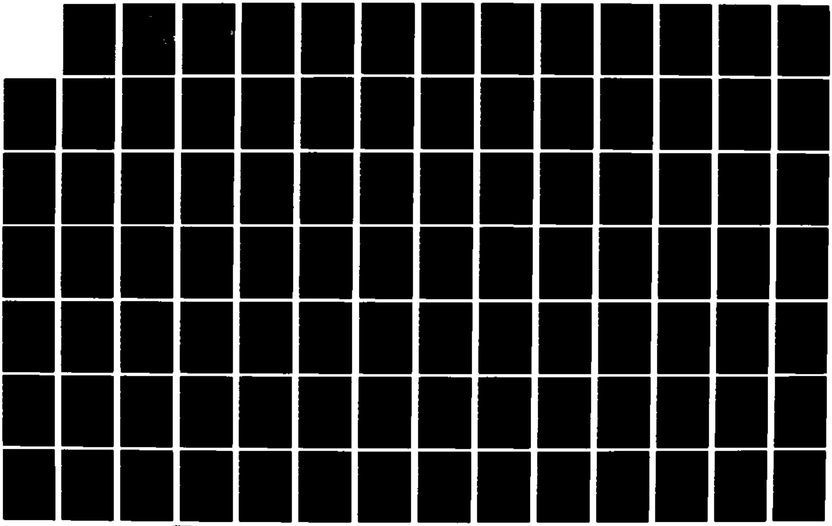
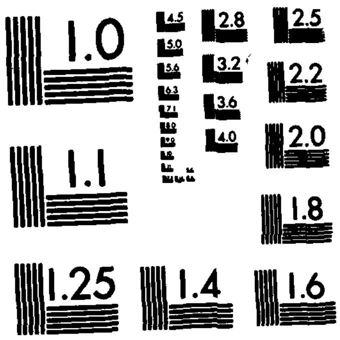
AD-A124 779 THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES WI..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. K L LAWSON 1/3

UNCLASSIFIED DEC 82 AFIT/GOR/OS/82D-8 F/G 5/9 NL






MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY (ATC)

# AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GOR/OS/82D-8



THE ROTATION/ASSIGNMENT SYSTEM OF
IMBALANCED AIR FORCE SPECIALTY CODES
WITHIN AIR FORCE COMMUNICATIONS COMMAND:
A SYSTEM DYNAMICS MODEL AND ANALYSIS

THESIS

AFIT/GOR/OS/82D-8 Kevin L. Lawson
1LT USAF

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

**1. REPORT NUMBER**
AFIT/GOR/OS/82D-8

**2. GOVT ACCESSION NO.**
A124 449

**3. RECIPIENT'S CATALOG NUMBER**

**4. TITLE (and Subtitle)**
THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES WITHIN AIR FORCE COMMUNICATIONS COMMAND: A SYSTEM DYNAMICS MODEL AND ANALYSIS

**5. TYPE OF REPORT & PERIOD COVERED**
MS Thesis

**6. PERFORMING ORG. REPORT NUMBER**

**7. AUTHOR(s)**
Kevin Lee Lawson
1Lt

**8. CONTRACT OR GRANT NUMBER(s)**

**9. PERFORMING ORGANIZATION NAME AND ADDRESS**
Air Force Institute of Technology (AFIT-EN)
Wright-Patterson AFB, Ohio 45433

**10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS**

**11. CONTROLLING OFFICE NAME AND ADDRESS**

**12. REPORT DATE**
December, 1982

**13. NUMBER OF PAGES**
247

**14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)**

**15. SECURITY CLASS. (of this report)**
Unclassified

**15a. DECLASSIFICATION/DOWNGRADING SCHEDULE**

**16. DISTRIBUTION STATEMENT (of this Report)**
Approved for public release; distribution unlimited

**17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)**

**18. SUPPLEMENTARY NOTES**
Approved for public release: IAW AFR 190-17
LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (AIC)
Wright-Patterson AFB OH 45433

Approved for public release; IAW AFR 190-17
~~FREDERIC C. LYNCH, Major,~~ USAF
D~~irector of Public Affai~~rs

**19. KEY WORDS (Continue on reverse side if necessary and identify by block number)**
Rotation
Airman Assignment
System Dynamics
Policy Models
Simulation

**20. ABSTRACT (Continue on reverse side if necessary and identify by block number)**
A dynamic policy model of the airman assignment and rotation system has been developed and tested. The model incorporates aggregate flows, broad-based system structure, and decision rules that can be used as a tool for studying the effects of alternative assignment and rotation policies. Literature research and personal interviews with Air Force personnel active in the airman assignment and rotation system were used as information sources in the model development. The model structure is developed around the system

goal of providing the proper number of enlisted personnel in the overseas and CONUS tours so the Air Force mission can be achieved. The model includes the important information feedback control loops of the airman assignment and rotation system for imbalanced AFSCs. Preliminary use of the model for policy analysis indicates that rotation policies should center around expansion of the CONUS rotation base.

AFIT/GOR/OS/82D-8

# THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES WITHIN AIR FORCE COMMUNICATIONS COMMAND: A SYSTEM DYNAMICS MODEL AND ANALYSIS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Kevin L. Lawson
1LT USAF

Graduate Operations Research

December 1982

Approved for public release;distribution unlimited.

## Preface

The rotation of military personnel assigned to specialties in which there are a large number of overseas long and overseas short tours relative to the number of CONUS tours presents unique problems for the individuals in those specialties and for the policy makers who must manage those individuals. Specifically, there are negative effects on retention due to a high frequency of overseas tours during a military career that can result in (1) high system costs due to the movement and replacement of personnel, (2) an undesirable force mix of experienced and inexperienced personnel, and (3) a decrease in force readiness due to an improper force mix or an actual shortage of personnel in a specialty. Research in the area of the rotation of personnel in imbalanced Air Force specialties resulted in a policy model based on the system dynamics approach. This report is intended primarily for decision makers concerned with the rotation of personnel in imbalanced specialties but may prove useful for individuals with related interests. No prior knowledge of the Air Force Manpower and Personnel System nor of the rotation of personnel within that system is assumed. In addition, no prior knowledge of the system dynamics methodology is required to read this report.

I would like to thank Col. Ed Wilson, Ret. and Capt.

Scott Hammel, who independently suggested this research topic. I would also like to thank Lt. Col. Tom Clark, my research advisor, for suggesting a suitable research approach and guiding me throughout this effort. To Lt. Col. Jim Dunne, Ret. and Lt. Col. Jim Bexfield, I owe my thanks for reading this document and for lending helpful suggestions throughout the research process. Thanks also go to Gail Fraley for proof-reading and making technical corrections to this report. A special note of thanks is extended to Lt. Mark Reid, a fellow classmate. Working together, Mark and I developed the conceptual and formal model structure upon which this research was based. The synergism of working with Mark enabled the initial research topic to be expanded and the overall quality of the work to improve.

A number of individuals with experience in the Air Force Manpower and Personnel System gave freely of their time to answer questions and to impart some of their knowledge of the airman assignment and rotation process. Ed Wilson and Scott Hammel were already mentioned. Other individuals who granted me interviews include Major General Stuart Sherman, Major Stan Polk, Major Haldeman, Major Mike Hoffman, Captain Dan Almond, Dr. Joe Ward, and SMSGT Unger. Their input proved to be invaluable in the process of obtaining a useful policy model.

Lastly, I want to express my gratitude to my wife and

best friend, Debra. Her patience and assistance throughout this research will be difficult to repay. She became my typist, illustrator, technical advisor, and moral supporter. The largest debt of gratitude goes to her. The woman who promised to love and honor me has come through again, and I thank her.

## Contents

## List of Figures

## List of Tables

Table | Page

AFIT/GOR/OS/82D-8


## Abstract

A dynamic policy model of the airman assignment and rotation system has been developed and tested. The model incorporates aggregate flows, broad-based system structure, and decision rules that can be used as a tool for studying the effects of alternative assignment and rotation policies. Literature research and personal interviews with Air Force personnel active in the airman assignment and rotation system were used as information sources in the model development. The model structure is developed around the system goal of providing the proper number of enlisted personnel in the overseas and CONUS tours so the Air Force mission can be achieved. The model includes the important information feedback control loops of the airman assignment and rotation system for imbalanced AFSCs. Preliminary use of the model for policy analysis indicates that rotation policies should center around expansion of the CONUS rotation base.

# THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES WITHIN AIR FORCE COMMUNICATIONS COMMAND: A SYSTEM DYNAMICS MODEL AND ANALYSIS

## I Introduction

### Background

United States defense policy dictates that U.S. military personnel be stationed in different areas of the world. Assigning personnel to meet these defense requirements is a complex management process. Smith (Ref 46:1) pointed out that "assignment policies must take several objectives into account, including maintaining a high level of readiness and loyalty among overseas personnel, treating military personnel and their families equitably, developing successful careers, and minimizing the cost to the manpower system" (Ref 46:1). Resulting from the set of multiple and often conflicting objectives is a complex set of assignment policies for military personnel. These policies govern such things as lengths of assignments (tours), compensation, accompaniment status for tours, and availability of personnel.

In general, U.S. policy is to change overseas personnel continuously. The alternative to this policy would be to permanently assign personnel to autonomously managed U.S. commands. For social, political, and military reasons, this alternative is considered unacceptable to most U.S. policy makers (Ref 46:1). Therefore, military personnel are sent to specific assignments for a set length of time and then relocated. "Periodic relocation is referred to as rotation" (Ref 46:1).

The assignment and rotation process in the United States Armed Forces has two basic classes of tours: CONUS (Continental United States and Hawaii) and non-CONUS. Rotation can occur within a class or between classes. For example, personnel can move from one CONUS assignment to another CONUS assignment or from a CONUS assignment to a non-CONUS assignment. Non-CONUS assignments include long overseas tours and short overseas tours. Short overseas tours are generally located in remote areas and are unaccompanied. CONUS contains a manpower pool referred to as the rotation base. Individuals are drawn from this pool to rotate to non-CONUS tours.

Smith (Ref 46:1) pointed out the reasons for the concern the Department of Defense (DoD) has over rotation policies and the rotation base:

> Rotating service personnel is expensive and affects force size, productivity, efficiency, and morale. Recent emphasis on reduction of costs incurred from permanently relocating military personnel and their dependents (Permanent Change of Station or PCS moves) has implications for the size and composition of the rotation base. Additionally, the rotation system affects first-term attrition and career-force retention and has implications for

> manpower policies such as first-term/career mix, civilian/military subsititution, and the number and type of occupations women are assigned to in the military. To fully assess future manpower policies and these rotation-related issues, DoD needs a better understanding of each service's rotation policies and practices along with the rationale supporting them. (Ref 46:2)

In addition to Smith's work, Chow and Poich (Ref 11) showed that rotation imbalance in a specialty has moderate correlation with reenlistment rates.

<u>USAF Rotation Policies</u>. Each branch of the United States Armed Forces has its own set of problems associated with the rotation of its personnel. Smith (Ref 46) pointed that the United States Air Force (USAF) has a minor problem with rotation when compared with the other services. "In 35 of the 358 Air Force Specialties (AFS), overseas requirements create imbalances in personnel flows between overseas and CONUS assignments. These specialties are referred to as CONUS/Overseas Imbalanced Skills. This condition affects 34,000 of the 422,000 Air Force enlisted military personnel" (Ref 46:1).

The USAF has a general rotation policy that "minimizes family separation and thereby negative effects on retention behavior" (Ref 46:1). This policy has three facets:

1. There can be no more than eight years overseas service time in a 20 year career.

2. Airmen must have at least 24 months CONUS time between involuntary overseas tours.

3. There can be no more than two remote tours in a 20 year career. (Ref 6:69)

Air Force Manpower and Personnel Center (AFMPC) resource managers report that the ideal ratio for CONUS to overseas authorizations in a given Air Force Specialty Code (AFSC) is 3:1 (Ref 54:1). That is, if an AFSC has at least three CONUS authorizations for every overseas authorization, the conditions outlined above can be achieved. Those AFSCs for which any one of the above conditions are not met are referred to as imbalanced AFSCs and are placed on the Unsatisfactory Rotation Index (URI) list (Ref 6:69). "An AFSC can be imbalanced due to a disproportionate number of remote tours, overseas long tours, or both" (Ref 8).

The Air Force seems to be concerned that failure to achieve its rotational objectives causes a decrease in morale and job satisfaction and an increase in the separation rates. Policy guidelines have been given with the intention of creating a more desirable ratio of CONUS to overseas authorizations (Ref 6:69-71). Programs have been initiated at AFMPC with the intention of increasing individuals' participation in the assignment system (Ref 8 and Ref 25).

An increase in separation rates can also be partly attributed to the need for skilled technical people outside of the military. There is evidence that the level of compensation has some affect on separation rates (Ref 25). For example, two imbalanced AFSCs within Air Force Communications Command (AFCC) are Telecommunications System/Equipment Maintenance Specialist and Telecommunications Systems Control Specialist (see Table 1.1). If the demand for individuals with these types of skills is higher than the supply, it is likely that salaries will be increased to a level that is higher than that received by military personnel possessing those skills.

| AFSC | Specialty Title |
|---|---|
| 293X3 | Ground Radio Operator |
| 304X0 | Wideband Communicaions Equipment Specialist |
| 304X6 | Space Communications System Equipment Operator/Specialist |
| 30499 | Ground Radio Communications Superintendent |
| 306X1 | Electronics Mechanical Comm & Crypto Eqp Sys Specialist |
| 306X2 | Telecommunications Sys/Eqp Maintenance Specialist |
| 307X0 | Tele-Comm System Control Specialist |

Table 1.1. Airmen Communications and Electronic Specialties With Unsatisfactory Rotation Indexes

<u>Rotation Problems within Air Force Communications Command</u>

Accounting for a portion of the heaviest USAF imbalances are AFSCs in the communications and electronics areas. The majority of personnel with these communications and electronics AFSCs are assigned to locations under the responsibility of Air Force Communications Command (AFCC) (Ref 25). Table 1.2 shows the space imbalances in these career fields. Table 1.1 shows airmen specialties primarily assigned within AFCC that have been given Unsatisfactory Rotation Indexes (URI). Refer to Appendix A for a description of the AFSCs listed in Table 1.1.

| Airmen Career Field | Group | No. of AFSCs | Strength CONUS | Strength O/S | Authorizations CONUS | Authorizations O/S | Rotation Base Requirement |
|---|---|---|---|---|---|---|---|
| Communications | 304 | 4 | 2751 | 2873 | 2052 | 3351 | 4602 |
| Electronics | 306 | 1 | 120 | 172 | 147 | 153 | 184 |
| | 307 | 4 | 2017 | 2567 | 1269 | 2308 | 3069 |

Table 1.2. CONUS/OVERSEAS Space Imbalances In Communications and Electronics Career Groups

Due to the great complexity of the assignment and rotation process, USAF rotation policies must have a systems orientation. The assignment and rotation system effectiveness is largely determined by how well the implemented policies control the assignment and rotation system as the rotation process is acted on by internal and external environmental factors. The internal environment includes the processes of training, promotion, assignment and rotation. Associated with these processes are such things as tour lengths, overseas requirements, size of the rotation base, promotion and separation rates from one airman grade to another, bonuses paid for reenlistment, and delay times for training, promotion and rotation. The external environment encompasses the perceived need for overseas personnel, the reaction of U.S. policymakers to the perception, the U.S. national labor market, the needs and problems faced by the other branches of the U.S. Armed Forces, and requirements and constraints placed on the system by the executive and legislative branches of the U.S. government. The interrelationships and interactions between the environment and the assignment and rotation process define the assignment and rotation system within the USAF. Understanding the structure of the relationships and interactions and developing appropriate policies are necessary for decision makers to be able to effectively and efficiently control the system.

Policy makers have previously relied on their judgement, intuition, and experience in setting policies. Analytical models of portions of the system have been built as a supporting tool. Some of these analytical models are reviewed in Chapter Two of this thesis. In short, these models fail to take into account the interrelationships and interactions of the complex assignment and rotation system. Large-scale, isomorphic simulation models have also been built as a supporting tool. Although these models were built with the capability of reflecting the complex interactions and interrelationships of the system, they have seen very limited use. The data required for a typical "run" of one of these large-scale models is generally very extensive, and the cost of computer time for a run is generally quite high. These models are also reviewed in Chapter Two.

Forrester (Ref 16:1) developed a methodology for dealing with problems that resulted from complex system behavior. This methodology, originally referred to as industrial dynamics, is now referred to as system dynamics. This methodology allows the policy maker to benefit from the development of dynamic models, from the understanding of the system gained in developing the model and from the information gained from operating a "completed" model. A dynamic policy model of the airmen assignment and rotation system would provide policy makers with a valuable tool to use in the evaluation of potential rotation policies.

## Problem Statement

A dynamic policy model of the airmen assignment and rotation system did not exist prior to the beginning of this research. A dynamic policy model incorporating aggregate flows, system structure, and decision rules will enable policy makers to study the effects of policies and environmental changes over time. Additionally, a policy model would allow policy makers to easily test the behavior of the system under different structural assumptions.

## Study Purpose

The purposes of this research are to examine the structure of the airman assignment and rotation system, determine how to capture that structure in a dynamic model, and demonstrate how the model can be used to evaluate rotation policies. With an increased understanding of the structure and behavior of the airman assignment and rotation system, progress can be made toward addressing undesirable system performance.

## Objectives

The objectives of the research described in this report were:

1. To review possible methodologies that could be used for developing a model of the airman assignment and rotation system and to choose the most appropriate methodology for addressing undesirable system performance.

2. To determine the important factors and relationships that exist in the internal and external environment of the airman assignment and rotation system.

3. To develop a policy model of the airman assignment and rotation system.

4. To verify and validate the model.

5. To use the model to evaluate a specific policy area and provide information on the use of the model for policy analysis.

6. To use the model to identify a policy which leads to improved behavior of the airman assignment and rotation system.

## Scope

The primary thrust of this research was to understand and model the airman assignment and rotation system. The following methodologies were reviewed as candidates for modeling the system: (1) Markov modeling, (2) Isomorphic modeling, and (3) the System Dynamics approach. A dynamic model of the airman assignment and rotation system was developed using the system dynamics approach. The model presented here was developed at a fairly high level of aggregation. The model examines one Air Force Specialty at a time. Model inputs are taken from AFSCs within the Communications and Electronics areas (see Table 1.1). A description of these AFSCs is given in Appendix A. The output of the model was designed to show short-term effects as well as long-term trends associated with a specific policy implementation.

Exogenous input factors include desired manning levels by skill level, desired manning levels for overseas long and short tours, inital manning levels, "normal" separation rates from skill levels, pay and compensation levels, and the length of the national economic business cycle. Bonuses are generated in the model as a response to manning levels subject to political constraints. Separation rates are affected in the model by pay and compensation, bonuses, and rotation conditions subject to economic constraints.

Overview of the Report

The literature relating to manpower planning models is reviewed in Chapter Two, Manpower and Personnel Planning Approaches. Three primary approaches dominate: (1) fractional-flow Markov modeling, (2) isomorphic simulation modeling, and (3) system dynamics modeling. The basic assumptions of Markov modeling are flow conservation, equilibrium, and the Markov property. Isomorphic models simulate individual entities from the system being modeled. The system dynamics approach focuses on feedback processes. Two rotation of forces models have been developed. One uses a Markov model, and the other uses an entity simulation model. These two examples, as well as other examples of manpower planning models, are presented. An overview of the system dynamics approach is presented and reasons are given for choosing the system dynamics methodology for the development of the model of the airman assignment and rotation system.

Described in Chapter Three, The Model, are the airman assignment and rotation system, the system dynamics model, and how the model reflects system behavior. The conceptual structure of the system and the two sectors are presented. The introduction to the chapter includes an introduction to system dynamics concepts as well as the major concepts of the airman assignment and rotation system.

Described in Chapter Four, Model Testing and Validation, are the structural and behavioral tests that were performed on the model.

Described in Chapter Five, Policy Experimentation, are the five policy tests that were conducted, as well as the results of those tests.

Chapter Six, Summary, Recommendations and Conclusions, contains the summary of the model, recommendations for further study, and concluding comments on the research effort.

## Summary

Chapter One has presented the problem, study purpose, research objective, and a brief summary of the issues involved in the rotation of military personnel. Chapter Two will present other methodologies that were investigated. An overview of system dynamics, the methodology used in this research, is presented in the fourth section of Chapter Two.

# II Manpower Planning Model Literature Review

## Introduction

The objective of this literature review is to examine approaches to manpower and personnel policy analysis. Three approaches dominate: (1) fractional-flow "Markov" modeling, (2) "isomorphic" simulation modeling, and (3) system dynamics modeling. The fractional-flow approach to manpower modeling is quite prevalent within the Department of Defense (DoD). The basis of many U.S. Armed Forces manpower planning models, "though not explicitly stated, is the cross-sectional model with its fractional flow assumptions" (Ref 20:89). "Isomorphic" simulation models, also known as entity models, "treat personnel as individuals" (Ref 55:2). Each person in the system being modeled is classified and accounted for in the model of the system. System dynamic models of manpower and personnel systems are primarily concerned with aggregate flows rather than the occurence of discrete events. Although system dynamics has been applied to many areas of marketing and industry, the approach has not been widely used in policy analysis for manpower and personnel systems. For reasons that will be given in this chapter, system dynamics promises to be a useful methodology for approaching the research topic described in Chapter One of this thesis.

