to the 600-plus ship level. The alternative we have chosen may not be the ultimate solution to the manpower

deficiencies projected, but it appears to be a solution that will work.

In the years ahead, we will probably see many changes in requirements for FT's. These possible variations emphasize the imporatnce of having a good model with which to work and a simulation language, such as SLAM, in which changes can be made easily. Having the flexibility to extend course length, increase class size, expand school capacity, decrease or increase the number of instructors, and change the mode of training to allow expansion or contraction in the training cycle are but a few features of a SLAM model. Experimentation without large outlays of capital expenditures or making physical changes to the present schooling structure is paramount and can be conducted with the SLAM program. Additionally, varying degrees of cost-benefit analysis are possible by this simulation process. A basic knowledge of instructor, student, and school material costs is all that is necessary to accomplish quick computations to see what effect changes to the training pipeline will bring. The advantages are many, with the shortfalls few. However, caution is advised, for any proposed change to an existing organizational system will bring about unforeseen responses within that organization. Although simulation modeling is an excellent tool to develop new and experimental ideas, it must also be used with discretion.

In conjunction with the modeling process, it is possible for pipeline managers to identify the bottlenecks that may

develop in the training cycle as a result of increased student loading or a decrease in instructor availability. For example, assume a newly developed, highly sophisticated missile system is introduced into the fleet. Apparently, an increase in the number of FTM's required will be the result. If the pipeline manager has access to the SLAM program, he can introduce this requirement into the program and examine what the total effect will be on the FT pipeline, as well as on the specific FTM schools. A manager will find it highly desirable to have such a system available for use. In addition, it is quite feasible for the Navy to utilize the SLAM program to evaluate accession policies that may occur as a result of fluctuating retention rates or the introduction of new hardware. This ability to look at alternative means to access individuals, whether through direct or lateral entry, and then examine the impacts that occur is very valuable.

It is therefore our recommendation that a language such as SLAM be available for use by the pipeline managers. Besides being a benefit as an analytical tool, the simulation program can be used to evaluate various proposals offered the manager by subordinates, peers, and superiors. Without having to implement a proposal, even in an experimental fashion for evaluation, policy decisions can be made with minimum expenditures of time and money. These savings are substantial and can pay for the installation of a system capable of this modeling process. The computers are available in almost every

area of the Navy to handle the programs suggested. Once installed, the learning process and operation of the program are rather straightforward.

B. RECOMMENDED SUPPLY ACTIONS

In the particular cases of the FTG's and FTM's, we have proposed a specific set of actions for filling the billets required by a 600-plus ship Navy. To alleviate existing manpower deficits in the senior technician billets and to aid in filling the increasing demands for FT's in the 1980's, we recommend that the Navy augment the current yearly input of 75 fleet personnel into intermediary pipeline schools by intensifying the recruiting efforts focused on the population of service veterans. These prior service accessions can be added annually into the training pipeline in the following numbers without significantly increasing the time requirements for processing students through the various Service schools:

1. 167 trainees into Phase II of A School (surface);
2. 20 trainees into FTG (surface) C School;
3. 20 trainees into FTM C School;
4. Five trainees into FTG(SS) A School.

Furthermore, if the envisioned 1990 fleet is to be fully manned with FT's, the Service must identify a manpower source to supply 250 recruits, to be inputted yearly into RTC training beginning in 1987, in addition to the anticipated mental group I, II, and IIIA accessions.

C. POSSIBLE FUTURE RESEARCH

In developing our policy options, we have assumed that the training capabilities of today's schools will remain constant through the upcoming nine years and we have disregarded financial considerations both within the training and recruiting commands. For example, the results of our baseline and alternative simulations would be modified considerably if the Navy decides to build added classrooms or to schedule classes more frequently. We have not attempted to determine the relative expenses between inputting service veterans into intermediary schools and the processing of non-prior service accessions through the entire pipeline. Similarly, cost-benefit analysis of recruiting in the many eligible manpower pools for the FT ratings has not been addressed in our study. However, the SLAM modeling techniques that we have utilized are capable of supporting further research into these questions.

It is our intent to give the reader a tool by which new ideas, suggestions, and requirements can be developed. Hopefully, SLAM can be utilized to improve the already burdened training command. We fully appreciate the fact that this is only the beginning of the modeling process for training pipelines and offer the thesis not as an end or final solution to the dilemmas faced by training specialists, but as a stepping stone to further research and development.

