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An Analysis of Chronic Personnel Shortages in the B-52 Radar Navigator Career Field

Thesis

Kenneth E. Charpie, Jr.
Captain, USAF

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An Analysis of Chronic Personnel Shortages in the B-52 Radar Navigator Career Field

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Kenneth E. Charpie, Jr., B.S.

Captain, USAF

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Preface

After learning of the request from HQ SAC/DPROR for a thesis of this nature, it became a labor of love for me due to the applicability to my own career in the Air Force. In doing the research at Offutt AFB for this thesis, I learned more about the management of my career field in one day than I had in the previous seven years of actually serving as a crew member.

I wish to thank those in the Personnel Offices at Offutt AFB who provided much of the data required for this work, but especially Major Tom Loose for taking the day to guide me to the appropriate offices for the different inputs. I also thank Captain Bruce Wong for his continual interest in this project and support. I wish to thank those with B-52 backgrounds who sat down and looked at the model as I was developing it, and for their inputs in ensuring its accuracy. The encouragement of my adviser, Lt Col Tom Schuppe was also invaluable. The presence of the Linear Programming Model is due to his encouraging me when it looked insoluble.

I also wish to thank my wife for all her love and support during the past year and a half as I spent most of my time and energy doing my schoolwork, and working on this thesis.

Ken Charpie

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Abstract

This research effort developed two career progression models for the B-52 navigator and radar navigator career field: a linear programming model and a SLAM simulation model. The linear programming model calculated the steady state conditions well, whereas the simulation model showed the dynamics present in the transient states.

An analysis of the present crew force and current conditions was accomplished using these two models. Also examined were several changes currently occurring in the crew force: the reduction of some staff positions, and the reduction of the draw on the B-52 crew force to man the B-1B. An increase in the size of the crew force was also studied, as were several variations on the retention rate. The last condition examined was changing the policy of allowing crewmembers to go to career broadening positions after six years of active flying experience to a policy of requiring nine years of flying experience. The only condition determined to have a serious impact on meeting manning requirements was a decrease in the retention rate. The difficulty with managing the crew force when the retention rate changed was the long lead time necessary to replace the crewmembers lost.

An Analysis of Chronic Personnel Shortages
in the B-52 Radar Navigator Career Field

I. Introduction

For an extended period of time, the B-52 radar navigator career field (AFSC 1525 A,C) has been in a constant state of change. Periodically, a critical manning situation would develop, and no radar navigators would be released for career broadening assignments. This situation would last a few months, then, with the manning situation improving, some radar navigators would be released to other jobs. By releasing these few however, the manning situation would again become critical. This cycle has persisted over the years, and the Air Force has not been able to strike a balance in the manning. Headquarters Strategic Air Command (SAC) is attempting to determine what means are necessary to put the career field in balance.

Background

Each B-52 crew has two navigators: the navigator, and the radar navigator. New navigators from Undergraduate Navigator Training (UNT) are assigned as B-52 navigators, and are responsible for general, point-to-point navigation. After gaining a few years experience, B-52 navigators may be given the opportunity to upgrade to B-52 radar navigator. Radar navigators are responsible for navigation during those phases of flight in which precision is essential, such as bombing and air refueling rendezvous, and for maintaining the accuracy of the bombing and navigation computers. Experienced radar navigators may then be assigned to staff duties after completing a minimum of six years of flying duty (2:12).

There are a wide variety of staff jobs available to the radar navigators after getting at least six years of flying credit. These include career broadening opportunities such as going to the Separate Operating Agencies for a tour of duty, further education at AFIT followed by a staff tour, or just going to a staff job at SAC or the Pentagon. Those radar navigators going to these jobs will have a minimum of three years out of the cockpit.

During the Vietnam War Strategic Air Command increased the number of crews in the B-52s to support combat operations out of Guam and Thailand. After the conclusion of the conflict the Air Force retired all the B-52 models except the D, G, and H models and the excess crews were released from the Air Force or reassigned to other, nonflying, rated supplement duties. The crew ratio, or number of crews required per aircraft, was reduced from 1.7 to 1.29, requiring the dissolution of many of the existing aircrews. Simultaneously, the navigator production rate at Undergraduate Navigator Training at Mather AFB was reduced because of the manpower reduction. The training rate was reduced below that required for long term sustainment of the navigator career force (3:8-1). One result of these actions was that by 1979 an Air Force deficit of 110 navigators existed. This also resulted in the current shortage of experienced radar navigators capable of filling many of the staff and instructor positions for senior captains and junior majors. In response, SAC recalled experienced navigators from the rated supplement and Air Training Command increased the training rate. These actions reduced the manning shortage, but did not eliminate it. It was hoped the retirement of the B-52D would allow the distribution of enough radar navigators and navigators to eliminate the deficit. This helped, but did not solve the problem because of new manning requirements due to the introduction of the new Offensive Avionics System to replace the old bombing and navigation computers, the introduction of the new Weapon System Trainers, and the introduction of the B-1B bomber. All three systems created more positions needing to be filled by experienced radar navigators (5).

Currently SAC has 36 fewer radar navigators than required to fill all designated positions. To lessen the impact on individual units, SAC has placed emphasis on manning the bomb squadrons completely, leaving some staff positions empty. ATC is lowering the production of new navigators, attempting to stabilize the training rate at a replacement level. MPC is currrently attempting to manage the career field more efficiently by more accurately forecasting future needs (10). It is not yet evident that the currently planned lower training rates will sustain the required force levels and provide adequate manning for the staffs, since there has been no effort to model the career progress of the B-52 navigator/radar navigator crew force.

Research Problem

Currently 150 new navigators per year are trained in the B-52. This accession rate is forecast to increase to 160 in fiscal year 1989. However, a substantial portion of these will go to the B-1B, not the B-52. Therefore, the actual B-52 accession rate will decline at that time (3:8-2 to 8-5). To justify changing the accession rate into the B-52 navigator career field, it must be shown that another shortage will not arise, as it did in the late 1970s. A shortage occurs when there are insufficient navigators and radar navigators to fill all the designated crew, training, and staff positions. However, there is no career progression model for this career field to determine the adequacy of the manning levels. Therefore, it is difficult to assess the future impact on the radar navigator career field of any changes in the career field, or related career fields.

Scope, Limitations, and Assumptions

The career progression will only be modeled from Combat Crew Training School (CCTS) graduation till the end of connection with flying status. No effort will be made to model the prior career experiences of prior service members.

No attempts will be made to include effects on retention by pay raises, bonuses or outside economic conditions. These are beyond Air Force control and, given Congressional control, impossible to predict. Retention factors must be included, but will not be connected with a cause.

Objectives

Research Objective The objective of this research is to develop a method to model the progression of the B-52 navigator force through their careers from the end of undergraduate navigator training until the end of their connection with flying status, by separation, retirement, permanent medical grounding, or promotion and assignment out of flying duties. This method is intended to indicate the general results of policy changes that affect the B-52 navigator career field. This will not attempt to forecast the exact results that might occur.

Subsidiary Objectives To accomplish this research, the manning levels in the career field must be examined under a variety of conditions. Not only the resulting steady state conditions, but also the dynamics of the transient states are of interest. The specific conditions to be examined are:

1. The current manning levels and assignment policies. This provides a baseline for comparing the subsequent runs.

2. The current manning levels and assignment policies with the elimination of some positions due to the creation of the AFSC 19xx Operations career field. The positions eliminated will be eliminated over a three year period.

3. Variations on the current retention rate. The retention rate will not change for those with commitments, but can vary for more senior personnel. The current aggregate retention rate for radar navigators in all positions is 95 percent. The effects of varying this in a range from 91 to 97 percent will be studied.

4. The conditions necessary to increase the crew force from a crew ratio of 1.29 to 1.7. As the remaining B-52s acquire more of a conventional role the increased workload will require more crews.

5. Changing the policy of allowing career broadening assignments after meeting the six year flying gate to not allowing them until the nine year gate is met.

Data Requirements To accomplish this research, much information must be acquired from the personnel offices that control the B-52 navigators' careers. This information is:

1. The possible career progression routes the navigators can take.

2. The number of crews required to fully man the B-52s in the inventory.

3. The number of B-52 radar navigators required for training and staff positions.

4. The number B-52 radar navigators in career broadening positions out of SAC at any given time.

5. The retirement and separation rates for B-52 navigators and radar navigators.

6. The training rates for new navigators, and for upgrading navigators to radar navigators.

7. The impact on the numbers of navigators and radar navigators required of any future force changes such as the creation of the Operations career field, and full operational capability of the B-1B.

This information will accurately define the current state of the career field, and allow modeling the career field mathematically. The known future force changes will be input into the model at the appropriate times to evaluate their impact on the future state of the system.

Terminology

The following are some terms used throughout this study that may not be familiar.

AFSC - Air Force Specialty Code - A four digit code indicating the career field associated with a given job. The AFSC may also have a prefix and/or a suffix to further define the job. The AFSC for the B-52 navigator career field is 1525 A and C. The A suffix designates the B-52 navigator, the C the radar navigator.

Accession Rate - The number of new navigators trained each year in the B-52 as B-52 navigators.

CCTS - Combat Crew Training School - The school at Castle AFB which trains new navigators in the B-52, and upgrades most of the navigators to radar navigators.

CFIC - Central Flight Instructor Course - The school at Castle AFB which trains radar navigators to be instructor radar navigators.

Crew Ratio - The number of crews authorized to be formed for each B-52 in the force. This does not include the aircraft at Castle AFB used for training. With a crew ratio of 1.29, 288 crews are authorized. A crew ratio of 1.7 requires 379 crews.

Flying Gates - Flying personnel are required in the first 12 years of active duty to accumulate a minimum of 6 years of active flying. This is the six year gate. To continue drawing flight pay to 22 years of active duty the flyer must accumulate 9 years of flying time in his first 18 years of active duty. This is the 9 year gate. To draw flight pay until 26 years of active duty, the flyer must accumulate 11 years of active flying in his first 18 years. This is the third and last flying gate (2:12).

MPC - Military Personnel Center - The Air Force Agency located at Randolph AFB responsible for maintaining all personnel files for active duty personnel, conducting promotion boards, and determining assignments for all personnel.

Operations Career Field - A new career field created in 1986 to handle many of the miscellaneous staff positions that do not require rated exoerience. The career field is designated by the AFSC 19xx. Positions covered by this new career field include many of the Command Post and Base Operations positions that have normally been held by rated personnel.

PME - Professional Miltary Education - Various courses at various locations taken after selection for promotion to major. The length of the course is less than a year. After the assignment, the radar navigator can either go back to a flying job, or to a career broadening assignment.

RNUP - Radar Navigator Upgrade - The training that allows a navigator to become qualified as a radar navigator.

RPI - Rated Position Indicator - A single digit code that indicates the level of the job, and the flying duties associated with it.

SAC - Strategic Air Command - The command in the Air Force that owns and operates the B-52 force.

WST - Weapon System Trainer - The new simulators for the B-52 located on some of the B-52 bases. Due to the complexity of the simulators, they have a small staff of instructors to serve as console operators.

II. Literature Review

Headquarters SAC

Currently there are two methods in use to predict the future manning status of the B-52 navigator career field. The simpler of these is used by Headquarters SAC as a crosscheck on the input numbers provided by the Military Personnel Center (MPC), and to determine the number of upgrade slots to offer the units each year. This method is a simple addition-subtraction model (10). The source of this program is a dynamic programming model with a stage representing a year. At each stage several decisions must be made. These include the number of navigator accessions from undergraduate navigator training (UNT), the number of navigators to upgrade to radar navigators, and the number of navigators and radar navigators to release to career broadening assignments. The advantage of this method is its simplicity, however, it suffers from a lack of fidelity: it cannot model the system in as great a level of detail as the MPC model.

Military Personnel Center (MPC)

The model used by MPC is called the Consolidated Absorption Analysis Model (CAAM) and attempts, by a mathematical solution with 169 variables, to accurately predict the manning requirements (10). The MPC CAAM program is a new model that attempts to use past flow data to predict absorption rates. The absorption rate is the maximum accession rate into flying positions that can be handled. This rate is determined by the experience level in the flying positions. The data in this model is intended to cover the past five years, but currently only covers the past two years (4:3-10). Consequently, SAC's planners do not fully accept the results, but use their own model (17,10). The results of the two models are generally similar, but not in total agreement (10). Both models are entirely deterministic, and do not allow for random chances such as being unable to fill a school slot because of low manning. They also concentrate on the navigators and radar navigators currently in flying positions. Neither model looks beyond the experience necessary for training new navigators in the B-52. The number of radar navigators qualified to fill the variety of staff positions available needs to be included to determine the capability to support the staff positions. The Navy has also studied methods for better managing its flying personnel.

Naval Aviator Study

The Air Force and SAC are not alone in the problems of managing flying personnel as evidenced by this quote by F. E. O'Connor from his study of the Naval Aviation personnel system:

> The problems evident in 1978 were not unique. Surpluses or shortages of Aviation Officers sufficient to cause dramatic changes in

> distribution patterns have occurred every 5 to 7 years since the mid 1950s. . . . The phenomenon is cyclic and is driven, at least in part, by forces outside the control of manpower planners. However, the increasing severity of these episodes over time suggests that manpower planners have lacked the tools necessary to evaluate the long term impact of their decisions. (12:2)

The result of O'Connor's study was a network formulation of the possible career paths for the aviators (12:18). O'Connor was unable to solve the resulting network as a linear programming problem due to the complexity and the inability to completely specify all the arcs necessary for a solution. Therefore, instead of a mathematical solution, he took the route of iteratively adding in accessions from flight training to satisfy the end conditions needed in each possible career path until enough new officers were starting to satisfy steady state conditions in the network (12:20). This approach works, but is cumbersome for making multiple runs, for example when comparing the results of several possible force changes.

Summary

There currently are several models available for this study. The two currently in use by MPC and SAC are inadequate in that they do not look at the experience required outside of flying positions. The Navy study is a promising start, but it needs a computationally easier solution technique to ease sensitivity analysis and parameter exploration.

III. Methodology

Model

Network Description In his naval aviation study, O'Connor noticed the network aspects of the career field, and was able to formulate a network representation of the system. Due to the complexity of the system, he was unable to solve it mathematically, but was able to complete the network through a series of iterations.

Cross-sectional Model The formulation derived by O'Connor is what is referred to by Richard C. Grinold and Kneale T. Marshall as a cross-sectional network model (7:18). A cross-sectional model is a network model that takes no account of the time spent in a given position. The cross-sectional model traces the net flows throughout the network (7:19). For the sake of convention, in all the network models state zero is the condition of being outside the system under consideration. Systems in which the length of time spent in a given state affects the movement out of the state require a different model.

Longitudinal Model In a longitudinal model the length of time spent in a given state affects the positions that can be moved to for the next time interval (7:91). To accomplish this requires the use of a node for each time interval spent in a given state. This increases the number of nodes and arcs in the network many fold. O'Connor encountered problems solving a cross-sectional model mathematically (12:18), with a longitudinal model these problems will increase. Figure 1 depicts a simple cross-sectional network diagram. This network has 5 nodes and 15 arcs. For simplicity no arrows are shown on the arcs. It must be understood that the flow on the arcs only moves from left to right, from time t to time t+1. Figure 2 depicts the same network as a longitudinal model and has 12 nodes and 38 arcs. The increase in nodes and arcs requires more equations to fully define the system.

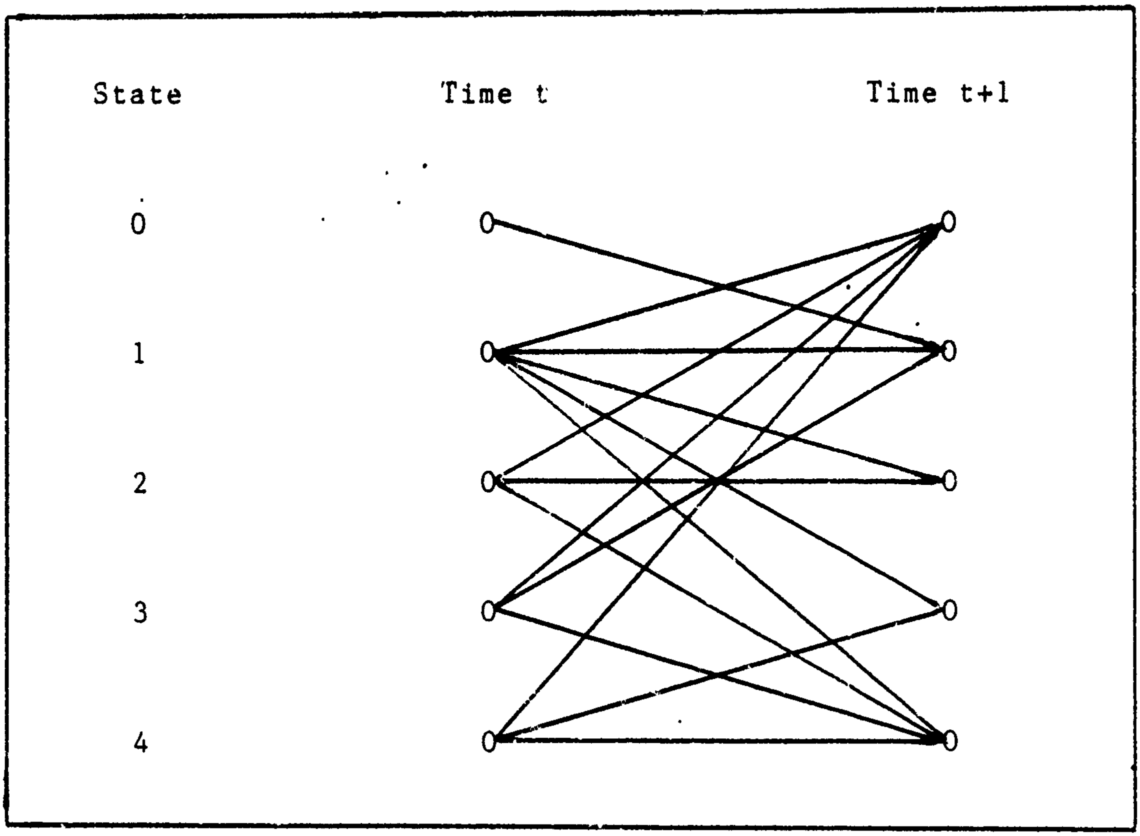


Fig. 1. Cross-sectional Network Flows.

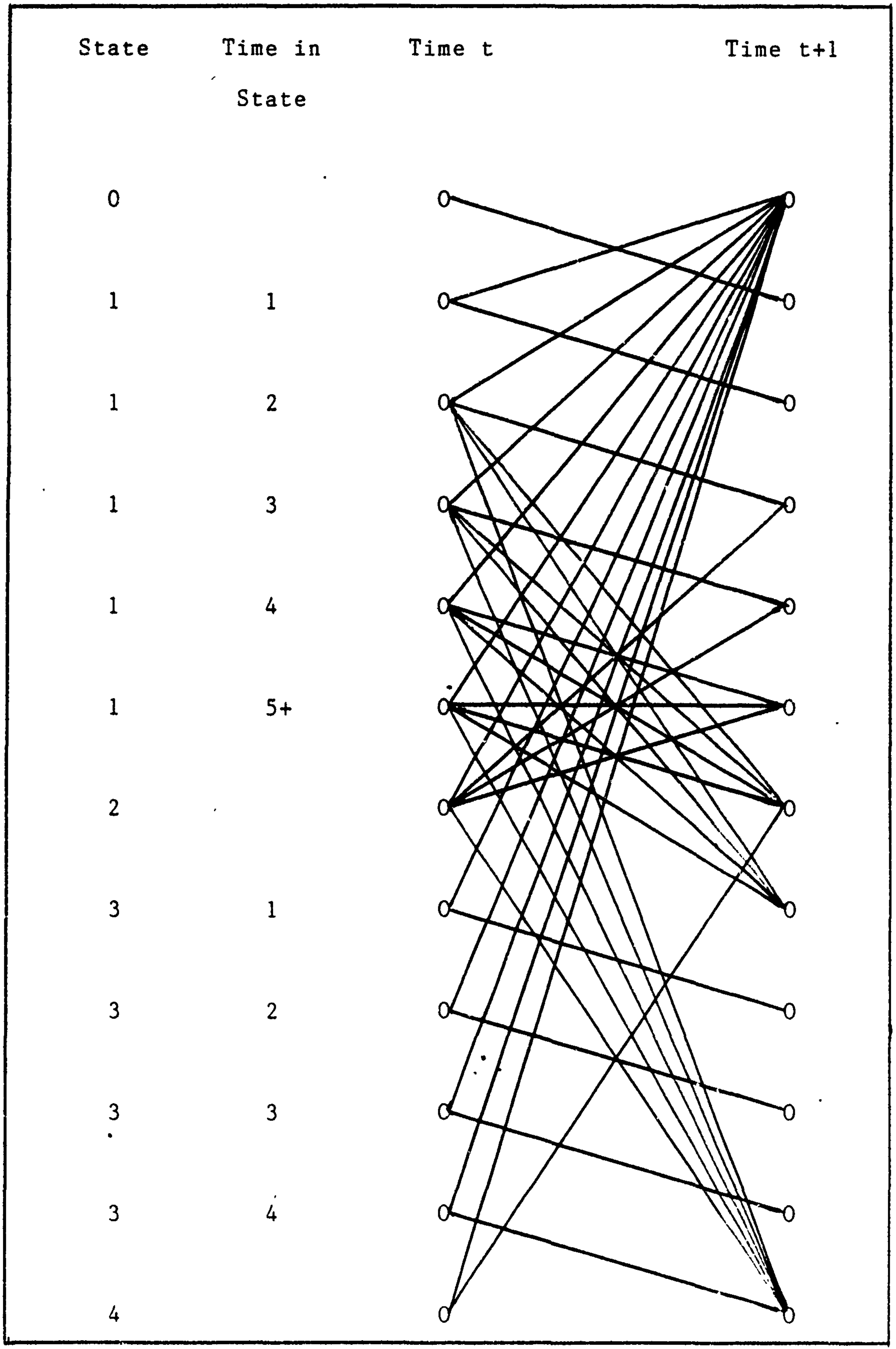


Fig. 2. Longitudinal Network Flows.

Implementation This study uses a network simulation to study the system dynamics. The advantages of the simulation are the ability to track individual people through the career field, to induce policy changes in the middle of a run and to model system changes because of the attributes of a single entity. The disadvantage of the simulation is that it is not an optimization technique. To determine an optimal policy would require many trial and error runs. A better method to determine an optimal policy is to use an optimization technique such as linear programming (13:201).

Linear programming has the advantage of being able to provide the optimal policy to follow given a specific set of conditions. The solution should remain valid as long as the conditions remain unchanged. Linear programming provides a "steady state" solution. That is, over time the career field will maintain the same numbers of navigators, radar navigators, instructor radar navigators, and staff personnel. Once a steady state condition is established the system should remain in it unless the system is perturbed. The disadvantage of linear programming is the inability to model actions on the entity level of the system. For example, it is impossible to model the accrual of flying credit toward meeting the three flying gates.

Since these two methods are complementary, they will be used to examine different aspects of the problem.

Linear Programming Formulation A network diagram can be formulated as a linear programming model (8:242).

The solution obtained will be the optimal steady state condition based on the objective function used. The objective function of the system is to minimize a subset of the decision variables. Likely candidates for the objective function in the radar navigator career network are the numbers of navigators, radar navigators and instructor radar navigators to hold down personnel costs, plus the number of upgrades going on to minimize the training costs. This minimization will be subject to a set of constraints. The constraints on the system will consist of bounds on the size of the stocks in each state, limits on the flows in and out of the various states, and various other relationships between these variables.

Simulation Implementation Once the network is set up, it is easy to visualize the people in the career field as entities flowing through the network. The set of possible jobs and the possible paths between them can then be considered as a system. The state of this system changes any time one or more people change jobs. With a set of rules specified for job changes this system fulfills the requirements for a discrete event network simulation (14:6).

System Structure

System The B-52 radar navigator career field consists of crewmembers in several categories: the force structure, the instructor force, and the staff positions. The force structure consists of those navigators, radar navigators, and instructor radar navigators that are on crews at the various SAC bases. The instructor force consists of those instructor radar navigators assigned to aircrew training positions such as CCTS and CFIC, and those operating the Weapon System Trainers. The third category, staff positions, consists of those individuals from the career field currently filling any of a number of staff and school positions.

Entities The individuals in the three categories are the entities in the simulation system. They "flow" through the network from position to position ver time according to a set of rules governing the eligibility for the position changes. These rules include rules on what moves are permissible, manning requirements, and loss rates from the system. In the real system these movements are governed by Career Managers at the Air Force Military Personnel Center and at Headquarters SAC. In the simulation model each entity is endowed with a set of "attributes" that distinguish it from all other entities. These attributes relate directly to attributes possessed by the individuals in the real system and include time in service, months flying credit, time accumulated toward fulfilling flying commitments incurred for upgrade training, and tour length for staff and school positions. Movement between positions in this model will be determined by testing these attributes for meeting certain conditions, and by random draws.

Movement Aircrew members are limited in the position changes they may make. Out of the first twelve years a new navigator must spend a minimum of six years in a flying position (2:12). These six years will normally be consecutive starting with undergraduate flying training. The only exception is for a few exceptional performers to attend the Air Staff Training Program (ASTRA) for twelve months. After meeting this six year flying "gate," more opportunities arise for career broadening. Most career broadening assignments will go to instructor radar navigators rather than navigators or radar navigators (11).