Distinction between "Manpower" and "Personnel". To avoid confusion on terminology, the distinction between the terms "manpower" and "personnel" must be established. This distinction is unique to the Air Force. The terms appear to be interchangeable in the literature that is not written for Air Force applications, including that written for the other Armed Forces.

The term "manpower" refers to the authorization for people. A manpower function would be concerned with the proper number of people of a certain skill or rank that are needed by specific organizations. A manpower organization concerns itself with these people requirements. The term "personnel" refers to the acquisition, training, and assignment of people to authorizations or billets with people. The two terms will be used interchangeably except during discussions of models written specifically for Air Force applications.

Scope and Method of Assessment. Each of the three approaches to manpower and personnel modeling will be reviewed in the following manner:

1. An overview of the approach will be given, and the assumptions and basic structure of the models will be stated.

2. Several examples of the approach will be explored.

3. The validity and utility of models developed under

the approach will be examined.

This review will conclude with a summary of the advantages and disadvantages of possible methodologies that could be used to investigate policy issues that apply to the research topic. A choice will be made from these methodologies. This choice will be justified in terms of suitability and utility.

## Fractional Flow Models

Overview. Fractional flow models are often called "Markov" models. The latter term may be misleading, since it implies "a stochastic decision rule that governs promotion policy for each individual in the system" (Ref 21:1). The deterministic, fractional flow interpretation of the model was preferred by Grinold and Stanford (Ref 21). "The organization as a mattter of policy decides to promote a fraction of people in rank 1 to rank 2 each year" (Ref 21:2). This deterministic interpretation implies that fractional flow models are essentially "expected value" models.

Fractional flow models employ Markov-chain theory. That is, the systems being modeled are assumed to have the Markov property. Knowledge of historical personnel movement prior to some accounting time t is not required. There are three types of fractional flow models that employ Markov-chain theory. First, cross-sectional models use information about the current stock of manpower to predict future manpower behavior. Second, longitudinal models are based on the assumption of persistent patterns over time. Unlike cross-sectional models, information about the current stock of manpower is not sufficient to predict manpower behavior over time. Third, hybrid models employ cross-sectional data yet capture longitudinal effects. (Ref 20)

In this section, overviews will be given of cross-sectional models and longitudinal models. Following the overviews, some general examples will be given of both types of models. Hybrid models will not be specifically addressed. An excellent discussion of hybrid models is given in Grinold and Marshall (Ref 20). This section will conclude with two important examples:

1. Hall and Moore (Ref 24) developed a stochastic personnel flow model that addressed uncertainty and near-term aspects of work force modeling. This model is unique since these two aspects are usually ignored in Markov models.

2. Wilson and Griffin (Ref 54) developed a Markov model for the rotation of military personnel. This model is of special interest since it helps to define the problem at issue in this thesis.

Cross-sectional Models. Cross-sectional models are concerned with how a system changes from one set of stock levels $\{s_i(t)\}$ at time t to another set $\{s_i(t+1)\}$ at time (t+1). The required data comes from the cross-sectional structure of the system at time t.

Manpower is partitioned into N classes with class 0 representing manpower outside the organization. Flow from class i to class j is represented by $f_{ij}(t)$. Thus, $f_{i0}(t)$ represents the number of individuals who leave the system in period t. Flow conservation, a basic assumption of all fractional flow models, can be stated in the following form (Ref 20:7):

$$\sum_{j=0}^{N} f_{ji}(t) = s_i(t) f_{ij}(t+1) \quad f_{ij} \geq 0. \qquad (1)$$

Equilibrium is another basic assumption of the Markov-modeling approach to manpower systems. Manpower modeling experts do not believe that many manpower systems are in equilibrium (Ref 20:10). "However, the simplifications that result in analyzing an equilibrium system make for a useful approximation to the actual system and the equilibrium consequences of any fixed (stationary) policy is essential in uncoverng the direction of change implied by the policy and for discovering the policy's long run implications" (Ref 20:10). Most systems are probably transient systems on their way to equilibrium or steady state (which they may never reach). It should be noted that not all systems that are modeled using the Markov-modeling approach require the equilibrium assumption -- manpower systems do.

To complete the mathematical description of the Markov model, let $q_{ij}$ (where $0 \leq q_{ij} \leq 1.0$ for all i and j) partition the stock of manpower in class j into fractions that flow into each class i. Thus, in terms of stocks $s_j(t)$, flows $f_{ij}(t)$, and fractions of flow $q_{ij}$, the model can be stated as follows (Ref 20:20):

$$s_j(t) = \sum_{i=0}^{N} f_{ij}(t) = f_{0j}(t) + \sum_{i=1}^{N} q_{ij} s_i(t-1) \quad \text{for } j = 1,2,\ldots,N \qquad (2)$$

For a more convenient matrix form.of the model, refer to Grinold and Marshall (Ref 20:21-22).

The model is deterministic; all flow rates for all future times must be known, and stock levels for each class can be found for a future point in time if the current stock levels are known. This type of cross-sectional model is useful because of its simplicity and the need for only current, cross-sectional data. A major drawback of this formulation lies in the assumption "that flow from one class to another is independent of the time an individual has spent in a class" (Ref 20:91). In many systems, time in a class is a key factor in determining availability for promotion or movement. Also, the distribution of time in a class is not constant over time. This is the case for military manpower systems. The assumption is not true in many applications.

Longitudinal Models. Longitudinal models "are based on the entire history of the group" (Ref 20:91). The assumption of time independence does not have to hold. The models are more general and try to describe the flow of a group through the manpower system over time. The models are more applicable in certain applications than are cross-sectional models. There are, however, much more extensive data requirements.

In the longitudinal model, the organization is assumed to contain N classes of manpower. Inflow is partitioned into K different paths or chains. (Ref 20:92) For example, airmen entering an Air Force Specialty Code (AFSC) could be classified according to status at the 4-year point; that is, whether the individual reenlists, separates after his initial commitment, or separates prematurely.

Longitudinal models also use Markov-chain theory. Probabilistic fractional flows are dealt with more easily. More general flow processes can be modeled. As stated before, longitudinal models have greater data requirements. "Hybrid" models have been developed that "seek some compromise between the basic longitudinal and cross-sectional models" (Ref 20:155).

Examples. Most manpower models are operated over relatively long time horizons and involve some uncertainty in future manpower requirements. These models are usualy formulated as "long-term optimization models" (Ref 20:186) and are built around particular objectives. Every organization has somewhat different constraints and objectives. Most sensitivity analysis is accomplished by varying policy parameters. The decision maker can vary the input data and explore a range of alternatives. Sensitivity analysis is not accomplished by varying the model assumptions. Once the basic structure is established, the model will generate results based on the assumptions of the model. In this ser e, the model is "solved" or "optimized". "Optimization" problems are concerned with finding good (in relation to the given set of objectives) long-range operating policies for the given structure of the planning model.

Flynn (Ref 13) developed a deterministic Markov decision model of a system consisting of productive units which age. The model is directed toward the military manpower system but could be used for any similar system. The model seeks to "optimize" retention policy and is formulated as an infinite-horizon deterministic model. The units in the model may leave the system early or ultimately retire. The production rate is assumed to be a linear function of the number of units in different age groups. Decisions on wage and recruitment are functions of time and the current state of the system. Under the productivity rate constraint, an optimal policy is one which minimizes the total present worth of all payments. The target-state is the long run force distribution that achieves the minimum total present worth. Flynn also showed that minimizing average cost as an alternative to the total present worth criterion will produce a fairly good target state.

Jaquette and Nelson (Ref 29) built upon Flynn's results by developing a Markov decision model of a military manpower system which seeks to determine the optimal steady state wage rate and force distribution by length of service. The transition parameters are accession and retention rates. The effectiveness of each force structure is measured by a productivity function similar to that in Flynn (Ref 13). An optimal policy is one which maximizes long run force effectiveness with a given budget. Essentially, Jaquette and Nelson used Flynn's constraint as their objective function and Flynn's objective function as their constraint.

Moore (Ref 36) examined specific AFSCs to generate a valid production function. "The new strategy is to determine how requirements can be changed to match actual supplies. New policies, plans, and programs could then be implemented that would continually shape the work force in accordance with operational and environmental changes" (Ref 36:iii). For example, Moores's research showed that "for Aerospace Ground Equipment maintenance workers, inexperienced people can require up to 2.5 times more time to accomplish some tasks than more experienced people" (Ref 36:v). This research indicates that manpower/personnel policy could be modeled with interrelationships between the supply of personnel and the manpower structure.

Grinold and Stanford (Ref 21) considered a "fractional flow model of a graded manpower system" (Ref 21:1). The model is designed as an aggregate planning device; it addresses the scheduling of organizational growth, the reaction of the system to promotion policy changes, and the relationships between operational costs, wage changes, and the rate the rate of growth. The model assumes that the initial distribution of workers by class is known, and the transition matrix P that governs fractional flow rates from class to class is known. The matrix P is independent of time t. The system hiring policy and growth rate are also assumed to be known. The objective function of the optimization models used in developing flow rates is a linear cost function of the staff distribution and the vector of new appointments. This function is minimized in a generalized Linear Program. Algorithms are developed for the following situations:

1. finite time horizon with no distribution constraints,

2. finite time horizon with distribution constraints,

3. infinite horizon with constraints on staff distribution, and

4. problems with a nonstationary transient stage and an infinite stationary stage. (Ref 21:ii)

Near Term Modeling with Uncertainty. "Analysis of the strategic aspects of manpower in an organization requires an aggregate and long-term view. We must allow enough time for natural evolution to change the current stock of manpower" (Ref 20:xiii). The bulk of personnel flow models that employ the Markov chain structure "is concerned more with the long-term (steady state) than near-term (dynamic) aspects of work force modeling" (Ref 24:7). One exception to this trend in analysis is a stochastic personnel flow model developed by Hall and Moore (Ref 24). Their model addresses two aspects of personnel flow that Markov models usualy ignore. First, their model concentrates on the near-term aspects of work force modeling. Second, their model is concerned with the nature and size of uncertainly in the setting of Air Force enlisted personnel management.

The analytical tool used by Hall and Moore was a Markov chain model representing flows in the first-term enlisted work force. The probability of changing states is assumed to depend only on the current state. As in the previous examples, the following components must be specified: (1) transition probabilities, (2) attrition rates, and (3) number of recruits and allocation of recruits at each accounting point in time.

In the previously mentioned examples, uncertainty has been ignored. However, stochastic variances can be quite large, with the "variances of the predictions being of the same order as the predicted values themselves" (Ref 10:110). Grinold and Marshall, in a longitudinal comparison of 2 groups of U.S. Marine Corps entrants, noted significant "instability between the groups in the 18-30 month period" (Ref 20:100).

Hall and Moore were concerned with the near-term aspects of the work force. Their model concentrates on the transient behavior of the system. The Markov chain model permits evaluation of standard deviations for "random quantities of interest" (Ref 24:6). The authors did "resort to simulation to augment (their) analytic Markov model in one situation (in order to consider uncertainty in estimates of the transition and accession probabilities) because the analytical stochastic model simply becomes too complex" (Ref 24:6). Since the flows and assumptions considered by the authors are relatively simplistic, simulation techniques are not necessary. The variances can be dealt with by using an analytical model.

Grinold (Ref 19) dealt with long-term uncertainty by measuring the "sensitivity of optimal policies and system performance to various assumptions on the nature of the stochastic nature of the demand process" (Ref 19:1). This is done by allowing transition rates to be a function of demand. Policies are then calculated for each potential demand level.

Rotation of Forces Example. Wilson and Griffin (Ref 54) obtain an assignment flow pattern using a generalized Linear Programming method. The same objective function (minimize cost) used in Grinold and Stanford (Ref 21) is used in this paper. "The LP solution is converted to transition probabilities and these probabilities are then used to depict the entire system as a stable absorbing Markov chain with several absorbing barriers and an initial probability distribution of replacement personnel" (Ref 54:1).

## Isomorphic and Large-Scale Simulation Models

Overview. Isomorphic simulation models have a one-to one correspondence between the individuals in the system being modeled and data elements in the program. These models are usually characterized by great detail, large data requirements, and long run-time. They have the advantage of being fairly simplistic for the model builders and programmers, but are often difficult to maintain and modify and understand.

"Large-scale" simulation models are not always isomorphic models, although isomorphic models are usually "large-scale" models. The term "large-scale" is a relative term. In this review, the term large-scale will imply the following: (1) running the model requires one or more large data bases (for example, a data file containing demographic information for each individual in the system), (2) the computer code contains over 5,000 source lines of some high-level language, and (3) any major modifications of the structure of the model require major "rewrites" of the computer code. Large-scale models may employ the mass-flow concept of categorizing individuals having similar characteristics. However, the manpower system itself is part of a much larger system. The modeler may feel that it is necessary to capture great detail in this larger system or in the manpower system itself. Such models, even with the mass-flow concept for personnel in the system, can become very large. The Integrated Simulation Evaluation Model Prototype (ISEM-P) (Ref 41), while not an isomorphic model, is a large-scale model. The other examples given are isomorphic models.

Examples. ISEM-P (Ref 41) is "a large-scale simulation model of the Air Force Manpower and Personnel System (AFMPS) which describes and analyzes the information flows and decision dynamics of the various subsystems comprising the total AFMPS" (Ref 41:i). Manpower planning, training program management, detailed personnel assignment, and personnel flows are modeled as interdependent, integrated activities.

ISEM-P uses SIMSCRIPT II.5. SIMSCRIPT is "an event oriented language in which time quanta are specified in advance, thereby scheduling the time of occurrence of events" (Ref 43:124). ISEM-P was developed as a prototype to determine the feasibility of building a model of the entire AFMPS that would be larger and more comprehensive than the prototype. Plans for building this large model have not yet been approved.

ISEM-P views the AFMPS as being responsible for procurement, development, maintenance, and deployment of the human resources available to the Air Force. The AFMPS determines for each individual the place of assignment, the job performed, and the training recieved. Through policies at its disposal, the AFMPS can influence the rates of entry into or exit from the Air Force. The overall goal of the AFMPS is to provide the "link between people and jobs that enables the Air Force to accomplish the objectives established in the Five-Year Defense Plan" (Ref 41:6).

ISEM-P takes a big step in treating the AFMPS as a complex system with highly interdependent components. The three components of the AFMPS organization (manpower, personnel and training) "are interrelated, and their performance can be highly interdependent" (Ref 41:9).

Functions within each component are also interrelated. The three components are "parts of a large information-feedback control system" (Ref 41:10).

Leupp (Ref 34) developed a manpower model of Seabee enlisted personnel. Given an initial distribution of a personnel into classes, the simulation model generates a report of changes in personnel status as a function of time. The model assumes a constant authorization structure and constant reenlistment rates. Attrition rates, promotion rates, and accession rates are constant for any particular run of the model. The program categorizes each individual in the system by given criteria. It is an isomorphic model.

Leupp's model is very similar in structure to the Markov models of Flynn (Ref 13), Jaquette and Nelson (Ref 29), Grinold and Stanford (Ref 21), and Wilson and Griffin (Ref 54). Leupp essentially has a fractional flow model that uses Monte-Carlo simulation techniques. Random numbers are generated for decisions on individual promotions, separations, accessions, and rotations.

Leupp's model could have been written very easily as an analytic Markov model. The relative simplicity of the personnel flows in this model makes the extra computational expense of simulation unnecessary. No information feedback is captured in the model. The system is represented as a straight-forward, fractional flow situation with constant mean rates of flow from one class to another.

<u>A Rotation of Forces Example</u>. The Career Area Rotation Model (CAROM) (Ref 35 and Ref 53) is an isomorphic or entity model. Each entity (for example, individual airman) is processed separately with a given logic applied to each entity. This processing is similar to that of Leupp's model. A description of CAROM follows.

> CAROM is an entity simulation model providing long-term (up to thirty years) projections of the consequences of a given set of rotation, deployment and assignment policies under a wide variety of assumptions regarding manning requirements, attrition rates, early-out policies, promotion policies, output from the entry-level training line, etc. Due to its level of detail and the optimal assignment capability imbedded within the model, CAROM is perfectly suited for gaming applications to assess the relative effects of proposed changes in policies and parameters (Ref 53:3).

CAROM was developed primarily to provide AFMPC with a policy assessment tool. Although CAROM has been used in conjunction with other personnel research at the Air Force Human Resources Laboratory (Ref 35:3-5), it has not been used extensively as a policy assessment tool at AFMPC (Ref 8, Ref 23, Ref 38 and Ref 54). Reasons given for this lack of use include the following: (1) the extensive data base required to run the model, (2) the high computational expense of a "run", and (3) the difficulty in changing the source code of CAROM to reflect the structure of the particular problem being studied (Ref 8, Ref 23, Ref 38 and

Ref 54).

Since CAROM simulates the status of individual entities, the constraining factor on the maximum number of personnel simulated at one time is the size of the computer. "Each entity has an associated personnel record which consist of 20 parameters" (Ref 35:6). Thus, even for only one AFSC, the storage requirements can be very large. The computational expense can also be high.

CAROM includes much more detail than could easily be captured in an analytic Markov model. Some interrelationships between elements of the system are captured. Linear programming (LP) and Monte-Carlo simulation techniques are used. The LP techniques are used to determine "optimal" flows as in Flynn (Ref 13), Jaquette and Nelson (Ref 29), and Wilson and Griffin (Ref 54). As stated above, the utility of CAROM to decision makers at AFMPC is limited due to the level of detail, high computational expense, large data requirements, and difficulty in modifying the model structure.

<u>System Dynamics Models</u>

<u>Overview</u>. "Continuous models are useful when the behavior of the system depends more on aggregate flows than upon the occurence of discrete events" (Ref 38:1). Manpower systems typically depend on such aggregate flows. It is not essential for the decision maker to have

extremely accurate predictions for the stock of manpower at a given time in the future. It is more important to know how given policies will interact with components within a given system boundary to produce flow rates that ultimately affect the level of manpower. A manpower system can be studied by aggregating the events (discrete occurrences that take place as the system operates in time) "into a continuous flow and setting this flow in the context of the (continuous) variables that affect it and are affected by it" (Ref 38:1).

The system dynamics approach views systems as forming a closed-loop feedback system. The methodology of system dynamics "evolved from the concepts of servomechanisms and electrical circuits, where a central assumption is that the reference system is completely encompassed within a closed boundary" (Ref 18:75). The use of the word "system" in the system dynamics context indicates a "wholeness of perspective -- a systems approach -- which one attempts to achieve for a given problem" (Ref 39:1). System dynamics was developed by Forrester (Ref 16) and associates at MIT in the late 1950's and early 1960's. It began as industrial dynamics, and early work dealt with management problems in the corporate setting. Industrial dynamics grew into system dynamics, which can be defined as a "method for studying large and complex aggregations" (Ref 39:1).

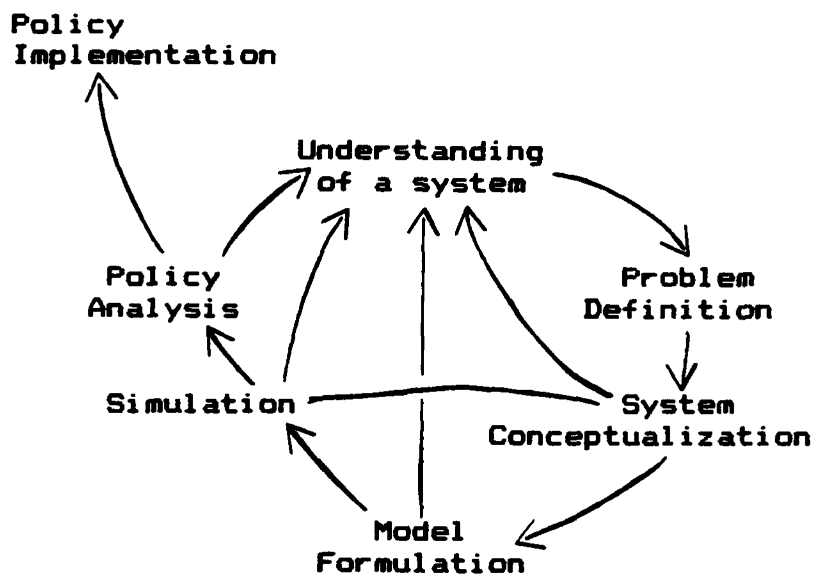



Figure 2.1. Overview of the System Dynamics Modeling Approach (Ref 39:17)

The focus of a system dynamics study is on a problem and not on the system itself. The system dynamics approach "applies to dynamic problems arising in feedback systems" (Ref 39:2). Rather than simplifying a problem, the system dynamics approach confronts the complexity of the problem by dealing with the interrelationships and interactions between the components of the system in which the problem exists. Forrester (Ref 16) believes that the "differences between engineering and social science models is largely the way the tools of model building have been used and the different emphasis on end objectives" (Ref 43:7). Too often, models of social systems seek only to explain existing reference systems -- engineering models serve as aids in designing new systems. The system dynamics approach involves the use of computer simulation models to perform policy analysis with the end objective of finding and implementing new policies (see figure 2.1). In this sense, system dynamics models of social systems also serve as aids in designing new systems.