APPENDIX A

SLAM PROGRAM FOR PIPELINE SIMULATION

```
GEN,THESIS,TRAINING PIPELINE,2/20/82,1;
LIMITS,65,7,8000;
INTLC,XX(1)=.25,XX(2)=.9,XX(3)=.74,XX(4)=.84,XX(5)=.97,XX(6)=.25;
INTLC,XX(7)=.84,XX(8)=.97,XX(9)=.80,XX(10)=.96,XX(11)=.385,XX(12)=.80;
INTLC,XX(13)=.96,XX(14)=.00,XX(15)=.00,XX(16)=.00,XX(17)=.95;
INTLC,XX(18)=.50,XX(19)=1.0,XX(20)=1.0,XX(21)=.85,XX(22)=.91;
INTLC,XX(23)=1.0,XX(24)=.87,XX(25)=.92,XX(26)=.87,XX(27)=.92;
INTLC,XX(28)=.50,XX(29)=.328,XX(30)=.761,XX(31)=.33;
;
NETWORK;
      RESOURCE/BEE QUOTA(360),5;                BE&E QUOTA AVAILABLE
      GATE/STRT,CLOSE,6;
      RESOURCE/SBEE QUOTA(40),40;               SUBSURFACE FTG BE&E QUOTA
      GATE/BGN/CLOSE,41;
;-----------------------------------------------------------------------
;
;                                  RTC PHASE
;
;-----------------------------------------------------------------------
;INPUT THE RATE OF ENLISTMENTS FOR WARM-UP PERIOD
      CREATE,.231,0,1,4740;                     INPUT AT RATE OF ENLISTMENTS
      ACT/76,,,RECR;
      CREATE,.235,1095,1,387;                   1ST YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.258,1186,1,353;                   1ST YR 2ND QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.190,1277,1,479;                   1ST YR 3RD QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.296,1368,1,311;                   1ST YR 4TH QTR ENLISTMENTS
      ACT/85,,,RECR;
      CREATE,.259,1460,1,351;                   2ND YR 1ST QTR ENLISTMENTS
      ACT/77,,,RECR;
      CREATE,.283,1551,1,321;                   2ND YR 2ND QTR ENLISTMENTS
      ACT/78,,,RECR;
      CREATE,.210,1642,1,434;                   2ND YR 3RD QTR ENLISTMENTS
      ACT/79,,,RECR;
      CREATE,.326,1733,1,282;                   2ND YR 4TH QTR ENLISTMENTS
      ACT/80,,,RECR;
      CREATE,.283,1825,1,321;                   3RD YR 1ST QTR ENLISTMENTS
      ACT/81,,,RECR;
      CREATE,.311,1916,1,293;                   3RD YR 2ND QTR ENLISTMENTS
      ACT/82,,,RECR;
      CREATE,.229,2007,1,398;                   3RD YR 3RD QTR ENLISTMENTS
      ACT/83,,,RECR;
      CREATE,.357,2098,1,258;                   3RD YR 4TH QTR ENLISTMENTS
      ACT/84,,,RECR;
      CREATE,.297,2190,1,306;                   4TH YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.326,2281,1,279;                   4TH YR 2ND QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.241,2372,1,378;                   4TH YR 3RD QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.376,2463,1,245;                   4TH YR 4TH QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.313,2555,1,291;                   5TH YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.343,2646,1,265;                   5TH YR 2ND QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.253,2737,1,359;                   5TH YR 3RD QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.395,2828,1,233;                   5TH YR 4TH QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.322,2920,1,283;                   6TH YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.353,3011,1,258;                   6TH YR 2ND QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.260,3102,1,350;                   6TH YR 3RD QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.405,3193,1,227;                   6TH YR 4TH QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.326,3285,1,279;                   7TH YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.357,3376,1,255;                   7TH YR 2ND QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.263,3467,1,346;                   7TH YR 3RD QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.411,3558,1,224;                   7TH YR 4TH QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.326,3650,1,279;                   8TH YR 1ST QTR ENLISTMENTS
      ACT,,,RECR;
      CREATE,.358,3741,1,254;                   8TH YR 2ND QTR ENLISTMENTS
```

```
82          ACT,,,RECR;
83          CREATE,,264,3832,1,345;                 8TH YR 3RD QTR ENLISTMENTS
84          ACT,,,RECR;
85          CREATE,,411,3923,1,224;                 8TH YR 4TH QTR ENLISTMENTS
86          ACT,,,RECR;
87          CREATE,,335,4015,1,272;                 9TH YR 1ST QTR ENLISTMENTS
88          ACT,,,RECR;
89          CREATE,,367,4106,1,248;                 9TH YR 2ND QTR ENLISTMENTS
90          ACT,,,RECR;
91          CREATE,,271,4197,1,336;                 9TH YR 3RD QTR ENLISTMENTS
92          ACT,,,RECR;
93          CREATE,,422,4288,1,218;                 9TH YR 4TH QTR ENLISTMENTS
94          ACT,,,RECR;
95  RECR    GOON,1;
96          ACT,,DRAND(1),LE,XX(1),RYO;
97          ACT,,,FYO;
98  RYO     ASSIGN,ATRIB(2)=1,1;                    DISTINGUISH 4YO'S
99          ACT,,DRAND(6),LE,XX(28),FYOG;           IDENTIFY FTG 4 YO'S
100         ACT,,,FYOM;                             IDENTIFY FTM 4 YO'S
101 FYOG    ASSIGN,ATRIB(7)=1;
102         ACT,,,DEPO;
103 FYOM    ASSIGN,ATRIB(7)=2;
104         ACT,,,DEPO;
105 SYO     ASSIGN,ATRIB(2)=2,1;                    DISTINGUISH 6YO'S
106         ACT,,DRAND(6),LE,XX(29),SYOG;           IDENTIFY FTG SURFACE
107         ACT,,DRAND(6),LE,XX(30),SYOM;           IDENTIFY FTM
108         ACT,,,SFTG;                             IDENTIFY FTG SUBSURFACE
109 SYOG    ASSIGN,ATRIB(7)=1;
110         ACT,,,DEPO;
111 SYOM    ASSIGN,ATRIB(7)=2;
112         ACT,,,DEPO;
113 SFTG    ASSIGN,ATRIB(7)=3;
114         ACT,,,DEPO;
115 DEPO    QUEUE(1),75;                            DELAYED ENTRY QUEUE
116         ACT/1;                                  TRAVEL TO RTC
117         QUEUE(2),30,30,BLOCK;                   RTC CLASS QUEUE
118         ACT(30),REL(TIM1);
119         ASSIGN,ATRIB(3)=TNOW;
120         COLCT,INT(1),DEP TIME,12/0/5,1;         DETERMINE DEP TIME
121         ACT/8,47,DRAND(2),LE,XX(2),RTCG;        DETERMINE RTC GRADUATES
122         ACT/40,54,DRAND(2),LE,XX(17),RTCG;      DETERMINE RTC ROLLBACK
123         ACT/9,,,RTCD;
124 RTCD    TERM;
125 RTCG    GOON,1;COLCT,INT(3),RTC STAY,10/30/5,1;  DETERMINE RTC STAY TIME
126         ACT,,ATRIB(7),EQ,3,SUBS;                BRANCH POINT FOR SUBS
127         ACT,,,BEE;
128 TIM1    CREATE,7,0;
129         TERM;
130 ;-------------------------------------------------------------------------
131 ;
132 ;                                BE&E PHASE
133 ;
134 ;-------------------------------------------------------------------------
135 BEE     GOON;
136         ACT,1;                                  TRAVEL TO BE&E SCHOOL
137         ASSIGN,ATRIB(4)=1,ATRIB(3)=TNOW;        RTC INPUTS
138         ACT,,,BQUC;
139         CREATE,0,3,0,1;                         FLEET INPUTS IDENTIFIED
140         ACT/2,30;                               WAIT FOR ORDERS
141         GOON,1;
142         ACT,,DRAND(7),LE,XX(18),FFTG;           FLEET INPUT TO FTG'S
143         ACT,,,FFTM;                             FLEET INPUT TO FTM'S
144 FFTG    ASSIGN,ATRIB(7)=1;
145         ACT,,,INBE;
146 FFTM    ASSIGN,ATRIB(7)=2;
147         ACT,,,INBE;
148 INBE    QUEUE(3),2;                             WAIT FOR OPENNING
149         ACT;
150         QUEUE(4),2,2,BLOCK;                     LIMIT TWO PER WEEK
151         ACT(2),REL(TIM2);
152         GOON;
153         ACT,2;                                  FLEET TRAVEL TO BE&E
154         GOON,1;
155         ACT,,DRAND(1),LE,XX(14),EEN;
156         ACT,,,REN;
157 EEN     ASSIGN,ATRIB(2)=2;                      DISTINGUISH 6 YO'S FR FLT
158         ACT/34,,,SCH;
159 REN     ASSIGN,ATRIB(2)=1;                      DISTINGUISH 4 YO'S FM FLT
160         ACT/35,,,SCH;
161 SCH     ASSIGN,ATRIB(4)=2,ATRIB(3)=TNOW;        FLEET INPUTS
162         ACT,,,BQUC;
163 TIM2    CREATE,7,0;
```

```
164          TERM;
165          CREATE,5000,5000,1;
166          GOON,1;
167          ACT,,DRAND(8).LE.XX(11),OFTG;                OSVETS TO FTG'S
168          ACT,,,OFTM;                                  OSVETS TO FTM'S
169  OFTG    ASSIGN,ATRIB(7)=1;
170          ACT,,,AVET
171  OFTM    ASSIGN,ATRIB(7)=2;
172          ACT,,,AVET;
173  AVET    QUEUE(22);                                   OSVET INPUT IDENTIFIED
174          ACT/15;
175          QUEUE(23),0,1,ABLOCK;                        WAIT FOR TRAVEL ORDERS
176          ACT(1),REL(TIM9);
177          GOON;
178          ACT,2;                                       TRAVEL TO BE&E SCHOOL
179          ASSIGN,ATRIB(2)=1,ATRIB(4)=10,ATRIB(3)=TNOW;  OSVETS INPUT
180          ACT,,,AQUC;
181  TIM9    CREATE,7,0;
182          TERM;
183  AQUO    QUEUE(34),30;                                ESTABLISH INITIAL SCH USE
184          ACT(500),,,AQRC;
185  AQRC    AWAIT(5),BEE QUOTA/1;
186          AWAIT(6),STRT;
187          ACT,,,AQUE;
188          CREATE,7,0;                                  NO STARTS ON WEEKENDS
189  WEEK    OPEN,STRT;
190          ACT,5;
191          CLOSE,STRT;
192          ACT,2,,WEEK;
193  AQUE    COLCT,INT(3),BEE QUEUE,5/0/1,1;              DETERMINE B QUEUE TIME
194          ACT/10,RNORM(42,28,2),DRAND(2).LE.XX(3),BEEG;     BE&E GRADUATES
195          ACT/11,RNORM(30,15,2),,BEED;                      BE&E DROPS
196  BEED    FREE,BEE QUOTA/1;                            BE&E QUOTA AVAILABLE
197          TERM;
198  BEEG    FREE,BEE QUOTA/1;                            BE&E QUOTA AVAILABLE
199          COLCT,INT(3),BEE STAY,15/0/10;               DETERMINE BE&E STAY TIME
200          ACT,,,APHO;
201  ;-----------------------------------------------------------------------
202  ;
203  ;                          A SCHOOL PHASE ONE
204  ;
205  ;-----------------------------------------------------------------------
206  APHO    GOON;
207          ACT,6;                                       TRAVEL TO A SCHOOL
208          ASSIGN,ATRIB(4)=3,ATRIB(5)=TNOW,ATRIB(3)=TNOW;   BE&E INPUT
209          ACT,,,APOO;
210          CREATE,5000,5000,1;                          FLEET INPUT IDENTIFIED
211          ACT/30,30;                                   WAIT FOR ORDERS
212          GOON,1;
213          ACT,,DRAND(9).LE.XX(18),ASAF;                FLEET INPUTS TO FTG'S
214          ACT,,,ASAM;                                  FLEET INPUTS TO FTM'S
215  ASAF    ASSIGN,ATRIB(7)=1;
216          ACT,,,INA;
217  ASAM    ASSIGN,ATRIB(7)=2;
218          ACT,,,INA;
219  INA     QUEUE(7),2;                                  WAIT FOR CLASS
220          ACT;
221          QUEUE(8),2,2,BLOCK;                          LIMIT TWO PER CLASS
222          ACT(2),REL(TIM3);
223          GOON;
224          ACT,6;                                       TRAVEL TO A SCHOOL
225          GOON,1;
226          ACT,,DRAND(3).LE.XX(15),SEN;
227          ACT,,,FEN;
228  SEN     ASSIGN,ATRIB(2)=2;                           DISTINGUISH 6 YO'S
229          ACT/36,,,ASCH;
230  FEN     ASSIGN,ATRIB(2)=1;                           DISTINGUISH 4 YO'S
231          ACT/37,,,ASCH;
232  ASCH    ASSIGN,ATRIB(4)=4,ATRIB(5)=TNOW,ATRIB(3)=TNOW; FLEET INPUTS
233          ACT,,,APOO;
234  TIM3    CREATE,7,0;
235          TERM;
236          CREATE,5000,5000,1;                          OSVET INPUT IDENTIFIED
237          GOON,1;
238          ACT,,DRAND(1).LE.XX(11),OASG;                OSVET INPUT TO FTG'S
239          ACT,,,OASM;                                  OSVET INPUT TO FTM'S
240  OASG    ASSIGN,ATRIB(7)=1;
241          ACT,,,AOVT;
242  OASM    ASSIGN,ATRIB(7)=2;
243          ACT,,,AOVT;
244  AOVT    QUEUE(24),0;
245          ACT/27;                                      WAIT FOR ORDERS
```

```
246          QUEUE(25),0,2,BLOCK;                          LIMIT TWO PER CLASS
247          ACT(2),REL(TIL0);
248          GOON;
249          ACT,3;                                        TRAVEL TO A SCHOOL
250          ASSIGN,ATRIB(2)=1,ATRIB(4)=4,ATRIB(5)=TNOW,ATRIB(3)=TNOW; OSVETS
251          ACT,,APOO;
252  TIL0    CREATE,7,0;
253          TERM;
254  APOO    QUEUE(9),25;                                  WAIT FOR CLASS ASSIGNED
255          ACT/4;
256          QUEUE(10),25,25,BLOCK;                        WAIT FOR CONVENING DATE
257          ACT(25),REL(TIM4);
258          GOON,1;COLCT,INT(5),A SCH PH1 QUEUE,10/0/3,1;DETERMINE PHASE 1 QUE
259          ACT/12,75,DRAND(4),LE,XX(4),POAG;             ON-TIME PHASE ONE GRAD
260          ACT/13,89,DRAND(4),LE,XX(5),POBG;             ROLLBACK PHASE ONE GRAD
261          ACT/14,RNORM(30,15,4),,APOO;                  PHASE ONE DROPS
262  APOO    TERM;
263  POAG    ASSIGN,ATRIB(6)=1;
264          ACT,,TIME;
265  POBG    ASSIGN,ATRIB(6)=2;
266          ACT,,TIME;
267  TIME    COLCT,INT(3),PH ONE STAY,10/70/5,1;
268          ACT,,ATRIB(6),EQ,1,POAS;                      ON-TIME GRADS
269          ACT,,ATRIB(6),EQ,2,POBS;                      LATE GRADS
270  POAS    GOON,1;
271          ACT,,ATRIB(2),EQ,2,QUAL;                      6YO'S CONTINUE
272          ACT,,ATRIB(2),EQ,1,CHOS;                      4YO'S EXTENSION DECISION
273          ACT,,ORIG;                                    INITIAL INPUTS
274  QUAL    GOON,1;                                       LOWER GRADS CONVERT
275          ACT,,DRAND(7),LE,XX(31),REV;                  CONVERTERS
276          ACT,,CONT;                                    CONTINUE ON