Navigators After completing undergraduate navigator training (UNT) the new navigators go to Combat Crew Training School (CCTS) at Castle AFB. Six months of training prepare them to go to a B-52 unit. Because of variations in the time taken to complete CCTS and get to their gaining units, the arrivals at the units can be modeled as random. For the simulation model, this was modeled as an exponential interarrival time. The training rate at Castle AFB is currently 150 new navigators each year, or approximately 12 to 13 per month. Once the new B-52 navigator arrives at the unit, he will spend a minimum of two years at his first unit gaining experience, unless for some reason he exits the career field. Reasons for these premature losses are basically unforeseen problems: medical grounding, accidental death, and nonselection for promotions. After approximately two years several opportunities become available.

<u>Other Aircraft</u> Currently 36 navigators per year crosstrain into other aircraft. These aircraft include the B-1B and FB-111A. For the purposes of this study of B-52 crew members, these 36 navigators exit the system each year.

<u>Air Staff Training Program (ASTRA)</u> Every year approximately 4 navigators are chosen for a year of training at the Pentagon in ASTRA. After this twelve month program, they return to flying duties.

<u>Air Training Command (ATC)</u> SAC is maintaining 60 B-52 navigators at Mather AFB as ATC instructor navigators This is a four year controlled tour, so approximately 15 navigators per year are required to fill the openings. After the four year tour, most of these navigators return to the B-52 as radar navigators.

<u>Radar Navigator Upgrade (RNUP)</u> Most experienced navigators undergo RNUP training at Castle AFB to upgrade to radar navigator. This is a four month training program, after which the new radar navigator returns to his unit. Currently 108 navigators per year upgrade to radar navigator, 9 per month. Consequently, at any one time 36 navigators are in the process of upgrading to radar navigator.

<u>Summary</u> Figure 3 depicts a cross-sectional network diagram for the navigators and their possible movements.

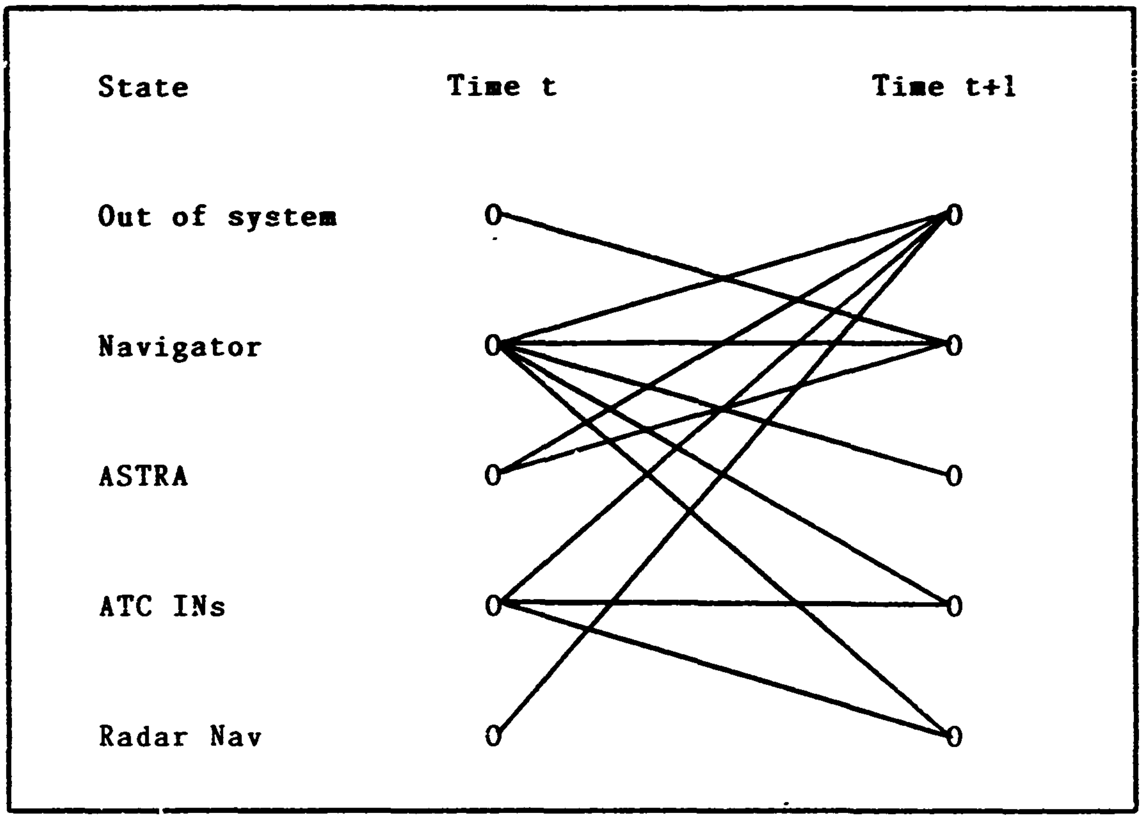


Fig. 3. Navigator Cross-sectional Network Flows.

Radar Navigators After completing RNUP training the new radar navigators will spend a minimum of one year in that position before any further changes are made unless they leave the career field through separation or medical grounding. After the first year there are again a variety of positions that may be filled.

Other Aircraft Radar navigators also have the opportunity to crosstrain to other aircraft. These are principally the B-1B and FB-111A. Radar navigators crosstraining to these are lost to the B-52 career field.

ASTRA Every year a small number of radar navigators are chosen to attend one year at the Pentagon for the Air Staff Training program. After one year there, they will return to flying duties.

Staff Positions A large number of staff positions exist that require a minimum of a radar navigator. Most will be filled by former instructor radar navigators due to their greater experience.

Central Flight Instructor Course (CFIC) Every month CFIC has seven openings for radar navigators to upgrade to instructor radar navigator. This upgrade commits the new instructor to another 18 months of flying duty.

Summary Figure 4 adds in the radar navigators to the cross-sectional diagram to show the additional movements possible.

Instructor Radar Navigators (IRNs) After completing CFIC, the new instructor radar navigator is committed to spending another 18 months in a flying position. This time might not all be spent on a line crew. Instructors may be given the chance to serve on a Standardization/Evaluation crew as a flight examiner, or might get a chance to work in the wing Bomb/Nav shop in a flying position. A large number of the IRNs are in training positions, either as instructors at CCTS and CFIC at Castle AFB, or as console operators at the various Weapon System Trainer (WST) locations. Once an IRN gets a total of six years of flying credit ("meets the six year gate") he becomes eligible for the full range of broadening assignments available.

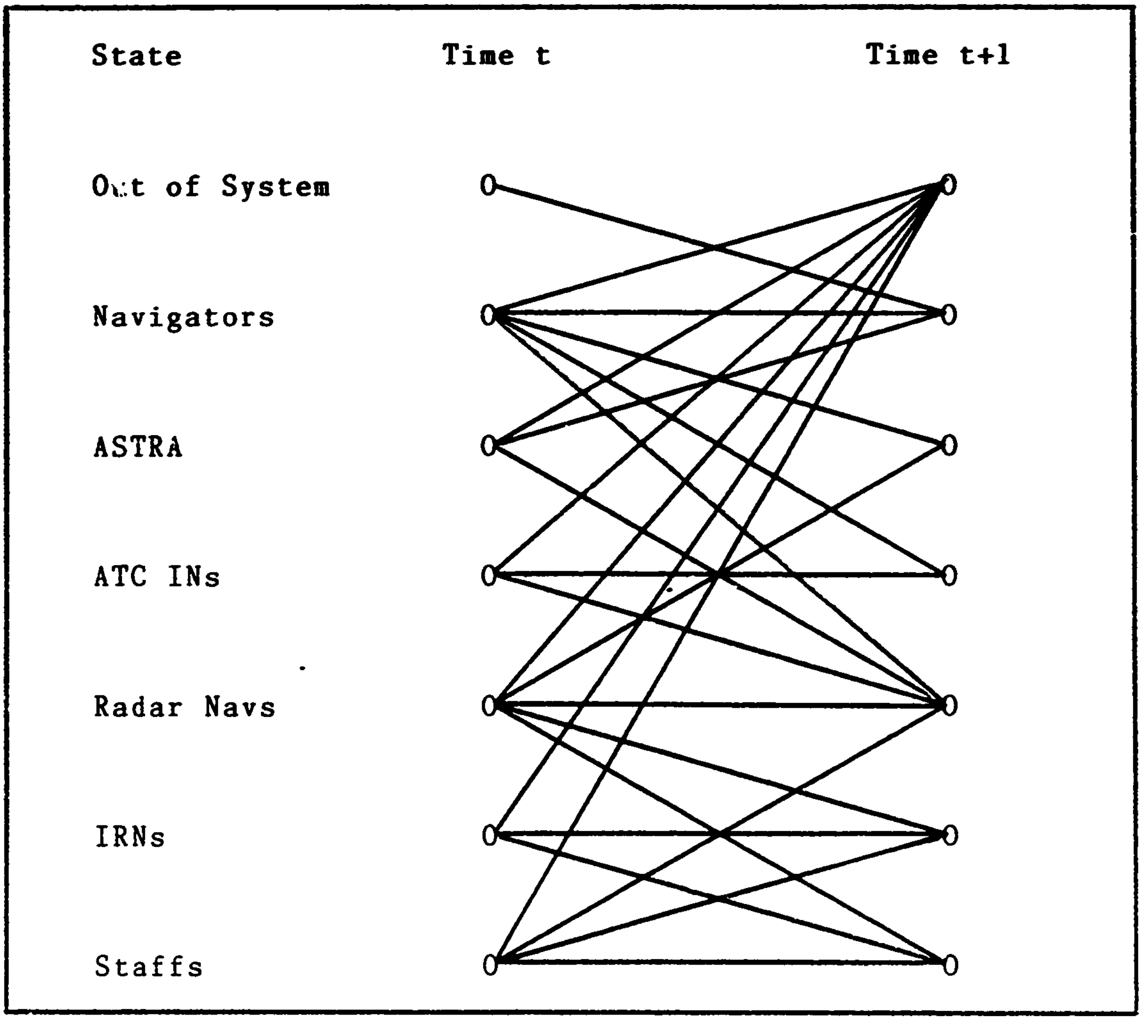


Fig. 4. Navigator and Radar Navigator Network Flows.

<u>Air Force Institute of Technology (AFIT)</u> At any one time, up to eight radar navigators and instructor radar navigators may be studying for an advanced degree under the auspices of AFIT. This takes 18 months. Afterward, these graduates will normally spend three to four years in a nonflying position that requires this advanced degree.

SAC Staff The staffs at Headquarters SAC, and various lower headquarters in it have 135 slots specifically for RNs/IRNs. This does not include the approximately 130 slots at wing level. Most SAC staff positions are three year tours. Subsequent jobs may be back to the cockpit, or to other staff jobs.

General Staff There are also staff positions throughout the Air Force that require any navigator to fill them. These include positions at Command Posts in all the commands of the Air Force. Due to the number of B-52 navigators, SAC is allocated 195 of these positions to fill. Most of these are three year controlled tours. Due to the introduction of the AFSC 19xx Operations career field, B-52 navigators will lose 35 general staff positions over the next three years (9).

Professional Military Education (PME) After promotion to major, a possibility exists to attend PME in residence. Approximately 35 RNs/IRNs are chosen for this each year. These 35 will spend somewhat less than one year at school before proceeding to their next assignment.

Separate Operating Agencies The various separate operating agencies in the Air Force need 60 B-52 RNs/IRNs to fill the technical positions that also require rated experience. These positions are three to four year tours. Typical of such jobs is being an analyst for strategic aircraft tests at the Air Force Operational Test and Evaluation Center (AFOTEC).

Pentagon The Air Staff and Joint Staff need 37 RNs/IRNs for three to four year tours of duty in the Pentagon.

Rated Supplement The rated supplement is a collection of various positions in the Air Force that do not require any rated experience, but that are filled by rated personnel to provide an experienced pool that can be drawn upon as needed. SAC is currently attempting to maintain 130 RNs/IRNs in this pool.

Summary Figure 5 depicts the resulting cross-sectional network diagram for this career field. This diagram consists of 13 nodes and 95 arcs. It is possible to convert this diagram into a longitudinal diagram which consists of close to 50 nodes and over 300 arcs. Many of the nodes in this longitudinal model are too similar to distinguish between with the equations that may be written. Since there is not enough information available to distinguish between these nodes, further work with the network formulation for the linear programming and simulation approaches will be done from the cross-sectional diagram, Figure 5.

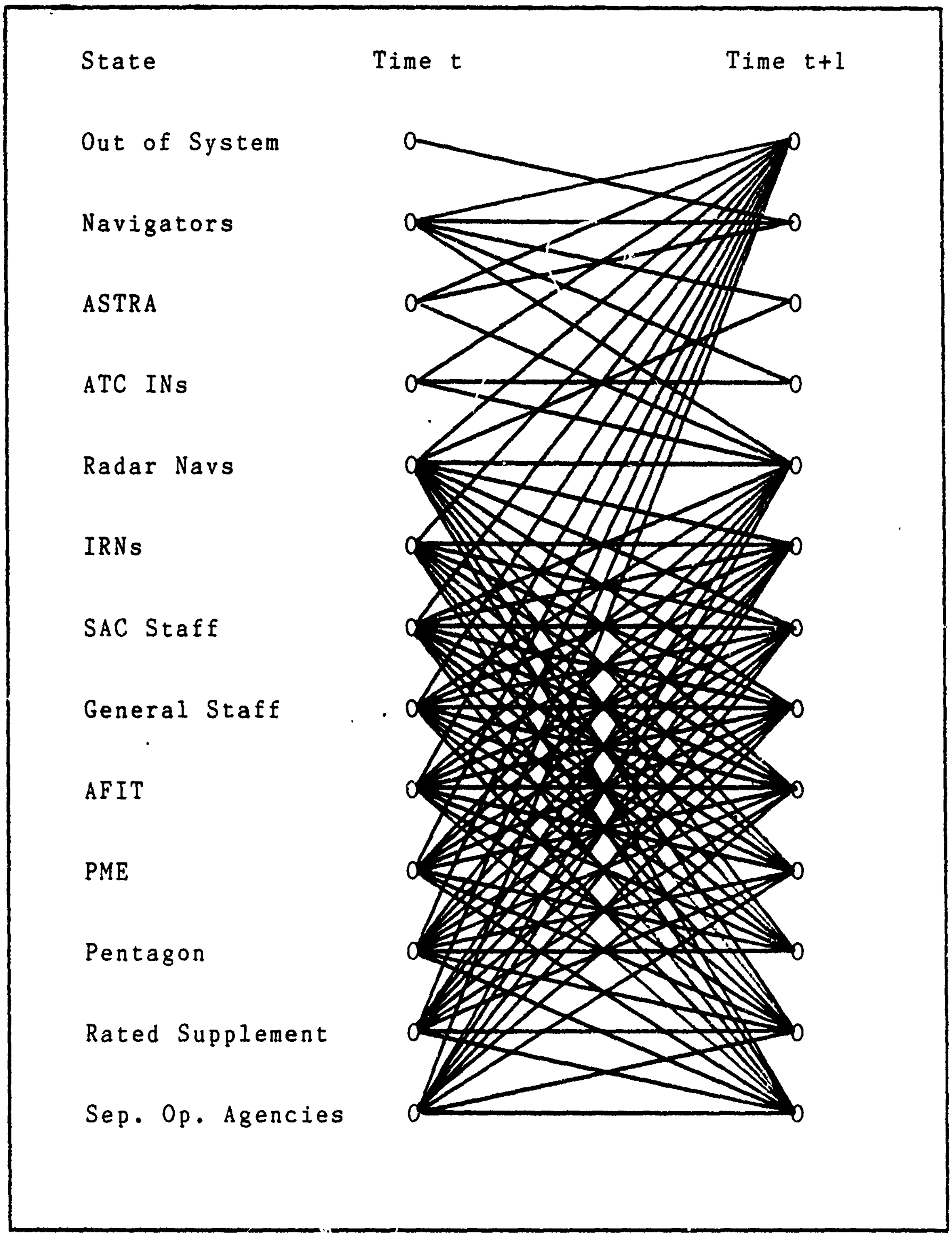


Fig. 5. Network Flow for Entire Career Field.

Method

Linear Programming Once the network is drawn up, it is a simple matter to convert it to a set of equations for constraints. The linear program uses variables for every manpower level and flow in the system. A simple example can be demonstrated using Figure 1. The manpower levels in states 0 through 4 are designated as variables S(0) through S(4). The flow from one state i to another state j is designated as variable f(ij). Using state 1 as an example, the development of constraints may be demonstrated. At any time t, the flow of people into the state is represented by the sum of all the flows into the state, and must equal the manning level at time t, S(1). Therefore:

$$S(1) = f(01) + f(11) + f(31)$$

Or:

$$f(01) + f(11) + f(31) - S(1) = 0$$

Similarly, approaching time t+1 all the people in state 1 must flow to another state for the next time increment. This requirement yields the equation:

$$f(10) + f(11) + f(13) + f(14) - S(1) = 0$$

Other types of equations derive from various relationships between the variables. Once the equations are determined, the variables may be renumbered from the mnemonic variables used during the formulation to the subscripted X variables used in the linear programming package. Equations such as these have been developed for the system, and are contained in Appendix A.

The linear programming (LP) problem will be solved using the ADBASE package by Ralph Steuer (15). ADBASE is a multiple objective linear programming package, but may be used to solve single objective linear programs as well. The program was set to obtain an optimal solution from the one objective function (15:259). Appendix A contains the variables and constraints developed for the linear programming model. The LP model will be run under the current manning situation for a reference. The LP model will then be run with 35 fewer general staff positions to reflect their loss. The LP model will then be run with varying separation rates. The separation rate is the difference between the retention rate and 100 percent. If there is a retention rate of 95 percent, then 5 percent are separating for some reason. The baseline model has a separation rate for radar navigators with no commitment of five percent. The other rates to be examined are three, seven, and nine percent. The last condition to be examined with linear programming is that needed to maintain the larger crew force necessary to have the B-52s assume a conventional role.

Simulation The simulation model is made by visualing individual entities flowing along throughout the network. The routes they may take are restricted by various conditions, and by some of the attributes possessed by the individual entities. These attributes include the flying time and total time in the system. The simulation program will keep track of these attributes for all the entities and perform conditional testing with these attributes to determine the available paths for the entities to follow. The simulation model will be formulated in the Simulation Language for Alternative Modeling (SLAM) to take advantage of its capability to handle network programs (14). Since the people in the system are represented by entities, the job categories are represented as activities. Conditional testing of attributes determines which entities are eligible for which jobs. As the attributes of an entity change they are updated by assigning the new value to the entity. Appendix B contains the SLAM network diagram for this model. Appendix C contains the actual SLAM code. Because of the long time required for a new navigator to become an instructor radar navigator, all runs of the SLAM model will be made for a period of ten years. This allows time for policy changes to take effect, and for the resulting crew force to mature and show the effects of the policy changes. Like the LP model, the simulation model will be run under varying conditions. These conditions will be the same as those for the linear programming model, with one addition. Since the simulation is capable of modeling time diretly, the effects of delaying career broadening assignments until after meeting the nine year gate will be examined.

IV. Verification and Validation

Building a conceptual model, then translating it to a mathematical model, does not necessarily lead to a definitive solution. The mathematical model must be shown to correspond to the conceptual model of the system. Once these two agree, it must be shown that this conceptual model reflects the actual situation. This is the process of verification and validation. Although listed as separate, sequential actions, they in reality occur throughout the entire model development. For example, if during validation the need for a change is discovered, the model must be changed. After changing the model, it must be once again verified to prevent it from causing unwanted changes in another portion of the model.

Verification

Verification is "the comparison of the conceptual model to the computer code that implements that conception" (1:376). Banks and Carson list a set of procedures to follow during verification of the model. Some of the steps are as follows:

1. Have others check the code.
2. Check outputs for reasonableness under a variety of settings.
3. Use a flow diagram.
4. Document the code.

(1:379)

These steps have been accomplished for this model. The outputs were examined under a variety of conditions: higher and lower retention, higher and lower accession rates. For the simulation model these conditions showed the manpower stocks increasing with higher retention and accession rates, and decreasing with lower rates. The linear programming model showed the lower accession rates required when the retention was high, and higher accession rates when retention was low. All these results were entirely reasonable. The flow diagram used to aid in drawing up the computer codes was that shown in Figure 5.

Another source of information for verification is given by Forrester and Senge. Among the methods they recommend are the structure and parameter verification tests (6:211-217). The structure verification test relates closely to Banks and Carson's recommendation to have others check the code. Forrester and Senge recommend not only the modeler verifying the structure of the model, but also " ... others with direct experience from the real system" (6:212). It has been possible to have other former B-52 crewmembers examine the structure of the model and verify that it resembles the real system.

Verifying the parameters is also a simple procedure. In this case, though, it turned up a small problem initially. The separation rates were obtained from Headquarters SAC (10), but did not include the number of radar navigators leaving the career field after finishing all eleven years of flying status for the last gate. It proved easy to incorporate conditional testing into the simulation model to handle these situations. The linear programming model does not handle individual entities, so it cannot be handled directly. To handle the problem in the linear programming model requires the use of a pseudo separation rate calculated to include the number meeting the last gate each year. The information needed to calculate this information may be obtained from the simulation model if unavailable from other sources.

Validation

Validation is the process of " ... determining that a model is an accurate representation of the real system" (1:377). Banks and Carson again have several suggestions for validating models. Two of these are to construct a model with "high face validity," and to compare the input-output transformations with the real system (1:385).

To ensure face validity for the model requires the participation of other knowledgable people. This step then is closely related to the verification step of having others check the computer code. One primary source for this was the personnel office in Headquarters Strategic Air Command.

Confirming the accuracy of the input-output transformations is similar to Forrester and Senge's behavior prediction test (1:396, 6:219). Since the model should predict the future behavior, a set of circumstances can be induced in the model that has or will occur in the real system. Comparing the results in the two will give an indication of the validity of the model. An example for this model is the creation of the AFSC 19xx career field. When the expected force changes were input into the system the results reflected what is expected to occur in the real system as the changes go into effect in the next three years (9).

Another test listed in Forrester and Senge is the surprise behavior test (6:221). For a considerable period of time the personnel offices at headquarters SAC have been saying "We cannot maintain that many people out of the cockpit for that long a time." (10,17). The initial runs of the linear programming model showed the system of constraints to be infeasible. This indicated a solution to the problem with the conditions imposed on it did not exist. By allowing the optimal stock levels in the career broadening areas to vary from the desired made the problem feasible. The one constraint preventing feasibility turned out to be the high number of rated supplement slots. This showed remarkable similarity with the remarks from the manpower offices, showing this model accurately reflected the real system.

Forrester and Senge also include an "extreme policy" test for the model. This test looks at the systems behavior at the fringes of permissble actions (6:221-222). Currently retention in the B-52 radar navigator career field is at its historic high. When the system was run with even higher retention, the model predicted that a lower accession rate would be needed, and that new navigators would need to spend more time as B-52 navigators before upgrading to radar navigator because of fewer openings for them. The first result was the anticipated answer, the second was somewhat surprising, but after examination is entirely reasonable.

Summary

Several tests for verification and validation have been examined and applied to the two models in use here. The application of these tests resulted in some changes in the models, but also indicated a strong resemblance between the models and the real system being modeled. These results indicate the usefulness of these models to the planning of accession and training rates in the real system.

V. Results

It has been possible to examine the system dynamics and optimal crew force structures under a variety of conditions. The linear programming solution provides the optimal steady state condition for the system. This steady state provides a replacement training rate and keeps the system in the same state. In other words, at any time the system will consist of the same number of navigators, radar navigators, and staff members. In the simulation runs, the current state was perturbed by a change in conditions. By changing the policies followed by the system, such as training and accession rates, steady state conditions were reimposed on the system. In all cases, after inducing a change in the steady state conditions, it was possible to reinstate steady state conditions. It is these conditions necessary to re-establishing a steady state condition that are of interest to this study.

Current Conditions

The linear programming solution under the current conditions is quite similar to the current force, except for the optimal linear programming solution needing a lower number of navigators and higher number of radar navigators compared to the current force structure. The accession rates and upgrade training rates are quite close to todays actual rates. There are currently 150 new navigators training in the B-52 every year, and 108 navigators upgrading to radar navigator. Since approximately 15 of these upgrades come from the navigators at ATC, the rate from B-52 navigators is approximately 93 per year. The optimal force has 296 navigators who spend an average of two and a half years as a navigator before upgrading to radar navigator. The simulation solution shows, starting with today's 350 navigators, a gradually decreasing number of navigators and an increasing number of radar navigators and instructor radar navigators. This will tend to correct today's surplus of navigators and deficit of radar navigators and instructor radar navigators over a period of time. These results are summarized in Table I. The indications from both models, then are that the career field is currently moving to a more stable manning situation. However, these results do not include the effects of planned future force changes.