Forrester (Ref 16:7-8) advocated long-range planning on the order of 5 to 20 years from the present. Policies which lead to system improvement in the short run often degrade the system in the long run. Policies which lead to long-run system improvement may initially depress the system (Ref 15:7). Pressures are often exerted on managers for short-term results. The long-term decisions "often lie outside the manager's personal time horizon" (Ref 16:8). System dynamics models show the long-term and short-term implications of particular policy actions.

The most important and fundamental concept of the system dynamics approach lies in the concept of servo-mechanisms or information feedback systems. In information-feedback control loops, the "regenerative process is continuous, and the new results lead to new decisions which keep the system in continuous motion" (Ref 16:15). The focus of the system dynamics approach on feedback processes is based on the premise that "dynamic behavior is a consequence of system structure" (Ref 39:15). Thus, system dynamics looks within the system for the source of the problem behavior.

System dynamics models are continuous, prescriptive, and homomorphic. That is, they depend primarily on "aggregate flows". They are intended to duplicate system behavior characteristics so that new policies may be tested, and they only superficially resemble the different groups found in the reference system. Homomorphic means "like in form but different in fundamental structure" (Ref 43:17). The two major constructs in a system dynamics model are "levels" and "rates". A level is a number which represents the state of some part of the system. A rate defines the amount by which a level will change during the next interval of time.

<u>The Use of DYNAMO</u>. "The basic tool of continuous simulation is the process of integration" (Ref 38:2). Integration is essential to the representation of change in real systems. Since digital computers cannot integrate exactly, the true integral must be approximated. System dynamics models are based on difference equations and can be formulated in a range of computer languages.

The simulation language "DYNAMO (Ref 38) and system dynamics have become almost synonymous to some" (Ref 39:xi). The system dynamics approach is "language-free", but the majority of system dynamics models are formulated using DYNAMO.

"To simulate a dynamic feedback system, DYNAMO steps through time a formal, quantitative model of the system, one DT at a time" (Ref 39:69). "DT" is the computation interval used by DYNAMO for performing numerical integration. The two constructs of levels and rates are represented in DYNAMO models as level variables and rate variables. A level variable accumulates over time the results of an inflow and/or an outflow (Ref 39:76). The variables representing the inflows and outflows in the level equations are called rate variables.

Examples. Knight (Ref 32) used the system dynamics approach to represent the Air Force pilot pipeline as a closed-loop feedback control system. The pilot pipeline system is "readily described as a continuous flow closed loop feedback system" (Ref 32:1). Three crucial levels identified in the system are: (1) number of active mission pilots, (2) size of the rated supplement, and (3) size of the Undergraduate Pilot Training (UPT) force. The model assumes that the authorized flying hours and aircraft available are given. Using these data with projected pilot levels, the model determines training requirements. The existing force is allocated among UPT instructors, the active mission force, and the rated supplement. Policies that can be tested include controlling the size of the UPT instructor force, controlling the UPT class size, variations in the instructor to student ratio, and sensitivity of the system to exogenous variables. Results are given for various structural formulations of the model.

Fekke (Ref 12), under Knight's suggestion, investigated in more detail the pilot production/allocation system. A cost module was added, and "various force build-up, draw-down, and attrition scenarios are analyzed" (Ref 12:vii).

Williams (Ref 53) developed a system dynamics model for evaluating policies relating to the Air Force Engineering officer shortage. The model provides force and cost projections under given levels of demand and salary for engineers. The ratio of expected military pay to expected civilian (engineers) pay affects the model's accession and retention rates.

Landis (Ref 33) developed a dynamic simulation model of engineering manpower needs that "interrelates economic driving factors with engineering employment and the generation of new engineers" (Ref 33:218). The nature of the cause and effect interactions are determined from an analysis of historical data established between 1950 and 1971. The system dynamics approach is taken for the following reasons:

1. many interrelations can be incorporated,

2. the system model can be refined to include subpatterns,

3. non-linear feedbacks can be incorporated in the

long, time delay factors associated with professional education. (Ref 33:218)

The two major sectors of Landis's model are the economic drivers sector and the manpower flow sector. The economic sector includes the fractions of GNP flow into the major users of engineers, with each major user requiring different levels of GNP dollars to keep an engineer on the job. The manpower flow sector includes built-in delays for flows of people and attrition and accession rates that are affected by the perceived level of employment. The main source of information in the model is an employment factor. The employment factor is the difference between the current number of funded engineers and the number that could be funded. The hire/fire rate is dictated by this factor.

Shreckengost and Gibson (Ref 45) developed a series of system dynamics models for use in the analysis of policies involving the hiring, promotion, retirement, and resignation of U.S. civil servants. The models are directed at the organizational level. Examples are given showing the effects of different structural formulations. Under one five-stage model formulation, "the overall system does not stabilize to the new set of desired values for nearly 24 months after the desired levels are changed" (Ref 45:8-11).

## Summary of Techniques

**Summary of Markov Models.** The following three assumptions are made in all of the Markov models reviewed in this chapter:

1. flow conservation -- the sum of all the flows into a class at time *t* is equal to the stock of the class at time *t*,

2. equilibrium -- systems are assumed to be in a steady-state or to be on their way to a steady-state condition, where a steady-state can be a constant size or controlled expansion or contraction, and

3. Markov property -- the probability of changing states depends only on the current state, and not on how that state was reached.

Additionally, "optimal" flow rates are generally computed using a cost function or production function. This objective function is usually assumed to be linear. Whether transition probabilities are taken as given information or are computed through Linear Programming, they are assumed to be constant throughout the time span of the model.

The structure of the Markov model is fairly rigid. No "feedback" within the system can change this basic structure. Sensitivity analysis is accomplished by varying the parameters, not the structure. Transition rates are fixed. Systems are modeled as static, equilibrium systems.

Summary of Isomorphic and Large-Scale Models. In isomorphic models, there is a one-to-one correspondence between entities in the model and the reference system being modeled. Large-scale models, as used here, are computer simulation models that require an extensive data base, contain over 5,000 source lines of some high-level language, and are difficult to modify in terms of model structure.

Shannon (Ref 43) lists several reasons for considering simulation models. The reasons that apply to the development of the manpower/personnel models reviewed in the section on isomorphic and large-scale models are presented in Table 2.1.

Simulation models of manpower systems in DoD are usually developed for one of the first four reasons. The fifth reason given is a major focus of the system dynamics approach to simulation. It was pointed out in the examples of isomorphic and large-scale models that, due to the complexity and size of most simulation models, sensitivity analysis is usually performed by varying input parameters. When the modeler is unsure of the assumptions of the model, sensitivity analysis should be performed on the structure itself. This can help the decision maker to not only understand his organization as a system, but to see how redesigning the structure of the system itself may produce more desirable results.

---

1. The assumptions required for using an analytical Markov model are realistic.

2. The analytical techniques, although realistic for modeling the system, are too complex.

3. The goal for modeling the system is one of understanding how complex interrelationships affect central tendencies.

4. The analytical techniques are beyond the mathematical background of personnel available for analysis.

5. The assumptions of the model are not easily measured, or the data describing the assumptions are costly to obtain.

---

Table 2.1. Reasons for Considering Simulation for Manpower Modeling (Ref 43:11)

---

The simulation approaches presented in section 2.3 can clearly encompass more detail and complexity than their Markov model counterparts. If it is necessary to include information feedback, the simulation models are more suitable than the Markov models. Markov models have great value in their simplicity and their mathematical tractability. If the modeler can approximate reality by making the assumptions required by the Markov models, the Markov formulation (as presented in section 2.2 of this review) should be used.

Summary of System Dynamics Models. System dynamics has been widely applied to industrial and social systems. The examples provided in section 2.4 show the potential of the methodology for policy analysis of manpower systems. Landis (Ref 33) has gone through more steps of the verification and validation of his model than have the other four authors listed. A system dynamics model does not become truly useful for policy analysis until the decision maker develops a high degree of confidence in the model.

System dynamics models are homomorphic, continuous, and prescriptive. They model reference systems that are perceived to be dynamic and causal. The system dynamics approach concentrates on problems occurring within closed-loop feedback systems. The end objective of a system dynamics study is the implementation of policies that wll overcome the problems at issue. Although system behavior in the short run is important and not ignored in the system dynamics approach, more emphasis is placed on long-term system behavior.

## Comparison of Models

Three primary approaches to manpower planning models have been reviewed. The purpose of this section is to compare the methodologies and evaluate their potential use for addressing the research problem stated in Chapter One, Introduction. This section will include a statement of the feedback nature of the assignment and rotation system, advantages of the computer simulation methodology in general for representing dynamic systems, shortcomings of Markov models and isomorphic models for representing the airman assignment and rotation system, and advantages as well as limitations of the system dynamics approach.

<u>The Causal, Dynamic Nature of the System</u>. The complex interactions within manpower systems are recognized by experts in manpower modeling:

> People, jobs, time, and money are the basic ingredients of a manpower system. A decision maker must be aware of the interactions among these four ingredients in order to formulate and evaluate manpower policy. (Ref 20:xix)

In addition to these four ingredients, the Air Force recognizes that imbalanced specialties (those specialties not satisfying the three requirements outlined in section 1.2 of Chapter One, Introduction) cause "undue turbulence and increased costs to the Air Force" (Ref 6:69). Sweeny and Tubbs (Ref 48) used factor analysis to yield nine social factors that influence the number of reenlistments after the first and second terms. The greatest contributions to variance came from seasonal cycles, excessive training, individual economic pressure, and second term reenlistment. Guinn (Ref 22) used regression analysis to develop a reenlistment potential index (RPI). Included in the regression model were biographical composite, aptitudinal, and Importance/Possibility (I/P) scores. The I/P scores were classified according to Herzberg's theory of motivation to work (Ref 26). The nature of work, work environment, and compensation were the major contributing I/P scores.

As stated in Chapter One of this thesis, the internal environment of the Air Force assignment and rotation system includes the processes of training, promotion, assignment, and rotation. The external environment includes the perceived need for overseas personnel, the reaction of U.S. policymakers to the perception, the U.S. national labor market, and problems and needs faced by the branches of the U.S. Armed Forces. The assignment and rotation system performance is a function of how well the implemented policies control the system as the rotation process is acted on by internal and external environmental factors. The Markov models reviewed here did not address the many interracting components that can affect system performance. The inherent internal feedback structure of manpower systems (specifically, the airman assignment and rotation system) suggest that other techniques be considered for the evaluation of the research problem stated in Chapter One of this thesis.

Kast and Rosenzweig summarized the key concepts of General Systems Theory (Ref 31:449-451). A manpower system clearly exhibits the important characteristics of systems. It is comprised of interrelated components. The manpower system can be explained only as a totality (holism). It interacts outside of the personnel system itself. It can be viewed as a transformation model. As an open system, the manpower system has permeable boundaries. The system itself must attain a state of "dynamic equilibrium". Feedback is an essential part of the system. The same objective can be achieved with diverse inputs and varying internal activities.

Kast and Rosenzweig (Ref 30) also pointed out the growing interest in dealing with ill-structured problems arising in dynamic systems. Computer simulation techniques have, in part, contributed to this growing interest. Using system dynamics simulation techniques, more realistic assumptions can be made in dealing with these ill-structured problems than are normally afforded by mathematical optimization techniques. Knowledge from the behavioral sciences will assume greater importance in the study of this type of problem. (Ref 30:8)

Ford (Ref 14) found several authors who argued "that organization will reduce uncertainty by creating requisite structures to deal with it" (Ref 14:567). System dynamics lends itself to the testing of these various structures. Unlike models presented earlier in sections 2.2 and 2.3, system dynamics simulation models can be set up for simplistic structural changes. For example, Armstrong

(Ref 9) has suggested the identification of alternative manning configurations for the AFMPS. He advocates the "use of economic criteria to select among the forcewide manning alternatives" (Ref 9:ix). Whisman (Ref 51) believes that "an accession policy designed to meet total end strength year by year can lead to large surpluses or shortages in critical force categories in future years" (Ref 51:vii). Alternative policies and criteria need to be tested by decision makers as part of policy analysis.

Advantages of Computer Simulation Models. Computer simulation models have the capacity to adequately represent dynamic behavior. There are other tools, such as analytical mathematical models, that can adequately represent portions of many complex systems. The shortcoming of these analytical tools, as their users freely admit, is that they fail to account for the dynamic feedback structure inherent in complex social systems. These analytical tools include mathematical programming models, Markov-chain models, inventory models, and queueing models. These tools are, and will continue to be, important for addressing policymaking tasks; however, the key is to have a model structure which properly represents the reference system. In reference to analytical mathematical models, House and McLeod (Ref 28) summarized the issue as follows:

True, they can be used to examine possibilities at other times, including the future, by making assumptions concerning the inputs at another time; but they are ill-adapted to the "march through time" that dynamic models based on differential equations do so well (Ref 28:14).

Shortcomings of Isomorphic and Markov Models. The ISEM-P model and the CAROM model both take holistic approaches to the Air Force Manpower and Personnel System and the Air Force Rotation System, respectively. They are discussed here to point out certain advantages for using the system dynamics approach in dealing with the research problem stated in Chapter One of this thesis. Both CAROM and ISEM-P fit many of the criteria for a system dynamics model. One shortcoming lies in the focus of these studies. The studies did not address potential "leverage points" for policy nor did they state the kind of implementation intended. The model purpose for a system dynamics study focuses on the audience for the study. "Statements of model purpose focus less on the nature of the problem and more on the audience for the study, potential leverage points for policies and the kind of implementation intended" (Ref 39:45). Also, the ISEM-P model and the CAROM model do not lend themselves to easy structural changes. As a result, sensitivity analysis is usually performed by varying system parameters (Ref 41:49-57). This was one of the limiting factors of the Markov models outlined previously. ISEM-P and CAROM do allow for information-feedback. This is a distinct advantage over the Markov models. The complexity of ISEM-P and CAROM, however, decrease the likelihood of their implementation by decision makers.

Forrester (Ref 16:Chapter One) points out that optimization models typically deal with problems at the "bottom of the management structure" (Ref 16:3). Rather than simplifying a problem to the point where "optimization" can be performed, the system dynamics approach confronts the complexity of the problem by dealing with the interrelationships and interactions between components of the system in which the problem exists.

One very important similarity between the system dynamics approach and most Markov models is the emphasis on long term planning. With the exception of Hall and Moore's model (Ref 24), the Markov models presented were more concerned with the long-term (steady state) than the near term aspects of work force modeling. The notion of equilibrium is used to uncover "the direction of change implied by the policy and for discovering the policy's long run implications" (Ref 20:10). Forrester (Ref 16:7-8) advocates long-range planning on the order of 5 to 20 years from the present. Pressures are often exerted on managers for short-term results. The long-term consequences of important decisions "often lie outside the manager's personal time horizon" (Ref 16:8).

The most important dissimilarity between the Markov approach and the system dynamics approach lies in the concept of servo-mechanisms or information feedback systems. This concept is fundamental for the system dynamics approach. In information-feedback control loops, the "regenerative process is continuous, and the new results lead to new decisions which keep the system in continuous motion" (Ref 16:15). The focus of the system dynamics approach on feedback processes is based on the premise that "dynamic behavior is a consequence of system structure" (Ref 39:15). Thus, system dynamics looks within the system for the source of the problem behavior.

---

-- Simple and easy to understand
-- Comprehensive approach
-- Lends itself to simple structural changes
-- Easy to program formal models
-- Relatively low cost of computer operations
-- Approach demands involvement of decision maker
-- Long-term consequences are emphasized
-- Models are continuous

---

Table 2.2. Advantages of the System Dynamics Approach (Ref 45)

---

Markov models reviewed here are "deterministic fractional flow (models)" (Ref 21:1). Internal information feedback loops are not allowed for in deterministic models. The simplifying assumptions made by Markov models are made so that the models can be used to provide "optimal" solutions. Both Markov models and system dynamics models are approximations of the actual systems being modeled. The formulations of the two types of models are fundamentally different.

<u>Advantages and Limitations of the System Dynamics Approach</u>. Shreckengost and Gibson (Ref 45) pointed out several advantages of the system dynamics approach for policy analysis of manpower personnel systems. These advantages have been previously mentioned and are summarized in Table 2.2. Disadvantages can arise due to situations including the following:

1. The reference system (system being modeled) may not lend itself to continuous modeling. The problems that need to be addressed may require more levels of detail and disaggregation than are easily handled using a system dynamics model.

2. The policymakers involved with the reference system may not be able to take part in the modeling process. The system dynamics approach is much less effective without the involvement of the decision makers.

3. There may be reasons to believe that transition rates within a system are fixed and not dynamically changed due to internal and external environmental factors. In such situations, simulation techiques are not necessary.

4. The system structure may be ill-defined with system components that are difficult to measure. Although the

system dynamics approach provides mechanisms for quantifying relatively "soft" variables, the process of verification and validation is very difficult for models of ill-defined systems.

## Conclusions

The three techniques most commonly used for manpower planning models are Markov models, isomorphic simulation models and system dynamics simulation models. Markov models have the advantages of simplicity, mathematical tractability, relatively low computational expense, and having a long-term viewpoint. Disadvantages of using the Markov modeling approach stem from the simplifying assumption that must be made. Isomorphic simulation models may require less mathematical expertise than Markov models. They can also have the advantage of being computationally simpler than analytic techniques, of requiring fewer or no simplifying assumptions, and of incorporating feedback. Disadvantages include higher computational expense, difficulty in making structural changes, and the large amount of data normally required. The system dynamics approach is simple and easy to understand, very comprehensive, and relatively efficient (computer operations costs are surprisingly low). System dynamics usually demands that the decision maker be involved in the modeling process in some manner.

Long-term consequences are emphasized. The main disadvantage of the system dynamics approach seems to be the time required to completely verify and validate the models. However, this criterion is too often overlooked in entity simulation models and Markov models. (Although Markov models are generally validated in terms of model performance, given the model assumptions, verification of model results with actual system performance is seldom addressed.) System dynamics model building is inherently an iterative process in building one's confidence of the model to a point where it can be implemented as a policy analysis tool.

The need for a rotation of forces model that is capable of addressing a wide variety of policy alternatives under varying assumptions and exogenous inputs is needed. The models that exist do not completely fulfill these requirements. The system dynamics approach is well suited for this application.

To begin to fill the void that exists in the models available to AFMPC and AFCC Headquarters the requirements for more useful tools, a system dynamics model should be developed that addresses the complex problems associated with the rotation of forces. It may take some time to get such a model to the point where it is useful to the decision maker as a policy analysis tool. However, merely structuring the problem in a system dynamics format is of value in understanding the behaviorial problems of that system. The initial model development is the first step in the process of acquiring a model that verified and validated to the point where the user has confidence in using the model for policy implementation.

# III The Model

## Introduction

This chapter describes the airman assignment and rotation model developed for imbalanced AFSCs within the Air Force Communications Command. The first section gives a brief description of the methodological approach. The second section presents a conceptualization of the important components of the airman assignment and rotation system. Included in this conceptualization are a breakdown and prioritization of the system goals, a division of the system into three functional sectors, and a description of the feedback structures involved within and between the components of each sector. The third section contains the goals of the model and a design for policy analysis. The fourth and fifth sections contain a detailed description of the formal model structure set forth by the major sectors.

## Methodological Approach

An overview of the system dynamics approach was given in Chapter Two, section 2.4.1. This section will discuss causal loop diagramming, level and rate equations, and flow diagramming.

Causal Loop Diagramming. Causal loop diagramming is a technique for representing feedback structures. It is usually used in conjunction with the initial step of hypothesizing the "underlying structure that is causing and maintaining the problems" (Ref 40:11). A causal loop diagram is a "visual model" that "shows the existence of all major cause-and-effect links, indicates the direction of each linkage relationship, and denotes major feedback loops and their polarity" (Ref 40:11).