277  ORIG    GOON,1;
278          ACT,,75,OSIX;
279          ACT,,25,OFOR;
280  OSIX    ASSIGN,ATRIB(2)=2;                            INITIAL SIX YO'S
281          ACT,,CONT;
282  OFOR    ASSIGN,ATRIB(2)=1;                            INITIAL FOUR YO'S
283          ACT,,CHOS;
284  CHOS    GOON,1;
285          ACT,,DRAND(5),LE,XX(6),CHG;                   EXTEND
286          ACT,,NOCH;                                    REMAIN 4YO'S
287  CHG     ASSIGN,ATRIB(2)=2;
288          ACT,,CONT;
289  NOCH    TERM;                                         4YO'S RETURN TO FLEET
290  POBS    GOON,1;                                       DETERMINE RB STAY
291          ACT,,ATRIB(2),EQ,2,LQUA;                      LATE 6YO'S CONTINUE
292          ACT,,ATRIB(2),EQ,1,LCHO;                      4YO'S EXTENSION DECISION
293          ACT,,LORI;                                    LATE ORIGINALS
294  LQUA    GOON,1;                                       LOWER PORTION CONVERT
295          ACT,,DRAND(8),LE,XX(31),REV;                  CONVERTERS
296          ACT,,LATE;                                    CONTINUE ON
297  REV     TERM;
298  LORI    GOON,1;
299          ACT,,75,LSIX;                                 LATE SIX YO'S
300          ACT,,25,LFOR;                                 LATE FOUR YO'S
301  LSIX    ASSIGN,ATRIB(2)=2;
302          ACT,,LATE;
303  LFOR    ASSIGN,ATRIB(2)=1;
304          ACT,,LCHO;
305  LCHO    GOON,1;
306          ACT,,DRAND(6),LE,XX(6),EXT;                   EXTEND
307          ACT,,STAY;                                    REMAIN 4YO'S
308  EXT     ASSIGN,ATRIB(2)=2;
309          ACT,,LATE;
310  STAY    TERM;                                         4YO'S RETURN TO FLEET
311  TIM4    CREATE,7,0;
312          TERM;
313  CONT    ASSIGN,ATRIB(1)=TNOW;                  START PH II QUEUE(ON-TIMERS)
314  QUE1    QUEUE(11),7,,SEL1;
315  LATE    ASSIGN,ATRIB(3)=TNOW;                    START PHII QUEUE(LATES)
316  QUE2    QUEUE(12),5,,SEL1;
317  ;-------------------------------------------------------------------------
318  ;
319  ;                          A SCHOOL PHASE II
320  ;
321  ;-------------------------------------------------------------------------
322          CREATE,5000,5000,1;                           A PH II FLEET INPUTS
323          ACT/26,30;                                    WAIT FOR ORDERS
324          GOON,1;
325          ACT,,DRAND(2),LE,XX(18),ASTG;                 FLEET INPUTS TO FTG'S
326          ACT,,ASTM;
327  ASTG    ASSIGN,ATRIB(7)=1;
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```
328             ACT,,,INA2;
329     ASTM    ASSIGN,ATRIB(7)=2;
330             ACT,,,INA2;
331     INA2    QUEUE(19);                              WAIT FOR CLASS
332             ACT;
333             QUEUE(20),2,2,BLOCK;                    LIMIT TWO PER CLASS
334             ACT(2),REL(TIM8);
335             GOON;
336             ACT,6;                                  TRAVEL TO A SCHOOL
337             GOON,1;
338             ACT,,DRAND(5).LE.XX(16),SXEN;
339             ACT,,,FREN;
340     SXEN    ASSIGN,ATRIB(2)=2;                      DISTINGUISH 6 YO'S
341             ACT/38,,,ATSC;
342     FREN    ASSIGN,ATRIB(2)=1;                      DISTINGUISH 4 YO'S
343             ACT/39,,,ATSC
344     ATSC    ASSIGN,ATRIB(3)=TNOW,ATRIB(4)=25,ATRIB(5)=TNOW; FLEET INPUTS
345     QUE5    QUEUE(21),2,,,SEL1;
346     TIM8    CREATE,7,0;
347             TERM;
348             CREATE,5000,5000,1;                     A PH II OSVETS INPUT
349             ACT;
350             GOON,1;
351             ACT,,DRAND(3).LE.XX(11),OATG;           OSVETS INPUT TO FTG'S
352             ACT,,,OATM;                             OSVETS INPUT TO FTM'S
353     OATG    ASSIGN,ATRIB(7)=1;
354             ACT,,,ATVT;
355     OATM    ASSIGN,ATRIB(7)=2;
356             ACT,,,ATVT;
357     ATVT    QUEUE(26);
358             ACT/28;                                 WAIT FOR ORDERS
359             QUEUE(27),0,3,BLOCK;                    LIMIT TWO PER CLASS
360             ACT(3),REL(TIL1);
361             GOON;
362             ACT,6;                                  TRAVEL TO A SCHOOL
363             ASSIGN,ATRIB(3)=TNOW,ATRIB(2)=1,ATRIB(4)=26,ATRIB(5)=TNOW;
364     QUE6    QUEUE(28),,,,SEL1;
365     TIL1    CREATE,7,0;
366             TERM;
367     SEL1    SELECT,POR,,,QUE1,QUE5,QUE6,QUE2;       ON-TIMERS,FLEET,LATE PRI'S
368             ACT/5,,,APOG;
369     APOG    QUEUE(13),25,25,BLOCK;                  WAIT FOR PH II CONVENING
370             ACT(25),REL(TIM5),,PHOG;
371     TIM5    CREATE,7,0;
372             TERM;
373     PHOG    COLCT,INT(3),A SCH PH2 QUEUE,10/0/1,1;  DETERMINE A PH II QUE
374             ACT/18,.82,DRAND(7).LE.XX(7),PTAG;      ON-TIME GRADS
375             ACT/19,.96,DRAND(7).LE.XX(8),PTBG;      ROLLBACK GRAD
376             ACT/20,RNORM(50,15,7),,APTD;            PH II DROPS
377     PTAG    GOON;
378             ACT,,,APTG;                             COMPLETE PH II ON-TIME
379     PTBG    GOON;
380             ACT,,,APTG;                             COMPLETE PH II LATE
381     APTD    TERM;
382     APTG    COLCT,INT(3),A2 STAY TIME,6/80/5,1;     DETERMINE PH II STAY
383             ACT/66,,ATRIB(4).EQ.25,COMB;            COUNT A PH II FLT INPUTS
384             ACT/67,,ATRIB(4).EQ.26,COMB;            COUNT A PH II OSVET INPUTS
385             ACT/68,,,COMB;                          COUNT A PH II OTHER INPUTS
386     COMB    COLCT,INT(5),A SCH STAY TIME,13/140/5,1; DETERMINE A SCH STAY
387             ACT/21,,.95,CSCH;                       CONTINUE TO C SCH
388             ACT/22,,.05,SHIP;                       RETURN TO FLEET
389     SHIP    TERM;
390     ;-------------------------------------------------------------------
391     ;
392     ;                           C SCHOOL PHASE
393     ;
394     ;-------------------------------------------------------------------
395     CSCH    GOON;
396             ACT,2;                                  TRAVEL TO C SCHOOL
397             GOON,1;                                 DISTINGUISH PH II SOURCES
398             ACT,,ATRIB(4).EQ.25,PHTI;               PHASE II FLEET INPUTS
399             ACT,,ATRIB(4).EQ.26,PHTI;               PHASE II OSVET INPUTS
400             ACT,,,OTH;                              OTHER INPUTS
401     OTH     ASSIGN,ATRIB(4)=5;
402     PHTI    ASSIGN,ATRIB(3)=TNOW,1;                 START C SCH QUEUE
403             ACT,,ATRIB(7).EQ.1,QUE3;                DESIGNATED AS FTG
404             ACT,,,QUE7;                             DESIGNATED AS FTM
405     ;-------------------------------------------------------------------
406     ;
407     ;                           SURFACE FTG'S
408     ;
409     ;-------------------------------------------------------------------
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410  QUE3   QUEUE(14),1,,,SEL2;
411         CREATE,50,0,1;                                  FLEET INPUT TO FTG C SCH
412         ASSIGN,ATRIB(4)=45,ATRIB(2)=1,ATRIB(7)=1;
413         ACT,30,,INC;
414         CREATE,5000,5000,1;                             OSVETS TO FTG C SCHOOL
415         ASSIGN,ATRIB(4)=46,ATRIB(2)=1,ATRIB(7)=1;
416         ACT,,,INC;
417  INC    QUEUE(15),1;
418         ACT/6;                                      WAIT FOR ORDERS TO FTG C SCH
419         QUEUE(16),0,2,BLOCK;                        LIMIT TWO PER CLASS
420         ACT(2),REL(TIM6);
421         GOON;COLCT,INT(1),NONSCH C FTG Q,10/0/20;
422         ACT,6;                                          TRAVEL TO FTG C SCH
423         ASSIGN,ATRIB(3)=TNOW;                           START FTG C SCH QUEUE
424  QUE4   QUEUE(17),1,,,SEL2;
425  TIM6   CREATE,28,0;
426         TERM;
427  SEL2   SELECT,POR,,,QUE4,QUE3;                         FLEET QUOTA PRIORITY
428         ACT/7;
429         QUEUE(18),25,25,BLOCK;
430         ACT(25),REL(TIM7),,CQUE;                        WAIT FOR CONVENING DATE
431  TIM7   CREATE,28,0;
432         TERM;
433  CQUE   COLCT,INT(3),FTG CSCH QUEUE,10/0/5,1;       DETERMINE C SCH QUE TIME
434         ACT/23,RNORM(200,77,7),CRAND(7).LE.XX(9),CAGR;  ON-TIME GRAD FTG
435         ACT/24,RNORM(214,77,7),CRAND(7).LE.XX(10),CAGR;  ROLLBACK GRAD FTG
436         ACT/25,RNORM(100,77,7),,CDRP;                    C SCHOOL DROPS FTG
437  CDRP   TERM;
438  CAGR   GOON,1;
439         ACT,,ATRIB(2).EQ.2,CGRA;
440         ACT,,ATRIB(2).EQ.1,CGRA;
441         ACT,,,ADDS;
442  ADDS   GOON,1;
443         ACT,,CRAND(3).LE.0.6,ASYO;     SIX YO'S INPUT INTO SYST AT START-UP
444         ACT,,,AFYO;                    FOUR YO'S INPUT INTO SYST AT START-UP
445  ASYO   ASSIGN,ATRIB(2)=2;
446         ACT,,,CGRA;
447  AFYO   ASSIGN,ATRIB(2)=1;
448         ACT,,,CGRA;
449  CGRA   COLCT,INT(3),FTG C SCH STAY,15/80/20,1;DETERMINE FTG C SCHOOL TIME
450         ACT,,ATRIB(2).EQ.2,LSTA;
451         ACT,,ATRIB(2).EQ.1,RTOT;
452  RTOT   COLCT,INT(1),FTG REG TOT TIME,18/100/20;
453         ACT,,,COUN;
454  LSTA   COLCT,INT(1),SYO FTG TIME,20/360/20;
455         ACT,,,COUN;
456  COUN   GOON,1;                                         COUNT A PHASE II INPUTS
457         ACT/69,,ATRIB(4).EQ.25,RET;                     COUNT FLEET A INPUTS
458         ACT/70,,ATRIB(4).EQ.26,RET;                     COUNT OSVETS A INPUT
459         ACT/95,,ATRIB(4).EQ.45,RET;                     COUNT FLEET C INPUT
460         ACT/96,,ATRIB(4).EQ.46,RET;                     COUNT OSVETS C INPUTS
461         ACT/71,,,RET;                                   COUNT OTHER INPUTS
462  RET    GOON;
463         TERM;
464  ;-------------------------------------------------------------------------
465  ;
466  ;                                  FTM'S
467  ;
468  ;-------------------------------------------------------------------------
469  QUE7   QUEUE(29),1,,,SEL3;
470         CREATE,50,,1;                                   FLEET INPUT TO FTM C SCH
471         ASSIGN,ATRIB(4)=45,ATRIB(2)=1,ATRIB(7)=2;
472         ACT,30,,INCM;
473  ;      CREATE,5000,5000,1;                         OSVETS INPUT TO FTM C SCHOOL
474  ;      ASSIGN,ATRIB(4)=46,ATRIB(2)=1,ATRIB(7)=2;
475  ;      ACT,,,INCM;
476  INCM   QUEUE(30),1;
477         ACT/29;                                         WAIT FOR ORDERS
478         QUEUE(31),0,2,BLOCK;                            LIMIT TWO PER CLASS
479         ACT(2),REL(TI12);
480         GOON;COLCT,INT(1),NONSCH FTM CSCH,10/0/20;
481         ACT,6;                                          TRAVEL TO C SCHOOL
482         ASSIGN,ATRIB(3)=TNOW;                           START C SCHOOL QUEUE
483  QUE8   QUEUE(32),1,,,SEL3;
484  TI12   CREATE,28,0;
485         TERM;
486  SEL3   SELECT,POR,,,QUE8,QUE7;                         FLEET QUOTA PRIORITY
487         ACT/75;
488         QUEUE(33),33,33,BLOCK;
489         ACT(33),REL(TI13),,MQUE;                        WAIT FOR CONVENING DATE
490  TI13   CREATE,28,0;
491         TERM;
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492   MQUE  COLCT,INT(3),FTM C SCH QUEUE,20/0/5,1;    DETERMINE C SCH QUE TIME
493         ACT/31,RNORM(200,77,9),DRAND(9).LE.XX(12),CMAG;      ON-TIME GRAD
494         ACT/32,RNORM(214,77,9),DRAND(9).LE.XX(13),CMAG;      ROLLBACK GRAD
495         ACT/33,RNORM(100,77,9),,CMDP;                        C SCHOOL DROPS
496   CMDP  TERM;
497   CMAG  GOON,1;
498         ACT,,ATRIB(2).EQ.2,CMGR;
499         ACT,,ATRIB(2).EQ.1,CMGR;
500         ACT,,MORE;
501   MORE  GOON,1;                                      ADD START-UP YO'S
502         ACT,,DRAND(4).LE.0.6,MSYO;                   SIX YO'S
503         ACT,,MFYO;
504   MSYO  ASSIGN,ATRIB(2)=2;
505         ACT,,CMGR;
506   MFYO  ASSIGN,ATRIB(2)=1;
507         ACT,,CMGR;
508   CMGR  COLCT,INT(3),FTM C SCH STAY,20/100/20,1;    DETERMINE C SCHOOL TIME
509         ACT,,ATRIB(2).EQ.2,SSTA;
510         ACT,,ATRIB(2).EQ.1,FSTA;
511   FSTA  COLCT,INT(1),FTM REG STAY,18/120/20;
512         ACT,,NMBS;
513   SSTA  COLCT,INT(1),FTM SYO STAY,25/360/20;
514         ACT,,NMBS;
515   NMBS  GOON,1;                                      COUNT A PH II INPUTS
516         ACT/72,,ATRIB(4).EQ.25,TRA;                  COUNT FLEET A INPUTS
517         ACT/73,,ATRIB(4).EQ.26,TRA;                  COUNT OSVETS A INPUTS
518         ACT/97,,ATRIB(4).EQ.45,TRA;                  COUNT FLEET C INPUTS
519         ACT/98,,ATRIB(4).EQ.46,TRA;                  COUNT OSVETS C INPUTS
520         ACT/74,,,TRA;                                COUNT OTHER INPUTS
521   TRA   GOON;
522         TERM;
523   ;-------------------------------------------------------------------
524   ;
525   ;                          FTG SUBSURFACE PIPELINE
526   ;
527   ;-------------------------------------------------------------------
528   ;
529   ;-------------------------------------------------------------------
530   ;
531   ;                                SUB BE&E SCHOOL
532   ;
533   ;-------------------------------------------------------------------
534   SUBR  GOON;
535         ACT,1;                                       TRAVEL TO BEE SCH
536         ASSIGN,ATRIB(4)=1,ATRIB(3)=TNOW;             RTC INPUTS
537         ACT,,SBQU
538         CREATE,21.5,0,1;                             FLEET INPUT IDENTIFIED