TABLE I

Comparison of Current System With Models

	Navigators	Radar Navs	CCTS Rates	RNUP Rates
Current Crew Force	359	445	150	108
Linear Programming	296	424	135	84
Simulation Model	339	450	150	108

Planned Changes

The career field currently has several force changes planned for the near future. Examples of these are the creation of the operations career field, and the reduction of the B-1B draw on the B-52 crew resources. By including these changes in the models, their impact may be estimated. Both solution techniques indicate no change from the present due to the loss of 35 staff positions due to the creation of the Operations career field. However, the reduction in the number of radar navigators and navigators cross-training to the B-1B has a major impact on the B-52 training rates required. If the cross-flow to the B-1B is completely eliminated, an accession rate of 100 and an upgrade rate of 90 will result in a modest surplus of B-52 crewmembers as shown in Table II. It is doubtful that the cross-flow will be reduced to zero even after UNT graduates are accepted directly into the B-1B. Therefore, this modest surplus will be reduced or eliminated, resulting in a steady state crew force, as long as current retention rates continue.

TABLE II

Comparison of Current System With Planned Changes

	Navigators	Radar Navs	CCTS Rates	RNUP Rates
Minimum Required	288	424	---	---
Current Crew Force	359	445	150	108
Linear Programming	296	424	115	60
Simulation Model	329	510	100	92

Retention

The retention rate may vary only after the initial commitment is fulfilled. This prevents changes in retention from affecting the navigators and junior radar navigators. More senior radar navigators, instructor radar navigators and members of the staffs may resign and retire at varying rates. Since the current five percent loss rate is historically low, the rate will probably only increase. However, variations on the loss rate up and down have been examined.

Higher Retention A loss rate of three percent was examined with both models. This generally resulted in fewer accessions required each year, and lower upgrade rates. Both models indicated that the navigators must spend approximately three years as a navigator before upgrading to radar navigator due to the lowered loss rate. Then, due to the longer time spent as a navigator, fewer new navigators are required each year. If the training rates were not decreased, the crew force would slowly grow, and career broadening opportunities would decrease due to the increased competition for them. An accession rate of 140 and an upgrade rate of 90 per year are required to maintain steady state conditions.

Lower Retention As the loss rate is increased from the current five percent, the results become more pronounced. At loss rates between five and seven percent, there is no significant change in the crew force structure. At a loss rate of seven percent, the force levels can be maintained easily by slightly increasing the accession rate to 160, and having navigators spend a little less time before upgrading to radar navigator. As the loss rate is increased to nine percent, action must be taken to prevent shortages in the instructor radar navigator force. The linear program shows a need to decrease the time spent as a navigator to approximately two years, and increase the accession rate to 175 new navigators per year. An upgrade rate of 135 per year is also required for this scenario. If the B-1B draw on the crewforce is lowered in this time period, it will partially compensate for the increased resignations. A problem with this result, is that the minimum time for a navigator to upgrade to radar navigator is two years because of the minimum flying time requirements. Not all navigators are ready to upgrade to radar navigator at this time, so a larger navigator force would be required to support an average time to upgrade of two and a half years. A navigator force of 362 will support the average of two and a half years to upgrade to radar navigator, and will require approximately 175 new navigators each year, with a total upgrade rate of 135 per year. Table III summarizes the effects of retention on required force sizing and training rates required.

TABLE III

Comparison of Various Loss Rates

Loss Rate	Navigators	Time to Upgrade	Radar Navs	CCTS Rates	RNUP Rates
3 %	329	3	454	140	90
5 %	339	2 1/2	450	150	108
7 %	358.	2 1/4	475	160	108
9 %	362	2 1/2	439	175	135
9 %	327	2	464	175	135

Crew Ratio

The number of crews authorized per airplane is currently 1.29 giving a total authorized crew force of 288 crews. A possible future course of action is to increase the crew ratio to 1.7 to allow an increased conventional role for the B-52s in the Air Force. This requires a force of 379 crews, an increase of 91 crews. Because of the training positions for instructor radar navigators, 500 radar navigators are required for the increased size. However, due to the current surplus of navigators, only 100 additional crewmembers are needed. Both methods suggest this increase can be accomplished within a period of two years by temporarily increasing the accession rate to 200 and the upgrade rate to 120. Once the crew force reaches the new desired size, the accession rate may be reduced back to 150 and the upgrade rate to 108 to maintain the new force size. Since this increase in the crewforce is being accomplished by bringing in more younger crewmembers, after seven years the number of radar navigators and instructor radar navigators eligible to resign after fulfilling their commitments will increase. This will then require a further adjustment in the training rates at that time to prevent a decline in the crewforce.

TABLE IV

Comparison of Crew Ratios

Crew Ratio	Navigators	Radar Navs	CCTS Rates	RNUP Rates
1.29	339	450	150	108
1.70				
First 2 Years	Incr.	Incr.	200	120
Next 5 Years	400	515	150	108
After 7 Years	385	515	Approximately 175	135

Delay Broadening

Another option being discussed for making more crewmembers available is to delay all career broadening assignments except ASTRA until after meeting the nine year flying gate. ASTRA assignments cannot be delayed like this because they are only for junior captains. This one year tour must be taken before the seventh year on active duty. Due to the inability of the linear programming model to model flying gate credits, the simulation model was the only model used on this portion. Delaying the possibility of career broadening assignments until after meeting the nine year gate results in an larger number of crewmembers without any other actions being taken, while providing an adequate number of staff members. Table V summarizes the reults of this set of runs. It should be noticed that an adequate force can be maintained with a lower training rate, by maintaining the current training rates a large surplus of radar navigators builds up.

TABLE V

Comparison of Broadening Policies

Gate Met	Navigators	Radar Navs	CCTS Rates	RNUP Rates
6	339	450	150	108
9	363	555	150	108
9	329	450	140	90

Summary

Both models provided information about the current system in the B-52 radar navigator career field and possible future changes. There are differences in the operation of the two models that are reflected by their results and their capabilities. The linear programming model is the more limited of the two: it cannot model time in service or flying gate credit. The training rates it gives are therefore lower than may be expected. By determining through the simulation model the effect of time in service and flying gates on the loss rate, the linear programming results may be corrected for those factors. The simulation model does appear to better portray the operation of the real system.

VI. Observations and Recommendations

Observations

In general, the simulation model has proven more useful than the linear programming model in accurately representing the career field. It has been possible to include all actions, requirements and conditions pertinent to the real world in the simulation model. The linear programming model is not capable of handling all aspects of the system such as the flying gates. The linear program also had a tendency to ignore realistic allocations. For example, when the loss rate was high it would allocate additional radar navigators to staff positions in order to keep the force strength high enough. But it would place all the additional people into one category such as the SAC staff instead of spreading them out. If additional constraints may be generated for the linear programming model, it should be possible to eliminate this problem.

The linear programming model also consistently had lower accession and training rates than the simulation model needed. This was due to the inability to model aspects of time. The linear programming model could not reflect losses from the crew force due to retirement or meeting all gates, resulting in lower than actual accession and training rates. It was possible to compensate for this by comparisons with the simulation model which explicitly models the flow of time and its consequences. The linear programming model, however, did have its positive results. This model provided a good general overview of what is needed in any set of circumstances to maintain a stable crew force. This pointed out when the simulation model was reacting, not to a problem with the inputs, but to an imbalance in the age structure of the crew force. The primary advantage of the linear programming model is as an easy to use planning tool. It is easy to modify the equations in the model, the results are easy to analyze, and it directly reports the steady state conditions for a given scenario. The simulation model then provides insight on what actions are required to get from the current conditions to the optimal steady state conditions shown by the linear programming.

Using these models did point up a problem in attempting to manage this career force. If the retention rate of the personnel having fulfilled their commitments goes down, those getting out need to be replaced immediately. However, it takes one year to train a new B-52 navigator, it takes a minimum of two years to upgrade that new navigator to radar navigator, and another year to upgrade that radar navigator to instructor radar navigator. Therefore there is a lead time required of four years to take a newly commissioned Lieutenant and replace one instructor radar navigator who decides to get out. It is not possible to anticipate four years ahead of time just what the retention rate is going to do. This makes the management of the crew force extremely difficult.

An aid to handling a decrease in retention shown to work in the simulation model is to decrease the amount of time spent as a navigator to the minimum and thereby decrease the lead time required to replace the experienced resources. An increase in the accession rate is also necessary to maintain the desired number of navigators. This prevents the retention problem from getting any worse, but does not improve the conditions until those new navigators age sufficiently to fill any of the positions available. The only aspect not addressed by this model is the length of time it takes to recognize that there is indeed a retention problem. The longer it takes to recognize the existence of the problem, the worse the situation will become.

It was shown that delaying career broadening assignments until after meeting the nine year gate will aid in meeting all manpower requirements. There are, however, three concerns should this become policy that these models are incapable of addressing. First, the use of this policy may be detrimental to retention since some crew members look forward to periodic breaks from crew duty. The additional three years before being able to leave the cockpit may be more than some crewmembers are willing to spend. This could cause the resignation rate to increase. Second, people would be leaving the cockpit at about the time they met the promotion board for major. Only having experienced crew duty is not seen as conducive to chances for promotion by most crew members (16). This may then compound the resignation rate going higher. Third, by enabling crew members to alternate between operational and staff assignments, the members of the staffs are fairly current on the happenings out in the field. By delaying career broadening assignments, it would be possible for the staff members to go from one staff job to another, and lose all connection with the happenings in the field.

Recommendations

There are more actions that may be taken to identify problems in this and other career fields. The first three of these recommendations may be accomplished by the appropriate modifications to these models. The last two recommendations would provide more information to the decision makers and system modelers, and hopefully, enable them to better predict the consequences of decisions affecting this career field.

1. A generic model may be made from this specific model. HQ MPC has expressed an interest in a simulation model for aircrews that may be adapted to other aircraft. This model provides a starting point for those other aircraft. Any other positions that involve an upgrade from one seat to another would be directly adaptable from this model by changing some of the constants. Examples of this are other multiple place aircraft with pilot/copilot or Nav 1/Nav 2 positions.

2. Instead of analyzing the situation, this model could be

adapted to forecasting the requirements. This change would entail changing the accession and upgrade training to be a replacement service. When a loss occurs in the system, the applicable replacement would be provided. By keeping track of the number of replacements needed during the run, a replacement rate could be calculated for the conditions.

3. This model may be enlarged to encompass the entire B-52 crew, not just the navigator compartment. A crew model may incorporate division into individual bases and crews, and determine shortages on a more localized level. To expand the current model to this extent will require information from the SAC Personnel offices on the B-52 Pilot, Electronic Warfare Officer, and Aerial Gunner career fields.

4. A better method of forecasting retention rates is needed. The current method of determining requirements based on the retention rates several years in the future has limitations. If the retention changes significantly from that forecast, there will be manning problems.

5. A determination needs to be made of the impact of delaying career broadening assignments until after completeing the nine year flying gate. If it has no adverse impact on retention, that may be a possible way to provide better manning levels in the crew force. Another consideration for this change is whether it will allow the staffs to be out of touch with the crew force and its requirements.

A. Variables and Constraints for the Linear Program

The following is a list of all the decision variables used in the linear programming model with their physical significance.

Manpower level variables:

Variables	Positions
X(0)	Out of System (OS)
X(1)	Navigators (Nav)
X(2)	Radar Navigators (RN)
X(3)	Instructor Radar Navigators (IRN)
X(4)	SAC Staff (SS)
X(5)	General Staff (GS)
X(6)	Rated Supplement (RS)
X(7)	AFIT, ASTRA, PME (AAP)
X(8)	Separate Operating Agencies (SOA)
X(9)	Air Training Command INs (ATC)
X(10)	Joint/Departmental Assignments (JD)

Flow Variables:

Variables	Flow from	to
X(11)	OS	Nav
X(12)	Nav	OS
X(13)	Nav	Nav
X(14)	Nav	RN
X(15)	Nav	ATC

Variables	Flow from	to
X(16)	RN	OS
X(17)	RN	RN
X(18)	RN	IRN
X(19)	RN	GS
X(20)	RN	RS
X(21)	RN	AAP
X(22)	IRN	OS
X(23)	IRN	IRN
X(24)	IRN	SS
X(25)	IRN	GS
X(26)	IRN	RS
X(27)	IRN	AAP
X(28)	IRN	SOA
X(29)	SS	OS
X(30)	SS	RN
X(31)	SS	SS
X(32)	SS	GS
X(33)	SS	RS
X(34)	SS	AAP
X(35)	GS	OS
X(36)	GS	RN
X(37)	GS	SS
X(38)	GS	GS
X(39)	GS	AAP

Variables	Flow from	to
X(40)	RS	OS
X(41)	RS	RN
X(42)	RS	SS
X(43)	RS	RS
X(44)	RS	AAP
X(45)	AAP	OS
X(46)	AAP	RN
X(47)	AAP	SS
X(48)	AAP	GS
X(49)	AAP	RS
X(50)	AAP	AAP
X(51)	AAP	SOA
X(52)	AAP	JD
X(53)	SOA	OS
X(54)	SOA	RN
X(55)	SOA	AAP
X(56)	SOA	SOA
X(57)	JD	OS
X(58)	JD	RN
X(59)	JD	AAP
X(60)	JD	JD
X(61)	ATC	OS
X(62)	ATC	RN
X(63)	ATC	ATC

The constraints on the system fall into several categories. The first category is that of flow conservation equations. These equations are:

$$X(1) - X(12) - X(13) - X(14) - X(15) = 0$$

$$-X(1) + X(11) + X(13) = 0$$

$$X(2) - X(16) - X(17) - X(18) - X(19) - X(20) - X(21) = 0$$

$$-X(2) + X(14) + X(17) + X(30) + X(36) + X(41) + X(46) + X(54) + X(58) + X(62) = 0$$

$$X(3) - X(22) - X(23) - X(24) - X(25) - X(26) - X(27) - X(28) = 0$$

$$-X(3) + X(18) + X(23) = 0$$

$$X(4) - X(29) - X(30) - X(31) - X(32) - X(33) - X(34) = 0$$

$$-X(4) + X(24) + X(31) + X(37) + X(42) + X(47) = 0$$

$$X(5) - X(35) - X(36) - X(37) - X(38) - X(39) = 0$$

$$-X(5) + X(19) + X(25) + X(32) + X(38) + X(48) = 0$$

$$X(6) - X(40) - X(41) - X(42) - X(43) - X(44) = 0$$

$$-X(6) + X(20) + X(26) + X(33) + X(43) + X(49) = 0$$

$$X(7) - X(45) - X(46) - X(47) - X(48) - X(49) - X(50) - X(51) - X(52) = 0$$

$$-X(7) + X(21) + X(27) + X(34) + X(39) + X(44) + X(50) + X(55) + X(59) = 0$$

$$X(8) - X(53) - X(54) - X(55) - X(56) = 0$$

$$-X(8) + X(28) + X(51) + X(56) = 0$$

$$X(9) - X(61) - X(62) - X(63) = 0$$

$$-X(9) + X(15) + X(63) = 0$$

$$X(10) - X(57) - X(58) - X(59) - X(60) = 0$$

$$-X(10) + X(52) + X(60) = 0$$

The second category of constraints is the set of constraints on manning levels required in the system.

$X(1) >= 288$

$X(3) >= 177$

$X(2) + X(3) >= 439$

$X(4) + X(66) - X(67) = 275$

$X(5) + X(68) - X(69) = 195$

$X(6) + X(70) - X(71) = 130$

$X(7) + X(72) - X(73) = 44$

$X(8) + X(74) - X(75) = 60$

$X(9) + X(76) - X(77) = 60$

$X(10) + X(78) - X(79) = 37$

The third category of constraints is the set of constraints on individual flows in the system.

$X(11) <= 150$

$X(14) <= 108$

$X(18) >= 80$

$X(52) = 10$

$X(21) + X(27) + X(34) + X(39) + X(44) + X(55) + X(59) = 40$

$X(20) + X(26) + X(33) + X(49) = 34$

$X(28) + X(51) = 16$

The fourth category of constraints is the set of constraints on the attrition from the various job areas.

$$-.02X(1) + X(12) = 34$$

$$-.03X(2) + X(16) = 29$$

$$-.03X(3) + X(22) = 0$$

$$-.05X(4) + X(29) = 0$$

$$-.05X(5) + X(35) = 0$$

$$-.06X(6) + X(40) = 0$$

$$-.05X(7) + X(45) = 0$$

$$-.05X(8) + X(53) = 0$$

$$-.02X(9) + X(61) = 0$$

$$-.05X(10) + X(57) = 0$$

The fifth and last category of constraints is the set of constraints on the length of tours in the various jobs available.

$$-.60X(1) + X(13) = 0$$

$$-.50X(2) + X(17) = 0$$

$$-.50X(3) + X(23) = 0$$

$$-.67X(4) + X(31) = 0$$

$$-.70X(5) + X(38) = 0$$

$$-.67X(6) + X(43) = 0$$

$$-.05X(7) + X(50) = 0$$

$$-.70X(8) + X(56) = 0$$

$$-.75X(9) + X(63) = 0$$

$$-.70X(10) + X(60) = 0$$

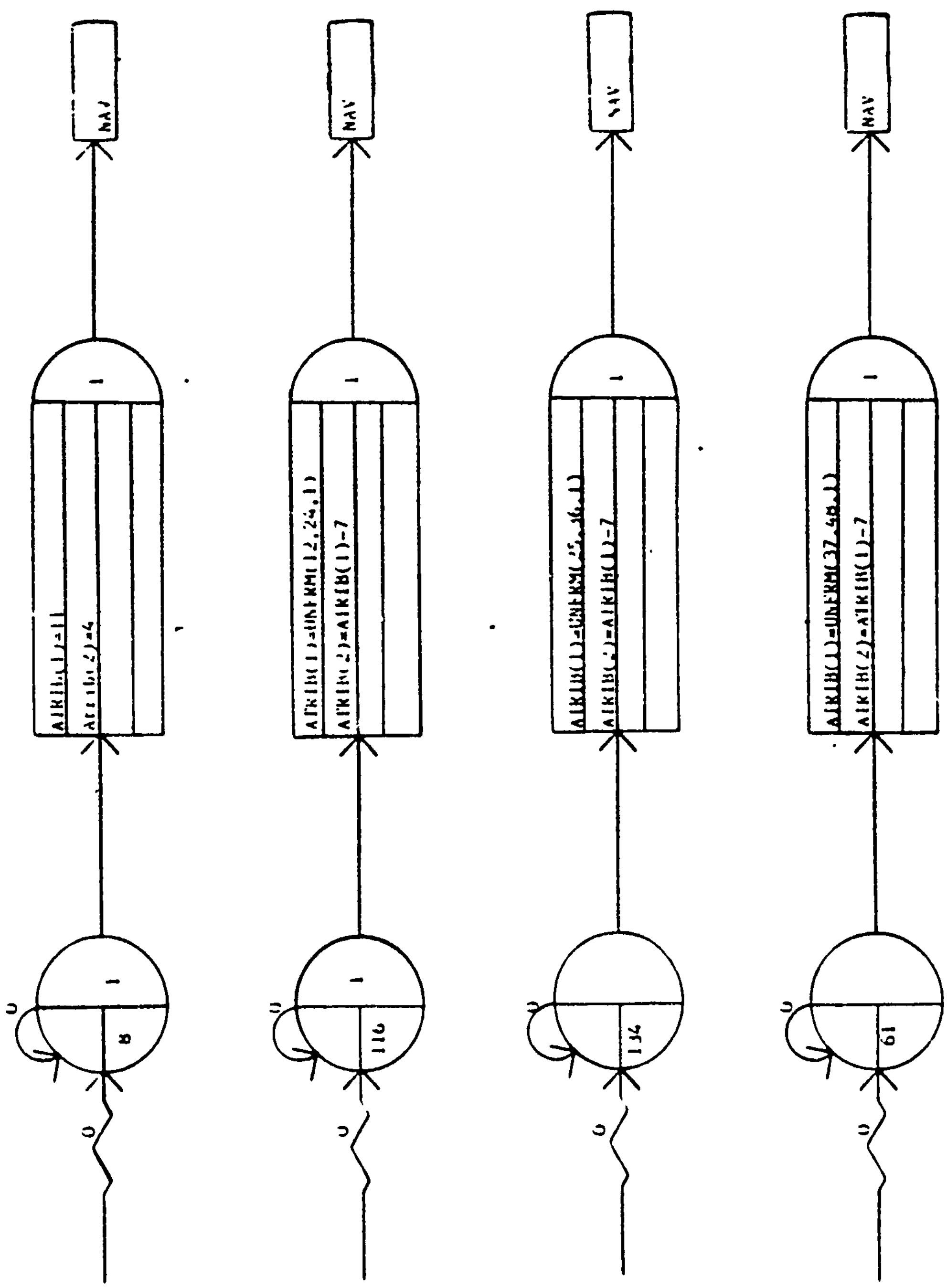
The objective function of the linear program can be any number of possible subsets of the decision variables. Any slack and surplus variables in the formulation may also be added to the objective function. These in fact should be in the objective function to minimize the deviations from strict equalities.

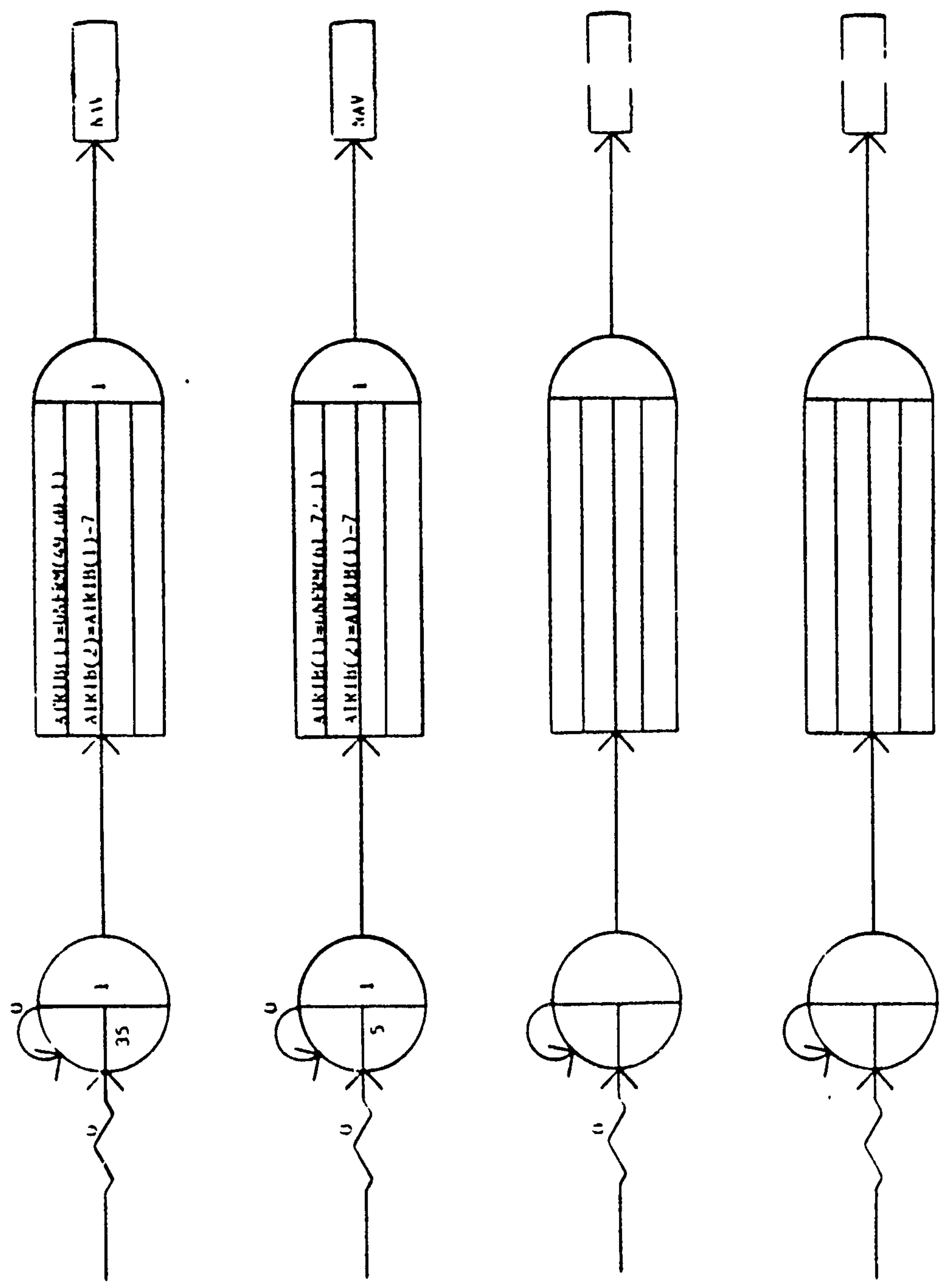
$$X(1) + X(2) + X(3) + X(11) + X(12) + X(14) + X(16) + X(22) + X(29) + X(35) + X(40) + X(45) + X(53) + X(57) + X(61) = Z$$

B. SLAM Network Diagram

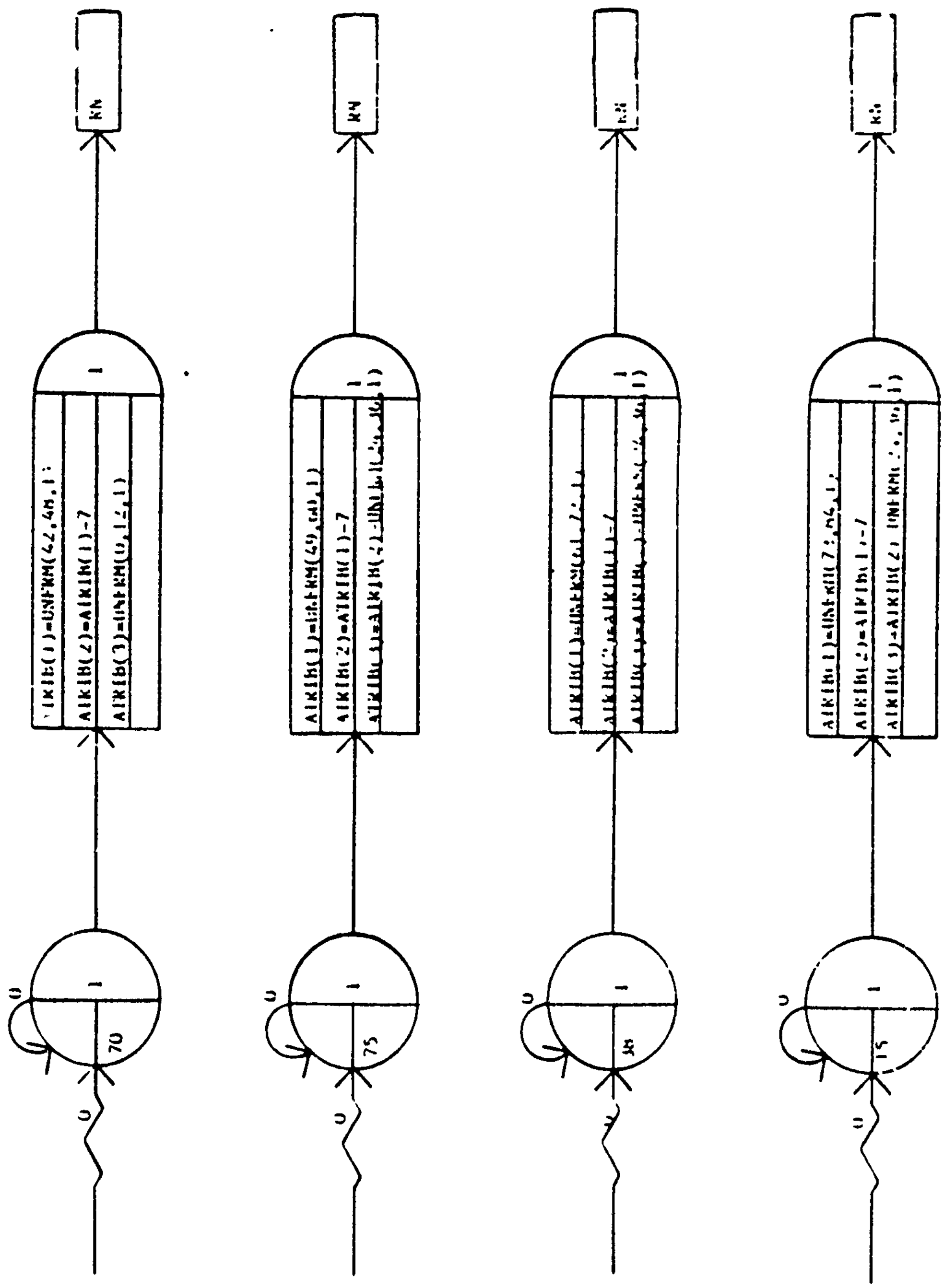
This section contains a diagram of the actual SLAM program using the network flow diagram figures used by Pritsker for representing SLAM networks. The program is a highly modularized network. All the modules are represented on the following pages, and a brief description of their function included.