---

-- variable - a quantity that is changeable as time evolves

-- linkage (link) - a cause-and-effect relationship between two variables

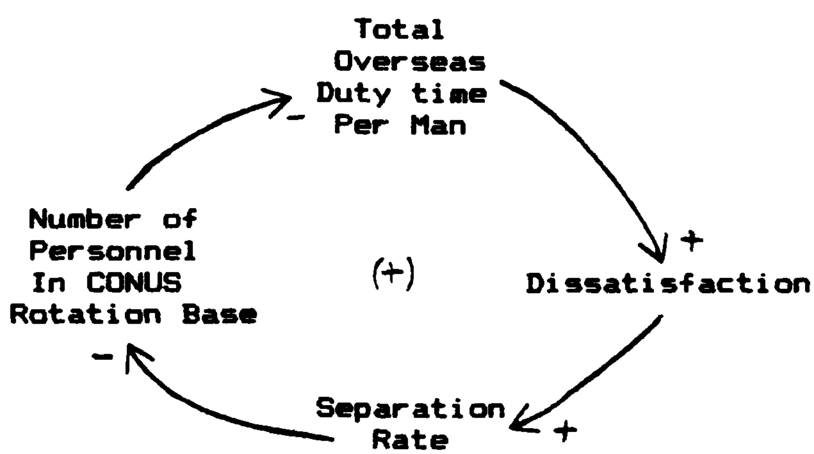
-- feedback loop - two or more linkages connected so that one can begin with any variable and follow the arrows back to the starting variable

-- feedback system - two or more connected feedback loops

Table 3.1. Four Levels of Feedback System Structure

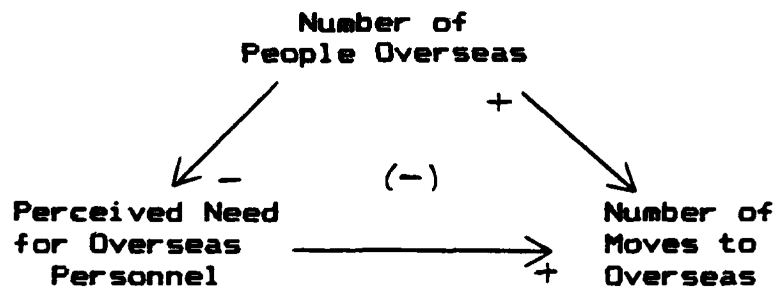
---

Four different levels of feedback system structure set forth by Roberts (Ref 40:7-10) are summarized in Table 3.1. The last level shown, a feedback system, does not include directional signs for each link. A causal loop diagram merely adds directional signs (+ or -) to the linkages in a feedback system and positive or negative polarities to the feedback loops within a feedback system. A positive directional sign for a link indicates that the variable at the tail of the arrow and that the variable at the head of the arrow move in the same direction. A negative directional sign for a link indicates that the variables in the link change in opposite directions. A positive polarity sign in a closed feedback loop indicates that the loop reinforces variable changes in the same direction. Such a loop is called a growth loop or a positive feedback loop (see figure 3.1). A negative polarity sign in a closed feedback loop indicates that the loop tends to resist variable changes. Such a loop is called a goal seeking loop or a negative feedback loop (see figure 3.2). (Ref 40:10-12)




An even number of negative linkages indicates a positive feedback loop.

Figure 3.1. Causal Loop Diagram Showing a Positive Feedback Loop




An odd number of negative linkages indicates a negative feedback loop

Figure 3.2. Causal Loop Diagram showing a Negative Feedback Loop

Level and Rate Equations. As stated in the Chapter Two discussion of DYNAMO, the two system dynamics contructs of levels and rates are represented in a DYNAMO model as level variables and rate variables. A level equation, preceded in a DYNAMO model by the letter L, is of the following form (Ref 39:76):

L LEVEL.K = LEVEL.J + DT*(INFLOW.JK − OUTFLOW.JK) (3)

The subscripts K and J indicate that the value for a level variable at time K (the present) is a function of its value at time J (one time increment before the present) and the net change due to the flows affecting it over the time interval JK. DT, as stated in Chapter Two, is the computation interval used by DYNAMO for performing numerical integration. DT is a user-specified constant whose value is the length of time from J to K. (Ref 39:76)

A rate equation, preceded in a DYNAMO model by the letter R, can be of the following form:

R OUTFLOW.KL = LEVEL.K/AVLIFE (4)

Here, the rate of flow out of the level is a function of the number of units in the level at time K divided by a constant that may represent the average lifespan of the units in the level. The subscript for rate computation, KL, implies that the rate equation is computed at time K, and its value is computed from K to L (K + DT). Unlike level equations, there is no standard form for rate equations. (Ref 39:79-80)

All "tangible" variables in a DYNAMO model are either levels or rates. Auxiliary variables aid in formulating rate equations. An auxiliary equation, preceded in DYNAMO by the letter A, can be of the following form:

A CHANGE.K = INFLOW.JK - OUTFLOW.JK (5)

Auxiliary equations represent information in a system. They are useful for clarification and simplification. (Ref 40:19-20 and Ref 39:81)

Flow Diagramming. Figure 3.3 shows the basic flow diagramming symbols. Each variable type is represented by a unique symbol.

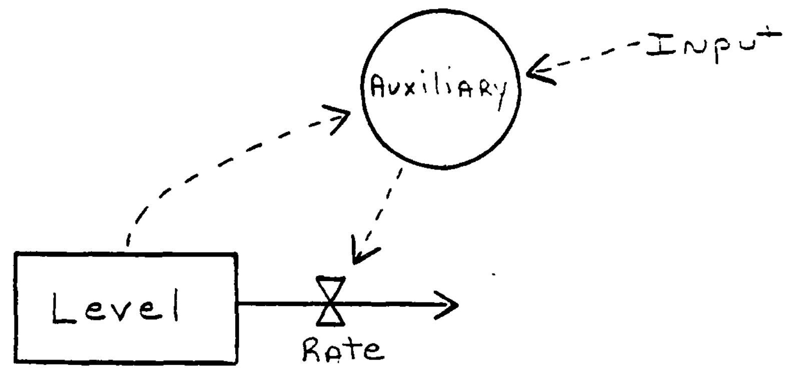



**Figure 3.3. Basic Flow Diagramming Symbols**

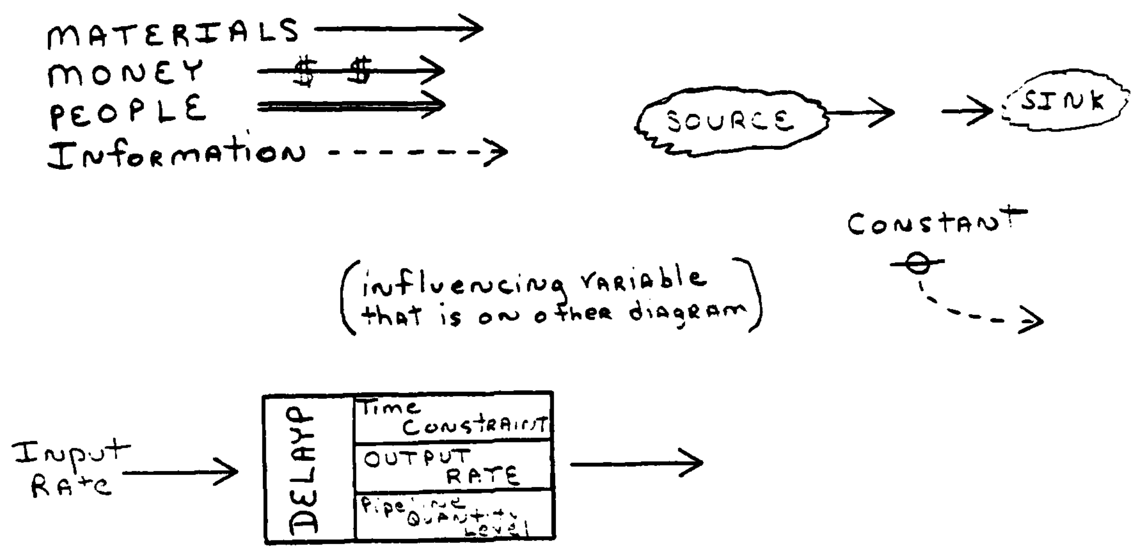



**Figure 3.4. Other Flow Diagramming Symbols (Ref 40:20-22)**

Other symbols are shown in figure 3.4. Alternate flow designators represent different types of flows. The segmented triangle is a third order exponential delay or filter of an input flow. The "cloud" symbol is a source or a sink when the origin or distinction of a flow is outside the modeler's concern. The small circle with the line is a constant, and the set of parentheses is the symbol for cross-referencing variables from other diagrams. (Ref 40:20-22)

## Conceptualization

The airman assignment and rotation system for imbalanced AFSCs exists within the Air Force Manpower and Personnel System (AFMPS). The key components, major interactions, and system goals of the airman assignment and rotation system are derived from the existence of the assignment and rotation system within the AFMPS. These key components, interactions, and goals were identified through literature research (Ref 11, Ref 35, Ref 41, Ref 46) and in interviews (Ref 8, Ref 25, Ref 27, Ref 38, Ref 49). The observable system goals were defined and listed in an hypothesized order of priority. After identification of the system goals, components, and interactions, the airman assignment and rotation system was divided in three sectors:

1. Personnel Fill Sector

2. Rotational Sector

3. Manpower Sector

These three sectors correspond to the key processes used in the control of the airman assignment and rotation system.

1. Sufficient assignments
2. Cost minimization
3. Non-voluntary PCS minimization
4. Morale maximization
5. Minimize separation rates to an acceptable level
6. Maximization of CONUS time between involuntary overseas tours
7. Minimize number of remote tours
8. Minimize involuntary overseas time
9. Skill level/experience distribution
10. Maximize total manning percentage

Table 3.2. Airman Assignment and Rotation System Goals

System Goals. The airman assignment and rotation system is a goal-directed system. Table 3.2 summarizes the goals against which the system performance is measured. Each goal is discussed in more detail below. Reassignments and rotations should be scheduled to:

1. Assure that sufficient personnel are assigned to authorizations to accomplish the Air Force mission. This requirement also implies the need to manage the force so that force needs of the future are not neglected in favor of satisfying the requirements of today.

2. Minimize costs. Cost source areas include but are not limited to basic training, technical school, pay levels, reenlistment bonuses, and Permanent Change of Station (PCS).

3. Minimize the number of non-voluntary moves. Voluntary moves only enter into consideration indirectly. Resource monitors seek to place people where they want to go, to realize a large percentage of first choice assignments. This goal could also be looked at as a parallel to minimization of cost. The fewer the number of PCS moves, the smaller the overall cost.

4. Maximize morale. The USAF has a general rotation policy that "minimizes" family separation and thereby the negative effects on retention behavior" (Ref 46:32). The consequences of assignment and rotation actions can cause a decrease in individual morale, which can have a negative effect on retention behavior. Minimizing non-voluntary PCS moves is a parallel thought. Even though other factors have an effect on morale, Chow and Polich (Ref 11) found more significance in retention decisions from rotational indicators than from other morale factors.

5. Minimize separation rates. Maintain a level of experience in the force adequate to train new personnel and provide the necessary technical expertise to accomplish the Air Force mission.

6. Maximize time spent in the CONUS between overseas tours. "Most personnel consider overseas assignments to be undesirable in comparison with assignments in the United States" (Ref 46:1). Goals 6, 7, and 8 correspond to the three facets of the USAF retention policy (Ref 6:69).

7. Minimize the number of remote tours in a 20 year career. Again, this assumes that a member would rather spend more (if not all) of his time at assignments in the CONUS and with his family.

8. Minimize the amount of involuntary time spent overseas. Involuntary is a qualifier which is used to exclude those tours which are requested. Requested tours may include those which are accompanied or are located in generally desirable locations. This goal addresses those tours that are generally undesirable, such as the cold or remote tour. Frequent involuntary assignments can have a negative effect on retention behavior.

9. Maintain the distribution of skill levels and experience within the Air Force and individual AFSC's. This goal is concerned with the ratio of experienced to relatively inexperienced people.

10. Maximize, up to a value of 1, the ratio of total personnel within an AFSC to the total number required (authorized). This ratio reflects the percentage strength at any given level and for the whole force. This goal is

concerned with force readiness and the efficient accomplishment of the "mission".

Priority Listing of Goals. The goals stated in 6, 7, and 8 can be thought of as being subordinate to goal 4. In turn, goal 4 can be affected by goal 5, and so on. These relationships exist between all ten of the goals identified. Some of the goals conflict with others, some are parallel, some subordinate others. It would be rare to find a situation involving a complex system where these conditions did not exist. In an effort to minimize the incongruities between the stated goals, the following priority sequence is defined: 10, 9, 1, 2, 3, 5, 4, 8, 6, 7.

This priority sequence is an hypothesized view of the system. Schoderbek, Schoderbek, and Kefalas (Ref 42) pointed out that "multiple organizational goals cannot all be maximized" (Ref 42:246). Conflict emerges as a result of less than complete compatibility of goals. Actual system goals emerge and can be determined by observing system behavior. The above priority sequence, showing the goal of manning percentage as the primary goal, stems from five observations:

1. Assignments can be made in a secondary AFSC if the airman's skill levels are the same in both the primary and the secondary, and a shortage (that is, total manning shortage) exists in the secondary (Ref 46:32).

2. An airman may be assigned to a tour requiring a grade two steps higher or one step lower that the one held (Ref 46:32 and Ref 8).

3. The AFMPS operates under end-strength constraints imposed by Congress (Ref 37).

4. Imbalanced AFSCs within AFCC are typically overmanned at skill level 3, undermanned at skill level 5, and close to 100% manned in the aggregate (Ref 1 and Ref 25).

5. Assignments to remote tours are made first, overseas long tours second, and CONUS tours last. This priority is followed even if it means not meeting one or more of the rotation objectives outlined in AFR 26-1, volume 1 (Ref 8).

The above priority sequence is not to say that managers within the airman assignment and rotation system are not concerned with goals such as maximizing morale or minimizing involuntary overseas tours. Indeed, the situation would be much worse than it currently is without such concern.

Structure verification interviews were conducted as part of the model verification tests that are discussed in Chapter Four, Model Testing and Verification. The majority of the individuals interviewed agreed with the priority sequence that was used for model development.

Sectorization. The goals of the system fall within three major sectors:

1. Personnel Fill
2. Air Force Rotation Objectives
3. Manpower Authorizations

For the purposes of this study, the Manpower sector will be considered constant and integrated into the other sectors. That [illegible] that force requirements will not increase with the passage of time. The implications of this assumption are that the manpower requirements will not change in response to changes in the mission, technology, or economy. The validity of this assumption is dependent on the time horizon of the study and the purposes for which the model is used.

The system goals are grouped into the three major sectors as shown in Table 3.3. The definition of goals and sectors allows causal loop diagrams of the system to be constructed. Use of the causal loop diagrams allows a more aggregate look at the system and at the same time an opportunity to examine the entities and cause and effect relationships at a higher level of resolution.

Personnel Fill

1. Sufficient assignments
5. Minimal separation rates
9. Skill level distribution
10. Manning percentage

Rotation

2. Cost minimization
3. Non-voluntary PCS minimization
4. Morale maximization
5. Minimal separation rates
6. Maximization of CONUS time between overseas and remote tours
7. Minimization of number of remotes
8. Minimize involuntary overseas time

Manpower

5. Minimal separation rates
9. Skill level/experience distribution

Table 3.3. Three Major Sectors with Corresponding System Goals

Feedback Structures. Figure 3.5 shows the interrelationships that occur when considering the priority sequence of goals stated earlier. As the number of people in any of the individual skill levels within the AFSC increases, the total number of people in the AFSC increases. As the total increases, the disparity between actual number and number required will go down, and the perceived need for more people in the AFSC will also go

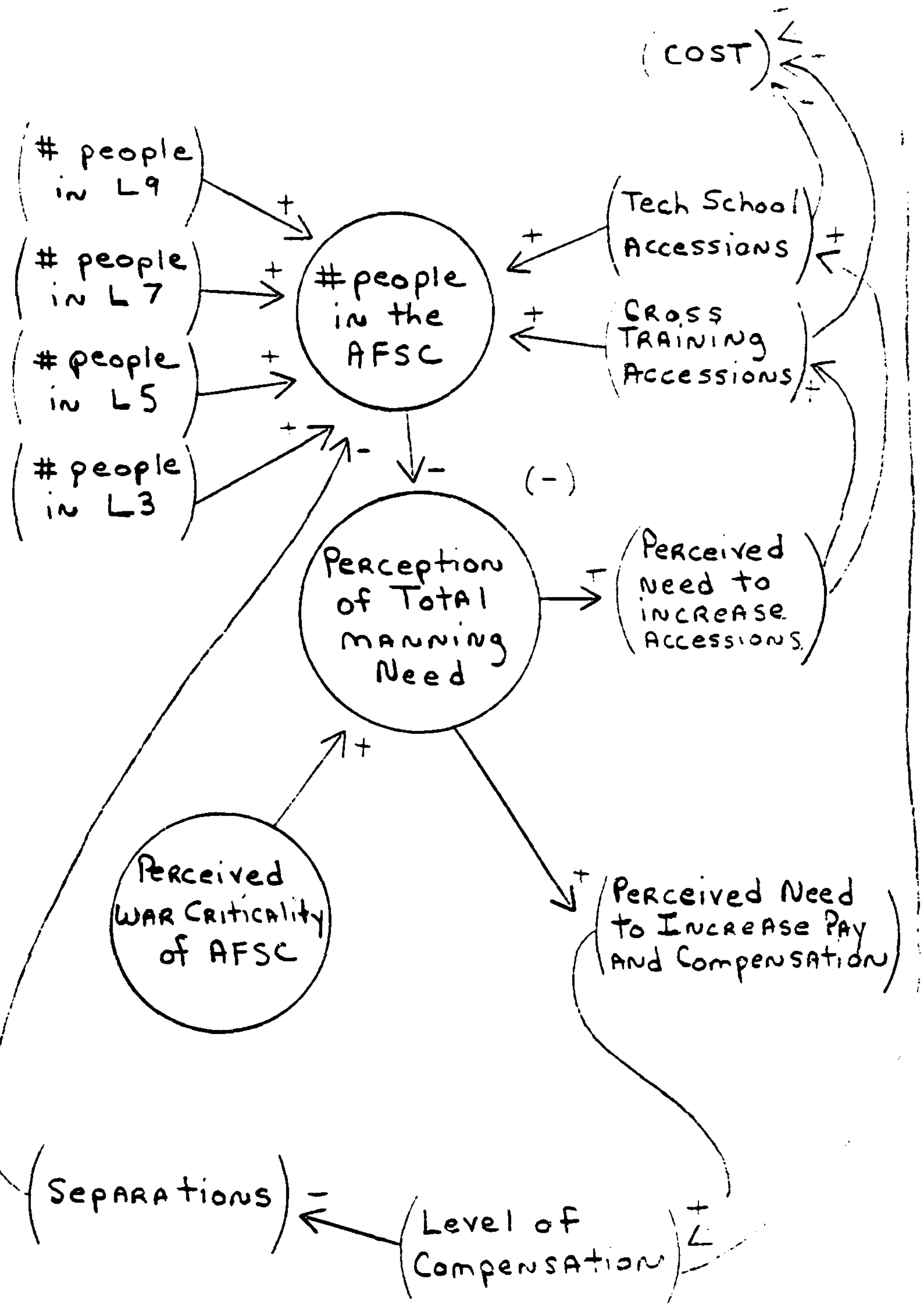



**Figure 3.5. Hypothesized Determinants under the Original Sequencing of Goals**

down. The perceived need is also affected by the perceived war criticality of the AFSC, which drives the number required.

As the perception of total manning need increases, so does the perceived need to increase pay and compensation with which to retain the currently existing force. This hopefully prevents the disparity from growing any larger while at the same time luring in more people to reduce the disparity. As pay and compensation increase, so does total system cost.

An increase in perceived need to increase manning also causes an increase in perceived need to directly increase accessions. Accessions are broken down into accession through technical school and accession through cross training. As both of those accessions go up, system cost goes up to reflect training expenditures. System cost is also affected proportionally by changes in pay and compensation.

Completing the loop, the number of people in the AFSC is increased by increases in the technical school and cross training accessions. Cost ties this aggregate diagram dealing with the system priorities to Figures 3.6 and 3.7 dealing with the Personnel Fill and Rotational sectors.