539         ACT/41,30;                                   WAIT FOR ORDERS
540   SBEE  QUEUE(35);                                   WAIT FOR CLASS
541         ACT;
542         QUEUE(36),0,2,BLOCK;                         WAIT FOR TRANSFER
543         ACT(2),RELI(TI21);
544         GOON;
545         ACT,2;                                       FLEET TRAVEL TO BEE SCH
546         GOON,1;
547         ACT,,DRAND(9).LE.XX(19),SGEX;                FLEET SIX YO'S
548         ACT,,SGFY;                                   FLEET FOUR YO'S
549   SGEX  ASSIGN,ATRIB(2)=2;
550         ACT/42,,,SGRE;
551   SGFY  ASSIGN,ATRIB(2)=1;
552         ACT/43,,,SGRE;
553   SGRE  ASSIGN,ATRIB(4)=2,ATRIB(3)=TNOW,ATRIB(7)=3; FLEET INPUTS TO BEE SCH
554         ACT,,,SBQU;
555   TI21  CREATE,7,0;
556         TERM;
557         CREATE,5000,5000,1;                          OSVET INPUT IDENTIFIED
558   SBVT  QUEUE(37);
559         ACT/44;
560         QUEUE(38),0,1,BLOCK;                         WAIT FOR TRAVEL ORDERS
561         ACT(1),RELI(TI22);
562         GOON;
563         ACT,2;                                       TRAVEL TO BEE
564         ASSIGN,ATRIB(2)=1,ATRIB(4)=10,ATRIB(3)=TNOW,ATRIB(7)=3; OSVETS
565         ACT,,,SBQU;
566   TI22  CREATE,7,0;
567         TERM;
568   SBQU  QUEUE(39),12;                                ESTABLISH INITIAL NUMBER
569         ACT,,,SBQA;
570   SBQA  AWAIT(40),SBEE QUOTA/1;
571         AWAIT(41),BGN;
572         ACT,,,SBEQ;
573         CREATE,7,0;
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574         ACT;
575   DAYS  OPEN,BGN;                                        NO STARTS ON WEEKENDS
576         ACT,5;
577         CLOSE,BGN;
578         ACT,2,,DAYS;
579   SBEQ  COLCT,INT(3),SBEE QUEUE,5/0/2,1;                DETERMINE SS FTG BEE Q
580         ACT/45,RNORM(40,14,5),,DRAND(6).LE.XX(3),SBEG;    SS FTG BEE GRAD
581         ACT/46,RNORM(20,7,5),,SBED;                       SS FTG BEE DROP
582   SBED  FREE,SBEE QUOTA/1;
583         TERM;
584   SBEG  FREE,SBEE QUOTA/1;
585         COLCT,INT(3),SBEE STAY,15/0/5;                  DETERMINE SS BEE STAY
586         ACT,,,SSCH;                                     CONTINUE TO SUB SCHOOL
587   ;-----------------------------------------------------------------------
588   ;
589   ;                              SUB SCHOOL PHASE
590   ;
591   ;-----------------------------------------------------------------------
592   SSCH  GOON;
593         ACT,5;                                          TRAVEL TO SUB SCHOOL
594         ASSIGN,ATRIB(4)=3,ATRIB(3)=TNOW;
595         ACT,,,SUBS;                                     BEE INPUTS
596         CREATE,5000,5000,1;                             FLEET INPUT IDENTIFIED
597         ACT/47,30;                                      WAIT FOR ORDERS
598   SGFI  QUEUE(42);                                      WAIT FOR CLASS
599         ACT;
600         QUEUE(43),0,2,BLOCK;                            LIMIT TWO PER CLASS
601         ACT(2),REL(TI23);
602         GOON;
603         ACT,6;                                          TRAVEL TO SUB SCHOOL
604         GOON,1;
605         ACT,,DRAND(1).LE.XX(20),SSSY;                   SIX YO'S
606         ACT,,,SSRY;                                     FOUR YO'S
607   SSSY  ASSIGN,ATRIB(2)=2;
608         ACT/48,,,SUBF;
609   SSRY  ASSIGN,ATRIB(2)=1;
610         ACT/49,,,SUBF;
611   SUBF  ASSIGN,ATRIB(4)=35,ATRIB(3)=TNOW,ATRIB(7)=3;FLEET INPUTS
612         ACT,,,SUBS;
613   TI23  CREATE,28,0;
614         TERM;
615         CREATE,5000,5000,1;                             OSVET INPUT IDENTIFIED
616   SGOV  QUEUE(44);                                      WAIT FOR CLASS
617         ACT/50;
618         QUEUE(45),0,2,BLOCK;                            LIMIT TWO PER CLASS
619         ACT(2),REL(TI24);
620         GOON;
621         ACT,6;                                          TRAVEL TO SUB SCHOOL
622         ASSIGN,ATRIB(4)=36,ATRIB(2)=1,ATRIB(3)=TNOW,ATRIB(7)=3; OSVETS
623         ACT,,,SUBS;
624   TI24  CREATE,28,0;
625         TERM;
626   SUBS  QUEUE(46);
627         ACT/51;
628         QUEUE(47),12,12,BLOCK;
629         ACT(12),REL(TI25);
630         COLCT,INT(3),SUB SCH QUEUE,10/0/5,1;
631         ACT/52,40,DRAND(3).LE.XX(21),SGAG;              ON-TIME GRADS
632         ACT/53,54,DRAND(3).LE.XX(22),SGBG;              ROLLBACK GRADS
633         ACT/54,,,SGOR;
634   SGAG  ASSIGN,ATRIB(6)=1;
635         ACT,,,LENG;
636   SGBG  ASSIGN,ATRIB(6)=2;
637         ACT,,,LENG;
638   LENG  COLCT,INT(3),SUB SCH STAY,12/30/5;              DETERMINE SUB SCH STAY
639         ACT,,,GRSG;
640   SGOR  TERM;
641   GRSG  GOON,1;
642         ACT/86,,ATRIB(6).EQ.35,ALL;                     COUNT FLT INPUT GRADS
643         ACT/87,,ATRIB(6).EQ.36,ALL;                     COUNT OSVET GRADS
644         ACT/88,,,ALL;                                   COUNT OTHERS
645   ALL   GOON,1;
646         ACT,,ATRIB(6).EQ.1,OTGR;
647         ACT,,ATRIB(6).EQ.2,LSGR;
648   TI25  CREATE,28,0;
649         TERM;
650   ;-----------------------------------------------------------------------
651   ;
652   ;                              FTG SS A SCHOOL PHASE
653   ;
654   ;-----------------------------------------------------------------------
655   OTGR  GOON;
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656          ACT,2;                                          TRAVEL TO A SCHOOL
657          GOON,1;
658          ACT,,ATRIB(4).EQ.35,SSIP;                       FLT SUB SCH INPUT
659          ACT,,ATRIB(4).EQ.36,SSIP;                       OSVET SUB SCH INPT
660          ACT,,,PIPE;                                     OTHER SS INPUTS
661  PIPE    ASSIGN,ATRIB(4)=5;
662  SSIP    ASSIGN,ATRIB(3)=TNOW;
663  Q10     QUEUE(48),7,,,SEL4;                             ON-TIMER'S QUEUE
664  LSGR    GOON;
665          ACT,2;                                          TRAVEL TO A SCHOOL
666          GOON,1;
667          ACT,,ATRIB(4).EQ.35,SSLI;                       FLT SS LATE INPUT
668          ACT,,ATRIB(4).EQ.36,SSLI;                       OSVET SS LATE INPUT
669          ACT,,,PIPL;
670  PIPL    ASSIGN,ATRIB(4)=5;
671  SSLI    ASSIGN,ATRIB(3)=TNOW;
672  Q11     QUEUE(49),1,,,SEL4;                             ROLLBACK'S QUEUE
673          CREATE,5000,5000,1;                           FLEET INPUT IDENTIFIED
674          ACT/55,30;                                      WAIT FOR ORDERS
675  SASQ    QUEUE(50);                                      WAIT FOR CLASS
676          ACT;
677          QUEUE(51),0,2,BLOCK;                            LIMIT TWO PER CLASS
678          ACT(2),REL(TI26);                               WAIT FOR TRANSFER
679          GOON;
680          ACT,5;                                          FLEET TRAVEL TO A SCH
681          GOON,1;
682          ACT,,ORAND(2).LE.XX(23),SASE;                   SIX YO'S
683          ACT,,,SAFY;                                     FOUR YO'S
684  SASE    ASSIGN,ATRIB(2)=2;
685          ACT,,,SGAS;
686  SAFY    ASSIGN,ATRIB(2)=1;
687          ACT,,,SGAS;
688  SGAS    ASSIGN,ATRIB(4)=35,ATRIB(3)=TNOW,ATRIB(7)=3;
689  Q12     QUEUE(52),,,,SEL4;                              FLEET INPUT QUEUE
690  TI26    CREATE,28.0;
691          TERM;
692          CREATE,15.0,1;                                OSVET INPUT IDENTIFIED
693          ACT;
694          GOON;
695          ACT/99;
696  SAVT    QUEUE(53),1;                                    WAIT FOR CLASS
697          ACT;
698          QUEUE(54),0,1,BLOCK;                            LIMIT ONE PER CLASS
699          ACT(1),REL(TI27);
700          GOON;
701          ACT,2;                                          OSVET TRAVEL TO A SCH
702          ASSIGN,ATRIB(2)=1,ATRIB(4)=36,ATRIB(3)=TNOW,ATRIB(7)=3; OSVETS
703  Q13     QUEUE(55),,,,SEL4;                              OSVET QUEUE
704  TI27    CREATE,28.0;
705          TERM;
706  SEL4    SELECT,POR,,,Q10,Q11,Q12,Q13;                   ON-TIME,FLT,OSVET PRI
707          ACT;
708          QUEUE(65),,,BLOCK;                            WAIT FOR CONVENING DATE
709          ACT(12),REL(TI28),,GSAS
710  TI28    CREATE,28.0;
711          TERM;
712  GSAS    COLCT,INT(3),FTG SS A SCH QUE,10/0/5,1;         DETERMINE A SCHOOL QUE
713          ACT/57.82,ORAND(3).LE.XX(24),GSAG;              ON-TIME GRAD
714          ACT/58.96,ORAND(3).LE.XX(25),GSBG;              ROLLBACK GRAD
715          ACT/59.45,,GSDP;                                A SCHOOL DROPS
716  GSDP    TERM;
717  GSAG    ASSIGN,ATRIB(6)=1;
718          ACT,,,DUR;
719  GSBG    ASSIGN,ATRIB(6)=2;
720          ACT,,,DUR;
721  DUR     COLCT,INT(3),SS A SCH STAY,10/80/5;             DETERMINE A SCH STAY
722          ACT,,,FIGS;
723  FIGS    GOON,1;
724          ACT/89,,ATRIB(4).EQ.35,CSER;                    COUNT FLT INPT GRADS
725          ACT/90,,ATRIB(4).EQ.36,CSER;                    COUNT OSVET INPT GRADS
726          ACT/91,,,CSER;                                  COUNT OTHERS
727  CSER    GOON,1;
728          ACT,,ATRIB(6).EQ.1,GTCS;
729          ACT,,ATRIB(6).EQ.2,LAGO;
730  ;-------------------------------------------------------------------------
731  ;
732  ;                          FTG SS C SCHOOL PHASE
733  ;
734  ;-------------------------------------------------------------------------
735  GTCS    GOON;
736          ACT,2;                                          TRAVEL TO C SCHOOL
737          GOON,1;
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738             ACT,,ATRIB(4).EQ.35,PROG;
739             ACT,,ATRIB(4).EQ.36,PROG;
740             ACT,,,IDEN;
741     IDEN    ASSIGN,ATRIB(4)=5;
742     PROG    ASSIGN,ATRIB(3)=TNOW;                   ON-TIME INPUT
743     Q20     QUEUE(56),7,,,SEL5;                     ON-TIMERS' QUEUE
744     LAGD    GOON;
745             ACT,2;                                  TRAVEL TO C SCHOOL
746             GOON,1;
747             ACT,,ATRIB(4).EQ.35,STRG;
748             ACT,,ATRIB(4).EQ.36,STRG;
749             ACT,,,LIDE;
750     LIDE    ASSIGN,ATRIB(4)=5;
751     STRG    ASSIGN,ATRIB(3)=TNOW;                   LATE SCHOOL INPUTS
752     Q21     QUEUE(57),3,,,SEL5;                     ROLLBACKS' QUEUE
753             CREATE,56,0,1;                          FLEET INPUT IDENTIFIED
754             ACT/60,30;                              WAIT FOR ORDERS
755     SCFI    QUEUE(58);                              WAIT FOR CLASS
756             ACT;
757             QUEUE(59),0,2,BLOCK;                    LIMIT TWO PER CLASS
758             ACT(2),REL(TI29);
759             GOON;
760             ACT,6;                                  TRAVEL TO C SCHOOL
761             ASSIGN,ATRIB(2)=1,ATRIB(4)=35,ATRIB(3)=TNOW,ATRIB(7)=3; OSVETS
762     Q22     QUEUE(60),,,,SEL5;
763     TI29    CREATE,28,0;
764             TERM;
765             CREATE,5000,5000,1;                     OSVET INPUT IDENTIFIED
766     SCVT    QUEUE(61);
767             ACT/61;                                 WAIT FOR ORDERS
768             QUEUE(62),0,1,BLOCK;                    LIMIT ONE PER CLASS
769             ACT(1),REL(TI30);
770             GOON;
771             ACT,6;                                  TRAVEL TO C SCHOOL
772             ASSIGN,ATRIB(2)=1,ATRIB(4)=36,ATRIB(3)=TNOW,ATRIB(7)=3; OSVETS
773     Q23     QUEUE(63),,,,SEL5;                      OSVETS' QUEUE
774     TI30    CREATE,28,0;
775             TERM;
776     SEL5    SELECT,POR,,,Q20,Q21,Q22,Q23;           ON-TIME, FLT OSVET PRI
777             ACT/62;
778             QUEUE(64),12,12,BLOCK;                  WAIT FOR CONVENING DATE
779             ACT(12),REL(TI31),,SCOU;
780     TI31    CREATE,28,0;
781             TERM;
782     SCOU    COLCT,INT(3),FTG SS C QUE,15/0/5,1;     DETERMINE C SCHOOL QUEUE
783             ACT/63,RNORM(200,77,9),DRAND(9).LE.XX(26),SCAG;  ON-TIMERS
784             ACT/64,RNORM(214,77,9),DRAND(9).LE.XX(27),SCAG;  ROLLBACKS
785             ACT/65,RNORM(100,77,9),,SCOO;           DROPS
786     SCOO    TERM;
787     SCAG    GOON,1;
788             ACT/92,,ATRIB(4).EQ.35,BRON;            COUNT FLT INPUT GRADS
789             ACT/93,,ATRIB(4).EQ.36,BRON;            COUNT OSVET INPUT GRADS
790             ACT/94,,,BRON;                          COUNT OTHERS
791     BRON    GOON,1;
792             ACT,,ATRIB(2).EQ.2,SCGR;
793             ACT,,ATRIB(2).EQ.1,SCGR;
794             ACT,,,EST;                              IDENTIFY ORIGINAL INPTS
795     EST     GOON,1;
796             ACT,,,9,PSYO;                           SIX YO'S
797             ACT,,,1,PFYO;                           FOUR YO'S
798     PSYO    ASSIGN,ATRIB(2)=2,ATRIB(7)=3;
799             ACT,,,SCGR;
800     PFYO    ASSIGN,ATRIB(2)=1,ATRIB(7)=3;
801             ACT,,,SCGR;
802     SCGR    COLCT,INT(3),FTG SS C STAY,15/100/20,1; DETERMINE C SCHOOL STAY
803             ACT,,ATRIB(2).EQ.2,SFST;
804             ACT,,ATRIB(2).EQ.1,SRST;
805     SRST    COLCT,INT(1),FTG SS REG TOT,20/100/20;
806             ACT,,,FORC;
807     SFST    COLCT,INT(1),FTG SS SIx TOT,20/340/20;
808             ACT,,,FORC;
809     FORC    GOON;
810             TERM;
811             END;
812     INIT,0,1460;
813     MONTR,CLEAR,1095;
814     MONTR,SUMRY,1460,365;
815     FIN;
```