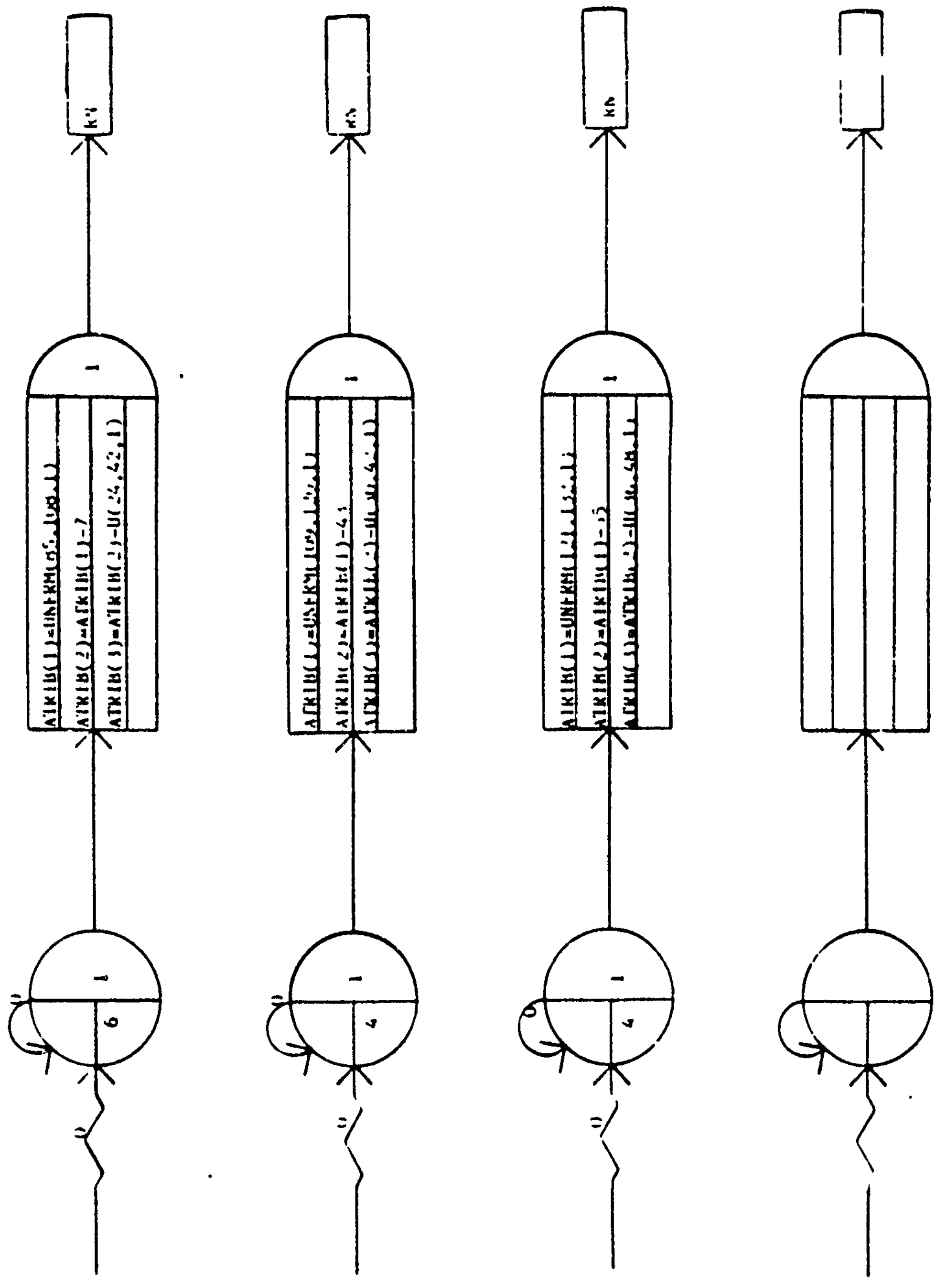
INITIAL NAVIGATOR FORCE CREATION



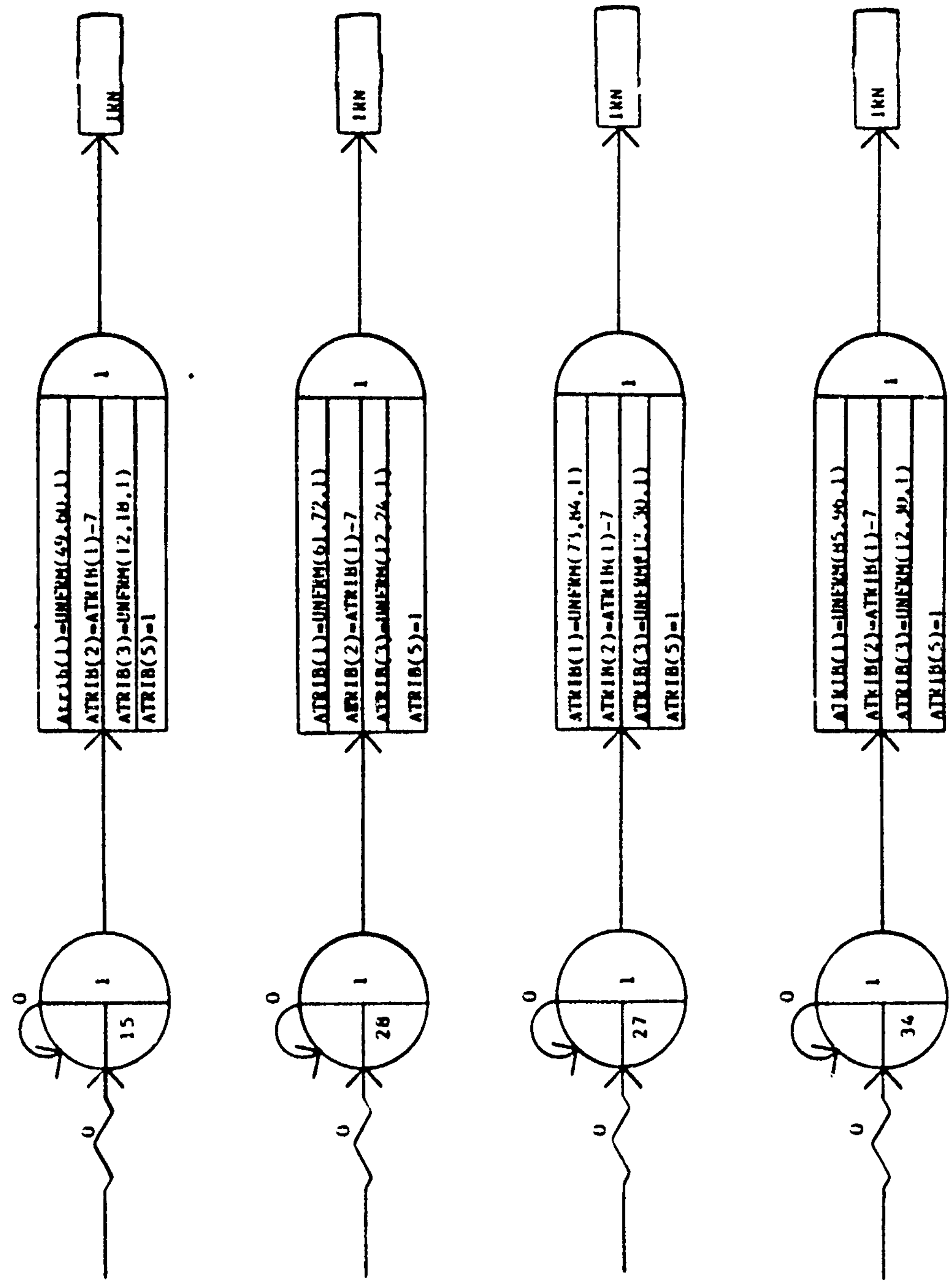


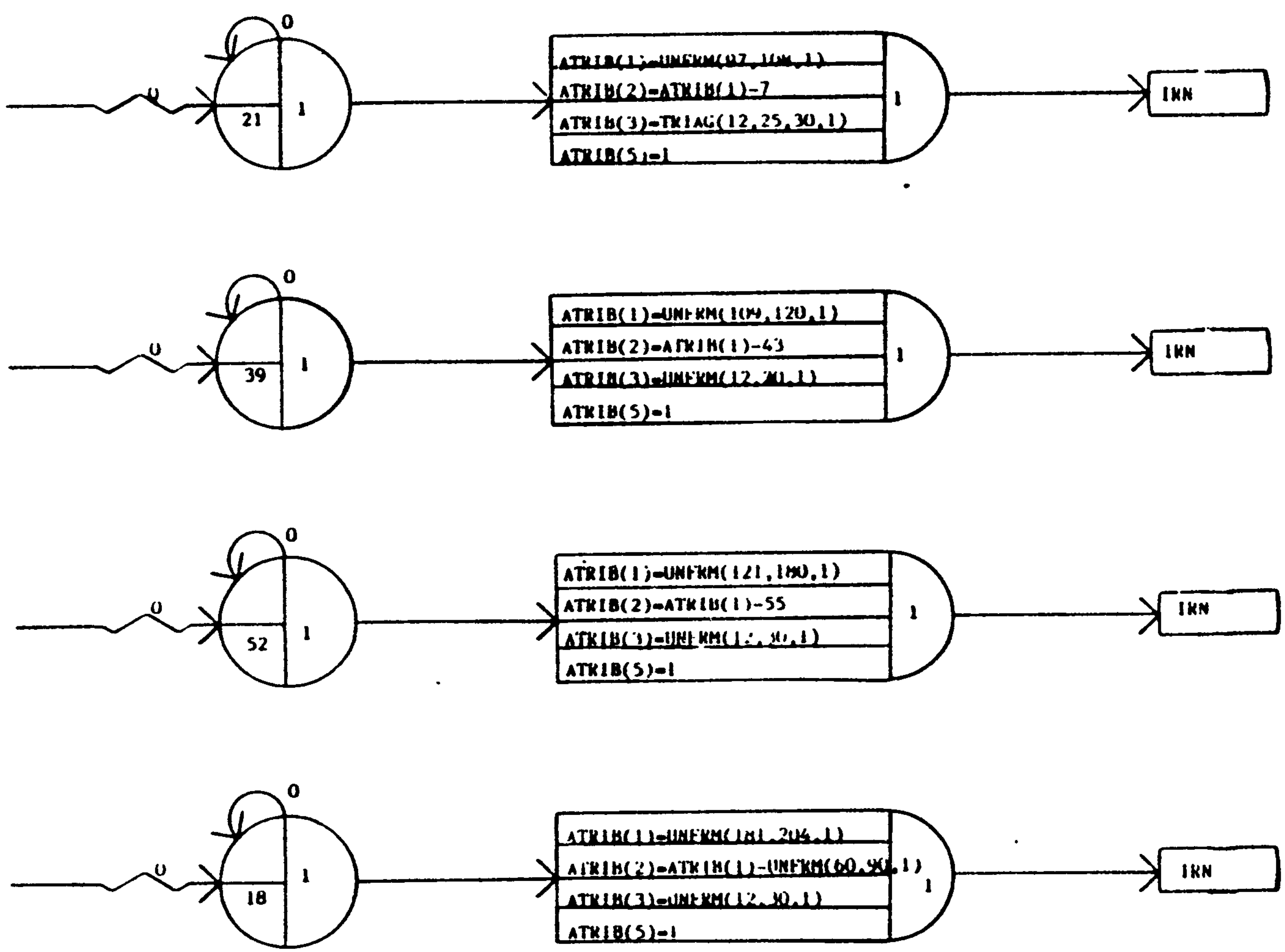
INITIAL RADAR NAVIGATOR FORCE CREATION




ATRIB(2)=ATRIB(1)-7

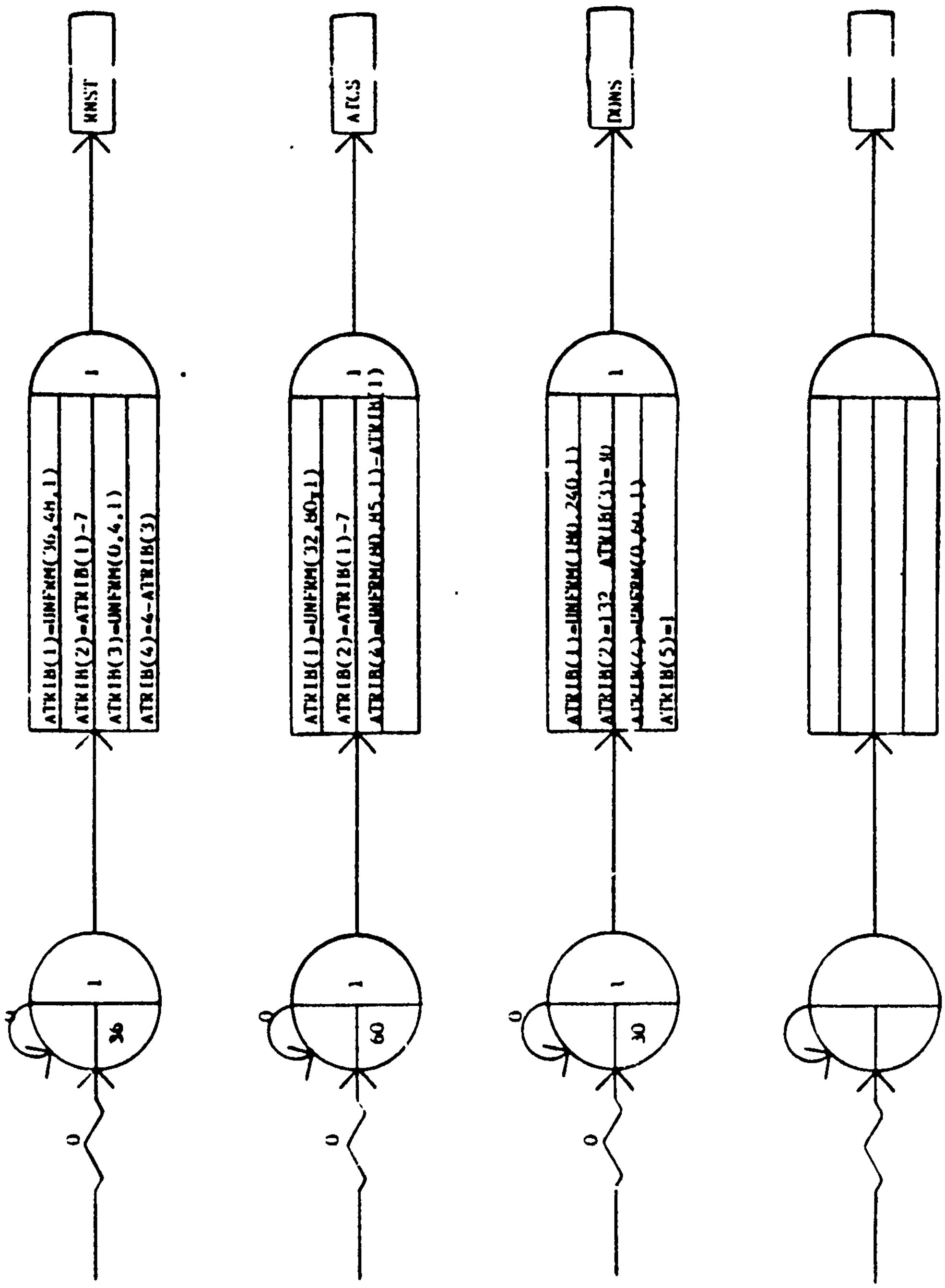
INITIALIZE INSTRUCTOR RADAR NAVIGATORS

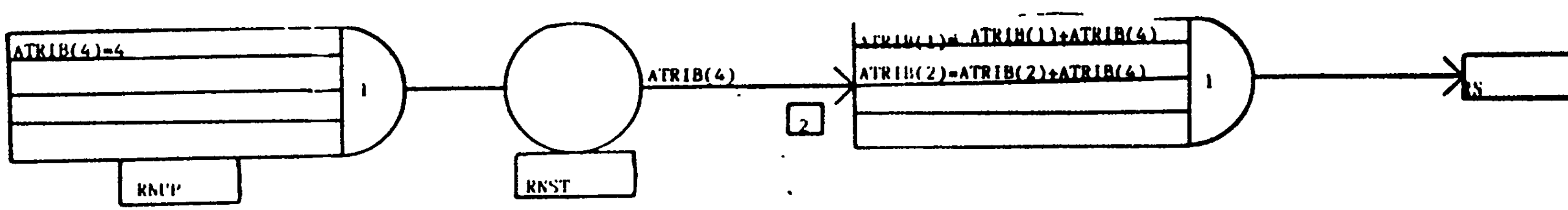




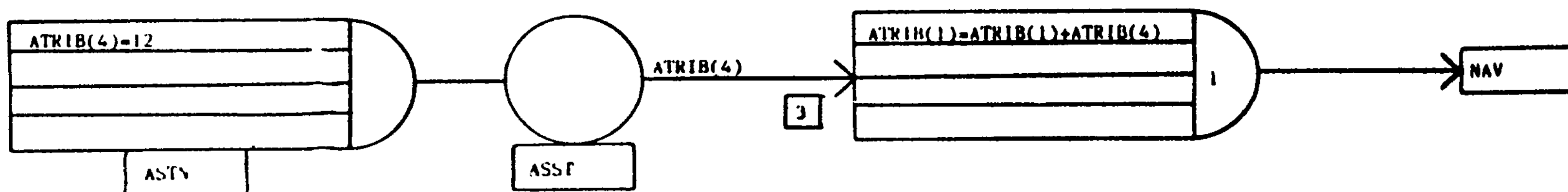
0
21
1
ATRIB(2)=ATRIB(1)-7
ATRIB(3)=TRIAG(12,25,30,1)
1
IRN
0
39
1
ATRIB(1)=UNFRM(109,120,1)
ATRIB(2)=ATRIB(1)-43
ATRIB(5)=1
1
IRN
0
52
1
ATRIB(1)=UNFRM(121,180,1)
ATRIB(2)=ATRIB(1)-55
ATRIB(5)=1
1
IRN
0
18
1
ATRIB(3)=UNFRM(12,30,1)
ATRIB(5)=1
1
IRN