Figure 3.6 delineates the skill level progression ladder. Table 3.4 shows roughly the correspondence

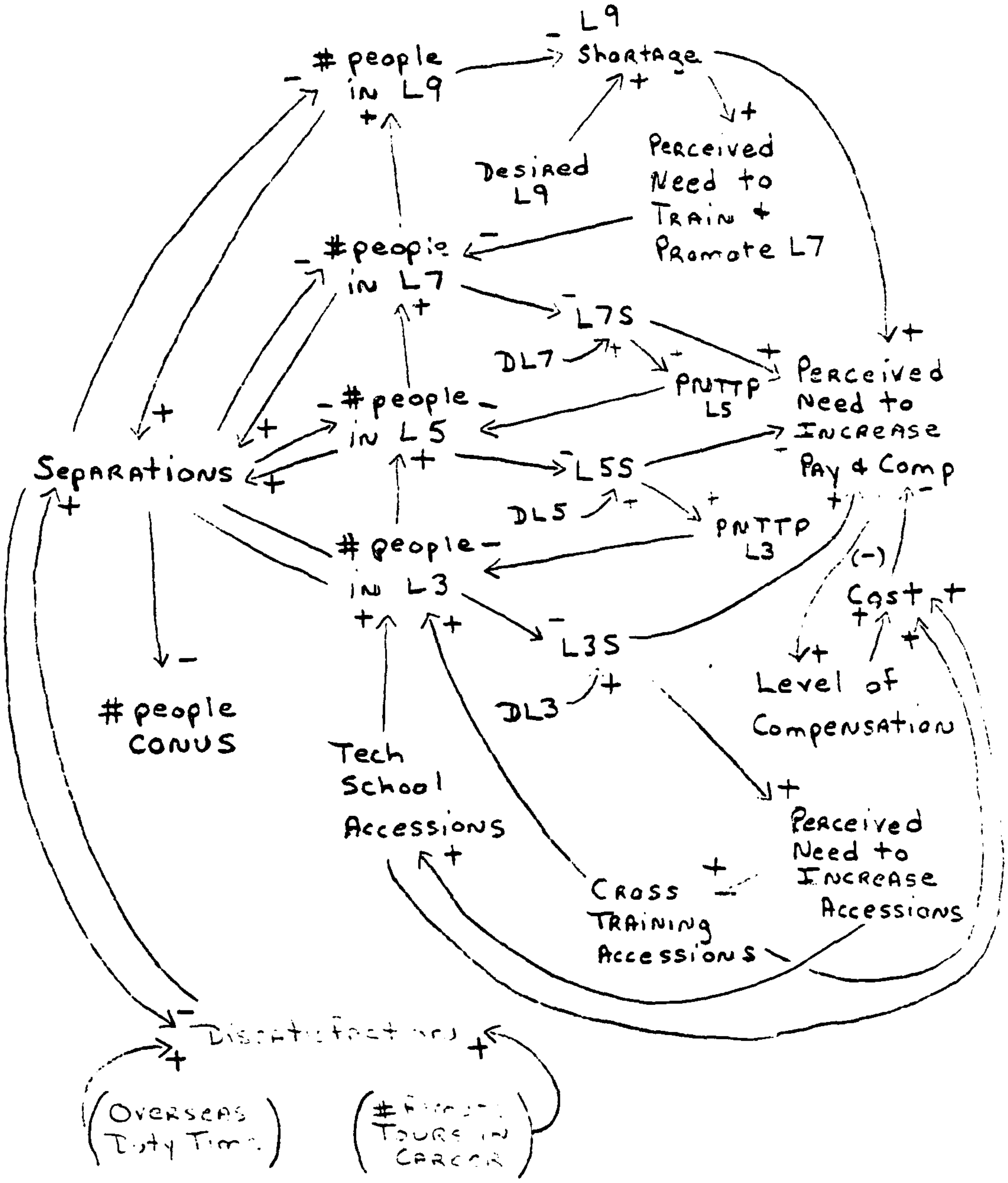



**Figure 3.6. Hypothesized Determinants of Personnel Fill Sector**

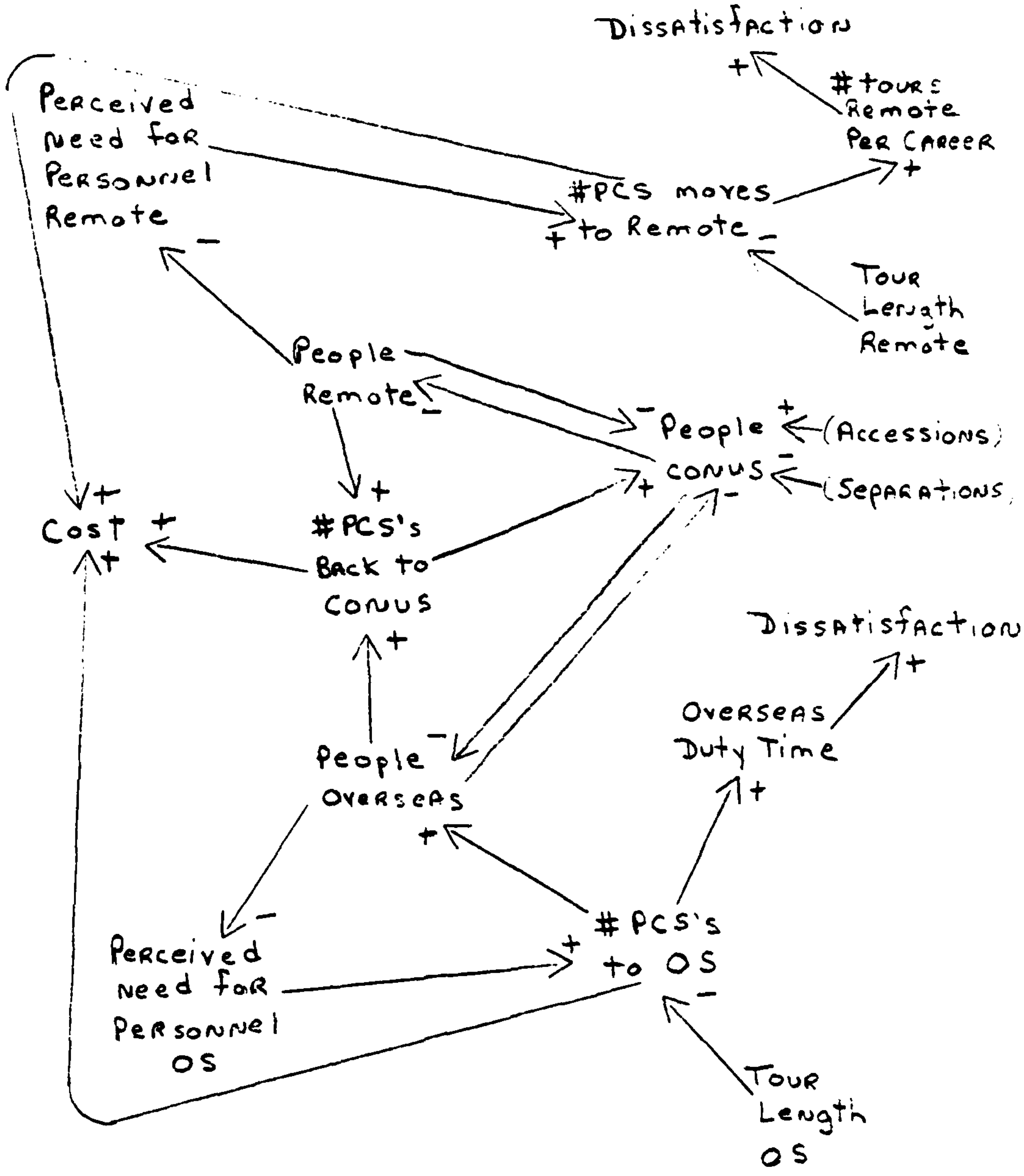



**Figure 3.7. Hypothesized Determinants of Air Force Rotation Sector**

between skill levels and enlisted grades. Beginning with the perceived need to increase accessions, an increase there causes increases in technical school and cross training accessions. As those accessions increase, the number of people in level three increases. As the number of people in level three increases, the level three shortage decreases, which causes a decrease in the perceived need to increase accessions. This is a goal seeking or negative-feedback loop.

| Skill Level | Enlisted Grade |
|---|---|
| Level 9 | E-9 |
| | E-8 |
| Level 7 | E-7 |
| | E-6 |
| Level 5 | E-5 |
| | E-4 |
| Level 3 | E-3 |
| | E-2 |
| Level 1 | E-1 |

Table 3.4. Correspondence Between Skill Level and Grade

The goal seeking loop described in the above paragraph depicts how personel enter the system. Behavior and movement within the sytem are driven by need in higher levels. As the number of people in level nine decreases, the level nine shortage increases. As that shortage increases, the perceived need to promote from below (the only place to draw from to make up the shortage) increases. As the perceived need to promote increases, the promotions increase and the number in level seven will decrease correspondingly. This process continues down the ladder for level seven drawing from level five, and level five drawing from level three.

At all levels, as the number of people increases, so too will the number of separations (since there are more there that can separate). As separations increase, the number in the level will decrease, and so on. The number of separations is affected by the dissatisfaction the member has with the service and level of pay and compensation being offered. Dissatisfaction is determined in the Rotation sector and will be discussed shortly. Pay and compensation are determined by the perceived need for the pay and compensation. The perceived need is a function of the individual skill level shortages (increased shortage increases need) and the level of cost (increased cost decreases need). Increasing the level of compensation in turn increases cost which completes another negative loop.

The Personnel Fill sector is connected to the Rotation sector through cost and dissatisfaction. Cost is incremented in the Rotational sector each time a PCS occurs. PCS moves rotate people from CONUS to overseas and remote, and back.

As the number of people overseas increases, the number of people making return PCS moves increases. As the number of people leaving overseas increases, the shortage of people overseas increases, the perceived need for people overseas increases, and the number of PCS moves from CONUS to overseas eventually increases.

A similar causal flow exists for remote assignments. For both flow subsystems, certain indicators cause individual dissatisfaction to rise and fall. The components of dissatisfaction are the time spent in the CONUS between remote and overseas assignments, the average number of remotes per career, and the average time spent remote and overseas per career. As dissatisfaction increases, the individual skill level separation rates in the Personnel Fill sector increase.

The Rotation sector models how people move from assignment to assignment and how closely the personnel system is achieving its goals. It supplies measures of dissatisfaction and cost to the Personnel Fill sector. The Personnel Fill sector models personnel movement within the AFSC and tradeoffs between manning efficiency and cost.

Summary. The purpose of the airman assignment and rotation system is to provide the proper number of enlisted personnel in the overseas and CONUS tours so the

Air Force mission can be achieved. Inexperienced personnel are brought into an AFSC from the civilian population through initial military training and technical school training. A portion of the personnel in an AFSC are accessed through cross-training from other specialties. Personnel progress, over time, to higher skill levels. Retention and separation decisions are made by individuals over time. Included in the factors that influence separation rates from skill levels are pay and compensation, bonuses paid, morale due to rotation indicators, and the national economy. Personnel within an AFSC are assigned to CONUS tours, overseas long tours, or remote tours. Rotation from overseas and remote tours is primarily a function of tour-length. Personnel assigned to CONUS tours form the rotation base from which assignments to overseas and remote tours are made. Assignments are made on a first-in-first-out basis with volunteers having priority.

## Model Development

Model Goals. The goals of this model are motivated by its potential implementation as a policy analysis tool. There is a need for such a tool at HQ AFCC at Scott AFB and AFMPC at Randolph AFB (Ref 8). Full implementation of a model as a policy analysis tool takes a considerable amount of model verification and validation. The short term goal for model implementation is for the use of the model in education of system structure. As individuals gain confidence in the model, experimentation with the model may aid in policy analysis.

With implementation goals in mind, the objectives in developing the model were as follows:

1. Develop a system of equations that incorporates the important information feedback control loops of the airman assignment and rotation system for one AFSC.

2. Produce a computerization that accurately translates the system of equations to a form that can be stepped through time.

3. Incorporate within the computerization the ability to easily change the system structure and parameters.

4. Within the given time constraints, perform structural verification and parameter verification.

5. Attempt to validate selected model results with actual system results.

6. Examine model behavior as a consequence of extreme conditions.

7. Examine model behavior sensitivity for counter-intuitive results that may be explainable by knowledge of the system.

8. Perform policy experimentation (Policy tests are addressed in the next section).

These objectives do not represent a "one-page" process. It is important to recognize that one must cycle through the objectives of the model. Keeping implementation goals in mind is useful in developing the above model objectives as well as the policy tests to be performed.

Design for Policy Analysis. The policy tests outlined below have derived from a general perception base on empirical work and analysis of the assignment/rotation system. This perception has been gained through conversations with individuals at AFMPC and AFCC, general reading of literature pertaining to the personnel system, reading of other personnel models, and education gained as a result of model development. To be more specific, the reference(s) following each policy test refer(s) to the report or interview in which the test was either suggested, tried previously in a model, or implemented previously in some portion of the airman assignment and rotation system. The following tests were implemented and will be addressed later in this report.

1. Vary compensation across the board. (Ref 44)

2. Target increased compensation to individual groups within the AFSC. (Ref 44)

3. Apply a bonus policy as a function of various manning percentages versus individual skill level manning percentages. (Ref 49 and Ref 27)

4. Vary the emphasis placed on total manning percentage versus individual skill level manning percentages. (Ref 25)

5. Vary the formulation of the separation rates from individual skill levels. (Ref 37)

6. Combine an imbalanced AFSC with a related but balanced AFSC. (Ref 8 and Ref 25)

7. Change the percentage of accessions allowed from cross training. (Ref 8)

8. Vary the formulation of dissatisfaction due to rotational factors. (Ref 37)

These tests are representative of policies that might be considered by policy makers. Policy tests during model analysis can help to increase confidence in the model.

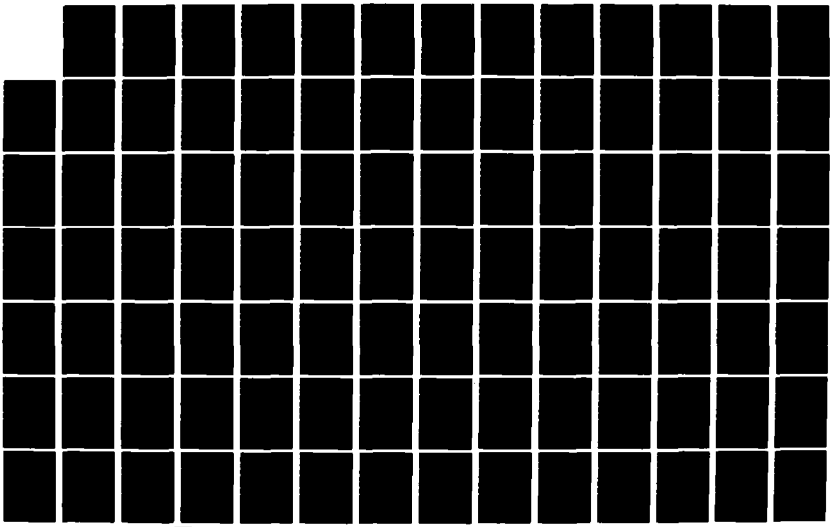
To facilitate policy testing, the model was built so that the DYNAMO "rerun" option could be used. The model contains the rerun option that "shifts" DYNAMO into the rerun model. A separate rerun file is then used to change any constants or tables appearing in the model. The statement RUN (new title) is placed in the rerun file following the changes to constants or tables. Either another rerun sequence or the statement QUIT is placed following the RUN statement. (Ref 39:99-101) All of the above policy tests can be run with the DYNAMO rerun option. Refer to Appendix B, Sample Rerun Files, for examples of how rerun files are used in the policy testing. This procedure minimizes the cost of examining behavioral sensitivity.

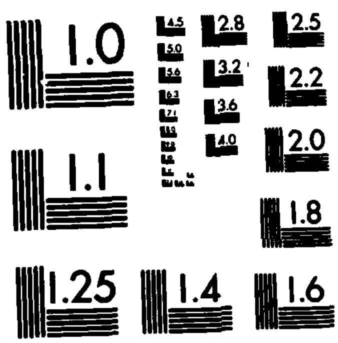
Summary. This model of the the airman assignment and rotation system was developed for use as a policy analysis tool for managers at AFMPC and AFCC Headquarters. The application of the model will depend on the degree of confidence placed in the model by the user. The use of the model will range from a tool for understanding the system structure to a tool to assist in the evaluation and implementation of new policies. The policies that were examined in this study are listed above. These policies were enumerated before the actual development of the model to assure that the proper "boundary" for the system structure was selected. They were presented here to assist the reader in following the direction of the formal model development given in the next two sections.

The airman assignment and rotation system consists of three major sectors. The Personnel Fill sector and the Rotation sector are discussed in detail below. The Manpower Authorization sector will be considered to be constant and integrated into the other sectors. The discussion of the Personnel Fill sector and Rotation sector will contain a summary of the inputs, outputs, and major processes of the sector. Following the summary, the model formalization including a description of the flows and levels and the formulation of the mathematical model

AD-A124 779 THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES WI..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. K L LAWSON 2/3

UNCLASSIFIED DEC 82 AFIT/GOR/OS/82D-8 F/G 5/9 NL






MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

testing. This procedure minimizes the cost of examining behavioral sensitivity.

Summary. This model of the the airman assignment and rotation system was developed for use as a policy analysis tool for managers at AFMPC and AFCC Headquarters. The application of the model will depend on the degree of confidence placed in the model by the user. The use of the model will range from a tool for understanding the system structure to a tool to assist in the evaluation and implementation of new policies. The policies that were examined in this study are listed above. These policies were enumerated before the actual development of the model to assure that the proper "boundary" for the system structure was selected. They were presented here to assist the reader in following the direction of the formal model development given in the next two sections.

The airman assignment and rotation system consists of three major sectors. The Personnel Fill sector and the Rotation sector are discussed in detail below. The Manpower Authorization sector will be considered to be constant and integrated into the other sectors. The discussion of the Personnel Fill sector and Rotation sector will contain a summary of the inputs, outputs, and major processes of the sector. Following the summary, the model formalization including a description of the flows and levels and the formulation of the mathematical model will be presented. The Personnel Fill sector will be presented first.

## Personnel Fill Sector

The Personnel Fill sector models personnel movement within the AFSC and tradeoffs between manning efficiency and cost. The major processes include accession into the specialty, promotion from one skill level to the next, separation from skill levels, and payment of bonuses. Exogenous inputs include the level of pay and compensation, and the perceived national labor market. Inputs from the Rotation sector include dissatisfaction due to rotational indicators and cost. The Personnel Fill sector will be discussed conceptually, and the formulation of the key equations will be presented. The four major skill levels are now presented and will be followed by a discussion of each level.

Major Levels. The Personnel Fill sector has four major levels:

1. Skill Level 3 (SL3)
2. Skill Level 5 (SL5)
3. Skill Level 7 (SL7)
4. Skill Level 9 (SL9)

These levels identify the number of people in each skill level within the AFSC. Table 3.4, presented previously in section two of this chapter, shows the correspondence between skill levels and enlisted grades. Skill level 1 personnel are those individuals in technical school and are counted in the pipeline delay between the source and skill level 3.

Individuals normally are promoted to E4 or skill level 5 before they reach the point where they are eligible to separate from the Air Force. If the individual does not separate, the expected time in skill level 5 is about eight years (Ref 8). The assumption that first term separation rates are skill level 3 separation rates has been made, since first term separation rates are usually higher than those rates of later year groups.

The process of promotion forms the flows into and out of each major level. Each inflow rate is, in part, a function of the level shortage which it increases. In this sense, the levels tend to pull in their required people. At a lower level of aggregation, such as an isomorphic model of the type described in Chapter Two, an alternative formulation could have been used. This alternative formulation would push people into the succeeding skill by computing the rates as a function of the amount of time spent in a level. The push formulation has the advantage of handling the situation in which one criterion for promotion is length of time in a level, even though the model structure would have to capture more detail of the system to accurately reflect that phenomenon. The pull formulation used in this model has the advantage of promoting only enough people to meet current needs. This formulation, as will be discussed in Chapter Four, Verification and Validation, appears to reflect system behavior.

The discussions of each slill level are presented below. The internal processes for each skill level will be developed by presenting the flow diagrams , corresponing DYNAMO equations, and variable definitions for portions of the each skill level section. A composite flow diagram for each skill level will be presented at the end of each section. A similar process will be used to develop the Rotation sector.

Skill Level 3. The lowest skill level captured in the model is Skill Level 3 (SL3). SL3 is increased by the Level 3 accession rate (L3AR) (see figure 3.8). L3AR, is delayed through the DYNAMO function DELAYP. DELAYP, a third order exponential delay filter, is used in equation PF2. The average time it takes an individual to pass through this level is L3AT (Level 3 Adjustment Time). L3AT is the average length of time to complete technical school for an AFSC. L13PQ (the pipeline quantity for the delay) is a level that represents the number of people in technical school. This representation derives from the fact that all individuals entering skill level 3 of an AFSC must enter through technical school.

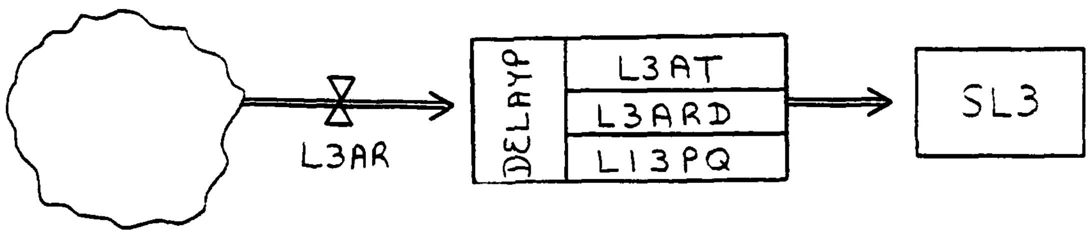



Figure 3.8. Input to Skill Level Three

```
R L3AR.KL=TEMPRT.K*TSCHM.K                          PF1
R L3ARD.KL=DELAYP(L3AR.JK,L3AT,L13PQ.K)             PF2
L SL3.K=SL3.J+DT*(L3ARD.JK-L3L5PR.JK)               PF3
```

L3AR=Level 3 Accession Rate (people/year)
L3ARD.K=Level 3 Accession Rate Delayed (people/year)
L3AT=Level 3 Adjustment Time (years)
L13PQ=Pipeline Quantity for Level 1 to Level 3 (people)
SL3=Slill Level 3 (people)

The training process, ranging from a few months to a year for the imbalanced AFSCs under study, has the effect of delaying the entry of personnel into skill level 3. A third-order delay was chosen because a sudden increase in requirements for personnel would probably not immediately result in an increased accession rate (Ref 8). A third-order delay is justifiable because some people would begin arriving before the normal length of training, some would arrive late, while the greatest number of arrivals would occur around the specified training time, L3AT (Ref 39:109).