APPENDIX B

SLAM SUMMARY REPORT FOR PIPELINE SIMULATION

S L A M S U M M A R Y R E P O R T

SIMULATION PROJECT TRAINING PIPELINE BY THESIS

DATE 2/20/1982 RUN NUMBER 1 OF 1

CURRENT TIME 0.1440E+04
STATISTICAL ARRAYS CLEARED AT TIME 0.1095E+04

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
JEP TIME	0.1914E+02	0.5244E+01	0.1340E+00	0.2660E+02	0.5397E+02	1560
JEP QUEUE	0.1468E+02	0.1733E+02	0.1179E+01	0.0	0.1030E+03	1560
JEP STAY	0.3317E+02	0.2772E+02	0.1309E+00	0.1000E+01	0.1491E+03	1560
JMP THE STAY	0.3111E+02	0.2641E+02	0.2491E+01	0.1500E+02	0.1477E+03	1560
A SCH PM2 QUEUE	0.2000E+01	0.0	0.0	0.2000E+01	0.2000E+01	1560
12 STAY TIME	0.1681E+02	0.3200E+01	0.1825E-01	0.1500E+02	0.1800E+02	1560
A SCH STAY TIME	0.1681E+02	0.3200E+01	0.1825E-01	0.1500E+02	0.1800E+02	1560
RTG CSCH QUEUE	0.1772E+01	0.1316E+01	0.1743E+01	0.0	0.1200E+02	1560
RTG CSCH STAY	0.2222E+01	0.1736E+01	0.1743E+01	0.1000E+01	0.1400E+02	1560
RTG SSM TOT TIME	0.2222E+01	0.1736E+01	0.1743E+01	0.1000E+01	0.1400E+02	1560
RTG TOT TIME	0.1611E+02	0.7808E+01	0.1743E+01	0.1000E+01	0.1481E+03	1560
CSCH QUEUE	0.1822E+01	0.1382E+01	0.1300E+01	0.0	0.1300E+02	1560
CSCH STAY	0.1822E+01	0.1382E+01	0.1300E+01	0.0	0.1300E+02	1560
REG STAY	0.1822E+01	0.1382E+01	0.1300E+01	0.0	0.1300E+02	1560
SSM STAY	0.1822E+01	0.1382E+01	0.1300E+01	0.0	0.1300E+02	1560
QUEUE	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
STAY	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
CSCH QUEUE	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
CSCH STAY	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
SSM 4 SCH QUE	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
SCH STAY	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
QUE	0.1914E+02	0.2480E+01	0.1300E+01	0.0	0.1300E+02	1560
STAY	0.3227E+03	0.7029E+02	0.2178E+00	0.3457E+02	0.3891E+03	1560
REG TOT	NO VALUES RECORDED					
SSM TOT	0.3259E+03	0.7455E+02	0.1417E+00	0.3670E+03	0.7114E+03	142

FILE STATISTICS

FILE NUMBER	ASSOCIATED NODE TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1	QUEUE	104.3350	23.2924	148	78	23.4258
2	QUEUE	30.0000	0.0	30	30	0.4864
3	QUEUE	0.0	0.0	0	0	0.0
4	AWAIT	0.0	0.0	0	0	0.0
5	AWAIT	1.7425	0.9286	3	0	0.0030
6	QUEUE	0.0	0.0	0	0	0.0
7	QUEUE	0.0	0.0	0	0	0.0
8	QUEUE	0.0	0.0	0	0	0.0
9	QUEUE	0.0	0.0	0	0	0.0
10	QUEUE	1.3600	0.4896	2	0	0.0200
11	QUEUE	0.0	0.0	0	0	0.0
12	QUEUE	0.0	0.0	0	0	0.0
13	QUEUE	0.0	0.0	0	0	0.0
14	QUEUE	0.0	0.0	0	0	0.0
15	QUEUE	0.0	0.0	0	0	0.0
16	QUEUE	0.0	0.0	0	0	0.0
17	QUEUE	0.0	0.0	0	0	0.0
18	QUEUE	0.0	0.0	0	0	0.0
19	QUEUE	0.0	0.0	0	0	0.0
20	QUEUE	0.0	0.0	0	0	0.0
21	QUEUE	0.0	0.0	0	0	0.0
22	QUEUE	0.0	0.0	0	0	0.0
23	QUEUE	0.0	0.0	0	0	0.0
24	QUEUE	0.0	0.0	0	0	0.0
25	QUEUE	0.0	0.0	0	0	0.0
26	QUEUE	0.0	0.0	0	0	0.0
27	QUEUE	0.0	0.0	0	0	0.0
28	QUEUE	0.0	0.0	0	0	0.0
29	QUEUE	0.0	0.0	0	0	0.0
30	QUEUE	0.0	0.0	0	0	0.0

50	0	FIFO
51	0	FIFO
52	0	FIFO
53	1	FIFO
54	0	FIFO
55	0	FIFO
56	7	FIFO
57	3	FIFO
58	0	FIFO
59	0	FIFO
60	0	FIFO
61	0	FIFO
62	0	FIFO
63	0	FIFO
64	0	FIFO
65	0	FIFO

STATISTICS BASED ON OBSERVATIONS

COLCT NUMBER	COLLECTION MODE	IDENTIFIER	HISTOGRAM SPECIFICATIONS NCEL	HLOW	HWID
1	NETWORK	DEP TIME	12	0.0	0.500E+01
2	NETWORK	BEE QUEUE	5	0.0	0.100E+01
3	NETWORK	BEE STAY	15	0.0	0.100E+02
4	NETWORK	PH DNE STAY	10	0.700E+02	0.500E+01
5	NETWORK	A SCH PHQ QUEUE	10	0.0	0.100E+01
6	NETWORK	A2 STAY TIME	6	0.400E+02	0.500E+01
7	NETWORK	A SCH STAY TIME	13	0.140E+03	0.500E+01
8	NETWORK	FTG C SCH QUEUE	10	0.0	0.500E+01
9	NETWORK	FTG C SCH STAY	15	0.400E+02	0.200E+02
10	NETWORK	FTG REG TOT TIME	18	0.100E+03	0.200E+02
11	NETWORK	SYO FTG TIME	20	0.360E+03	0.200E+02
12	NETWORK	FTN C SCH QUEUE	20	0.0	0.500E+01
13	NETWORK	FTN C SCH STAY	20	0.100E+03	0.200E+02
14	NETWORK	FTN REG STAY	18	0.120E+03	0.200E+02
15	NETWORK	FTN SYO STAY	25	0.360E+03	0.200E+02
16	NETWORK	SBEE QUEUE	5	0.0	0.200E+01
17	NETWORK	SBEE STAY	15	0.0	0.500E+01
18	NETWORK	SUB SCH QUEUE	10	0.0	0.500E+01
19	NETWORK	SUB SCH STAY	12	0.300E+02	0.500E+01
20	NETWORK	FTG SS A SCH QUE	10	0.0	0.500E+01
21	NETWORK	SS A SCH STAY	10	0.400E+02	0.500E+01
22	NETWORK	FTG SS C QUE	15	0.0	0.500E+01
23	NETWORK	FTG SS C STAY	15	0.100E+03	0.200E+02
24	NETWORK	FTG SS REG TOT	20	0.100E+03	0.200E+02
25	NETWORK	FTG SS SIX TOT	20	0.340E+03	0.200E+02

RANDOM NUMBER STREAMS

STREAM NUMBER	SEED VALUE	REINITIALIZATION OF STREAM
1	1274321477	NO
2	2135124613	NO
3	1743251541	NO
4	1624217675	NO
5	2014432579	NO
6	2036774231	NO
7	1452313571	NO
8	1254240657	NO
9	1410143363	NO
10	2135621895	NO

INITIALIZATION OPTIONS

BEGINNING TIME OF SIMULATION (TTBEG):	0.0
ENDING TIME OF SIMULATION (TTFIN):	0.1460E+04
STATISTICAL ARRAYS CLEARED (JJCLR):	YES
VARIABLES INITIALIZED (JJVAR):	YES
FILES INITIALIZED (JJFIL):	YES

NSET/QSET STORAGE ALLOCATION

DIMENSION OF NSET/QSET (NNSET):	100000
WORDS ALLOCATED TO FILING SYSTEM:	88000
WORDS ALLOCATED TO NETWORK:	7115
WORDS AVAILABLE FOR PLOTS/TABLES:	4885

SLAM ECHO REPORT

SIMULATION PROJECT TRAINING PIPELINE BY THESIS

DATE 2/20/1982 RUN NUMBER 1 OF 1

SLAM VERSION JAN 79

GENERAL OPTIONS

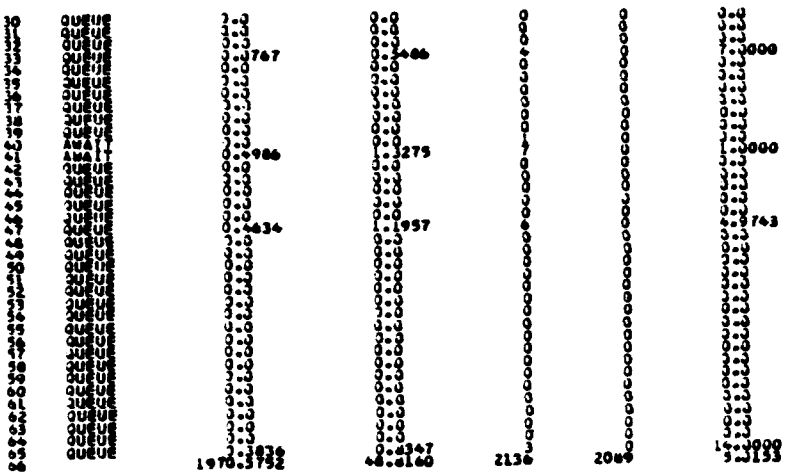
PRINT INPUT STATEMENTS (ILIST): YES
PRINT ECHO REPORT (IECHO): YES
EXECUTE SIMULATIONS (INOT): YES
PRINT INTERMEDIATE RESULTS HEADING (IPIRM): YES
PRINT SUMMARY REPORT (ISMRY): YES

LIMITS ON FILES

MAXIMUM NUMBER OF USER FILES (MFILS): 65
MAXIMUM NUMBER OF USER ATTRIBUTES (MATR): 7
MAXIMUM NUMBER OF CONCURRENT ENTRIES (MNTRY): 8000