INITIALIZE RN UPGRADES, ATC INs DONs

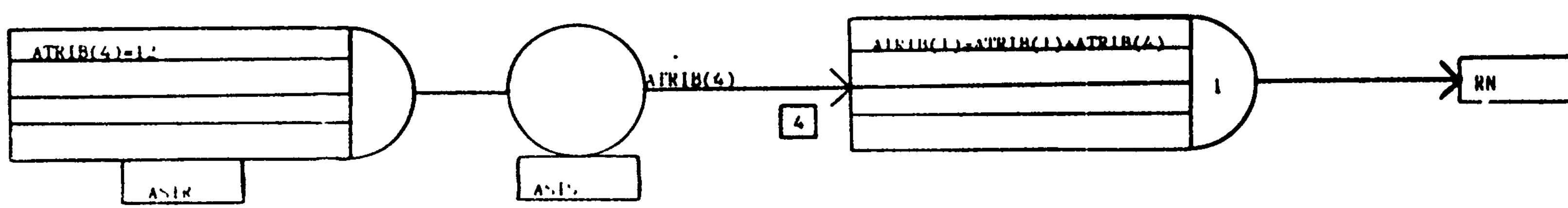




NAVIGATORS CURRENTLY UPGRADING TO RADAR NAVIGATOR

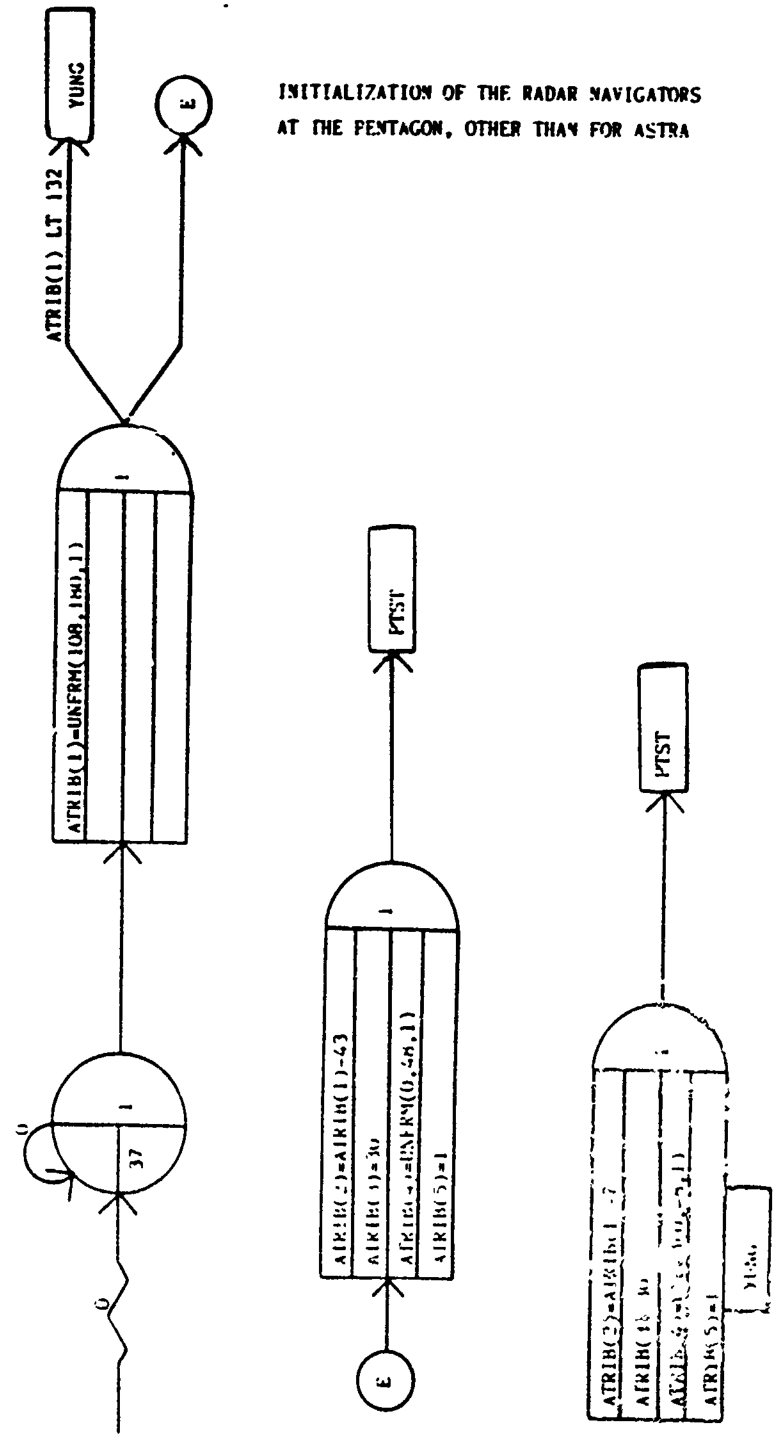


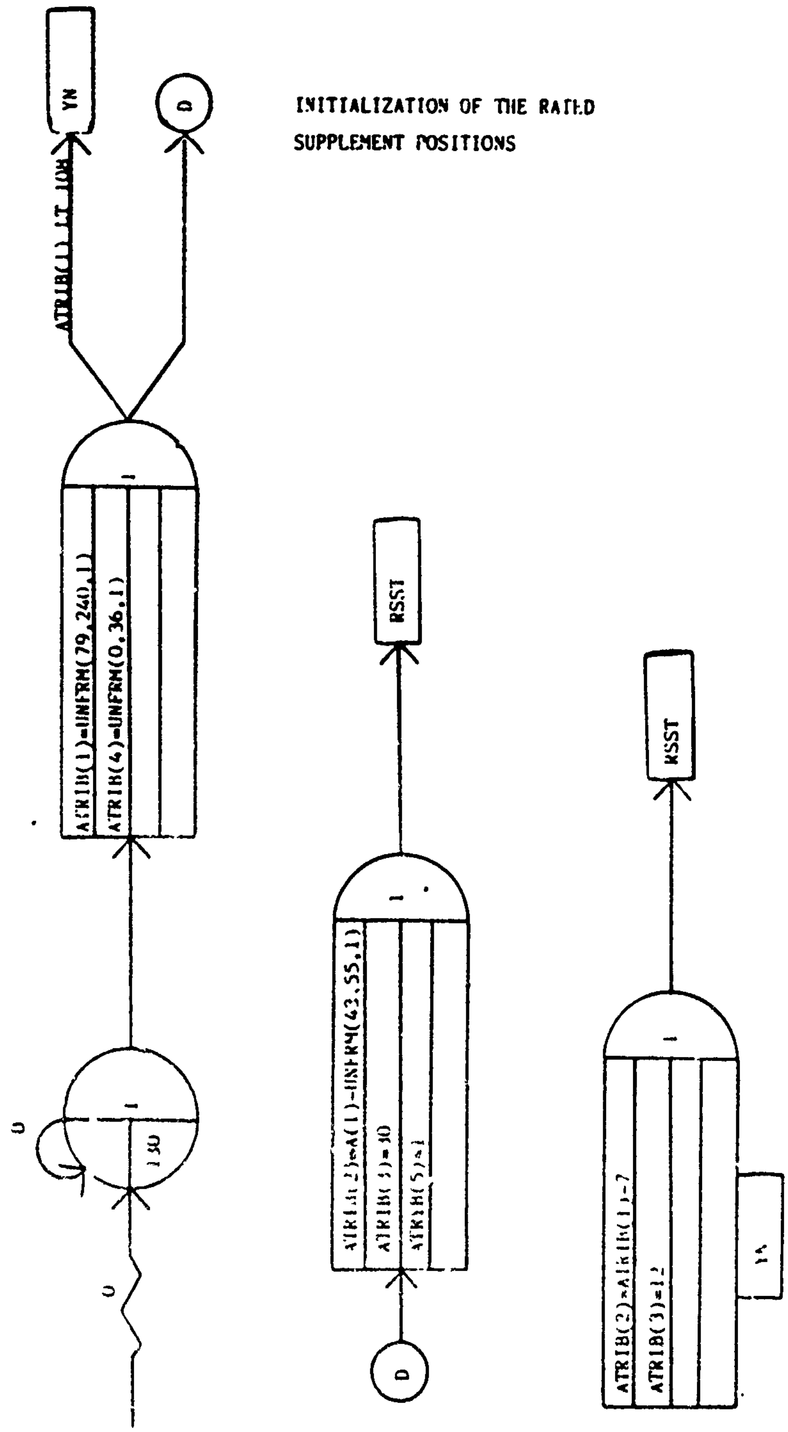
NAVIGATORS AT THE PENTAGON FOR ASTRA



RADAR NAVIGATORS AT THE PENTAGON FOR ASTRA

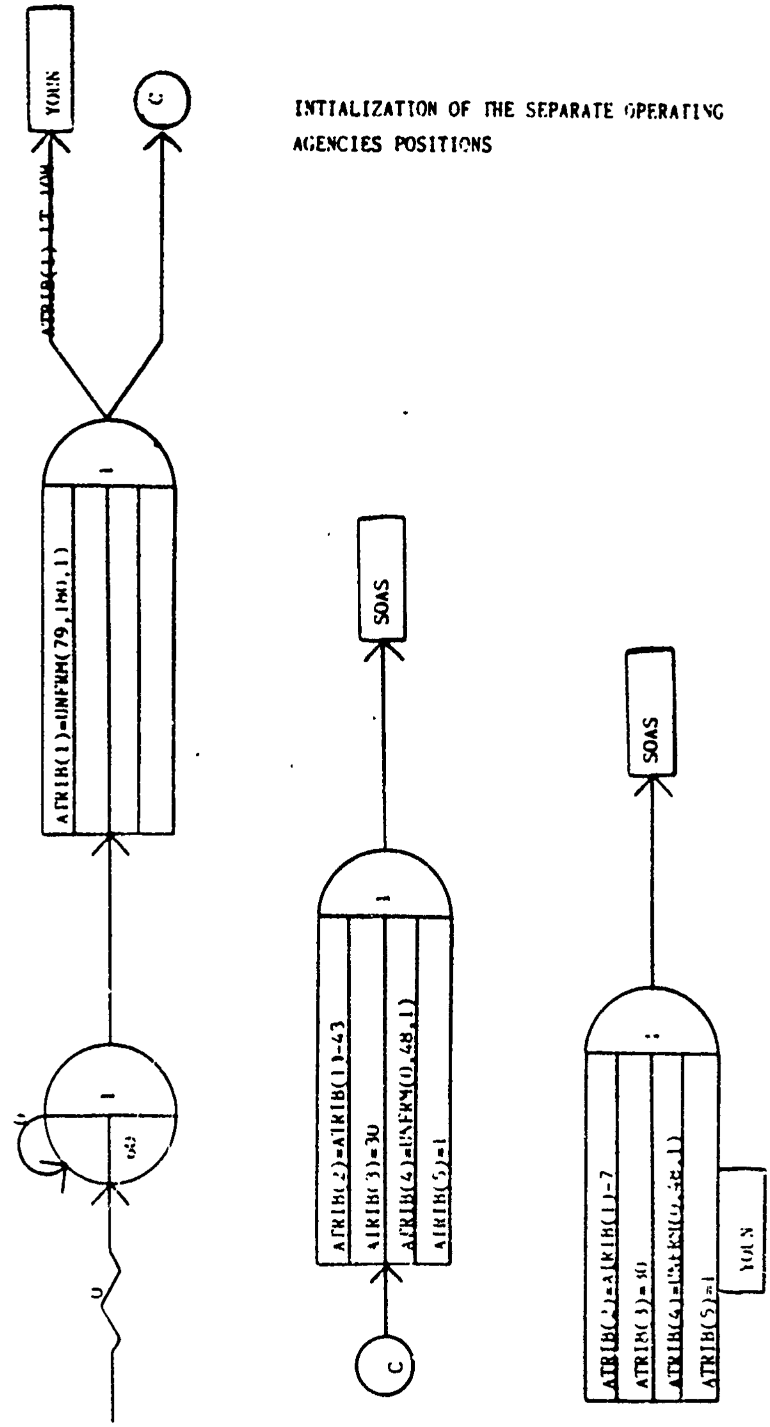
INITIALIZATION OF THE RADAR NAVIGATORS AT THE PENTAGON, OTHER THAN FOR ASTRA



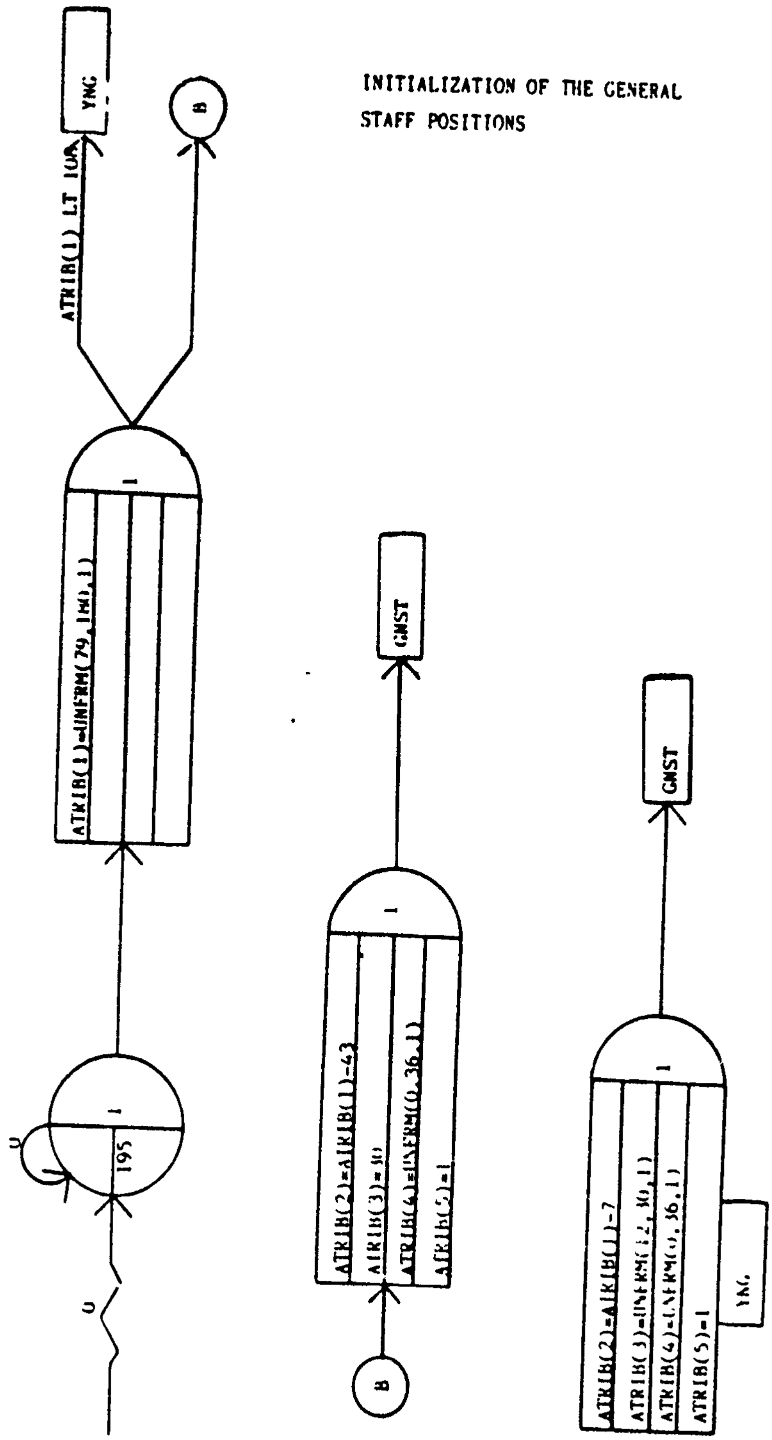


INITIALIZATION OF THE RATED
SUPPLEMENT POSITIONS

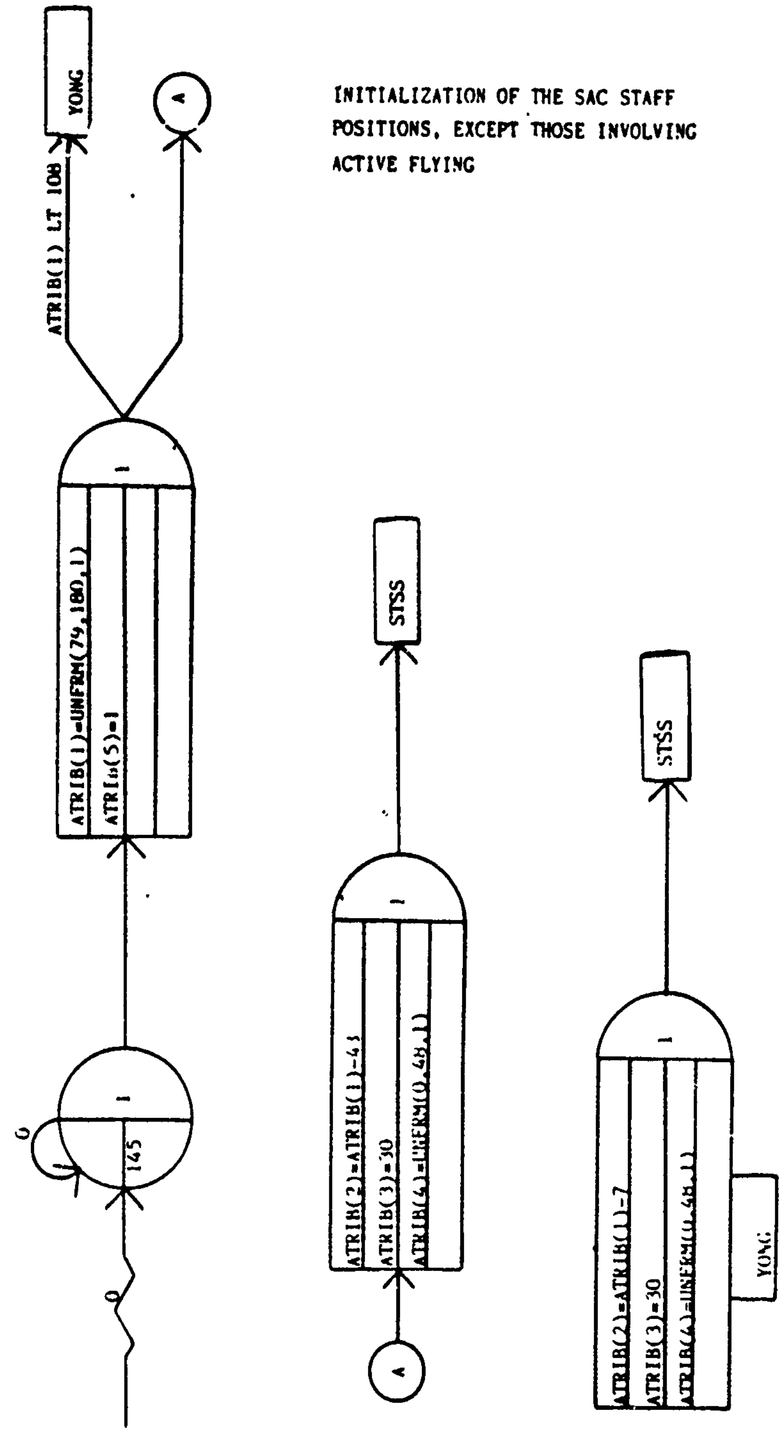
INTIALIZATION OF THE SEPARATE OPERATING AGENCIES POSITIONS



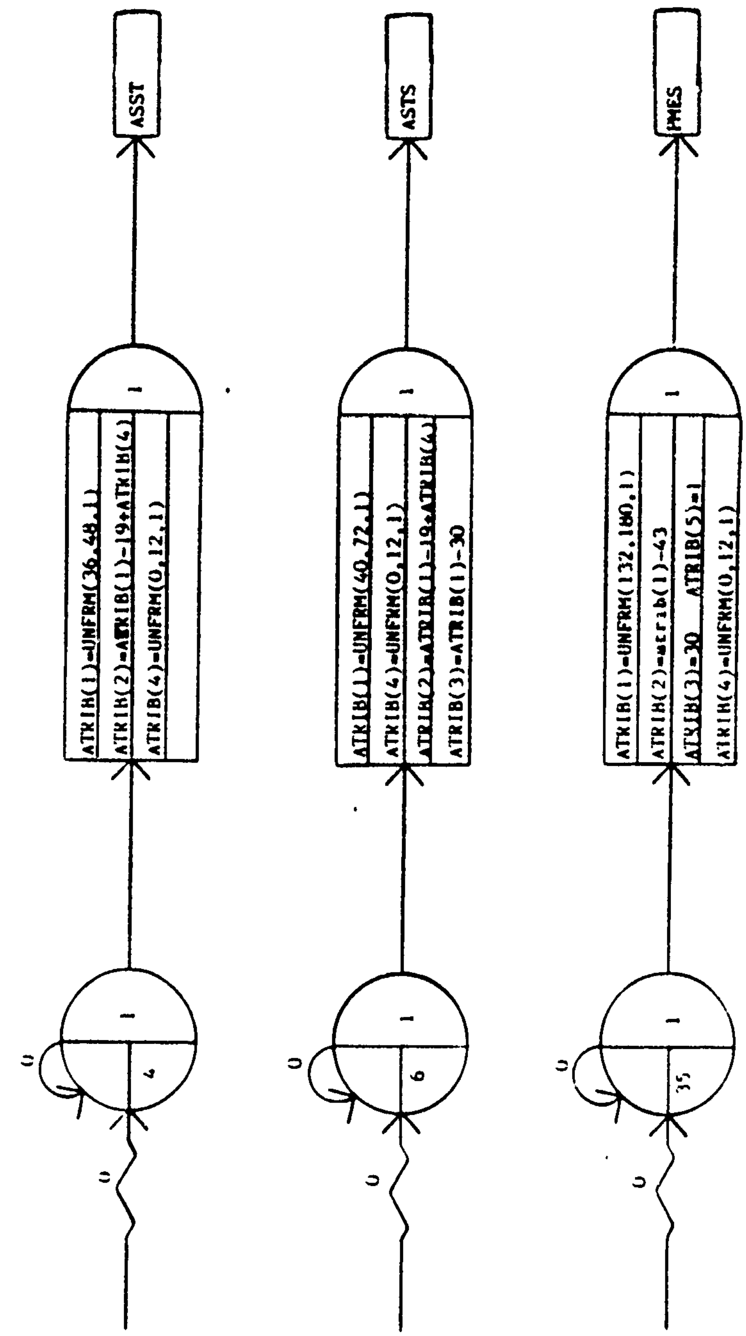
INITIALIZATION OF THE GENERAL STAFF POSITIONS



INITIALIZATION OF THE SAC STAFF POSITIONS, EXCEPT THOSE INVOLVING ACTIVE FLYING

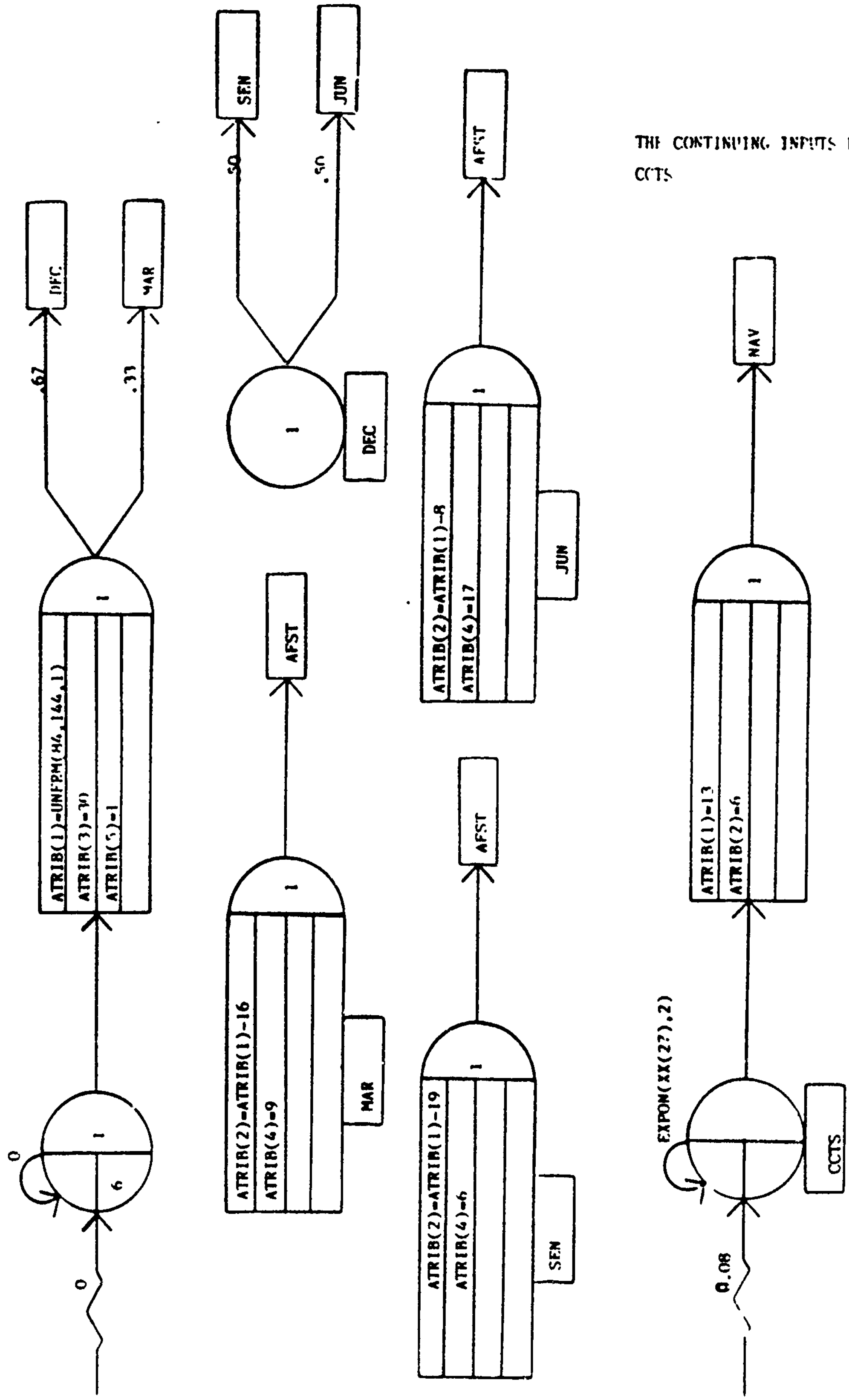


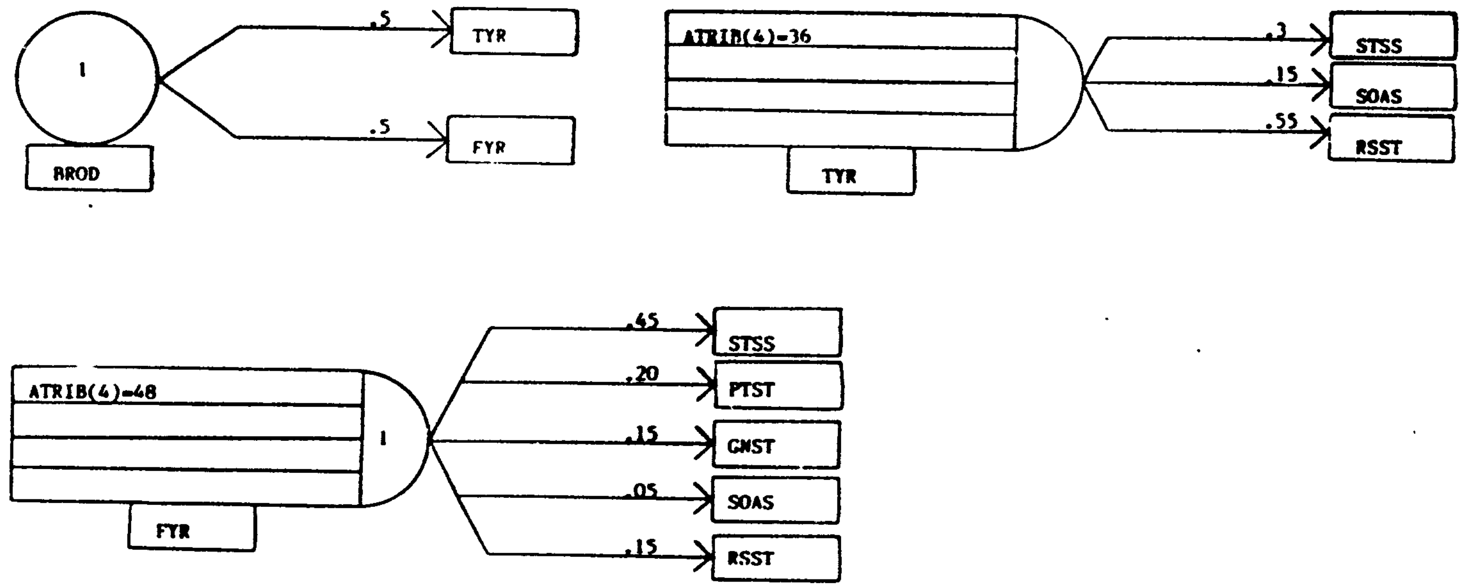
INITIALIZE ASTRA AND PME