The pipeline level, L13PQ, is used in equation PF5. Pipeline quantities are important in personnel systems for computing the total population of personnel in the system and in avoiding the tendency to "over-shoot" a desired level of personnel (Ref 45). Due to the order of computation in DYNAMO, it is necessary to use the pipeline quantity of the last time period for these computations. Figure 3.9 illustrates this process. PQ13CT (equation PF6) is a two-word array that supplies DPQ13 the last time period's pipeline quantity.

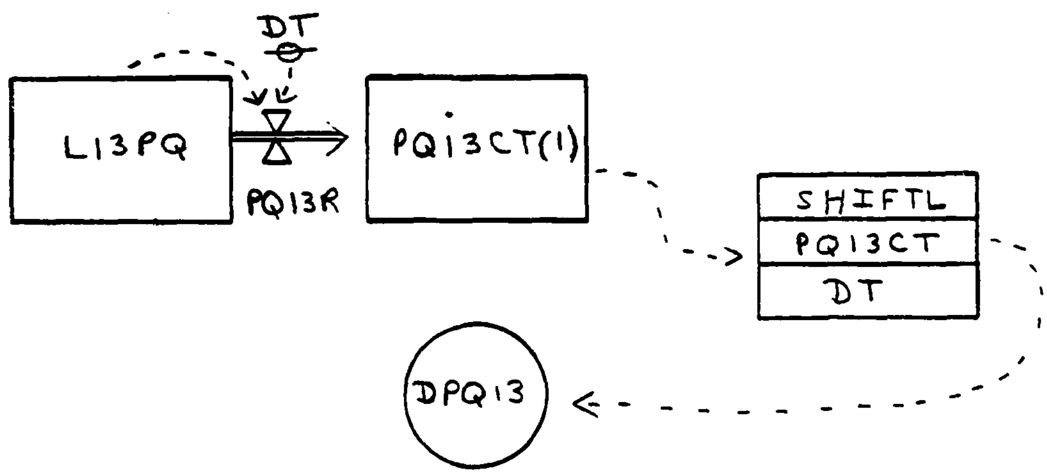



Figure 3.9. Flow Diagram of Obataining the Last Period's Pipeline Quantity

```
A DPQ13.K=SHIFTL(PQ13CT.K,DT)                  PF4
R PQ13R.K=L13PQ.K/DT                           PF5
```

L PQ13CT.K(1)=PQ13CT.J(1)+DT*PQ13R.JK PF6

DPQ13=Dummy Pipeline Quantity for Level 1 to Level 3 (people)

PQ13R=Pipeline Quantity Rate for Level 1 to Level 3 (people)

PQ13CT=Pipeline Quantity Level 1 to 3 Counter (2 word array of people)

This is done through the linear shift function SHIFTL. "The SHIFTL function permits the user to assign a value to the first element of a vector, shift that value periodically to higher and higher positions in the vector, and finally obtain its value when it reaches the last position" (Ref 39:392). DT was chosen as the shift period so the last period's value could be obtained.

The pipeline quantity DPQ13 is used in the computation of the Level 3 Shortage (L3SHRT). When resource managers compute the amount of new personnel required to fill current and projected vacancies, they must consider the expected number of personnel currently in technical school (Ref 8). Similarly, the Total Force Shortage (TFS) computation is a function of the Desired Total Force (DTF) and the actual Total Force. TF is obtained by summing the number of people in all the skill levels and the number of people in transition from one skill to another.

The MAX function is used in the shortage computations. If the computed value is negative, zero is taken as the shortage amount. This implies that overmanning is allowed. That is, the minimum is imposed to prevent overages from being forced out of a level.

Resource managers must consider a variety of information sources when determining the future needs of a given AFSC. These needs are translated into recruiting quotas and technical school positions. Resource managers keep records of past separation and promotions rates. They are also aware of current shortages in particular skill levels and in the AFSC as a whole. An overall shortage, due to end-strength constraints and the need for a specified manning level to accomplish the mission, must be alleviated quickly. (Ref 8, Ref 25, and Ref 37)

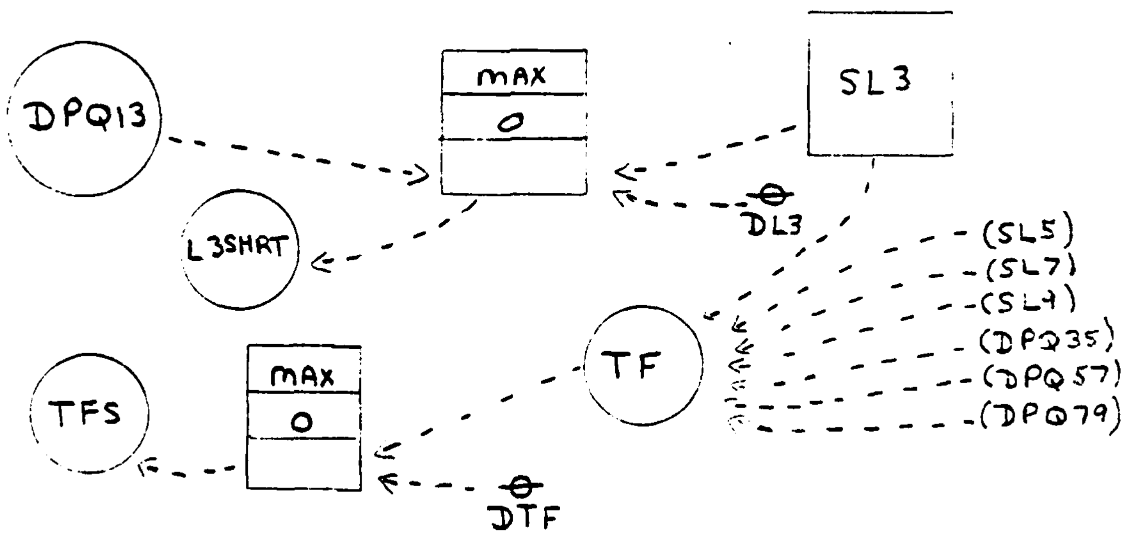



Figure 3.10. Flow Diagram for Computing Shortages

```
A L3SHRT.K=MAX(0,DL3-SL3.K-DPQ13.K)                    PF7
A TF.K=SL3.K+SL5.K+SL7.K+SL9.K+DPQ35.K+DPQ57K
      +DPQ79.K                                          PF8
```

A TFS.K=MAX(0,DTF.K-TF.K) PF9

L3SHRT=Level 3 Shortage (people)
DL3=Desired Level 3 (people)
TF=Total Force (people)
TFS=Total Force Shortage (people)
DTF=Desired Total Force

To capture the essential information, shortages were computed (figure 3.10). The shortages are used in the computation of the technical school accession rate (TSCHAR) and the cross-training accession rates. A small fraction of the personnel in a specialty may come in through cross-training. This fraction ranges from less than one percent to five percent (Ref 8). This fraction, XTNGFX, can be changed during reruns. Figure 3.11 illustrates the computation of rates that are used to obtain L3AR.

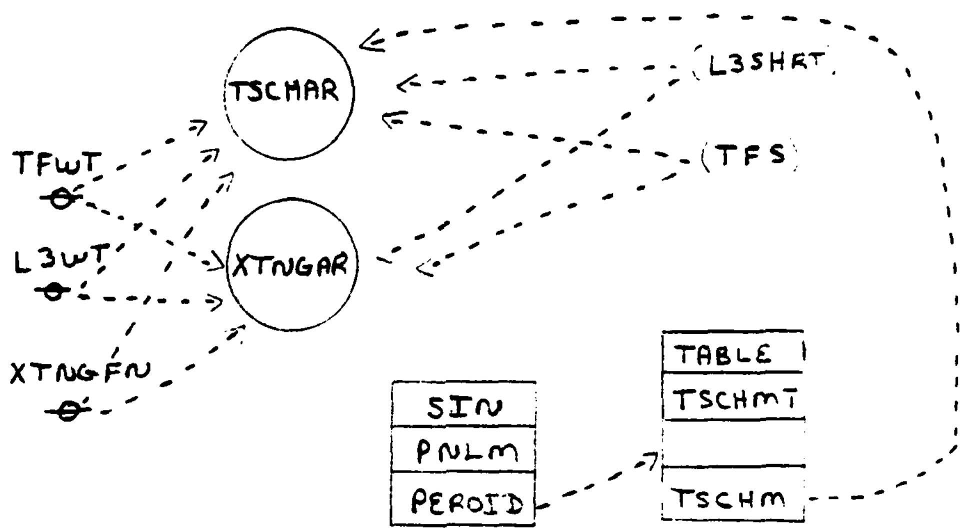



Figure 3.11. Flow Diagram for Level 3 Accession Rate Components

```
A TSCHAR.K=(L3WT*L3SHRT.K+TFWT*TFS.K)*(1-XTNGFX) PF10
A XTNGAR.K=XTNGFX*(L3WT*L3SHRT.K+TFWT*TFS.K)     PF11
A PNLM.K=SIN(6.283*TIME.K/PERIOD)                PF12
A TSCHM.K=TABLE(TSCHMT,PNLM.K,-1,1,4)            PF13
T TSCHMT=1/1/.9/.85/.8/.8                        PF14
```

TSCHAR=Technical School Accession Rate (people/year)
L3WT=Level 3 Weight
TFWT=Total Force Weight
XTNGX=Cross-Training Fraction
PNLM=Perceived National Labor Market
XTNGAR=Cross-Training Accession Rate (people/year)
TSCHM=Technical School Multiplier
TSCHMT=Technical School Multiplier Table
PERIOD=period of perceived "labor cycle"

TSCHAR and XTNGAR are used to make up shortages. These quantities are both functions of:

1. Level 3 Shortages (L3SHRT),
2. Total Force Shortage (TFS),
3. Cross-Training Fraction (XTNGFX), and
4. emphasis placed on managing the AFSC by TFS and by L3SHRT, reflected in TFWT and L3WT, respectively.

The use of "management weights" is a simplification of the actual process. A resource manager can never ignore shortages or overages in particular portions of the system. However, he must make a policy decision from which actions will be taken in regard to these shortages. By using these weights (which must sum to one), different policies can be reflected.

Exogenous inputs affect TSCHAR and XTNGAR in addition to the above four components. Major General Stuart H.

Sherman, former director of Manpower at AFMPC, believes the major driving force behind recruitment as well as retention in the Air Force is the national economy (Ref 44). Jay W. Forrester's System Dynamics National Model (Ref 15) displays three cycles associated with the national economy:

1. short-term business cycle,
2. 15-to-25-year Kuznets cycle, and
3. 45-to-60-year Kondratieff cycle. (Ref 15:50)

The business cycles exhibit a sinusoidal type of behavior with peaks three to seven years apart. The two long waves are useful in explaining many types of behavior and may be useful in determining the long-term behavior of the airman assignment and rotation system. However, Forrester explains that the business cycle behavior invokes response from many social systems in an effort to counter or take advantage of effects (Ref 15:50-51). For this reason, the SIN function is used to model the effects of the business cycle on the supply of personnel to the Air Force and in particular to the imbalanced specialty in question. PNLM (Perceived National Labor Market) is computed using the SIN function with a specified period. Initially, this period was set to a value of 7 years. PNLM is converted to a multiplier, TSCHM (technical school multiplier), to reflect the fraction of people the Air Force can successfully recruit as a function of PNLM. This value was initially set to range from a value of .8 for peak values of business to 1 for low values. These values were based on analysis by individuals at AFMPC and AFCC Headquarters (Ref 8 and Ref 25). The sensitivity of the model to these table values was explored in Chapter Four, Model Verification and Validation.

To complete the discussion of SL3, figure 3.12 illustrates the flows out of and into SL3.

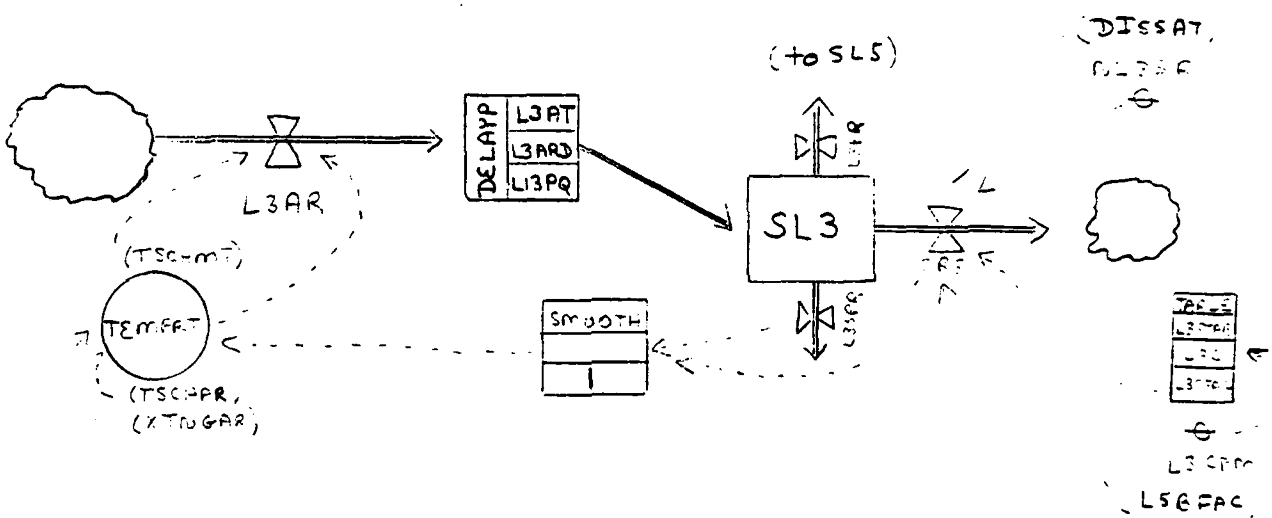



Figure 3.12. Flow Diagram of Flows into and out of Level 3

```
     A TEMPRT.K=XTNGAR.K+TSCHAR.K+SMOOTH(SR3.JK+L3L5PR.JK-
TFWT*(MAX(0,TF.K-DTF.K))-L3WT*(MAX(0,SL3.K+
                 DPQ35.K-DL3)),1)                    PF15
     R SR3.KL=MIN(SL3.K,NL3SR*DISSAT.K*L3CFAC.K*
               L5BFAC.K)                             PF16
     R L3L5PR.KL=MIN(SL3.K,L5SHRT.K)                 PF17
     A L3CFAC.K=TABLE(L3CTAB,L3CPM,5,15,2)           PF18
     T L3CTAB=2/1.5/1/.9/.8/.7                       PF19
     R  L3AR.KL=TEMPRT.K*TSCHM.K
(PF20)
```

TEMPRT=Temporary Rate for L3AR (people/year)
SR3=Separation Rate from SL3 (people/year)
L3L5PR=Level 3 to Level 5 Promation Rate (people/year)
L3CFAC=Level 3 Compensaion Factor
L3CTAB=Level 3 Compensation Table

The Separation Rate from Level 3, SR3, is a function of the following:

1. Normal Separation (NL3SR), obtained from rate data for FY80 through the first three quarters of FY82 (Ref 1, Ref 2, Ref 3, and Ref 4),

2. Dissatisfaction (DISSAT), a variable obtained from the Rotation sector,

3. Level 3 Compensation Factor (L3CFAC), and

4. Level 5 Bonus Factor (L5BFAC), from the Skill Level 5 section of the Personnel Fill sector, that is a measure of the increase or decrease in separation rate due to bonuses paid.

L3CFAC is a multiplier based on the Level Cost Per Man (L3CPM). L3CFAC is set to one if, based on the input to the table, the individual is ambivalent with regard to his pay. This point of ambivalence is currently set at $9,000. If the average pay decreases, the multiplier L3CFAC rises, and conversely. This formulation is based on the conclusion reached by Chow and Polich (Ref 11) with regard to the effect of pay and compensation on retention. The models formulated by Chow and Polich (Ref 11) showed that pay and compensation had a large contribution to the retention decision. The value of $9,000 was chosen as the point of ambivalence since this was roughly the pay for SL3 personnel for FY82. Two managers (Ref 8 and Ref 25) felt that, for the imbalanced AFSCs, that the level of pay for FY82 was perceived to be "adequate" by many individuals in those specialties. A portion of the improvement in separation rates for FY82 was attributed to the significant pay increase that was given. What is more important than this actual level of ambivalence is the recognition of the relationship of the value given to L3CPM. The "base" run of the model has L3CPM set slightly below the ambivalence point. This can be changed in a rerun to view the impact of the change on the model outputs. This was done in Chapter Five, Policy Experimentation.

As mentioned previously, resource managers keep records of separation rates, promotion rates, shortages, and overages. The promotion rate from Level 3 to Level 5 (L35PR) is computed as a function of the Level 5 Shortage. Knowing the history of flows out of a skill level allows resource managers to "smooth" out the randomness from data pertaining to personnel movement. The DYNAMO function SMOOTH allows accumulation and averaging of information. In equation PF15, the values of SR3, L3L5PR, and force overages are algebraically combined and then accumulated to produce an exponentially weighted moving average over one year. This smoothed value is then added to XTNGAR and TSCHAR to produce TEMPRT. TEMPRT represents the total number of people per year required to come into SL3. TEMPRT can be thought of as a "recruiting goal" for the given AFSC. TEMPRT is then multiplied by TSCHM to yield the actual number of people that do flow into the AFSC.

The above formulation was chosen after alternative formulations failed to reproduce system behavior. Further discussions with individuals at AFCC Headquarters, AFMPC, and USAF Headquarters (Ref 8, Ref 25, and Ref 49) revealed that managers consider not only the current situation of an AFSC, but its history as well. The SMOOTH function gives more weight to more recent observations but does not ignore past observations. The smoothing constant of 1 year was chosen based on the interviews mentioned here. Alternate smoothing constants produced similar results. Multiplying TEMPRT by TSCHM was also based primarily on interviews. Resource managers recognize that the Air Force does not always get the full number of recruits needed. Even though the situation in the Air Force has historically been better in terms of recruiting quotas than that of the other branches of the U.S. Armed Forces, there are years during which Air Force quotas are difficult to achieve (Ref 8). For this reason, TEMPRT is adjusted by the economy indicator, TSCHM.

The major portions of the Skill Level 3 section of the Personnel Fill sector have been presented. Figure 3.13 illustrates all of the process in one diagram. The Skill Level 5 (SL5) section is presented next.

Skill Level 5. The payment of bonuses is computed in the Skill Level 5 section of the Personnel Fill sector. The justification and methodology of bonus payments will be discussed followed by a discussion of the SL5 flows.

Many things are considered when paying a bonus to an AFSC. AFMPPP at USAF Headquarters is the program office that makes bonus payment recommendations for Air Force enlisted AFSC's (Ref 49). Each AFSC is reviewed twice a year. Table 3.5 summarizes the Office of Secretary of Defense (OSD) criteria for the payments of the selective reenlistment bonus (SRB). These criteria are somewhat general, allowing each branch of the U.S. Armed Forces some degree of flexibility in applying the bonus. The Air Force concentrates the greatest amount of bonus money on first reenlistment.