FILE SUMMARY

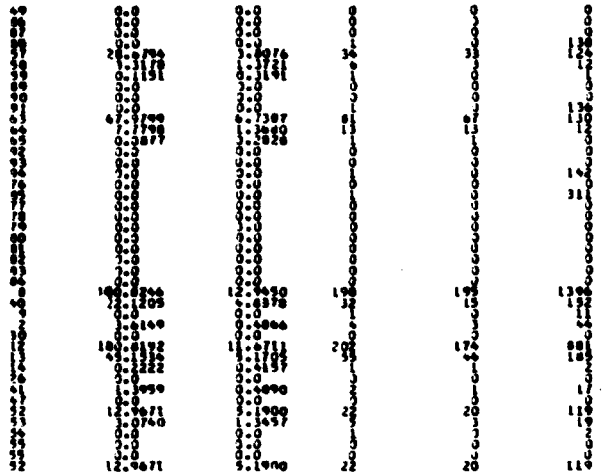
FILE NUMBER	INITIAL ENTRIES	RANKING CRITERION
1	75	FIFO
2	10	FIFO
3	2	FIFO
4	0	FIFO
5	0	FIFO
6	0	FIFO
7	0	FIFO
8	0	FIFO
9	0	FIFO
10	0	FIFO
11	0	FIFO
12	0	FIFO
13	25	FIFO
14	0	FIFO
15	0	FIFO
16	0	FIFO
17	0	FIFO
18	25	FIFO
19	0	FIFO
20	0	FIFO
21	0	FIFO
22	0	FIFO
23	0	FIFO
24	0	FIFO
25	0	FIFO
26	0	FIFO
27	0	FIFO
28	0	FIFO
29	0	FIFO
30	0	FIFO
31	0	FIFO
32	0	FIFO
33	0	FIFO
34	0	FIFO
35	0	FIFO
36	0	FIFO
37	0	FIFO
38	0	FIFO
39	0	FIFO
40	0	FIFO
41	0	FIFO
42	0	FIFO
43	0	FIFO
44	0	FIFO
45	0	FIFO
46	0	FIFO
47	0	FIFO
48	0	FIFO
49	0	FIFO
50	0	FIFO
51	0	FIFO
52	0	FIFO
53	0	FIFO
54	0	FIFO
55	0	FIFO
56	0	FIFO
57	0	FIFO
58	0	FIFO
59	0	FIFO
60	0	FIFO
61	0	FIFO
62	0	FIFO
63	0	FIFO
64	0	FIFO
65	0	FIFO



REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTILIZATION	CURRENT UTILIZATION	ENTITY COUNT
34	0.0	0.0	0	0	0
138	0.0	0.0	0	0	0
142	0.0	0.0	0	0	0
146	0.0	0.0	0	0	0
150	0.0	0.0	0	0	0
154	0.0	0.0	0	0	0
158	0.0	0.0	0	0	0
162	0.0	0.0	0	0	0
166	0.0	0.0	0	0	0
170	0.0	0.0	0	0	0
174	0.0	0.0	0	0	0
178	0.0	0.0	0	0	0
182	0.0	0.0	0	0	0
186	0.0	0.0	0	0	0
190	0.0	0.0	0	0	0
194	0.0	0.0	0	0	0
198	0.0	0.0	0	0	0
202	0.0	0.0	0	0	0
206	0.0	0.0	0	0	0
210	0.0	0.0	0	0	0
214	0.0	0.0	0	0	0
218	0.0	0.0	0	0	0
222	0.0	0.0	0	0	0
226	0.0	0.0	0	0	0
230	0.0	0.0	0	0	0
234	0.0	0.0	0	0	0
238	0.0	0.0	0	0	0
242	0.0	0.0	0	0	0
246	0.0	0.0	0	0	0
250	0.0	0.0	0	0	0
254	0.0	0.0	0	0	0
258	0.0	0.0	0	0	0
262	0.0	0.0	0	0	0
266	0.0	0.0	0	0	0
270	0.0	0.0	0	0	0
274	0.0	0.0	0	0	0
278	0.0	0.0	0	0	0
282	0.0	0.0	0	0	0
286	0.0	0.0	0	0	0
290	0.0	0.0	0	0	0
294	0.0	0.0	0	0	0
298	0.0	0.0	0	0	0
302	0.0	0.0	0	0	0
306	0.0	0.0	0	0	0
310	0.0	0.0	0	0	0
314	0.0	0.0	0	0	0
318	0.0	0.0	0	0	0
322	0.0	0.0	0	0	0
326	0.0	0.0	0	0	0
330	0.0	0.0	0	0	0
334	0.0	0.0	0	0	0
338	0.0	0.0	0	0	0
342	0.0	0.0	0	0	0
346	0.0	0.0	0	0	0
350	0.0	0.0	0	0	0
354	0.0	0.0	0	0	0
358	0.0	0.0	0	0	0
362	0.0	0.0	0	0	0
366	0.0	0.0	0	0	0
370	0.0	0.0	0	0	0
374	0.0	0.0	0	0	0
378	0.0	0.0	0	0	0
382	0.0	0.0	0	0	0
386	0.0	0.0	0	0	0
390	0.0	0.0	0	0	0
394	0.0	0.0	0	0	0
398	0.0	0.0	0	0	0
402	0.0	0.0	0	0	0
406	0.0	0.0	0	0	0
410	0.0	0.0	0	0	0
414	0.0	0.0	0	0	0
418	0.0	0.0	0	0	0
422	0.0	0.0	0	0	0
426	0.0	0.0	0	0	0
430	0.0	0.0	0	0	0
434	0.0	0.0	0	0	0
438	0.0	0.0	0	0	0
442	0.0	0.0	0	0	0
446	0.0	0.0	0	0	0
450	0.0	0.0	0	0	0
454	0.0	0.0	0	0	0
458	0.0	0.0	0	0	0
462	0.0	0.0	0	0	0
466	0.0	0.0	0	0	0
470	0.0	0.0	0	0	0
474	0.0	0.0	0	0	0
478	0.0	0.0	0	0	0
482	0.0	0.0	0	0	0
486	0.0	0.0	0	0	0
490	0.0	0.0	0	0	0
494	0.0	0.0	0	0	0
498	0.0	0.0	0	0	0
502	0.0	0.0	0	0	0
506	0.0	0.0	0	0	0
510	0.0	0.0	0	0	0
514	0.0	0.0	0	0	0
518	0.0	0.0	0	0	0
522	0.0	0.0	0	0	0
526	0.0	0.0	0	0	0
530	0.0	0.0	0	0	0
534	0.0	0.0	0	0	0
538	0.0	0.0	0	0	0
542	0.0	0.0	0	0	0
546	0.0	0.0	0	0	0
550	0.0	0.0	0	0	0
554	0.0	0.0	0	0	0
558	0.0	0.0	0	0	0
562	0.0	0.0	0	0	0
566	0.0	0.0	0	0	0
570	0.0	0.0	0	0	0
574	0.0	0.0	0	0	0
578	0.0	0.0	0	0	0
582	0.0	0.0	0	0	0
586	0.0	0.0	0	0	0
590	0.0	0.0	0	0	0
594	0.0	0.0	0	0	0
598	0.0	0.0	0	0	0
602	0.0	0.0	0	0	0
606	0.0	0.0	0	0	0
610	0.0	0.0	0	0	0
614	0.0	0.0	0	0	0
618	0.0	0.0	0	0	0
622	0.0	0.0	0	0	0
626	0.0	0.0	0	0	0
630	0.0	0.0	0	0	0
634	0.0	0.0	0	0	0
638	0.0	0.0	0	0	0
642	0.0	0.0	0	0	0
646	0.0	0.0	0	0	0
650	0.0	0.0	0	0	0
654	0.0	0.0	0	0	0
658	0.0	0.0	0	0	0
662	0.0	0.0	0	0	0
666	0.0	0.0	0	0	0
670	0.0	0.0	0	0	0
674	0.0	0.0	0	0	0
678	0.0	0.0	0	0	0
682	0.0	0.0	0	0	0
686	0.0	0.0	0	0	0
690	0.0	0.0	0	0	0
694	0.0	0.0	0	0	0
698	0.0	0.0	0	0	0
702	0.0	0.0	0	0	0
706	0.0	0.0	0	0	0
710	0.0	0.0	0	0	0
714	0.0	0.0	0	0	0
718	0.0	0.0	0	0	0
722	0.0	0.0	0	0	0
726	0.0	0.0	0	0	0
730	0.0	0.0	0	0	0
734	0.0	0.0	0	0	0
738	0.0	0.0	0	0	0
742	0.0	0.0	0	0	0
746	0.0	0.0	0	0	0
750	0.0	0.0	0	0	0
754	0.0	0.0	0	0	0
758	0.0	0.0	0	0	0
762	0.0	0.0	0	0	0
766	0.0	0.0	0	0	0
770	0.0	0.0	0	0	0
774	0.0	0.0	0	0	0
778	0.0	0.0	0	0	0
782	0.0	0.0	0	0	0
786	0.0	0.0	0	0	0
790	0.0	0.0	0	0	0
794	0.0	0.0	0	0	0
798	0.0	0.0	0	0	0
802	0.0	0.0	0	0	0
806	0.0	0.0	0	0	0
810	0.0	0.0	0	0	0
814	0.0	0.0	0	0	0
818	0.0	0.0	0	0	0
822	0.0	0.0	0	0	0
826	0.0	0.0	0	0	0
830	0.0	0.0	0	0	0
834	0.0	0.0	0	0	0
838	0.0	0.0	0	0	0
842	0.0	0.0	0	0	0
846	0.0	0.0	0	0	0
850	0.0	0.0	0	0	0
854	0.0	0.0	0	0	0
858	0.0	0.0	0	0	0
862	0.0	0.0	0	0	0
866	0.0	0.0	0	0	0
870	0.0	0.0	0	0	0
874	0.0	0.0	0	0	0
878	0.0	0.0	0	0	0
882	0.0	0.0	0	0	0
886	0.0	0.0	0	0	0
890	0.0	0.0	0	0	0
894	0.0	0.0	0	0	0
898	0.0	0.0	0	0	0
902	0.0	0.0	0	0	0
906	0.0	0.0	0	0	0
910	0.0	0.0	0	0	0
914	0.0	0.0	0	0	0
918	0.0	0.0	0	0	0
922	0.0	0.0	0	0	0
926	0.0	0.0	0	0	0
930	0.0	0.0	0	0	0
934	0.0	0.0	0	0	0
938	0.0	0.0	0	0	0
942	0.0	0.0	0	0	0
946	0.0	0.0	0	0	0
950	0.0	0.0	0	0	0
954	0.0	0.0	0	0	0
958	0.0	0.0	0	0	0
962	0.0	0.0	0	0	0
966	0.0	0.0	0	0	0
970	0.0	0.0	0	0	0
974	0.0	0.0	0	0	0
978	0.0	0.0	0	0	0
982	0.0	0.0	0	0	0
986	0.0	0.0	0	0	0
990	0.0	0.0	0	0	0
994	0.0	0.0	0	0	0
998	0.0	0.0	0	0	0

49	0.0	0.0	0	0	0
50	0.0	0.0	0	0	0
57	0.0	0.0	0	0	0
58	0.0	0.0	1	0	138
57	28.8794	3.8076	34	33	124
58	3.3178	1.3721	6	3	12
59	0.1151	0.3191	1	0	1
60	0.0	0.0	0	0	0
60	0.0	0.0	0	0	0
61	0.0	0.0	1	0	136
63	67.9799	6.7387	81	67	130
64	7.7798	1.3680	13	13	12
65	0.3877	0.2828	1	1	0
62	0.0	0.0	0	0	0
63	0.0	0.0	0	0	0
64	0.0	0.0	1	0	142
75	0.0	0.0	0	0	0
76	0.0	0.0	1	0	311
77	0.0	0.0	0	0	0
78	0.0	0.0	0	0	0
79	0.0	0.0	0	0	0
80	0.0	0.0	0	0	0
81	0.0	0.0	0	0	0
82	0.0	0.0	0	0	0
83	0.0	0.0	0	0	0
84	0.0	0.0	0	0	0
8	100.8246	12.9450	198	195	1396
40	22.1205	6.8378	32	15	152
9	0.0	0.0	1	0	11
2	3.6149	0.4866	4	3	44
30	0.0	0.0	0	0	0
12	180.8192	11.6711	202	174	881
13	45.1336	5.1705	55	44	185
14	0.2222	0.4157	1	1	2
26	0.0	0.0	0	0	0
41	1.3959	0.4890	2	1	17
47	0.0	0.0	0	0	0
52	12.9671	5.1900	22	20	119
53	3.0740	1.3457	5	3	19
54	0.0	0.0	1	0	2
55	0.0	0.0	0	0	0
55	0.0	0.0	0	0	0
52	12.9671	5.1900	22	20	119