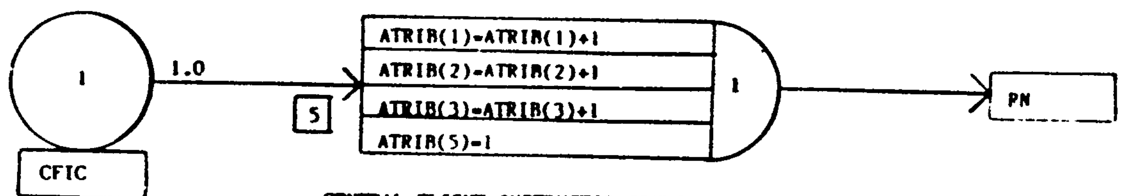
INITIALIZATION OF THOSE RADAR NAVIGATORS AT AFIT

THE CONTINUING INPUTS FROM CCTS

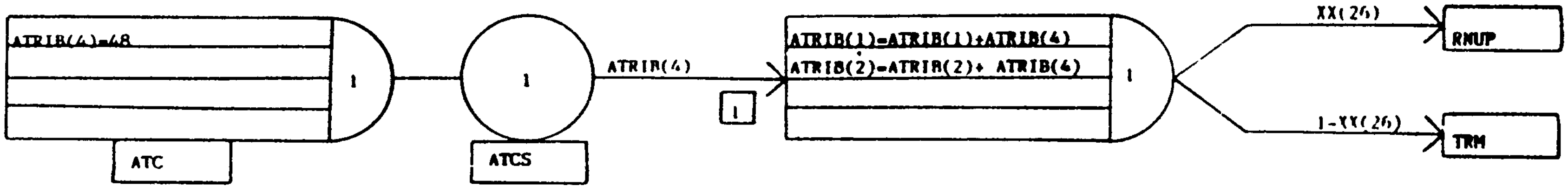




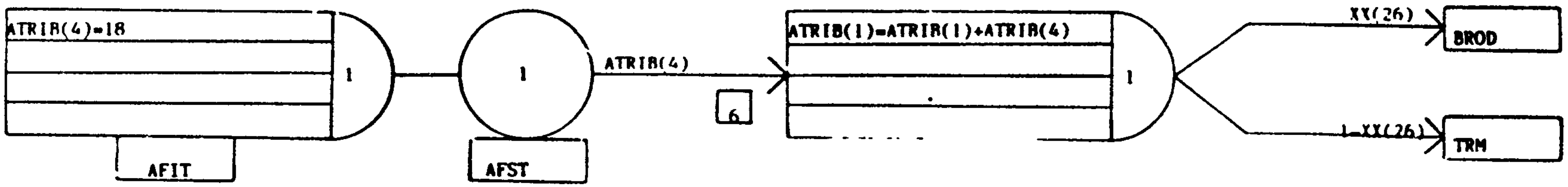
RADAR NAVIGATORS BEING ASSIGNED TO BROADENING POSITIONS



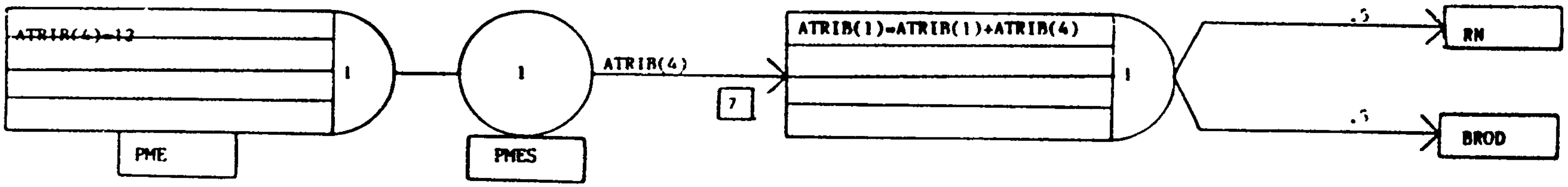
CENTRAL FLIGHT INSTRUCTOR COURSE



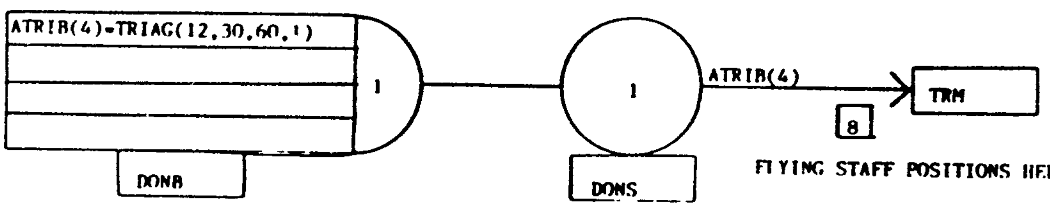
NAVIGATORS CURRENTLY AT MATHER AFB AS ATC INs



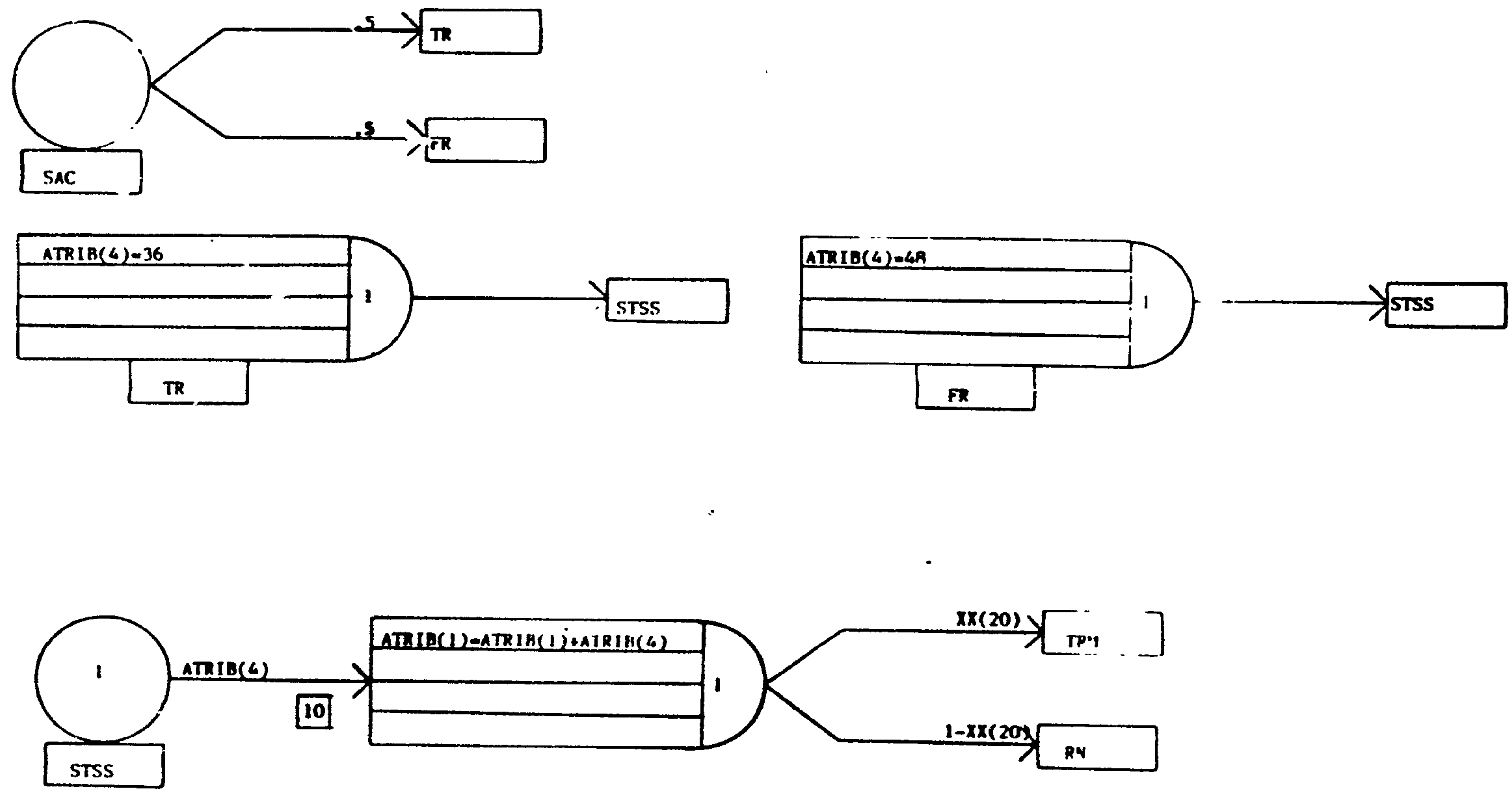
RADAR NAVIGATORS AT AFIT FOR ADVANCED EDUCATION



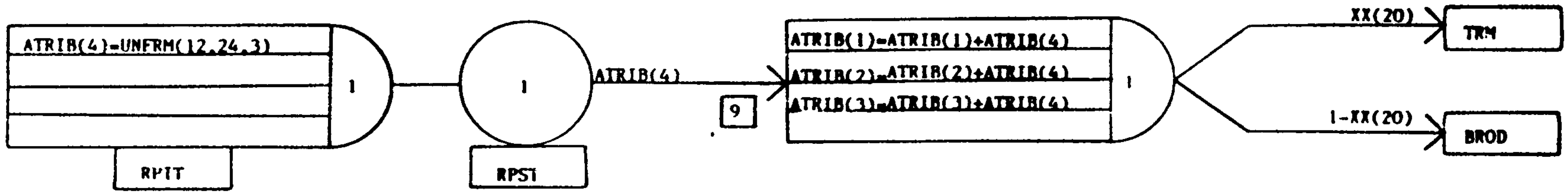
RADAR NAVIGATORS AT INTERMEDIATE SERVICE SCHOOL IN RESIDENCE



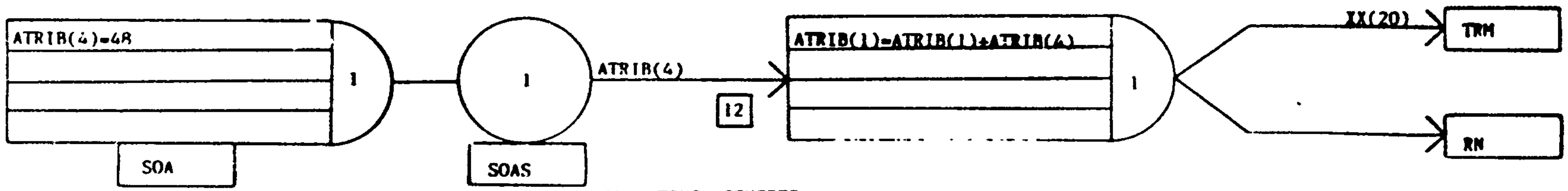
FLYING STAFF POSITIONS HELD BY SENIOR IRNs WITH ALL GATES MET



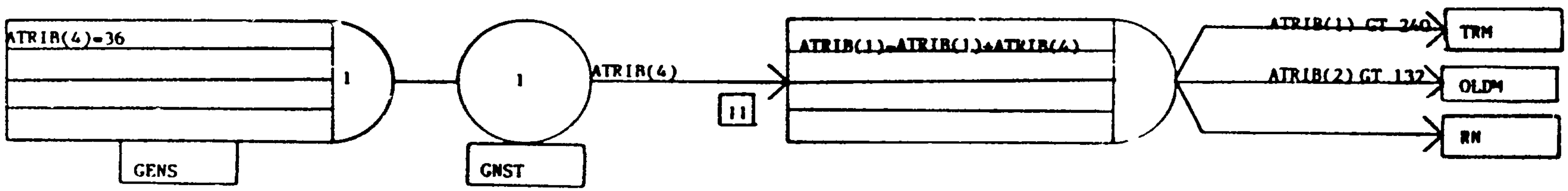
RADAR NAVIGATORS ASSIGNED TO NON FLYING SAC STAFF POSITIONS



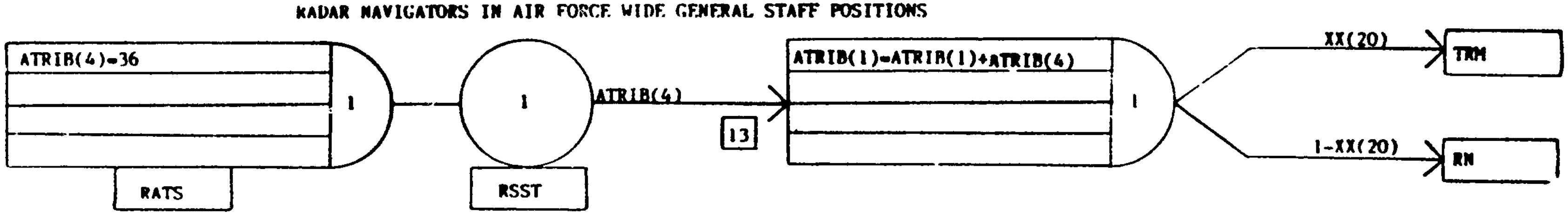
RADAR NAVIGATORS IN RPI 3 STAFF POSITIONS