-- Serious undermanning
-- Must hAve significant effect
-- Chronic or persistent shortage
-- High first term replacement cost
-- Relatively unattractive
-- Essential to defense mission
-- Cost effective

Table 3.5. OSD Criteria for Payment of SRB (Ref 49)

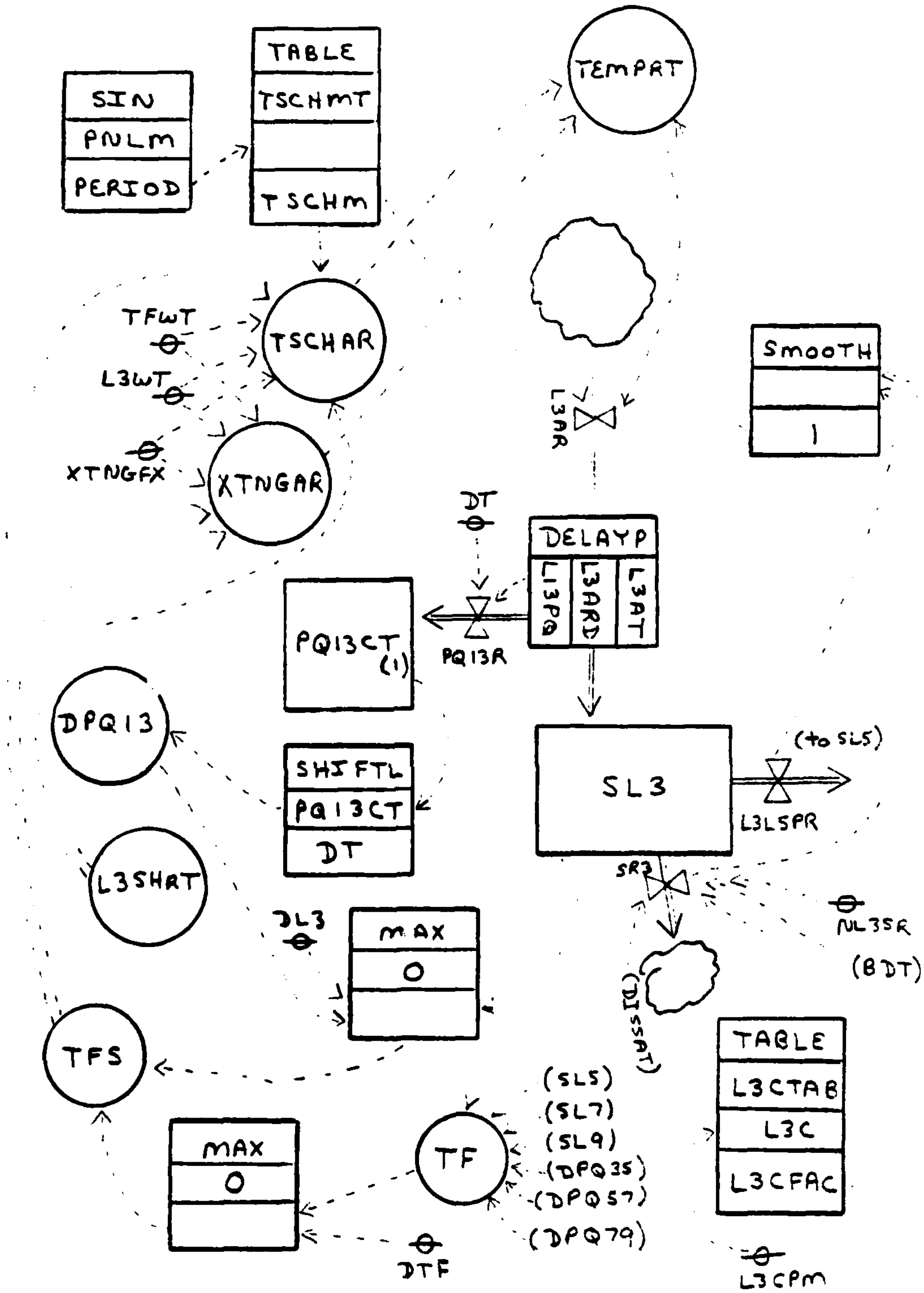



Figure 3.13. Flow Diagram for Skill Level Three

The annual value of the bonus under SRB legislation is a function of the SRB multiplier. This multiple is either 1, 2, 3, or 4. The bonus for an individual is equal to either:

1. one month basic pay times SRB multiplier, if eligible for SRB, or

2. 0, if not eligible for SRB (Ref 11:20).

Chow and Polich (Ref 11) found a "small position association between bonus level and reenlistment rate" (Ref 11:20). They also point out that the "actual causal effect of awarding a bonus may well be higher than the difference among bonus levels" (Ref 11:20). Table 3.6 tabulates the average amount of the bonus for SRB multiples 2 and 3 and shows the corresponding percentage reenlisting. This table is adapted from a DoD-wide study by Chow and Polich (Ref 11) published in 1980. The authors felt that the difference among specialties with varying levels of bonuses are due to the counteracting influences, civilian opportunities, and the nature of the job as well as to the bonus level itself (Ref 11:21). The effect of the bonus in models which control for nonbonus factors is usually higher than in models with no such controls, "but even then it is probable that the bonus coefficient remains underestimated" (Ref 11:21).

| Bonus Level | SRB offered | Pay Grade | Value of Bonus | No. of Potential | Reenlistment Percentage |
|---|---|---|---|---|---|
| 0 | No | E3 | 0 | 42 | 26.2 |
| | | E4 | 0 | 105 | 21.9 |
| | | E5 | 0 | 2 | 50.0 |
| 2 | Yes | E3 | 869 | 37 | 13.5 |
| | | E4 | 948 | 283 | 25.4 |
| | | E5 | 1026 | 116 | 37.9 |
| 3 | Yes | E3 | 1345 | 27 | 11.1 |
| | | E4 | 1438 | 102 | 27.5 |
| | | E5 | 1559 | 113 | 23.0 |

Table 3.6. Percent Reenlising by Bonus Levels (Ref 11:21)

Tables 3.7 and 3.8 tabulate the retention and SRB multiples for the imbalanced AFSCs within AFCC. The retention rate is expressed as a percentage using the following equation:

Retention rate = (Total Number Reenlistees)/
(Total Number eligible to reenlist)

Data was obtained for the last three years, with only the first three quarters shown for FY82. Retention rates are given for first term, second term, and career (third term to retirement). SRB multiples are given for zone A (first term), zone B (second term), and zone C (career). No payments for zone C have been made.

| AFSC | FY82-3 TERM 1 | 2 | 3 | FY81 TERM 1 | 2 | 3 | FY80 TERM 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|
| 293x3 | 50.8 | 81.0 | 84.0 | 20.7 | 49.1 | 72.6 | 26.2 | 63.5 | 61.2 |
| 304x0 | 47.0 | 67.9 | 70.9 | 36.6 | 60.7 | 70.6 | 21.7 | 58.6 | 65.5 |
| 304x6 | 40.0 | 62.5 | 75.0 | 37.1 | 70.6 | 66.1 | 16.9 | 62.1 | 77.2 |
| 306x1 | 22.0 | 43.7 | 67.5 | 13.7 | 28.6 | 67.6 | 6.0 | 38.5 | 66.0 |
| 306x2 | 48.5 | 62.5 | 67.0 | 27.3 | 67.6 | 68.1 | 20.4 | 60.0 | 72.7 |
| 307x0 | 35.2 | 66.9 | 64.4 | 25.4 | 48.7 | 74.4 | 17.9 | 54.4 | 57.7 |

Table 3.7. Retention Rates for AFCC Imbalanced AFSCs

| AFSC | FY82-3 ZONE A | B | C | FY81 ZONE A | B | C | FY80 ZONE A | B | C |
|---|---|---|---|---|---|---|---|---|---|
| 293x3 | 1 | 1 | - | - | - | - | - | - | - |
| 304x0 | 3 | 2 | - | 3 | 2 | - | 2 | 1 | - |
| 304x6 | 2 | 1 | - | 2 | 1 | - | 2 | 1 | - |
| 306x1 | 2 | - | - | 1 | - | - | - | - | - |
| 306x2 | 1 | - | - | 1 | - | - | - | - | - |
| 307x2 | 1 | 2 | - | 1 | - | - | - | - | - |

Table 3.8. SRB Multiplier for AFCC Imbalanced AFSCs

It is very difficult to establish an accurate correlation between retention rates and bonuses paid. The same difficulty arises in analyzing pay and compensation or rotation indicators with respect to the effect on retention rates. In the case of bonuses paid, the model examines skill level 5 manning percentages. This formulation is based on the fact that AFMPC must, by law, examine the following shortages for an AFSC:

1. 3 - 6 years,
2. 6 - 10 years, and
3. 10 - 14 years.

Other things considered in the payments of a bonus include retention rates, the nature of the job, civilian opportunities, overall shortages, projected retention rates and shortages, and the effect (in terms of "extra" people retained) of a bonus. (Ref 49)

Skill Level 5 in the Personnel Fill sector contains personnel in roughly the 3-12 year range. Because of this level of aggregation, the Level 5 Manning Percentage (L5MPCT) was used to determine the Perceived Need to Pay Bonus (PNTPB1). A factor is computed based on this manning percentage (see figure 3.14). AFMPC managers (Ref 49 and Ref 27) report that, in most cases, skills with severe shortages (under 40%) would receive a high bonus. Exceptions to this rule would be a skill for which the required manning levels were suddenly increased by a large amount. In such cases, the separation rate history would give more useful information.

Between 60% and 100% manning, PNTPB1 declines. The actual numbers are difficult to assess in the aggregate. Interviews (Ref 49 and Ref 27) and data on manning levels (Ref 1, Ref 2, and Ref ) were used as guides in obtaining these numbers. Chapter Four, Verification and Validation, addresses the sensitivity of the model results as a function of the structure of table values. An alternative formulation of PNTPB1 based on an exponential smooth of retention rates is also presented in Chapter Four.

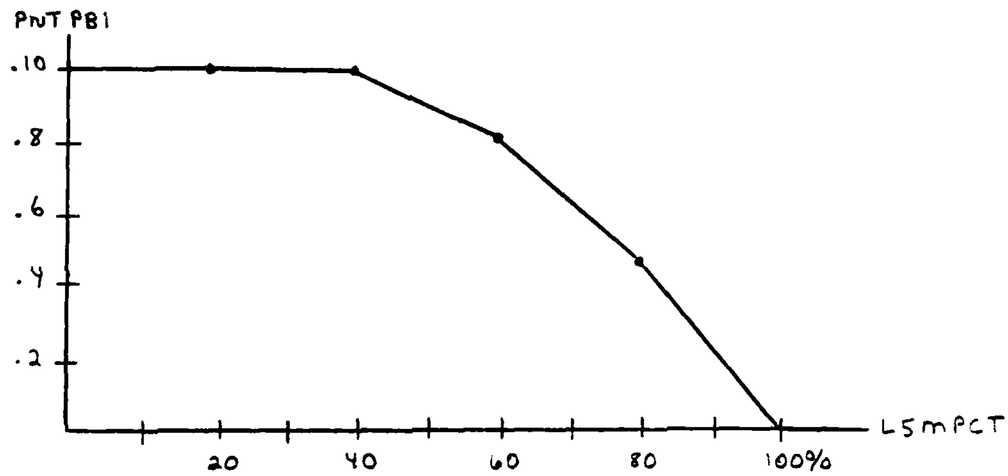



Figure 3.14. Table Formulation for PNTPB1

PNTPB1 is multiplied by a "pressure" factor, PNTPB2, to obtain the actual perceived need to pay a bonus (PNTPB). PNTPB2 is a number between 0 and 1 that is a function of the total cost of operating the AFSC due to past bonuses paid, PCS moves, and level of pay and compensation (not including bonuses). Lower amounts of money spent yield higher values of PNTPB2. This formulation is a simplification based on a description by an AFMPPP manager of the process involved in obtaining Congressional and OSD approval of bonuses paid (Ref 27).

The Air Force evaluates each skill twice a year. Requests and justifications for SRB multiples for each skill are submitted to Congress with the President's budget in January of each year. Justification information includes skill shortages for the three zones A, B, and C, reenlistment rate data, and the expected number of enlisted personnel gained from the bonus. Included in each request are:

1. bonus level awarded in current year,
2. specific requests for budget year, and
3. anticipated need for one out-year (Ref 27).

Based on these requests and Air Force testimony, SRB payments become incorporated (with possible modifications) in the budget from Congress. The actual numbers associated with PNTPB2 are shown in equation PF23. The sensitivity of model results to this table is addressed in Chapter Four.

PNTPB is translated into an SRB multiple in a table function. Figure 3.15 illustrates the formulation for Bonuses Paid (BONSPD). The BONSPD is an SRB multiple computed as a function of PNTPB. Historically, the highest SRB multiplier given has been 4. Although the SRB multiplier can go as high as 6, there is a maximum of $16,000 per man in each of zone A, B, and C. Under a multiplier of 4 and a 4-year obligation period, this maximum is usually reached.

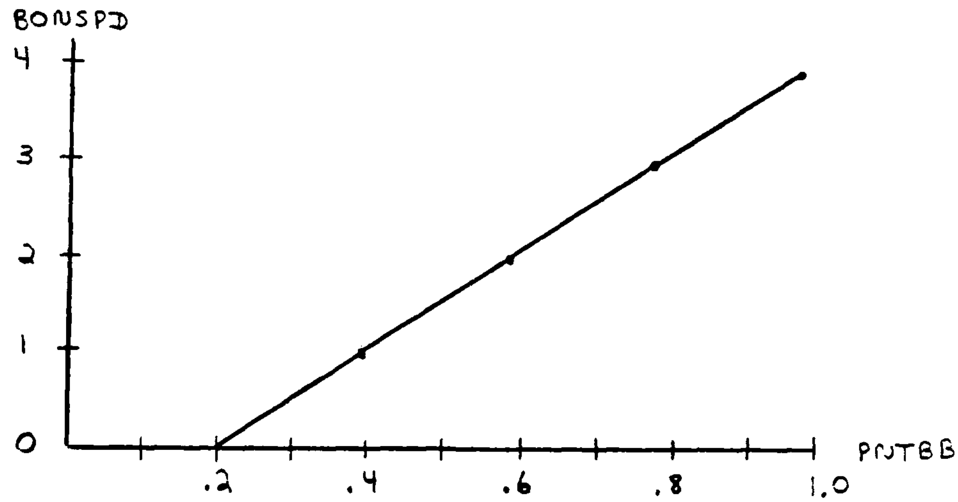



Figure 3.15. Table Formulation for BONSPD

Figure 3.16 depicts the flows, levels, and information used for the SL5 section. The computation of the bonus has been explained and is represented in the flow diagram. Equations PF20 to PF30 represent the mathematical formulation for the bonus effect. The SMOOTH function is used in equation PF to represent a first order information delay exponentially smoothed over a specified Bonus Delay Time (BDT). BDT represents the amount of time between the decision to pay bonuses and the point at which bonuses are received.

```
A L5MPCT.K=SL5.K/DL5                                     PF20
A PNTPB1.K=TABLE(L5BPTB,L5MPCT.K,0,1,.2)                 PF21
A L5BPTB=1/.8/.6/.3/.1/0                                 PF22
A PNTPB2.K=TABLE(COSTAB,SHIFTL(PRVCST.K,DT),0,1000,
        100)                                             PF23
T COSTAB=1/.93/.86/.79/.72/.65/.55/.43/.2/.1/0           PF24
```

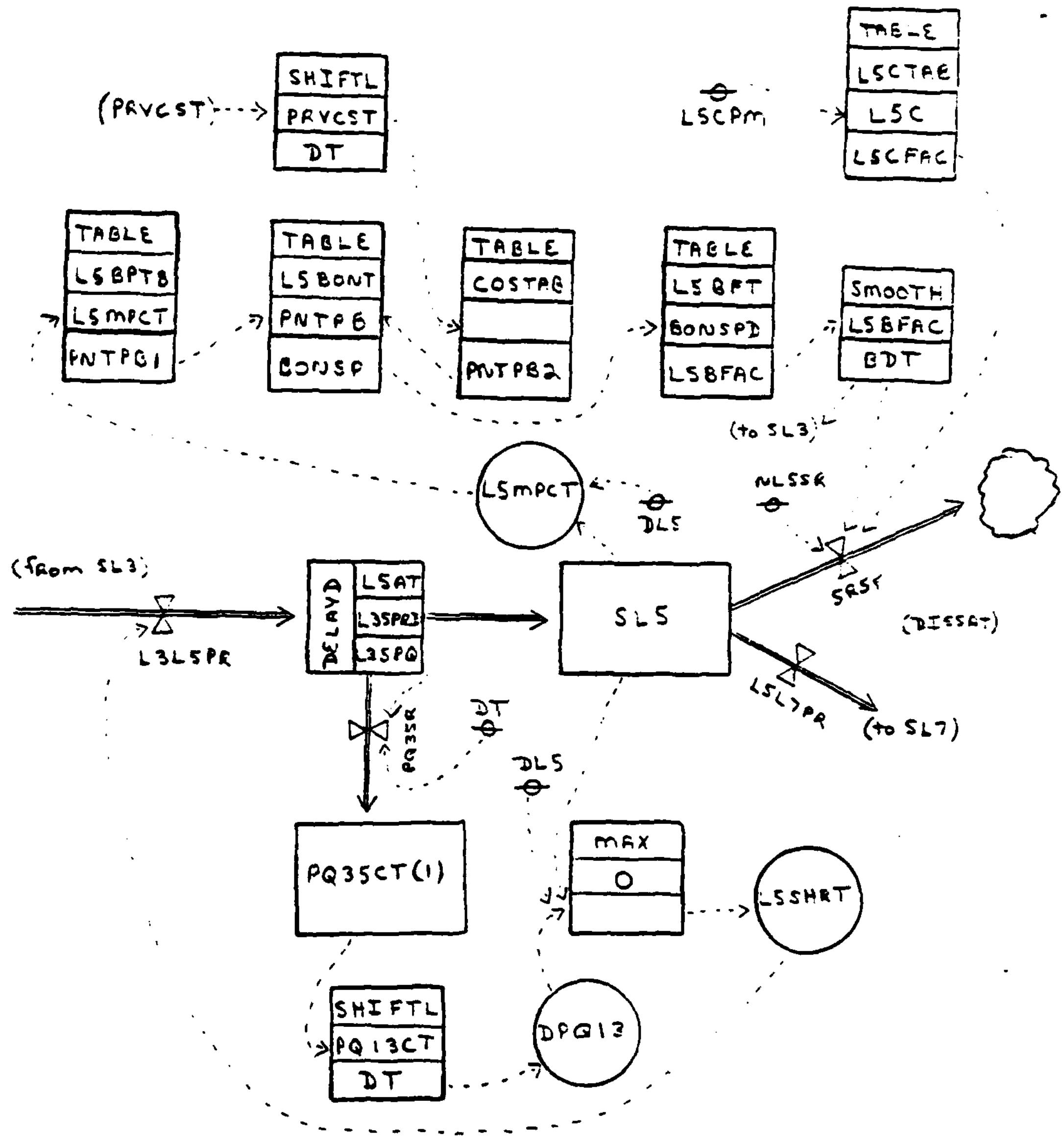



Figure 3.16. Flow Diagram for Skill Level 5

```
A PNTPB.K=PNTP1.K*PNTPB2.K                                    PF25
A BONSPC.K=TABLE(L5BONT,PNTPB.K,0,1,.2)                       PF26
T L5BONT=0/0/1/2/3/4                                          PF27
A L5BF.K=TABLE(L5BFT,BONSPD.K,0,4,1)                          PF28
T L5BFT=1.2/1.05/.8/.65/.5                                    PF29
A L5BFAC.K=SMOOTH(L5BF.K,BDT)                                 PF30
```

L5MPCT=Level 5 Manning Percentage
PNTPB1=Perceived Need to pay Bonuses from L5MPCT
L5BPTB=Level 5 Bonuses Paid Table
PNTPB2=Perceived Need to Pay Bonus from COST
COSTAB=Cost Table for PNTPB2
PNTPB=Perceived Need to Pay Bonuses
BONSPD=Bonuses Paid Multiple (0 to 4)
L5BONT=Level 5 Bonus Table for PNTPB1
L5BF=Level 5 Bonus Factor
L5BFT=Level 5 Bonus Factor Table
L5BFAC=Actual Level 5 Bonus Factor (delayed)

Other than the bonus portion of the SL5 flow process, the computation of levels and flows is very similar to the SL3 flow process. The Level 3 to Level 5 Promotion Rate (L3L5PR) is delayed with DELAYP to form the rate flowing into SL5. This delayed rate, L35PRD, employs the delay time, L5AT (Level 5 Accession Time) which represents the time from the initial identification of people being promoted to the actual time of promotion. L35PQ (Level 3 and Level 5 Pipeline Quantity) represents the number of people in transition from Level 3 to Level 5. This formulation is based on the fact that there is a certain amount of "lead time" associated with promotions. The personnel in the pipeline are still actually in the lower level; however, they are not used in computing the actual number of skill level 3. L35PQ is added to the level SL5 to determine the actual number of people in skill level 5.

```
R L35PRD.KL=DELAYP(L3L5PR.JK,L5AT,L35PQ.K)              PF31
L SL5.K=SL5.J+DT*(L35PRD.JK-SR5.JK-L5L7PR.JK)           PF32
R PQ35R.KL=L35PQ.K/DT                                   PF33
L PQ35CT.K(1)=PQ35CT.5(1)+DT*PQ35,JK                    PF34
A DPQ35.K=SHIFTL(PQ35CT.K,DT)                           PF35
A L5SHRT.K=MAX(0,DL5-SL5.K-DPQ35.K)                     PF36
R SR5.KL=MIN(SL5.K,NL5SR*DISSAT.K*L5CFAC.K*
        (1+L5BFACK)*.5)                                 PF37
R L5L7PR.KL=MIN(SL5.K,L7SHRT.K)                         PF38
A L5CFAC.K=TABLE(L5CTAB,L5CPM,8,18,2)                   PF39
T L5CTAB=211.5/1/.91/.8/.75                             PF40
```

L35PRD=Level 3 to Level 5 Promotion Rate Delayed
SL5=Skill Level 5
PQ35R=Pipeline Quantity Rate for Level 3 to 5
PQ35CT=Pipeline Quantity 3 to 5 Counter (2 word array of people)
DPQ35=Dummy Pipeline Quantity Level 3 to 5
L5SHRT=Level 5 Shortage
SR5=Separation Rate from Level 5
L5L7PR=Level 5 to Level 7 Promotion Rate
L5CFAC=Level 5 Cost Factor
L5CTAB=Level 5 Cost Table

As with SR3, SR5 is a function of the Normal Separation Rate (NL5SR), L5BFAC, L5CFAC, and DISSAT (from the Rotation Sector). The Level 5 Compensation Factor (L5CPM) is the multiplier based on Level 5 Cost Per Man. The ambivalence point is currently set at $12,000. The rationale for the above formulations is similar to the corresponding formulations in the SL3 section of the Personnel Fill sector.