SERVICE ACTIVITY STATISTICS

ACTIVITY INDEX	START NODE LABEL/TYPE	SERVER CAPACITY	AVERAGE UTILIZATION	STANDARD DEVIATION	CURRENT UTILIZATION	AVERAGE BLOCKAGE	MAXIMUM IDLE TIME/SERVERS	MAXIMUM BUSY TIME/SERVERS	ENTITY COUNT
1	DEPO QUEUE	1	0.0	0.0	0	1.0000	4.0000	0.0	1560
2	INRE QUEUE	1	0.0	0.0	0	0.0	6.2498	0.0	
15	BVET QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	0
0	HOLD QUEUE	500	0.0	0.0	0	0.0	500.0000	1.0000	
3	INA QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
27	ADVT QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	0
4	APOQ QUEUE	1	0.0	0.0	0	0.0	2.1465	0.0	1052
0	INA2 QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
28	ATVT QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	0
5	SEL1 SELECT	1	0.0	0.0	0	0.0	7.0000	0.0	607
0	APOQ QUEUE	25	3.3760	5.6997	0	0.0	25.0000	18.0000	
6	INC QUEUE	1	0.0	0.0	0	0.0	56.0000	0.0	6
7	SEL2 SELECT	1	0.0	0.0	0	0.0	14.0000	0.0	235
29	INC4 QUEUE	1	0.0	0.0	0	0.0	56.0000	0.0	6
35	SEL3 SELECT	1	0.0	0.0	0	0.0	7.0000	0.0	137
0	SBEE QUEUE	1	0.0	0.0	0	0.0	21.0000	0.0	
44	SBVT QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
0	SBOU QUEUE	1	0.0	0.0	0	0.0	7.0000	0.0	
0	SGFI QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
50	SGOV QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	0
51	SUBS QUEUE	1	0.0	0.0	0	0.0	21.0045	0.0	150
0	SASQ QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
0	SAVT QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
0	SEL4 SELECT	1	0.0	0.0	0	0.0	28.0000	0.0	
0	SCPI QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	
61	SCVT QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0	0
62	SEL5 SELECT	1	0.0	0.0	0	0.0	28.0000	0.0	136
0	QUEUE	10	10.0000	0.0	10	0.0	0.0	30.0000	
0	QUEUE	2	0.4204	0.4936	1	0.0	2.0000	1.0000	
0	QUEUE	2	0.0	0.0	0	0.0	365.0000	0.0	
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0	

0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	25	10.4022	6.6896	0	0.0	25.0000	25.0000
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	2	0.0	0.0	0	0.0	3.0000	0.0
0	QUEUE	2	0.4959	0.5000	0	0.0	2.0000	1.0000
0	QUEUE	25	10.4822	6.0255	0	0.0	25.0000	25.0000
0	QUEUE	2	0.4959	0.5000	0	0.0	2.0000	1.0000
0	QUEUE	33	16.6548	8.1282	5	0.0	33.0000	33.0000
0	QUEUE	2	0.1288	0.3349	0	0.0	2.0000	1.0000
0	QUEUE	1	0.0	0.0	0	0.0	365.0000	0.0
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	12	7.3175	3.5666	6	0.0	12.0000	12.0000
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	12	7.3175	3.5666	6	0.0	12.0000	12.0000
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0
0	QUEUE	2	0.0	0.0	0	0.0	2.0000	0.0

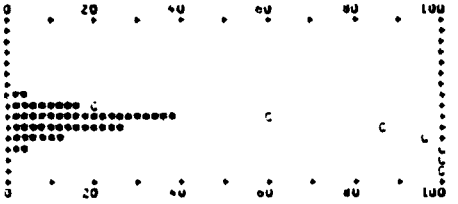
RESOURCE STATISTICS

RESOURCE NUMBER	RESOURCE LABEL	CURRENT CAPACITY	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTILIZATION	CURRENT UTILIZATION
1	REE QUOT	360	272.4197	13.7636	304	263
2	SAFE QUO	40	19.6072	3.2221	29	19

HISTOGRAM NUMBER 1

DEP TIME

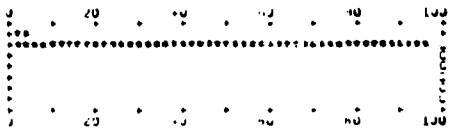
OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	0.0	0.0	0.0
0	0.0	0.0	0.5000E+01
0	0.0	0.0	0.1000E+02
0	0.0	0.0	0.1500E+02
0	0.0	0.0	0.2000E+02
0	0.0	0.0	0.2500E+02
45	0.035	0.035	0.3000E+02
265	0.170	0.205	0.3500E+02
607	0.389	0.594	0.4000E+02
408	0.262	0.856	0.4500E+02
173	0.111	0.967	0.5000E+02
52	0.033	1.000	0.5500E+02
0	0.0	1.000	0.6000E+02
0	0.0	1.000	INF
1560			

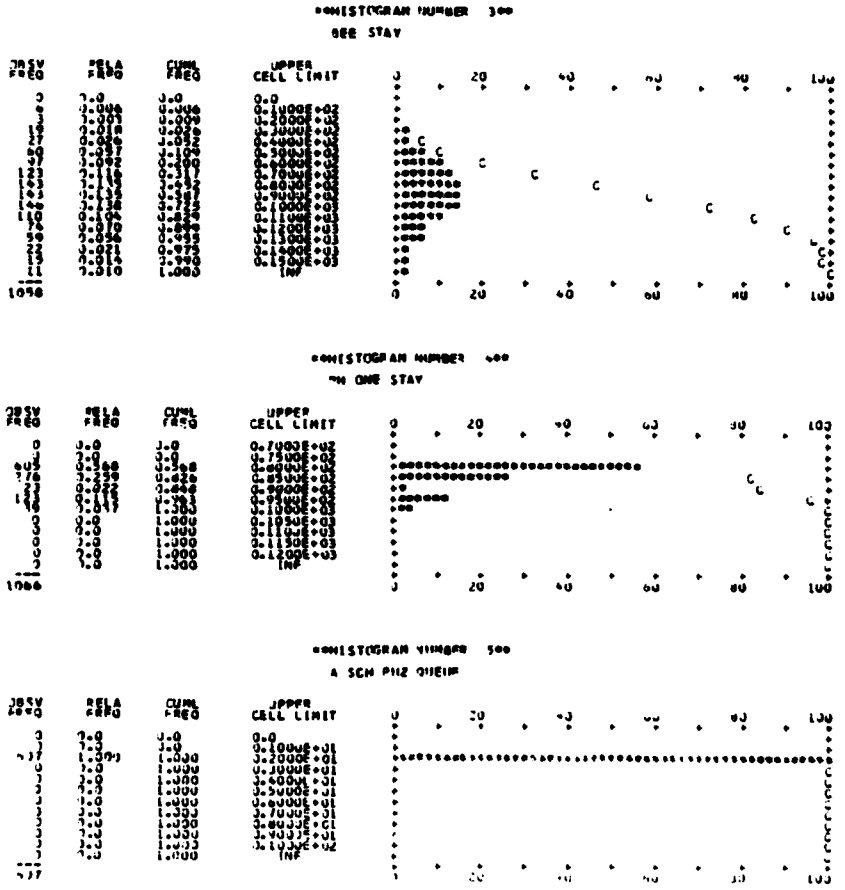


HISTOGRAM NUMBER 2

REE QUEUE

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
46	0.031	0.031	0.0
1366	0.969	1.000	0.1000E+01
0	0.0	1.000	0.2000E+01
0	0.0	1.000	0.3000E+01
0	0.0	1.000	0.4000E+01
0	0.0	1.000	0.5000E+01
0	0.0	1.000	INF
1410			

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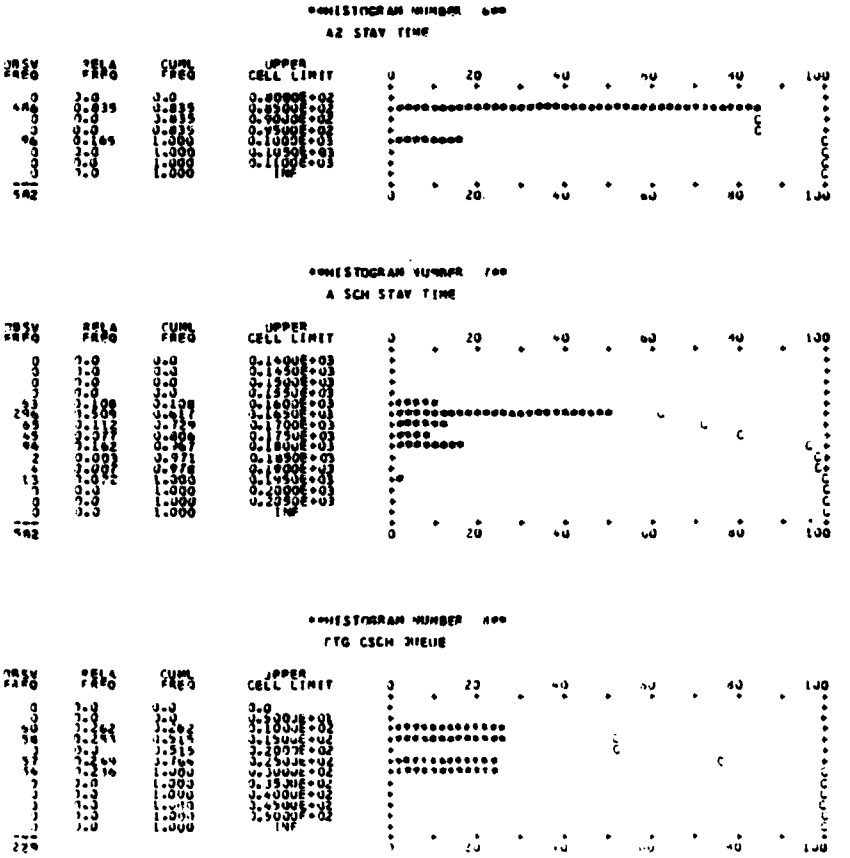
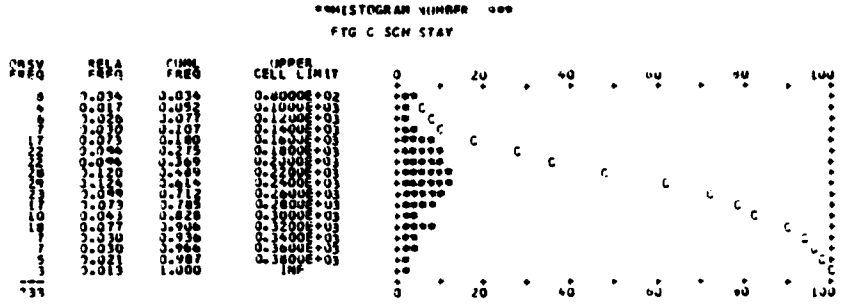
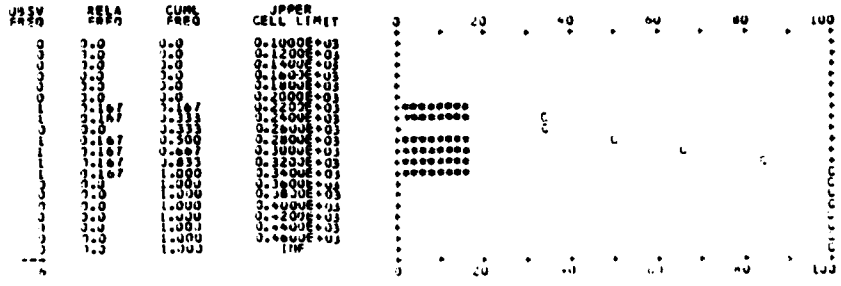
SEE STAY
OBSV FREQ
RELA FREQ
CUML FREQ
UPPER CELL LIMIT
INF
1000
0
20
40
60
80
100

**HISTOGRAM NUMBER 400
** ONE STAY
OBSV FREQ
RELA FREQ
CUML FREQ
UPPER CELL LIMIT
INF
1000
0
20
40
60
80
100

**HISTOGRAM NUMBER 500
A SCH PHZ QUEUE
OBSV FREQ
RELA FREQ
CUML FREQ
UPPER CELL LIMIT
INF
0
20
40
60
80
100


**HISTOGRAM NUMBER 600
A2 STAY TIME
OBSV FREQ
REL FREQ
CUML FREQ
UPPER CELL LIMIT
0 20 40 60 80 100
**HISTOGRAM NUMBER 700
A SCH STAY TIME
**HISTOGRAM NUMBER 800
FTG CSCH DELIVE


HISTOGRAM NUMBER *
FTG C SCH STAY
OBSV FREQ
RELA FREQ
CUML FREQ
UPPER CELL LIMIT
0
20
40
60
80
100
INF


HISTOGRAM NUMBER 100
FTG REG INT TIME
OBSV FREQ
RELA FREQ
CUML FREQ
UPPER CELL LIMIT
0
20
40
60
80
100
INF

AD-A122 434 A SIMULATION MODEL DEPICTING FLEET EXPANSION [illegible]
THE FIRE CONTROL TECHNICIANS TRAINING PIPELINE(U) NAVAL
POSTGRADUATE SCHOOL MONTEREY CA L W NELMS ET AL.
UNCLASSIFIED JUN 82 F/G 15/5 NL