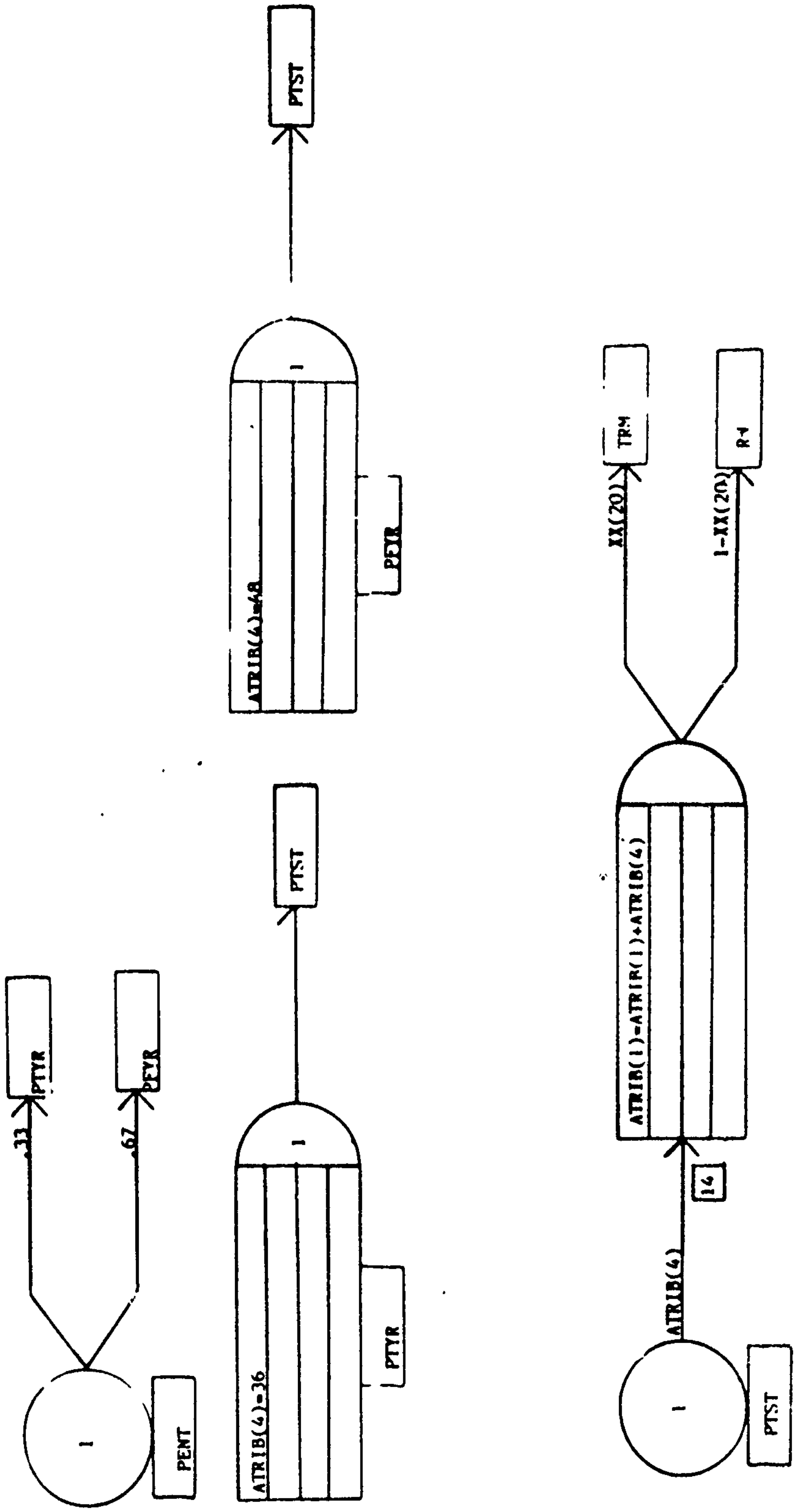
RADAR NAVIGATORS AT SEPARATE OPERATING AGENCIES



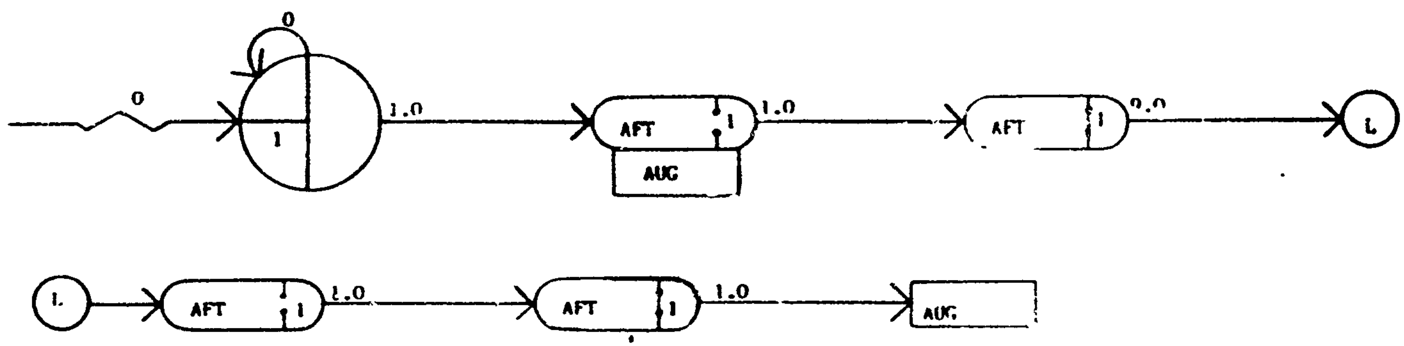
RADAR NAVIGATORS IN AIR FORCE WIDE GENERAL STAFF POSITIONS



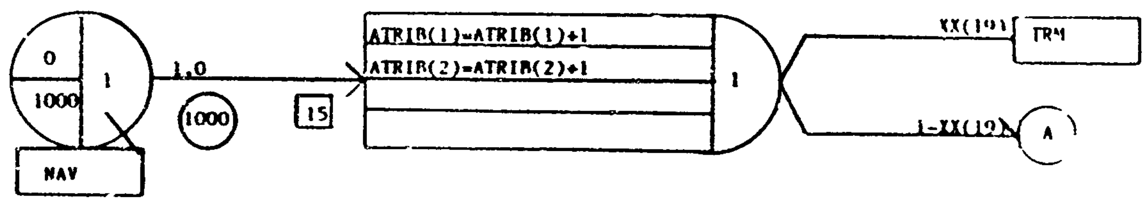
RADAR NAVIGATORS IN RATED SUPPLEMENT POSITIONS



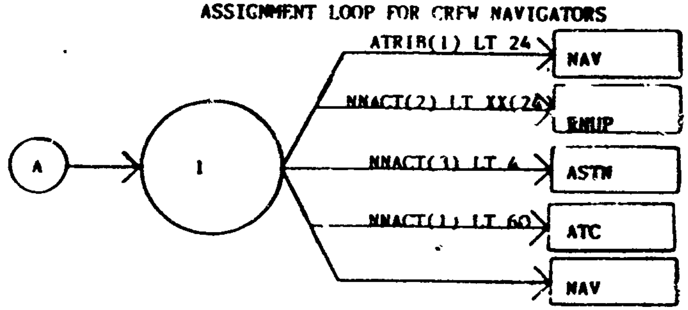
RADAR NAVIGATORS ASIGNED TO THE PENTAGON

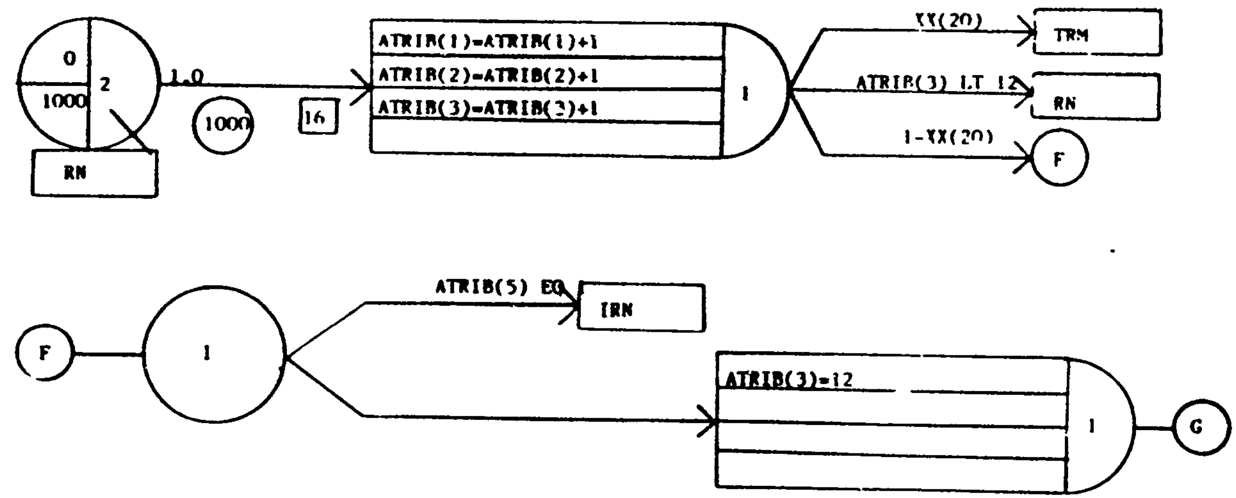


CONTROLLING ROUTINE FOR GATE CONTROLLING ENTRY INTO AFIT

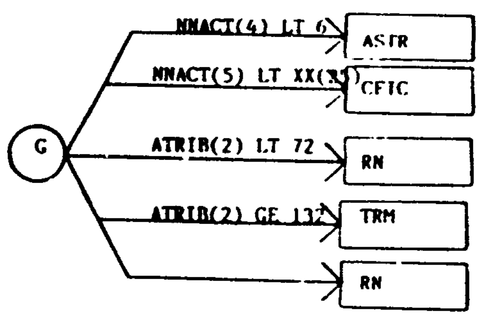


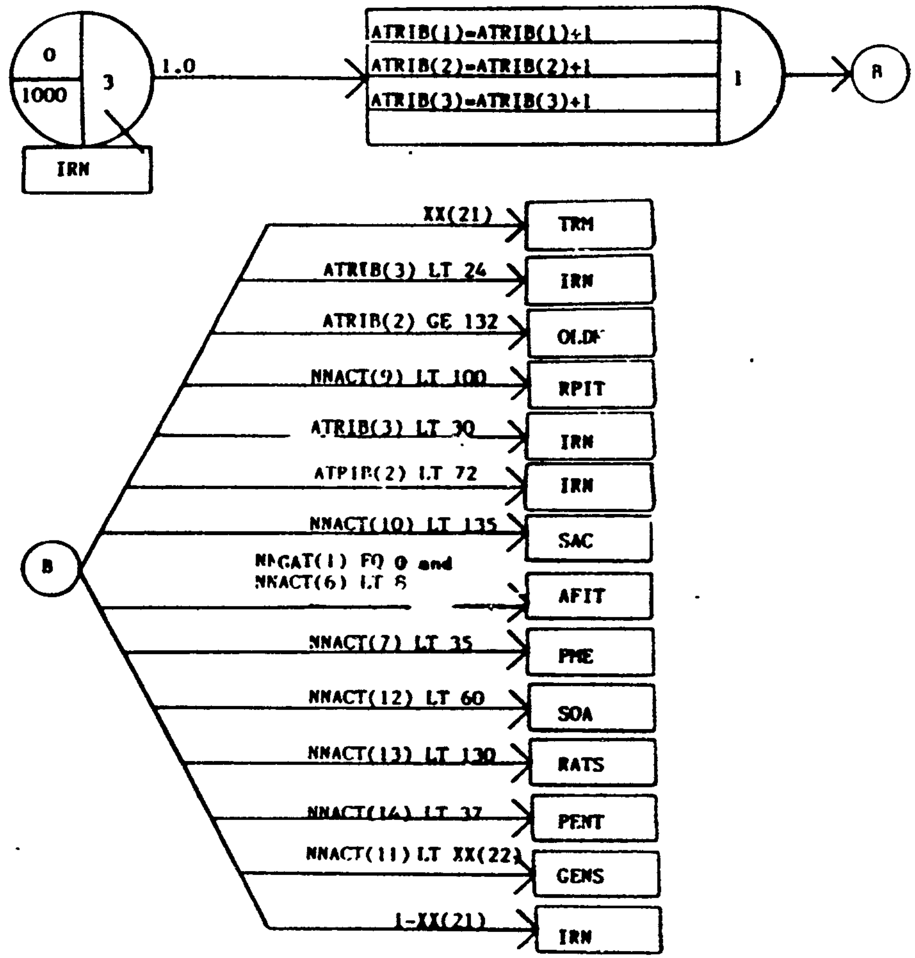
ASSIGNMENT LOOP FOR CREW NAVIGATORS



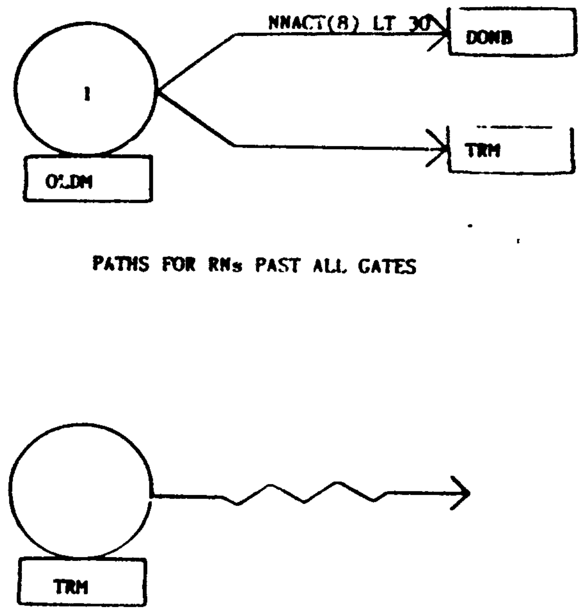


ASSIGNMENT LOOP FOR RADAR NAVIGATORS





ASSIGNMENT LOOP FOR INSTRUCTOR RADAR NAVIGATORS


1
OLDM
NNACT(8) LT 30
DONB
TRM
PATHS FOR RNs PAST ALL GATES
TRM

C. SLAM Network Code

This section contains the listing for the SLAM program. The first page is the Main FORTRAN program. This is mainly the default program except for the increased size of NSET/QSET due to the large number of entities in the network. A second change is the use of subroutine EVENT for calling GPLOT so that more than one plot and/or table may be printed per run.

```
      PROGRAM MAIN
      DIMENSION NSET(100000)
      INCLUDE 'PARAM.INC'
      COMMON/SCOM1/ATRIB(MATRB), DD(MEQT), DDL(MEQT), DTNOW, II, MFA,
     1MSTOP, NCLNR, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS(MEQT),
     2SSL(MEQT), TNEXT, TNOW, XX(MMXXV)
      COMMON QSET(100000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=100000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END


      SUBROUTINE EVENT(N)
      DIMENSION NSET(100000)
      COMMON/SCOM1/ATRIB, DD, DDL, DTNOW, II, MFA,
     1MSTOP, NCLNR, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS,
     2SSL, TNEXT, TNOW, XX
      COMMON QSET(100000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=100000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL GPLOT(N)
      RETURN
      END
```

```
GEN,KCHARPIE,RN MANNING,12/05/86,10,NO,NO,YES,NO,YES,72;
LIMITS,5,5,5000;
INITIALIZE,0,120,YES,YES,YES;
RECORD(1),TNOW,ELAPSED TIME,0,P,1.0,0,120,YES;
VAR,XX(15),N,NAVS,300,400;
VAR,XX(16),R,RADARS,200,300;
VAR,XX(17),I,IRNS,200,400;
INTLC,XX(18)=0.05;           ANNUAL SEPARATION RATE FOR BROADENING ASSIGN.
INTLC,XX(19)=0.0097;         MONTHLY SEPARATION AND X-TRAIN RATE FOR NAVS
INTLC,XX(20)=0.01;           MONTHLY SEPARATION AND X-TRAIN RATE FOR RNS
INTLC,XX(21)=0.005;          MONTHLY SEPARATION AND X-TRAIN RATE FOR IRNS
INTLC,XX(22)=195;            INITIAL NUMBER OF GENERAL STAFF POSITIONS
INTLC,XX(23)=0.08;           NAVIGATOR CREATION RATE
INTLC,XX(24)=36;             TOTAL NUMBER OF NAV TO RN UPGRADES AT ONE TIME
INTLC,XX(25)=7;              RN CFIC SLOTS PER MONTH
INTLC,XX(26)=0.98;           PERCENT RETURNING ATC INs FOR RNUP
;
; EXPLANATION OF ACTIVITIES IN NETWORK
;
; ACTIVITY      JOB ASSOCIATED
; NUMBER        WITH THIS ACTIVITY
;   1           TOUR WITH ATC AS AN IN
;   2           RN UPGRADE
;   3           NAVS AT ASTRA
;   4           RNS AT ASTRA
;   5           CFIC
;   6           AFIT
;   7           PME
;   8           FLYING SLOTS FILLED BY SENIOR IRNS WITH ALL GATES MET
;   9           WING LEVEL STAFF SLOTS
;  10           OTHER SAC STAFF POSITIONS
;  11           GENERAL STAFF POSITIONS
;  12           SEPARATE OPERATING AGENCIES
;  13           RATED SUPPLEMENT POSITIONS
;  14           JOINT/DEPARTMENTAL POSITIONS
;
; EXPLANATION OF USE OF ATTRIBUTES
;
; ATTRIBUTE     USE
;
;    1          TOTAL SERVICE TIME
;    2          GATE CREDIT
;    3          CONTROL FOR FLYING COMMITMENTS ASSOCIATED WITH
;               UPGRADE TRAINING
;    4          TOUR LENGTH FOR OUT OF COCKPIT TOURS
;
; USAGE OF RANDOM NUMBER STREAMS
;
; STREAM        USE
;
;    1          INITIALIZATION FOR EXISTING FORCE
;    2          ACCESSIONS FROM NAV SCHOOL
;    3          TOUR LENGTH IN FLYING STAFF JOBS
```

```
;    4          TOUR LENGTH FOR FLYERS PAST ALL GATES IN STAFF
;
NETWORK;
;
;  This gate controls the entry dates into AFIT.
;
      GATE/AFT,CLOSE,4;
;
;  Network controlling the data collection routine.
;
      CREATE,0,,,1,1;
      ACT,1;
COLL  ASSIGN,XX(7)=NNACT(7),XX(10)=NNACT(10),XX(11)=NNACT(11);
      ACT;
      ASSIGN,XX(12)=NNACT(12),XX(13)=NNACT(13),XX(14)=NNACT(14);
      ACT;
      ASSIGN,XX(15)=NNACT(15),XX(16)=NNACT(16),XX(17)=NNACT(17);
      ACT;
      COLCT,XX(15),LINE NAVIGATORS,30/290/5,1;
      ACT;
      COLCT,XX(16),LINE RADARS,30/200/5,1;
      ACT;
      COLCT,XX(17),INSTR RADARS,30/220/5,1;
      ACT;
      COLCT,XX(10),SAC STAFF,30/120/1,1;
      ACT;
      COLCT,XX(11),GENERAL STAFF,30/180/1,1;
      ACT;
      COLCT,XX(12),SEP OP AGENCIES,30/45/1,1;
      ACT;
      COLCT,XX(14),PENTAGON,30/20/1,1;
      ACT;
      COLCT,XX(7),PME,30/15/1,1;
      ACT;
      EVENT,1,1;
      ACT,1,,COLL;
;
; Initialize the flying personnel with the force structureas of
; July 1986 for numbers of navs, radars, IRNs, and their time in
; service, and flying experience.
;
; CREATION OF THE NAVIGATOR CREW FORCE
;
      CREATE,0,,,8,1;
      ACT;
      ASSIGN,ATRIB(1)=11,ATRIB(2)=4;
      ACT,,,NAV;
      CREATE,0,,,116,1;
      ACT;
      ASSIGN,ATRIB(1)=UNFRM(12,24,1),ATRIB(2)=ATRIB(1)-7;
      ACT,,,NAV;
      CREATE,0,,,134,1;
      ACT;
```

```
    ASSIGN,ATRIB(1)=UNFRM(25,36,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,61,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(37,48,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,35,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(49,60,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,5,1;
    ACT;
    ASSIFN,ATRIB(1)=UNFRM(61,72,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
;
;  CREATION OF EXISTING FORCE STRUCTURE IN THE RADAR NAVIGATOR
;  POSITION.
;
    CREATE,0,,,70,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(42,48,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=UNFRM(0,12,1);
    ACT,,,RN;
    CREATE,0,,,75,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(49,60,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,38,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(61,72,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,15,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(73,84,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,6;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(85,108,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1),ATRIB(5)=1;
    ACT,,,RN;
    CREATE,0,,,4,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(109,120,1),ATRIB(2)=ATRIB(1)-43,
          ATRIB(3)=ATRIB(2)-UNFRM(30,42,1);
    ACT,,,RN;
    CREATE,0,,,4,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(121,132,1),ATRIB(2)=ATRIB(1)-55,
          ATRIB(3)=ATRIB(2)-UNFRM(36,48,1);
    ACT,,,RN;
```

```
    ASSIGN,ATRIB(1)=UNFRM(25,36,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,61,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(37,48,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,35,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(49,60,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
    CREATE,0,,,5,1;
    ACT;
    ASSIFN,ATRIB(1)=UNFRM(61,72,1),ATRIB(2)=ATRIB(1)-7;
    ACT,,,NAV;
;
; CREATION OF EXISTING FORCE STRUCTURE IN THE RADAR NAVIGATOR
; POSITION.
;
    CREATE,0,,,70,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(42,48,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=UNFRM(0,12,1);
    ACT,,,RN;
    CREATE,0,,,75,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(49,60,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,38,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(61,72,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,15,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(73,84,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1);
    ACT,,,RN;
    CREATE,0,,,6;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(85,108,1),ATRIB(2)=ATRIB(1)-7,
          ATRIB(3)=ATRIB(2)-UNFRM(24,36,1),ATRIB(5)=1;
    ACT,,,RN;
    CREATE,0,,,4,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(109,120,1),ATRIB(2)=ATRIB(1)-43,
          ATRIB(3)=ATRIB(2)-UNFRM(30,42,1);
    ACT,,,RN;
    CREATE,0,,,4,1;
    ACT;
    ASSIGN,ATRIB(1)=UNFRM(121,132,1),ATRIB(2)=ATRIB(1)-55,
          ATRIB(3)=ATRIB(2)-UNFRM(36,48,1);
    ACT,,,RN;
```

```
; NAVS CURRENTLY UNDERGOING RNUP AT CASTLE OR IN UNIT
;
     CREATE,0,,,36,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(36,48,1),ATRIB(2)=ATRIB(1)-7,
             ATRIB(3)=UNFRM(0,4,1),ATRIB(4)=4.0-ATRIB(3);
     ACT,,,RNST;
;
; NAVS CURRENTLY AT MATHER AS ATC INs
;
     CREATE,0,,,60,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(32,80,1),ATRIB(2)=ATRIB(1)-7,
             ATRIB(4)=UNFRM(80,85,1)-ATRIB(1);
     ACT,,,ATCS;
;
; EXPERIENCED IRNs FILLING SLOTS IN DONB, THAT ARE IN FLYING POSITIONS,
; BUT WILL NOT RETURN TO THE COCKPIT AFTER BEING DCN OR DONB.
;
     CREATE,0,,,30,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(180,240,1),ATRIB(2)=132,ATRIB(3)=30,
             ATRIB(4)=UNFRM(0,60,1),ATRIB(5)=1;
     ACT,,,DONS;
;
; NAVS CURRENTLY AT ASTRA
;
     CREATE,0,,,4,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(36,48,1),ATRIB(4)=UNFRM(0,12,1),
             ATRIB(2)=ATRIB(1)-19+ATRIB(4);
     ACT,,,ASST;
;
; RADARS CURRENTLY AT ASTRA
;
     CREATE,0,,,6,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(40,72,1),ATRIB(4)=UNFRM(0,12,1),
             ATRIB(3)=ATRIB(1)-30,ATRIB(2)=ATRIB(1)-19+ATRIB(4);
     ACT,,,ASTS;
;
; RADARS PAST THEIR FIRST GATE (MINIMUM) AT AFIT FOR MASTERS
;
     CREATE,0,,,6,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(84,144,1),ATRIB(3)=30,ATRIB(5)=1,1;
     ACT,,0.67,DEC;
     ACT,,0.33,MAR;
DEC  GOON,1;
     ACT,,0.5,SEN;
     ACT,,0.5,JUN;
SEN  ASSIGN,ATRIB(4)=6,ATRIB(2)=ATRIB(1)-19;
     ACT,,,AFST;
```

```
; NAVS CURRENTLY UNDERGOING RNUP AT CASTLE OR IN UNIT
;
     CREATE,0,,,36,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(36,48,1),ATRIB(2)=ATRIB(1)-7,
            ATRIB(3)=UNFRM(0,4,1),ATRIB(4)=4.0-ATRIB(3);
     ACT,,,RNST;
;
; NAVS CURRENTLY AT MATHER AS ATC INs
;
     CREATE,0,,,60,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(32,80,1),ATRIB(2)=ATRIB(1)-7,
            ATRIB(4)=UNFRM(80,85,1)-ATRIB(1);
     ACT,,,ATCS;
;
; EXPERIENCED IRNs FILLING SLOTS IN DONB, THAT ARE IN FLYING POSITIONS,
; BUT WILL NOT RETURN TO THE COCKPIT AFTER BEING DCN OR DONB.
;
     CREATE,0,,,30,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(180,240,1),ATRIB(2)=132,ATRIB(3)=30,
            ATRIB(4)=UNFRM(0,60,1),ATRIB(5)=1;
     ACT,,,DONS;
;
; NAVS CURRENTLY AT ASTRA
;
     CREATE,0,,,4,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(36,48,1),ATRIB(4)=UNFRM(0,12,1),
            ATRIB(2)=ATRIB(1)-19+ATRIB(4);
     ACT,,,ASST;
;
; RADARS CURRENTLY AT ASTRA
;
     CREATE,0,,,6,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(40,72,1),ATRIB(4)=UNFRM(0,12,1),
            ATRIB(3)=ATRIB(1)-30,ATRIB(2)=ATRIB(1)-19+ATRIB(4);
     ACT,,,ASTS;
;
; RADARS PAST THEIR FIRST GATE (MINIMUM) AT AFIT FOR MASTERS
;
     CREATE,0,,,6,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(84,144,1),ATRIB(3)=30,ATRIB(5)=1,1;
     ACT,,0.67,DEC;
     ACT,,0.33,MAR;
DEC  GOON,1;
     ACT,,0.5,SEN;
     ACT,,0.5,JUN;
SEN  ASSIGN,ATRIB(4)=6,ATRIB(2)=ATRIB(1)-19;
     ACT,,,AFST;
```

```
     ACT,,ATRIB(1).LT.108,YOUN;
     ACT;
     ASSIGN,ATRIB(2)=ATRIB(1)-43,ATRIB(3)=30,ATRIB(4)=UNFRM(0,48,1);
     ACT,,,SOAS;
YOUN ASSIGN,ATRIB(2)=ATRIB(1)-7,ATRIB(3)=30,ATRIB(4)=UNFRM(0,48,1);
     ACT,,,SOAS;
;
; INTIALIZATION OF THE RATED SUPPLEMENT POSITIONS
;
     CREATE,0,,,130,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(79,240,1),ATRIB(4)=UNFRM(0,36,1);
     ACT;
     ASSIGN,ATRIB(5)=1,1;
     ACT,,ATRIB(1).LT.108,YN;
     ACT;
     ASSIGN,ATRIB(2)=ATRIB(1)-UNFRM(43,55,1),ATRIB(3)=30,ATRIB(5)=1;
     ACT,,,RSST;
YN   ASSIGN,ATRIB(2)=ATRIB(1)-7,ATRIB(3)=12;
     ACT,,,RSST;
;
; INITIALIZATION OF THE RADARS AT THE PENTAGON OTHER THAN ASTRA
;
     CREATE,0,,,37,1;
     ACT;
     ASSIGN,ATRIB(1)=UNFRM(108,180,1),ATRIB(5)=1,1;
     ACT,,ATRIB(1).LT.132,YUNG;
     ACT;
     ASSIGN,ATRIB(2)=ATRIB(1)-43,ATRIB(3)=30,ATRIB(4)UNFRM(0,48,1);
     ACT,,,PTST;
YUNG ASSIGN,ATRIB(2)=ATRIB(1)-7,ATRIB(3)=30,ATRIB(4)=UNFRM(0,48,1);
     ACT,,,PTST;
;
; THE ACTUAL NETWORK
;
; A series of small mndules to control entities out of flyiLg duties.
; They control the length of time people spend in other positions, and
; termination rates from them.
;
; Navs that go to ATC as INs
;
ATC  ASSIGN,ATRIB(4)=48;
ATCS GOON;
     ACT/1,ATRIB(4);
     ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),ATRIB(2)=ATRIB(2)+ATRIB(4),1;
     ACT,,XX(26),RNUP;
     ACT,,1-XX(26),RM;
;
; New navs from nav school
;
CCTS CREATE,EXPON(XX(23),2),0.08;
     ACT;
     ASSIGN,ATRIB(1)=13,ATRIB(2)=6;
```

```
      ACT,,,NAV;
;
; Navs upgrading to radar nav
;
RNUP  ASSIGN,ATRIB(4)=4;
RNST  GOON;
      ACT/2,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),ATRIB(2)=ATRIB(2)+ATRIB(4);
      ACT,,,RN;
;
; Navs at ASTRA for one year
;
ASTN  ASSIGN,ATRIB(4)=12;
ASST  GOON;
      ACT/3,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4);
      ACT,,,NAV;
;
; Radars at ASTRA for one year
;
ASTR  ASSIGN,ATRIB(4)=12;
ASTS  GOON;
      ACT/4,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4);
      ACT,,,RN;
;
; Radars at Central Flight Instructor Course to upgrade to IRN
;
CFIC  GOON;
      ACT/5,1.0;
      ASSIGN,ATRIB(1)=ATRIB(1)+1,ATRIB(2)=ATRIB(2)+1,ATRIB(3)=12;
      ACT;
      ASSIGN,ATRIB(5)=1;
      ACT,,,RN;
;
; RNs/IRNs at AFIT for advanced education
;
AFIT  ASSIGN,ATRIB(4)=18;
AFST  GOON;
      ACT/6,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4);
      ACT,,,BROD;
      CREATE,0,,,1,1;
      ACT,1
AUG   OPEN,AFT,1;
      ACT,1;
      CLOSE,AFT,1;
      ACT,9;
      OPEN,AFT,1;
      ACT,1;
      CLOSE,AFT,1;
      ACT,1,,AUG;
;
```

```
; RNs/IRNs at Intermediate Service School in residence
;
PME   ASSIGN,ATRIB(4)=12;
PMES  GOON;
      ACT/7,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,0.5,RN;
      ACT,,0.5,BROD;
;
; IRNs in Rated Position Indicator #3 positions
;    Wing Bomb-Nav
;
RPIT  ASSIGN,ATRIB(4)=UNFRM(12,24,3);
RPST  GOON;
      ACT/9,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),ATRIB(2)=ATRIB(2)+ATRIB(4),
             ATRIB(3)=ATRIB(3)+ATRIB(4),1;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),BROD;
;
; RNs/IRNs at HQ SAC, numbered AF staff positions
;
SAC   GOON,1;
      ACT,,0.5,TR;
      ACT,,0.5,FR;
TR    ASSIGN,ATRIB(4)=36;
      ACT,,,STSS;
FR    ASSIGN,ATRIB(4)=48;
      ACT,,,STSS;
STSS  GOON;
      ACT/10,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),RN;
;
; RNs/IRNs at general staff positions throughout Air Force
;      Wing Command Post, and others
;
GENS  ASSIGN,ATRIB(4)=36;
GNST  GOON;
      ACT/11,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,ATRIB(1).GT.240,TRM;
      ACT,,ATRIB(2).GT.132,OLDM;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),RN;
;
; Selection routine for AFIT/PME graduates and others for
; staff positions
;
BROD  GOON,1;
      ACT,,0.5,TYR;
      ACT,,0.5,FYR;
```

```
TYR   ASSIGN,ATRIB(4)=36,1;
      ACT,,0.3,STSS;
      ACT,,0.15,SOAS;
      ACT,,0.55,RSST;
FYR   ASSIGN,ATRIB(4)=48,1;
      ACT,,0.45,STSS;
      ACT,,0.20,PTST;
      ACT,,0.15,GNST;
      ACT,,0.05,SOAS;
      ACT,,0.15,RSST;
;
; Senior IRNs past all gates, still in RPI 3 positions
;      Many DONs, DONBs are in this position
;
DONB  ASSIGN,ATRIB(4)=TRIAG(12,30,60,4);
DONS  GOON;
      ACT/8,ATRIB(4),,TRM;
;
; RNs/IRNs at separate operating agencies
;       AFOTEC
;
SOA   ASSIGN,ATRIB(4)=48;
SOAS  GOON;
      ACT/12,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),RN;
;
; RNs/IRNs in rated supplement positions
;
RATS  ASSIGN,ATRIB(4)=36;
RSST  GOON;
      ACT/13,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),RN;
;
; IRNs in pentagon positions
;     Air Staff/Joint Staff
;
PENT  GOON,1;
      ACT,,0.33,PTYR;
      ACT,,0.67,PFYR;
PTYR  ASSIGN,ATRIB(4)=36;
      ACT,,,PTST;
PFYR  ASSIGN,ATRIB(4)=48;
      ACT,,,PTST;
PTST  GOON;
      ACT/14,ATRIB(4);
      ASSIGN,ATRIB(1)=ATRIB(1)+ATRIB(4),1;
      ACT,,XX(18),TRM;
      ACT,,1-XX(18),RN;
;
```

```
; Navigators in flying positions
;
NAV   QUEUE(1),0,1000;
      ACT(1000)/15,1;
      ASSIGN,ATRIB(1)=ATRIB(1)+1,ATRIB(2)=ATRIB(2)+1,1;
      ACT,,XX(19),TRM;
      ACT,,1-XX(19);
      GOON,1;
      ACT,,ATRIB(2).LT.24, NAV;
      ACT,,NNACT(2).LT.XX(24), RNUP;
      ACT,,NNACT(3).LT.4, ASTN;
      ACT,,NNACT(1).LT.60, ATC;
      ACT,,,NAV;
;
; Radar navigators in flying positions
;
RN    QUEUE(2),0,1000;
      ACT(1000)/16,1;
      ASSIGN,ATRIB(1)=ATRIB(1)+1,ATRIB(2)=ATRIB(2)+1;
      ACT;
      ASSIGN,ATRIB(3)=ATRIB(3)+1,1;
      ACT,,XX(20),TRM;
      ACT,,ATRIB(3).LT.12,RN
      ACT,,1-XX(20);
      GOON,1;
      ACT,,ATRIB(5).EQ.1,IRN;
      ACT;
      ASSIGN,ATRIB(3)=12,1;
      ACT,,NNACT(4).LT.6,ASTR;
      ACT,,NNACT(5).LT.XX(25),CFIC;
      ACT,,ATRIB(2).LT.72,RN;
      ACT,,ATRIB(2).GE.132,TRM;
      ACT,,,RN;
;
; Instructor radars in flying or training positions
;
IRN   QUEUE(3),0,1000;
      ACT(1000)/17,1;
      ASSIGN,ATRIB(1)=ATRIB(1)+1,ATRIB(2)=ATRIB(2)+1;
      ACT;
      ASSIGN,ATRIB(3)=ATRIB(3)+1,1;
      ACT,,XX(21),TRM;
      ACT,,ATRIB(3).LT.24,IRN;
      ACT,,ATRIB(2).GE.132,OLDM;
      ACT,,NNACT(9).LT.100,RPIT;
      ACT,,ATRIB(3).LT.30,IRN;
      ACT,,ATRIB(2).LT.72,IRN;
      ACT,,NNGAT(1).EQ.0.AND.NNACT(6).LT.8,AFIT;
      ACT,,NNACT(10).LT.135,SAC;
      ACT,,NNACT(11).LT.XX(22),GENS;
      ACT,,NNACT(7).LT.35,PME;
      ACT,,NNACT(12).LT.60,SOA;
      ACT,,NNACT(13).LT.130,RATS;
```

```
      ACT,,NNACT(14).LT.37,PENT;
      ACT,,1-XX(21),IRN;
OLDM  GOON,1;
      ACT,,NNACT(8).LT.30,DONB;
      ACT,,,TRM;
TRM   TERMINATE;
      ENDNETWORK;
FIN;
```

D. Sample SLAM Output

This section contains the output from one sample run of the SLAM simulation model.

```
*************************************************************************
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*                     * * * * * * * * * * * * * * *                     *
*                     *                           *                     *
*                     *    SLAM II VERSION 3.2    *                     *
*                     *                           *                     *
*                     * * * * * * * * * * * * * * *                     *
*                                                                       *
*                                                                       *
*                                                                       *
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*************************************************************************
```