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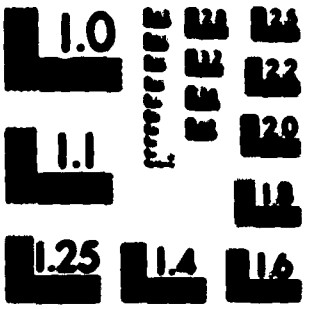
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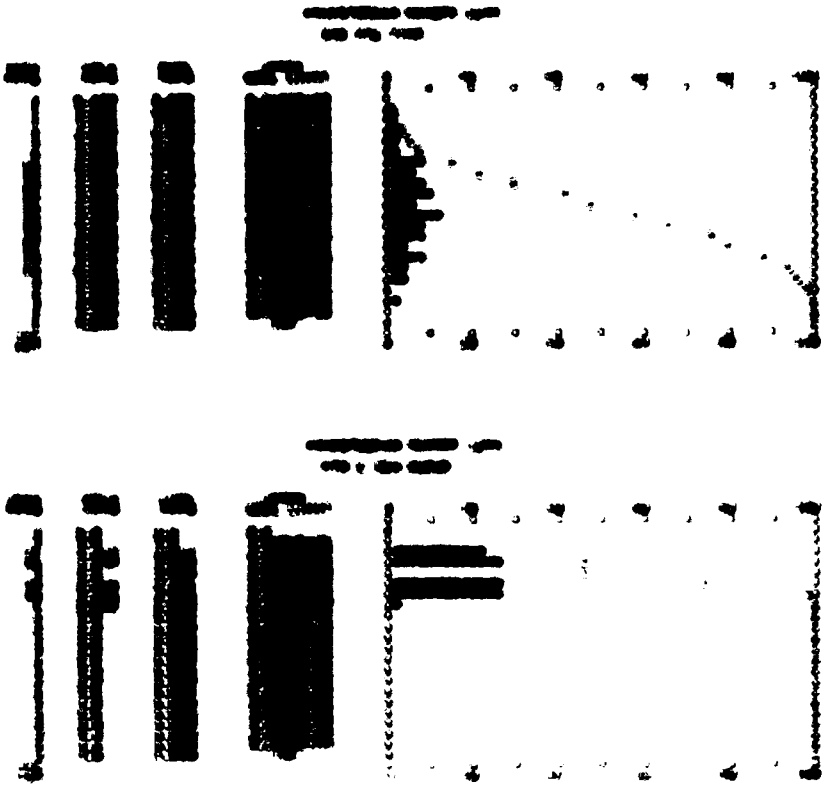

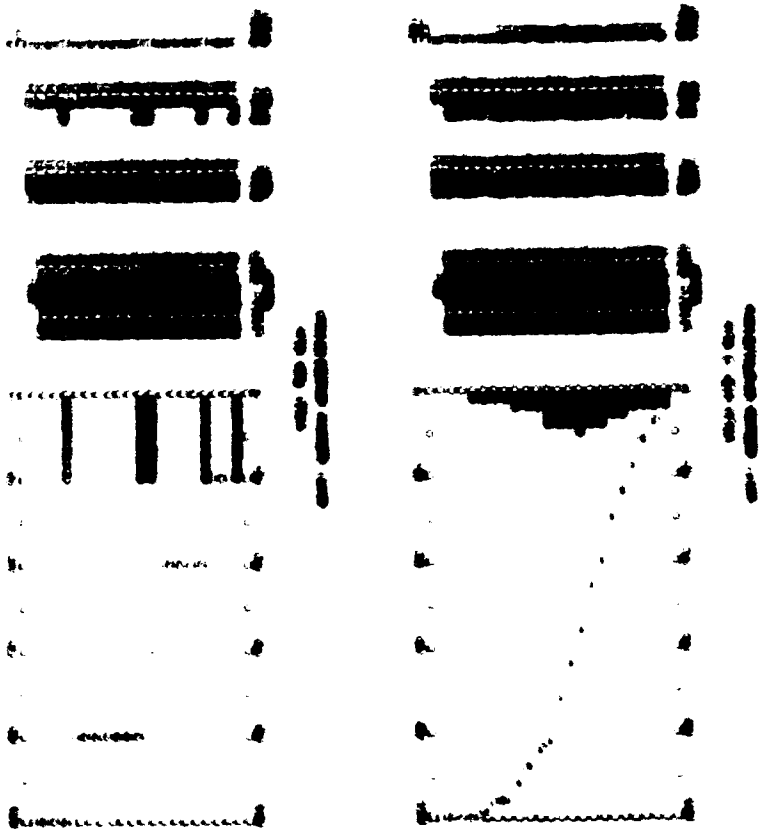

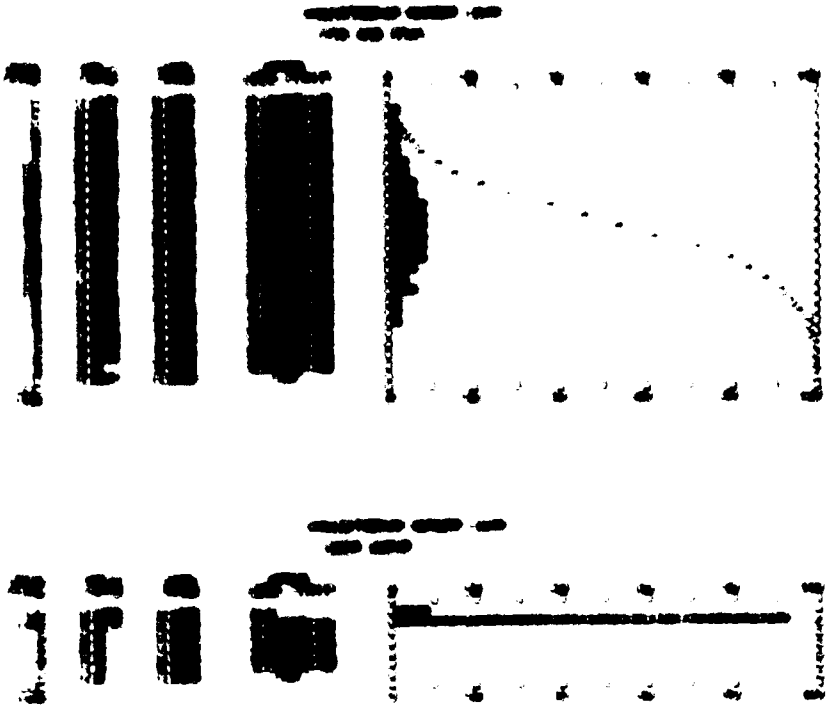

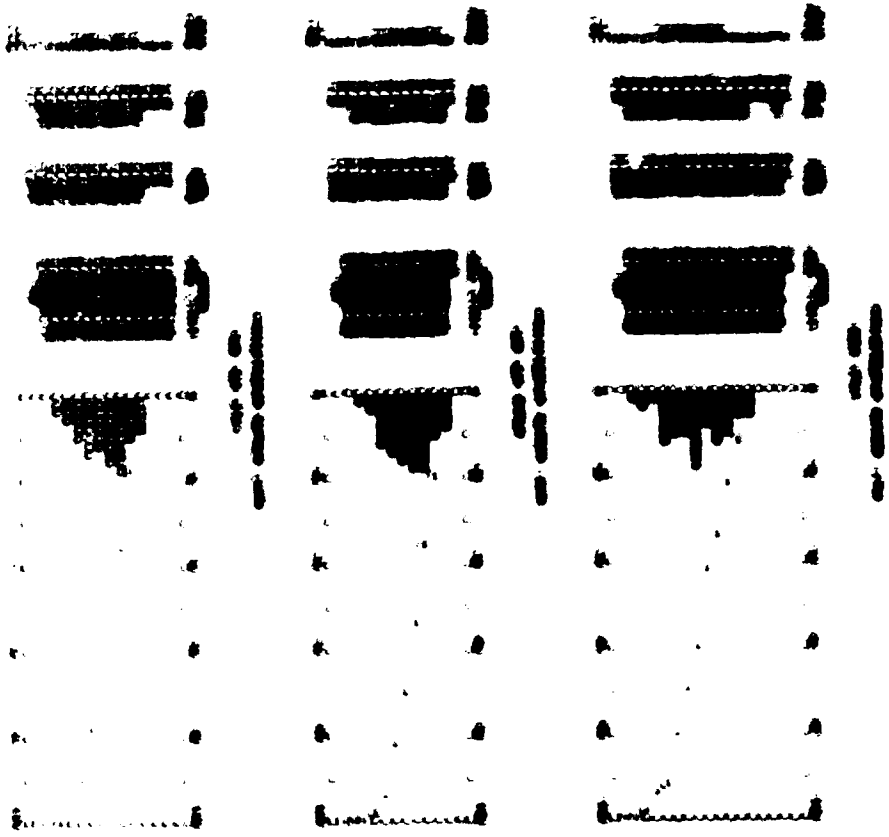

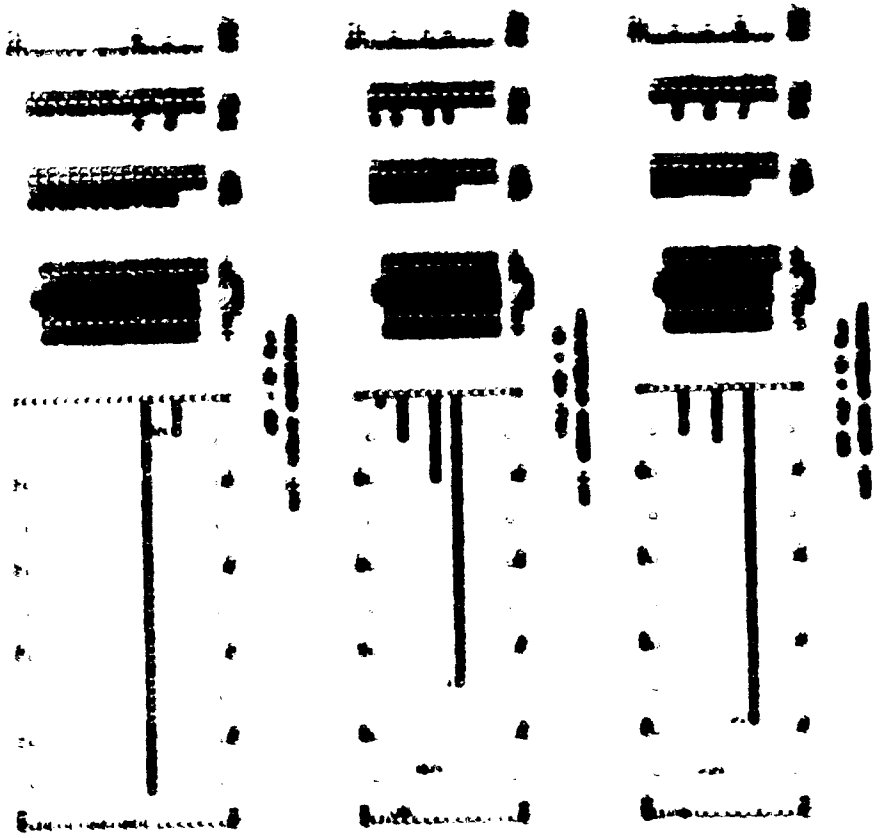

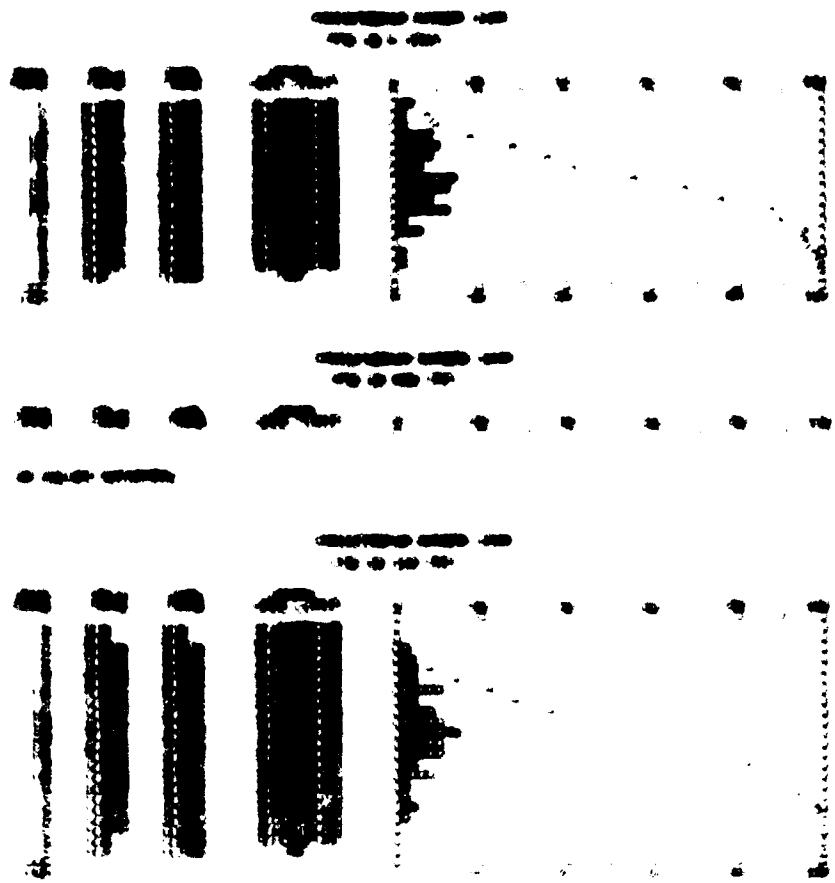

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