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

SIMULATION PROJECT RN MANNING   BY KCHARPIE

DATE 12/ 5/1986   RUN NUMBER   1 OF   1

CURRENT TIME   .1200e+03
STATISTICAL ARRAYS CLEARED AT TIME   .0000e+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
LINE NAVIGATORS	.360e+03	.997e+01	.277e-01	.328e+03	.379e+03	40
LINE RADARS	.240e+03	.933e+01	.389e-01	.221e+03	.263e+03	40
INSTR RADARS	.274e+03	.260e+02	.947e-01	.223e+03	.313e+03	40
TOTAL RNs	.514e+03	.321e+02	.625e-01	.457e+03	.567e+03	40
SAC STAFF	.139e+03	.333e+01	.240e-01	.134e+03	.146e+03	40
GENERAL STAFF	.194e+03	.174e+01	.897e-02	.190e+03	.196e+03	40
SEP OP AGENCIES	.599e+02	.119e+01	.198e-01	.570e+02	.620e+02	40
PENTAGON	.388e+02	.180e+01	.465e-01	.360e+02	.440e+02	40
PME	.325e+02	.353e+01	.109e+00	.260e+02	.350e+02	40

FILE STATISTICS

FILE NUMBER	LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	NAV QUEUE	.000	.000	0	0	.000
2	RN QUEUE	.000	.000	0	0	.000
3	IRN QUEUE	.000	.000	0	0	.000
4		.000	.000	0	0	.000
5		.000	.000	0	0	.000
6	CALENDAR	1713.627	38.561	1770	1676	.563

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1	59.9097	.4083	60	60	145
2	35.8336	1.5079	40	36	1074
3	3.9754	.1548	4	4	40
4	5.9921	.1062	6	6	60
5	6.7503	1.1099	7	7	805
6	6.1500	1.9691	8	8	40
7	34.9725	.5232	35	35	350
8	29.7238	.5958	30	30	86
9	99.7273	.6415	100	100	655
10	138.8005	3.1517	148	140	386
11	194.6959	.9193	196	195	641
12	60.4596	.8844	63	61	164
13	131.5137	2.6205	140	130	423
14	38.9388	1.8875	45	40	95

SERVICE ACTIVITY STATISTICS

ACT NUM	ACT LABEL OR START NODE		SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX IDL TME/SER	MAX BSY TME/SER	ENT CNT
15	NAV	QUEUE	***	357.928	11.03	367	.00	1000.00	383.00	****
16	RN	QUEUE	***	232.880	9.07	232	.00	1000.00	268.00	****
17	IRN	QUEUE	***	272.468	25.08	222	.00	1000.00	320.00	****

GATE STATISTICS

GATE NUMBER	GATE LABEL	CURRENT STATUS	PCT. OF TIME OPEN
1	AFT	CLOSED	.1667

1 **HISTOGRAM NUMBER 1**

LINE NAVIGATORS

```
OBS  RELA   UPPER
FREQ FREQ  CELL LIM 0        20        40        60        80       100
                    +    +    +    +    +    +    +    +    +    +    +
  0  .000  .290e+03 +                                                 +
  0  .000  .295e+03 +                                                 +
  0  .000  .300e+03 +                                                 +
  0  .000  .305e+03 +                                                 +
  0  .000  .310e+03 +                                                 +
  0  .000  .315e+03 +                                                 +
  0  .000  .320e+03 +                                                 +
  0  .000  .325e+03 +                                                 +
  1  .025  .330e+03 +*                                                +
  0  .000  .335e+03 +C                                                +
  1  .025  .340e+03 +* C                                              +
  1  .025  .345e+03 +*  C                                             +
  1  .025  .350e+03 +*   C                                            +
  7  .175  .355e+03 +*********    C                                   +
  7  .175  .360e+03 +*********             C                          +
 11  .275  .365e+03 +**************                     C             +
  5  .125  .370e+03 +******                                    C      +
  5  .125  .375e+03 +******                                          C+
  1  .025  .380e+03 +*                                                C
  0  .000  .385e+03 +                                                 C
  0  .000  .390e+03 +                                                 C
  0  .000  .395e+03 +                                                 C
  0  .000  .400e+03 +                                                 C
  0  .000  .405e+03 +                                                 C
  0  .000  .410e+03 +                                                 C
  0  .000  .415e+03 +                                                 C
  0  .000    INF    +                                                 C
---                 +    +    +    *    +    +    +    +    +    +    +
 40                 0        20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
LINE NAVIGATORS	.360e+03	.997e+01	.277e-01	.328e+03	.379e+03	40

1 **HISTOGRAM NUMBER 2**

LINE RADARS

```
OBS  RELA    UPPERM FREQ FREQ  CELL LIM 0        20        40        60
  80         100
                      +    +    +    +    +    +    +    +    +    +    +
  0  .000  .200e+03 +                                                 +
  0  .000  .205e+03 +                  $                              +
  0  .000  .210e+03 +                                                 +
  0  .000  .215e+03 +                                                 +
  0  .000  .220e+03 +                                                 +
  3  .075  .225e+03 +****                                             +
  3  .075  .230e+03 +****    C                                        +
  8  .200  .235e+03 +**********       C                               +
  8  .200  .240e+03 +**********                 C                     +
  7  .175  .245e+03 +*********                          C             +
  6  .150  .250e+03 +********                                   C     +
  3  .075  .255e+03 +****                                           C +
  1  .025  .260e+03 +*                                               C+
  1  .025  .265e+03 +*                                                C
  0  .000  .270e+03 +                                                 C
  0  .000  .275e+03 +                                                 C
  0  .000  .280e+03 +                                                 C
  0  .000  .285e+03 +                                                 C
  0  .000  .290e+03 +                                                 C
  0  .000  .295e+03 +                                                 C
  0  .000  .300e+03 +                                                 C
  0  .000  .305e+03 +                                                 C
  0  .000  .310e+03 +                                                 C
  0  .000  .315e+03 +                                                 C
  0  .000  .320e+03 +                                                 C
  0  .000  .325e+03 +                                                 C
  0  .000    INF    +                                                 C
 ---                +    +    +    +    +    +    +    +    +    +    +
 40                 0         20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
LINE RADARS	.240e+03	.933e+01	.389e-01	.221e+03	.263e+03	40

1

****HISTOGRAM NUMBER 3****

INSTR RADARS

```
 OBS RELA   UPPER
FREQ FREQ  CELL LIM 0        20        40        60        80       100
                    +    +    +    +    +    +    +    +    +    +    +
  0  .000  .220e+03 +                                                 +
  1  .025  .225e+03 +*                                                +
  0  .000  .230e+03 +C                                                +
  1  .025  .235e+03 +* C                                              +
  2  .050  .240e+03 +*** C                                            +
  4  .100  .245e+03 +*****    C                                       +
  4  .100  .250e+03 +*****         C                                  +
  1  .025  .255e+03 +*              C                                 +
  1  .025  .260e+03 +*                C                               +
  1  .025  .265e+03 +*                 C                              +
  1  .025  .270e+03 +*                  C                             +
  4  .100  .275e+03 +*****                   C                        +
  0  .000  .280e+03 +                        C                        +
  3  .075  .285e+03 +****                        C                    +
  2  .050  .290e+03 +***                           C                  +
  4  .100  .295e+03 +*****                            C             +
  4  .100  .300e+03 +*****                                 C        +
  4  .100  .305e+03 +*****                                      C   +
  2  .050  .310e+03 +***                                             C+
  1  .025  .315e+03 +*                                                C
  0  .000  .320e+03 +                                                 C
  0  .000  .325e+03 +                                                 C
  0  .000  .330e+03 +                                                 C
  0  .000  .335e+03 +                                                 C
  0  .000  .340e+03 +                                                 C
  0  .000  .345e+03 +                                                 C
  0  .000    INF    +                                                 C
 ---                +    +    +    +    +    +    +    +    +    +    +
 40                 0        20        40        60        80       100
```

****STATISTICS FOR VARIABLES BASED ON OBSERVATION****

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
INSTR RADARS	.274e+03	.260e+02	.947e-01	.223e+03	.313e+03	40

```
1                          **HISTOGRAM NUMBER 4**
                                TOTAL RNs

OBS  RELA    UPPER
FREQ FREQ  CELL LIM 0        20        40        60        80       100
                    +    +    +    +    +    +    +    +    +    +    +
  0  .000  .375e+03 +                                                 +
  0  .000  .380e+03 +                                                 +
  0  .000  .385e+03 +                                                 +
  0  .000  .390e+03 +                                                 +
  0  .000  .395e+03 +                                                 +
  0  .000  .400e+03 +                                                 +
  0  .000  .405e+03 +                                                 +
  0  .000  .410e+03 +                                                 +
  0  .000  .415e+03 +                                                 +
  0  .000  .420e+03 +                                                 +
  0  .000  .425e+03 +                                                 +
  0  .000  .430e+03 +                                                 +
  0  .000  .435e+03 +                                                 +
  0  .000  .440e+03 +                                                 +
  0  .000  .445e+03 +                                                 +
  0  .000  .450e+03 +                                                 +
  8  .000  .455e+03 +                                                 +
  1  .025  .460e+03 +*                                                +
  0  .000  .465e+03 +C                                                +
  3  .075  .470e+03 +****C                                            +
  3  .075  .475e+03 +****    C                                        +
  4  .100  .480e+03 +*****        C                                   +
  2  .050  .485e+03 +***            C                                 +
  0  .000  .490e+03 +               C                                 +
  1  .025  .495e+03 +*                C                               +
  0  .000  .500e+03 +                 C                               +
 26  .650     INF   +*********************************                C
----                +    +    +    +    +    +    +    +    +    +    +
 40                 0        20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
TOTAL RNs	.514e+03	.321e+02	.625e-01	.457e+03	.567e+03	40

1

HISTOGRAM NUMBER 5
SAC STAFF

```
OBS  RELA    UPPER
FREQ FREQ  CELL LIM 0         20        40        60        80        100
                    +    +    +    +    +    +    +    ;    +    +    +
  0  .000  .125e+03 +                                                 +
  0  .000  .126e+03 +                                                 +
  0  .000  .127e+03 +                                                 +
  0  .000  .128e+03 +                                                 +
  0  .000  .129e+03 +                                                 +
  0  .000  .130e+03 +                                                 +
  0  .000  .131e+03 +                                                 +
  0  .000  .132e+03 +                                                 +
  0  .000  .133e+03 +                                                 +
  1  .025  .134e+03 +*                                                +
  4  .100  .135e+03 +*****C                                           +
  5  .125  .136e+03 +******      C                                    +
  8  .200  .137e+03 +**********            C                          +
  4  .100  .138e+03 +*****                      C                     +
  6  .150  .139e+03 +********                          C              +
  2  .050  .140e+03 +***                                  C           +
  0  .000  .141e+03 +                                     C           +
  2  .050  .142e+03 +***                                    C         +
  3  .075  .143e+03 +****                                       C     +
  1  .025  .144e+03 +*                                           C    +
  2  .050  .145e+03 +***                                            C +
  2  .050  .146e-03 +***                                              C
  0  .000  .147e+03 +                                                 C
  0  .000  .148e+03 +                                                 C
  0  .000  .149e+03 +                                                 C
  0  .000  .150e+03 +                                                 C
  0  .000    INF    +                                                 C
 ---                +    +    +    +    +    +    +    +    +    +    +
 40                 0         20        40        60        80        100
```

STATISTICS FOR VARIABLES BASED@ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
SAC STAFF	.139e+03	.333e+01	.240e-01	.134e+03	.146e+03	40

1

HISTOGRAM NUMBER 6
GENERAL SDAFF

```
OBS   RELA  UPPER
FREQ  FREQ  CELL LIM 0         20        40        60        80       100
                     +    +    +    +    +    +    +    +    +    +    +
   0  .000  .180e+03 +                                                 +
   0  .000  .181e+03 +                                                 +
   0  .000  .182e+03 +                                                 +
   0  .000  .183e+03 +                                                 +
   0  .000  .184e+03 +                                                 +
   0  .000  .185e+03 +                                                 +
   0  .000  .186e+03 +                                                 +
   0  .000  .187e+03 +                                                 +
   0  .000  .188e+03 +                                                 +
   0  .000  .189e+03 +                                                 +
   4  .100  .190e+03 +*****                                            +
   1  .025  .191e+03 +*    C                                           +
   2  .050  .192e+03 +***     C                                        +
   3  .075  .193e+03 +****        C                                    +
   8  .200  .194e+03 +**********            C                          +
  18  .450  .195e+03 +***********************                     C    +
   4  .100  .196e+03 +*****                                            C
   0  .000  .197e+03 +                                                 C
   0  .000  .198e+03 +                                                 C
   0  .000  .199e+03 +                                                 C
   0  .000  .200e+03 +                                                 C
   0  .000  .201e+03 +                                                 C
   0  .000  .202e+03 +                                                 C
   0  .000  .203e+03 +                                                 C
   0  .000  .204e+03 +                                                 C
   0  .000  .205e+03 +                                                 C
   0  .000    INF    +                                                 C
 ---                 +    +    +    +    +    +    +    +    +    +    +
  40                 0         20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
GENERAL STAFF	.194e+03	.174e+01	.897e-02	.190e+03	.196e+03	40

```
1                          **HISTOGRAM NUMBER 7**
                              SEP OP AGENCIES

OBS  RELA   UPPER
FREQ FREQ  CELL LIM 0         20        40        60        80        100
                    +    +    +    +    +    +    +    +    +    +    +
  0  .000  .500e+02 +                                                 +
  0  .000  .510e+02 +                                                 +
  0  .000  .520e+02 +                                                 +
  0  .000  .530e+02 +                                                 +
  0  .000  .540e+02 +                                                 +
  0  .000  .550e+02 +                                                 +
  0  .000  .560m+02 +                                                 +
  2  .050  .570e+02 +***                                              +
  1  .025  .580e+02 +*  C                                             +
  9  .225  .590e+02 +***********    C                                 +
 19  .475  .600e+02 +************************             C           +
  4  .100  .610e+02 +*****                                     C      +
  5  .125  .620e+02 +******                                           C
  0  .000  .630e+02 +                                                 C
  0  .000  .640e+02 +                                                 C
  0  .000  .650e+02 +                                                 C
  0  .000  .660e+02 +                                                 C
  0  .000  .670e+02 +                                                 C
  0  .000  .680e+02 +                                                 C
  0  .000  .690e+02 +                                                 C
  0  .000  .700e+02 +                                                 C
  0  .000  .710e+02 +                                                 C
  0  .000  .720e+02 +                                                 C
  0  .000  .730e+02 +                                                 C
  0  .000  .740e+02 +                                                 C
  0  .000  .750e+02 +                                                 C
  0  .000    INF    +                                                 C
 ---                +    +    +    +    +    +    +    +    +    +    +
 40                 0         20        40        60        80        100


             **STATISTICS FOR VARIABLES BASED ON OBSERVATION**

                          MEAN     STANDARD  COEFF. OF  MINIMUM    MAXIMUM   NO.OF
                          VALUE    DEVIATION VARIATION   VALUE      VALUE     OBS

SEP OP AGENCIES         .599e+02  .119e+01  .198e-01  .570e+02  .620e+02    40
```

1 **HISTOGRAM NUMBER 8**

PENTAGON

```
OBS  RELA   UPPER
FREQ FREQ   CELL LIM 0        20        40        60        80       100
                     +    +    +    +    +    +    +    +    +    +    +
   0  .000  .300e+02 +                                                 +
   0  .000  .310e+02 +                                                 +
   0  .000  .320e+02 +                                                 +
   0  .000  .330e+02 +                                                 +
   0  .000  .340e+02 +                                                 +
   0  .000  .350e+02 +                                                 +
   2  .050  .360e+02 +***                                              +
  10  .250  .370e+02 +************* C                                  +
   7  .175  .380e+02 +*********              C                         +
   8  .200  .390e+02 +**********                       C               +
   7  .175  .400e+02 +*********                                 C      +
   4  .100  .410e+02 +*****                                         C +
   0  .000  .420e+02 +                                              C +
   1  .025  .430e+02 +*                                              C+
   1  .025  .440e+02 +*                                               C
   0  .000  .450e+02 +                                                C
   0  .000  .460e+02 +                                                C
   0  .000  .470e+02 +                                                C
   0  .000  .480e+02 +                                                C
   0  .000  .490e+02 +                                                C
   0  .000  .500e+02 +                                                C
   0  .000  .510e+02 +                                                C
   0  .000  .520e+02 +                                                C
   0  .000  .530e+02 +                                                C
   0  .000  .540e+02 +                                                C
   0  .000  .550e+02 +                                                C
   0  .000       INF +                                                C
 ---                 +    +    +    +    +    +    +    +    +    +    +
  40                 0        20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
PENTAGON	.388e+02	.180e+0	.465e-01	.360e+02	.440e+02	40

1 **HISTOGRAM NUMBER 9**

PME

```
 OBS  RELA    UPPER
FREQ  FREQ  CELL LIM 0        20        40        60        80       100
                     +    +    +    +    +  0 +    +    +    +    +
   0  .000  .250e+02 +                                                 +
   8  .200  .260e+02 +**********                                       +
   1  .025  .270e+02 +          C                                      +
   0  .000  .280e+02 +          C                                      +
   0  .000  .290e+02 +          C                                      +
   0  .000  .300e+02 +          C                                      +
   0  .000  .310e+02 +          C                                      +
   0  .000  .320e+02 +          C                                      +
   0  .000  .330e+02 +          C                                      +
  19  .475  .340e+02 +************************          C              +
  12  .300  .350e+02 +***************                                  C
   0  .000  .360e+02 +                                              0  C
   0  .000  .370e+02 +                                                 C
   0  .000  .380e+02 +                                                 C
   0  .000  .390e+02 +                                                 C
   0  .000  .400e+02 +                                                 C
   0  .000  .410e+02 +                                                 C
   0  .000  .420e+02 +                                                 C
   0  .000  .430e+02 +                                                 C
   0  .000  .440e+02 +                                                 C
   0  .000  .450e+02 +                                                 C
   0  .000  .460m+02 +                                                 C
   0  .000  .470e+02 +                                                 C
   0  .000  .480e+02 +                                                 C
   0  .000  .490e+02 +                                                 C
   0  .000  .500e+02 +                                                 C
   0  .000    INF    +                                                 C
 ---                 +    +    +    +    +    +    +    +    +    +    +
  40                 0        20        40        60        80       100
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
PME	.325e+02	.353e+01	.109e+00	.260e+02	.350e+02	40

1 **TABLE NUMBER 1**

RUN NUMBER 1

ELAPSED TIME	NAVS	RADARS	IRNS
MINIMUM	.3280e+03	.2210e+03	.2230e+03
MAXIMUM	.3790e+03	.2630e+03	.3130e+03

```
1                                     **PLOT NUMBER  1**
                                       RUN  NUMBER  1

                                           SCALES OF PLOT
N=NAVS         .300e+03            .350e+03              .400e+03
R=RADARS       .200e+03            .250e+03              .300e+03
I=IRNS         .200e+03            .300e+03              .400e+03
               0   10   20   30   40   50   60   70   80   90   100 DUPS
ELAPSED TIME

    .0000e+00  +        I      R        +         N              +
    .3000e+01  +     I          R       +      N                 +
    .6000e+01  +          I      R      +      N                 +
    .9000e+01  +        I        R     N+                        +
    .1200e+02  +          I R           +  N                     +
    .1500e+02  +           I    R N     +                        +
    .1800e+02  +             N   IR     +                        +
    .2100e+02  +                I    RN +                        +
    .2400e+02  +              I R       + N                      +
    .2700e+02  +                R I     +    N                   +
    .3000e+02  +                   RI   + N                      +
    .3300e+02  +                    I  R+         N              +
    .3600e+02  +                 I    R +          N             +
    .3900e+02  +                 I      +   R N                  +
    .4200e+02  +                      I +R      N                +
    .4500e+02  +                     R  I          N             +
    .4800e+02  +                    R I +           N            +
    .5100e+02  +                  R    I+        N               +
    .5400e+02  +                        R I   N                  +
    .5700e+02  +                        +I     R N               +
    .6000e+02  +                      I R   N                    +
    .6300e+02  +                   R    I    N                   +
    .6600e+02  +                      I + R  N                   +
    .6900e+02  +                      R +I     N                 +
    .7200e+02  +                    R  I+  N                     +
    .7500e+02  +                    I   + R     N                +
    .7800e+02  +                       R+ I     N                +
    .8100e+02  +                       R+  I      N              +
    .8400e+02  +                    R   +I    N                  +
    .8700e+02  +             R          +I             N         +
    .9000e+02  +               R        I          N             +
    .9300e+02  +                   R   I+      N                 +
    .9600e+02  +               I  R     + N                      +
    .9900e+02  +          R I           +N                       +
    .1020e+03  +            R           + N                      + RI
    .1050e+03  +           I    R       +   N                    +
    .1080e+03  +          IR            +N                       +
    .1110e+03  +         I         R    +   N                    +
    .1140e+03  +           I  R         +      N                 +
    .1170e+03  +        I            R  +          N             +
               0   10   20   30   40   50   60   70   80   90   100 DUPS
ELAPSED TIME
```

```
OUTPUT  CONSISTS  OF      40 POINT SETS (    120 POINTS)
STORAGE ALLOCATED FOR 10978 POINT SETS ( 43912 W
STORAGE  NEEDED   FOR     40 POINT SETS (    160 WORDS )

1                               **TABLE NUMBER  2**
                                  RUN  NUMBER   1
```

ELAPSED TIME	TOTAL
MINIMUM	.4570e+03
MAXIMUM	.5670e+03

```
1                               **PLOT NUMBER   2**
                                 RUN  NUMBER  1

                                   SCALES OF PLOT
B=TOTAL        .350e03               .450e+03              .550e+03
               0    10   20   30   40   50   60   70   80   90   100 DUPS
ELAPSED TIME

  .0000e+00    +                        +   B                    +
  .3000e+01    +                        + B                      +
  .6000e+01    +                        +      B                 +
  .9000e+01    +                        +     B                  +
  .1200e+02    +                        +    B                   +
  .1500e+02    +                        +       B                +
  .1800e+02    +                        +              B         +
  .2100e+02    +                        +              B         +
  .2400e+02    +                        +          B             +
  .2700e+02    +                        +              B         +
  .3000e+02    +                        +                 B      +
  .3300e+02    +                        +                   B    +
  .3600e+02    +                        +                B       +
  .3900e+02    +                        +                   B    +
  .4200e+02    +                        +                      B +
  .4500e+02    +                        +                       B+
  .4800e+02    +                        +                    B   +
  .5100e+02    +                        +                    B   +
  .5400e+02    +                        +                        +
  .5700e+02    +                        +                        +
  .6000e+02    +                        +                     B  +
  .6300e+02    +                        +                     B  +
  .6600e+02    +                        +                      B +
  .6900e+02    +                        +                        B
  .7200e+02    +                        +                     B  +
  .7500e+02    +                        +                     B  +
  .7800e+02    +                        +                        +
  .8100e+02    +                        +                        +
  .8400e+02    +                        +                       B+
  .8700e+02    +                        +                    B   +
  .9000e+02    +                        +                   B    +
  .9300e+02    +                        +                    B   +
  .9600e+02    +                        +            B           +
  .9900e+02    +                        +     B                  +
  .1020e+03    +                        +      B                 +
  .1050e+03    +                        +       B                +
  .1080e+03    +                        +    B                   +
  .1110e+03    +                        +       B                +
  .1140e+03    +                        +     B                  +
  .1170e+03    +                        +       B                +
               0    10   20   30   40   50   60   70   80   90   100 DUPS
ELAPSED TIME
```

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Vita

Kenneth E. Charpie, Jr. was born on 19 February 1956 in Albuquerque, New Mexico. After graduating from Gen'ral HH Arnold High School in Wiesbaden, Germany in 1974, he attended the U. S. Air Force Academy. He earned a Bachelor of Science in Chemistry degree and was commissioned in May 1978. After completing navigator training in 1979, he was stationed at Minot AFB as a B-5? navigator. While there, he served as navigator, Standardization/Evaluation Flight Examiner navigator, radar navigator, and instructor radar navigator. He entered the Strategic and Tactical Sciences Graduate Program at the School of Engineering, Air Force Institute of Technology in August 1985. He is married to the former Kathleen D. Reading.

Permanent Address:
446 N River Dr
Gwinn, MI 49841

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18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Navigators, Careers
Network Flows, Simulation

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Title: AN ANALYSIS OF CHRONIC PERSONNEL SHORTAGES
IN THE B-52 RADAR NAVIGATOR CAREER FIELD

Thesis Chairman: Thomas F. Schuppe, Lt. Col., USAF
Instructor of Operations Research

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LYNN E. WOLAVER 5 May 87
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

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22a. NAME OF RESPONSIBLE INDIVIDUAL
Thomas F. Schuppe, Lt Col, USAF

22b. TELEPHONE *(Include Area Code)*
(513) 255-3362

22c. OFFICE SYMBOL
AFIT/ENS

Abstract

This research effort developed two career progression models for the B-52 navigator and radar navigator career field: a linear programming model and a SLAM simulation model. The linear programming model calculated the steady state conditions well, whereas the simulation model showed the dynamics present in the transient states.

An analysis of the present crew force and current conditions was accomplished using these two models. Also examined were several changes currently occurring in the crew force: the reduction of some staff positions, and the reduction of the draw on the B-52 crew force to man the B-1B. An increase in the size of the crew force was also studied, as were several variations on the retention rate. The last condition examined was changing the policy of allowing crewmembers to go to career broadening positions after six years of active flying experience to a policy of requiring nine years of flying experience. The only condition determined to have a serious impact on meeting manning requirements was a decrease in the retention rate. The difficulty with managing the crew force when the retention rate changed was the long lead time necessary to replace the crewmembers lost. (Theses).