<u>Skill Level 7</u>. Figure 3.17 depicts the flows and levels associated with Skill Level 7 (SL7). As with the SL3 and SL5 sections, the promotion rate is a function of the Level 7 shortgage and is delayed with DELAYP. The Separation Rate from Level 7 (SR7) is a function of DISSAT

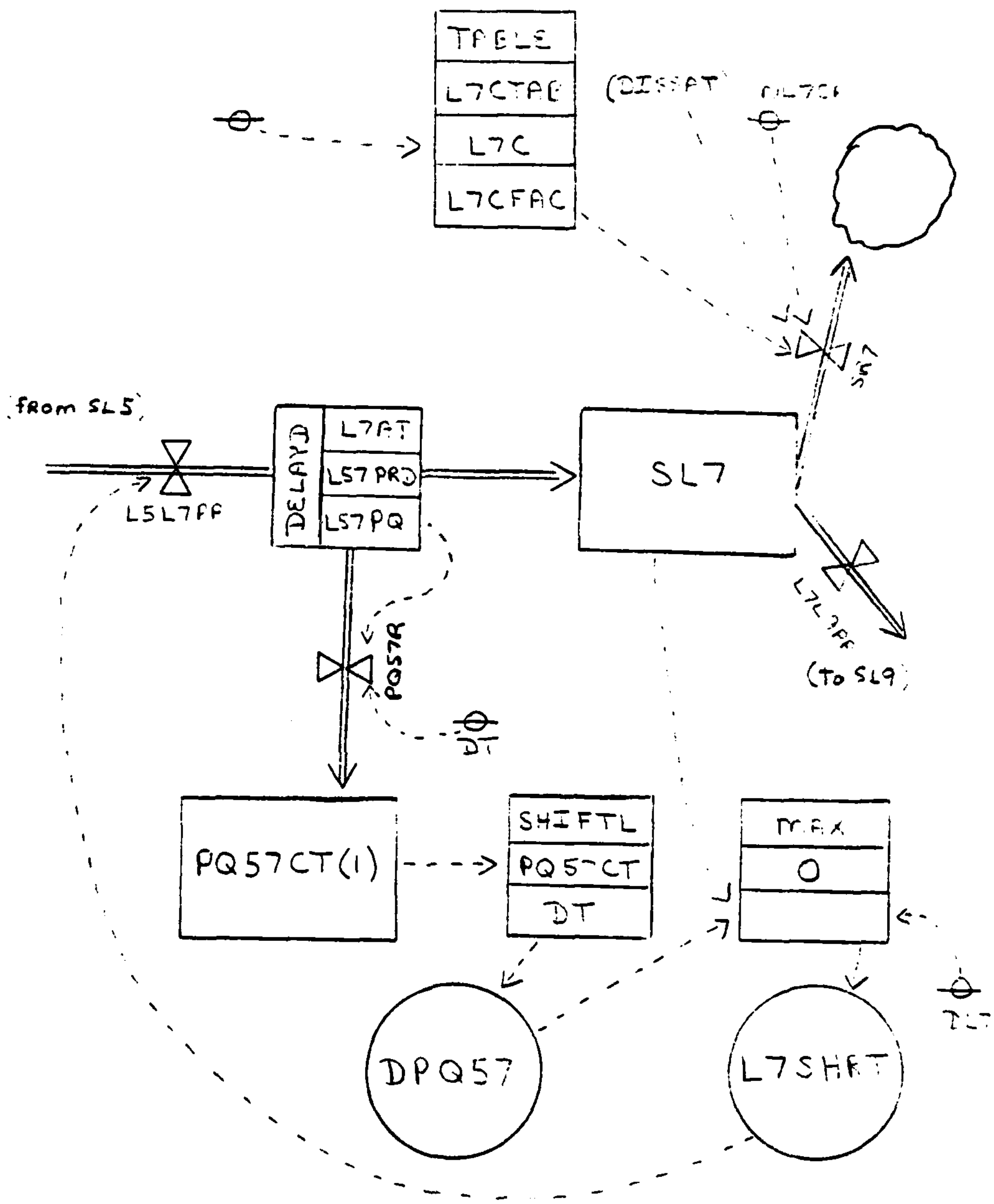



**Figure 3.17. Flow Diagram for Skill Level 7**

(from the Rotation sector), the Normal Level 7 Separation Rate (NL7SR), and the compensation multiplier for Level 7 (L7CFAC). The separation rates for the enlisted grades associated with skill level 7 did not vary with the FY82 to the same degree as the grades associated with the lower skill levels. However, managers feel that an "adequate" level of pay for skill levels 7 and 9 are a necessary, stabilizing force for separation rates in lower skill levels, as well as skill levels 7 and 9 (Ref 8, Ref 27). That is, SR7 may indeed decline only a little over the short-term if the pay and compensation per man (L7CPM) is significantly reduced; however, the future separation rates for SL3 and SL5 would probably increase due to lowered expectations of pay at higher levels. The ambivalence point was set at $14,000 for L7CFAC. As with the sections involving SL3 and SL5, L7CPM is currently set at a level slightly below the ambivalence level. Sensitivity of the model results to values of L7CPM relative to the ambivalence point is addressed in Chapter Four. The equations corresponding to figure 3.17 are contained in Appendix D, Documented DYNAMO Equations.

Skill Level 9. Figure 3.18 depicts the flows, levels, and information associated with Skill Level 9 (SL9). Separation from Level 9 (SR9) depletes SL9. There is no promotion to a higher level from SL9. The ambivalence point for L9CFAC is set at $19,000. This

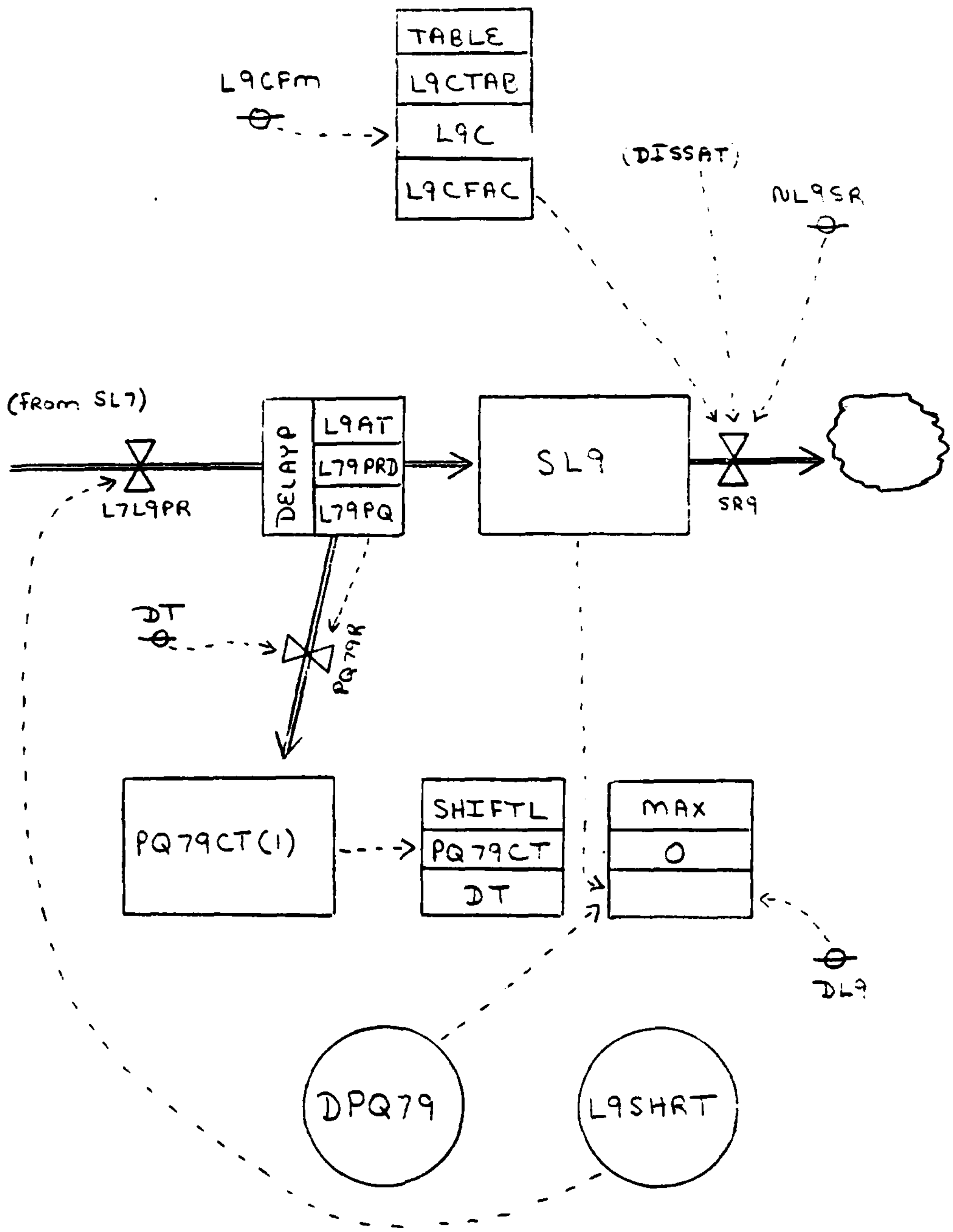



**Figure 3.18. Flow Diagram for Skill Level 9**

assignment is made somewhat arbitrarily, with sensitivity being examined in Chapter Four. The general feeling among those individuals interviewed was that any value close to the current level being paid for SL9 personnel could be considered to be a point of ambivalence. Due to retirement opportunities, a level significantly lower than current levels would probably cause an increase in SR9.

## Rotation Sector

The Rotation sector models how personnel move from assignment to assignment and how closely the airman assignment and rotation system is achieving its goals. The Personnel Fill sector provides the Rotation sector with a rotation base from which assignments are made to overseas long tours and remote tours. The Rotation sector provides the Personnel fill sector with a measure of cost due to PCS moves and a measure of dissatisfaction due to rotational indicators. The levels associated with remote tours, overseas long tours, and CONUS tours are output from the Rotation sector. These three major levels will be discussed separately, with the formulation of the key equations following the flow diagrams. Following the three levels will be a flow diagram and discussion of dissatisfaction due to rotation indicators. This section will conclude with a composite flow diagram of the Rotation sector.

CONUS. In the airman assignment and rotation system, military personnel can only leave the system (separate from the Air Force) from a CONUS assignment. In addition, personnel enter the system in either a CONUS tour or a CONUS technical school (Ref 8). These inflow and outflow rates are the same rates discussed in the Personnel Fill sector; Level 3 Accession Rate Delayed (L3ARD), and the separation rates from each Skill Level (SR3, SR5, SR7, SR9).

The level variable CONUS represents the number of people in CONUS tours. Thus, the value of CONUS is the rotation base for the AFSC being modeled. Personnel are rotated to remote tours and overseas long tours from this rotation base. Assignment priority for imbalanced AFSCs is as follows: (1) remote (short) tours, (2) overseas (long) tours, and (3) CONUS (Ref 8). Each overseas and remote tour has a given tour length, so as personnel complete their tours, other personnel from the CONUS rotation base must be assigned to those tours. Associated with each assignment is a delay due to the "lead time" for issuing orders and personal leave taken by the individual. Thus the rates of flow from CONUS to overseas and remote tours are based on overseas and remote requirements. The rates of flow from overseas and remote tours is a function of the tour lengths of those tours. (Ref 8 and Ref 25)

Figure 3.19 depicts the flows to and from CONUS. The rate variables obtained from the Personnel Fill sector are shown in parentheses. The flows coming into CONUS from the level variables OS (overseas long tours) and REMOTE (remote tours) are computed as a function of the number of people in the non-CONUS tours and their associated tour lengths, TOUROS (Overseas Tour Length) and TOUREM (Remote Tour Length). The rates of flow to OS and REMOTE will be discussed following the equations of the CONUS section of the Rotation sector.

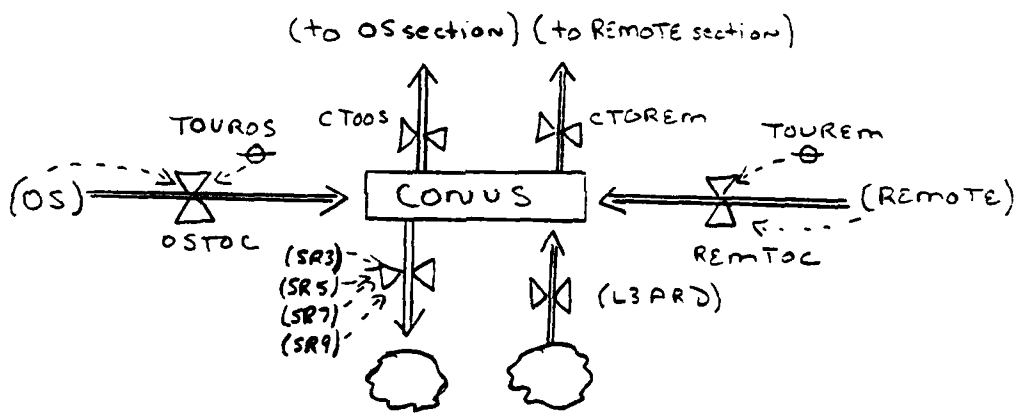



Figure 3.19. Flow Diagram for CONUS Section

<u>Overseas</u>. Assignments to overseas assignments are based on current shortages, projected shortages, and anticipated replacements. For example, if a particular remote base has three 306X2 vacancies, none leaving but two expected replacements coming in the next month, it will need one additional person assigned to the base in that AFSC. Figure 3.20 depicts the flow diagram of the

process of rotation of personnel from CONUS to OS. The CTOOS rate is delayed with DELAYP. The delay associated with assigning and rotating personnel is due to administrative delay and, in many cases, individual leave or temporary duty enroute. Given a specified delay time, some people arrive early, others arrive late, but the majority arrive after the time of delay time (Ref 25). In the model, the time of delay is specified as policy variable LAG1. The number in the pipeline is defined as CTOSPQ, the CONUS to OS Pipeline Quantity. OS is increased by CTOOSD, the delayed rate.

The flow lines from CTOSPQ (figure 3.20) are used in the model to capture the last period's pipeline value. This is the same process that was used in obtaining the pipeline values in the Personnel Fill sector. Conceptually, CTOSPQ is a level whose value must be considered along with the level OS in determining the need for more people. However, due to the order of computation in DYNAMO, the last period's pipeline value must be obtained through the use of the linear shift function SHIFTL. The last period's pipeline value, DCTOPQ (Dummy CONUS to Overseas Pipeline Quantity), is used in the calculation of the overseas shortage which determines the rate CTOOS.

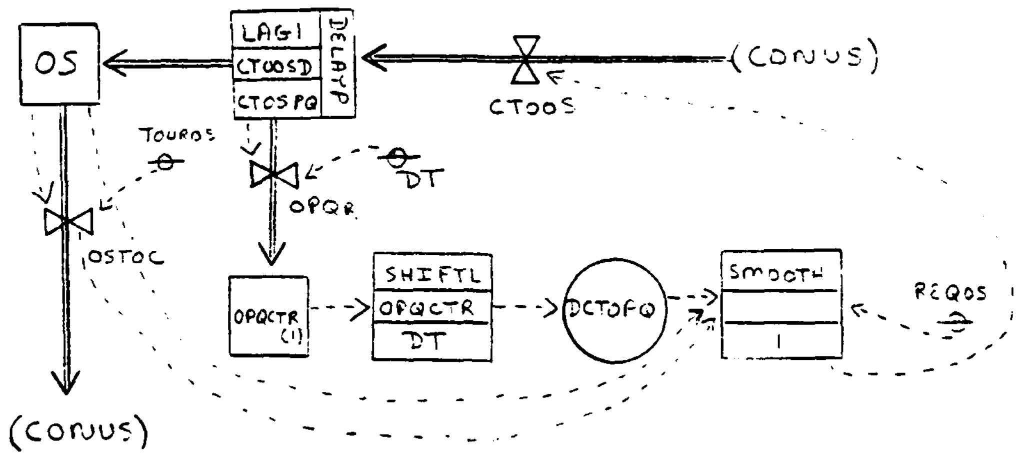



Figure 3.20. Flow Diagram for OS

```
R CTOOS.KL=SMOOTH(OSTOC.JK+(REQOS.K-OS.K-DCTOPQ.K),1)
                                                        R4
R CTOOSD.KL=SMOOTH(OSTOC.JK+(REQOS.K-OS.K-DCTOPQ.K)
           ,1)                                          R5
A DCTOPQ.K=SHIFTL(OPQCTR.K,DT)                          R6
R OPQR.KL=CTOSPQ.K/DT                                   R7
L OPQR.KL=CTOSPQ.K/DT                                   R8
```

CTOOS=CONUS to OS Rate (people per year)
CTOOSD=CONUS to OS Rate Delayed (people per year)
REQOS=Required OS level (people)
DCTOPQ=Dummay CONUS to OS Pipeline Quantity
LAG1=Delay Time for rotation to OS (years)
CTOOSPQ=CONUS to OS Pipeline Quantity (people)
OPQR=OS Pipeline Quantity Rate (people/years)
OPQCTR=OS Pipeline Quantity Counter (2-word array of people)

Also considered in the calculation of CTOOS is the historical rotation rate (in people per year) of OS personnel back to CONUS. For planning purposes, resource managers use rate histories to avoid "overreaction" to sudden shortages or overages (Ref 8 and Ref 37). Equation

R4 uses one year as the smoothing period for the calculation.

Remote. The process described for the OS assignments is duplicated for REMOTE assignments. Policy variables in the REMOTE section correspond to policy variables in the OS section but are named in accordance with their function in the REMOTE section. CTOREM (CONUS to Remote Rate) is computed similarly to CTOOS. It is then delayed with DELAYP.

```
R CTOREM.KL=SMOOTH(REMTOC.JK+(REQREM.K-REMOTE.K-
            DCTRPQ.K),1)                              R9
R CTORMD.KL=DELAYP(CTOREM.JK,LAG2,CTORPQ.K)           R10

CTOREM=CONUS to Remote Rate (people/year)
REMTOC=Remote to CONUS Rate (people/year)
REQREM=Required level of remote personnel (people)
REMOTE=Remote level of personnel (people)
DCTRPQ=Dummy CONUS to Remote Pipeline Quantity
                                            (people)
CTORMD=CONUS to Remote Rate Delayed (people/years)
CTORPQ=CONUS to Remote Pipeline Quantity (people)
LAG2=Delay Time for rotation to remote (years)
```

The remainder of the equations for the REMOTE section are contained in Apendix D, Documented DYNAMO equations.

Cost Calculations. The computation of COST that is used in the Personnel Fill sector employs variables from both the Rotation sector and the Personnel Fill sector. The reasons for computing cost and the use of cost as a "pressure" factor were discussed in the Personnel Fill sector of this chapter. This section will concentrate on how COST is computed in the model.

COST is the measure in thousands of dollars per year required to operate the airman assignment and rotation system for one AFSC. The inputs to COST (see figure 3.21) are the average levels of pay and compensation by skill level (L3CPM, L5CPM, L7CPM, and L9CPM), the number of persons receiving that level of compensation (SL3, SL5, SL7, SL9), the cost per PCS move (PCSCST), and the number of PCS moves per year (REMOTE, CTORMD, OSTOC, CTOOSD). The skill level compensation values are in terms of thousands of dollars per man-year, and the skill levels are in terms of men. The product of these results is in units of thousands of dollars per year. PCSCST is in terms of thousands of dollars per PCS move; REMTOC, CTORMD, OSTOC, and CTOOSD are in units of number of PCS moves per year. The product results in units of thousands of dollars per year. L5CPM is augmented by the approximate value of the bonuses paid. The data for the imbalanced AFSCs (see Table 3.8) show that the SRB multiple for Zone B or second term reenlistees is roughly half of the SRB multiple for zone A or first term reenlistees. Zone C personnel have not received a bonus in these AFSCs, at least since FY80. Since individuals receiving a bonus would be in SL5, the computation of bonuses utilizes the value of SL5. Equation R11 contains the bonus formulation used in computing the cost of bonuses. BONSPD is "normalized" over the SL5 population, since segments by this level are paid at varying rates.

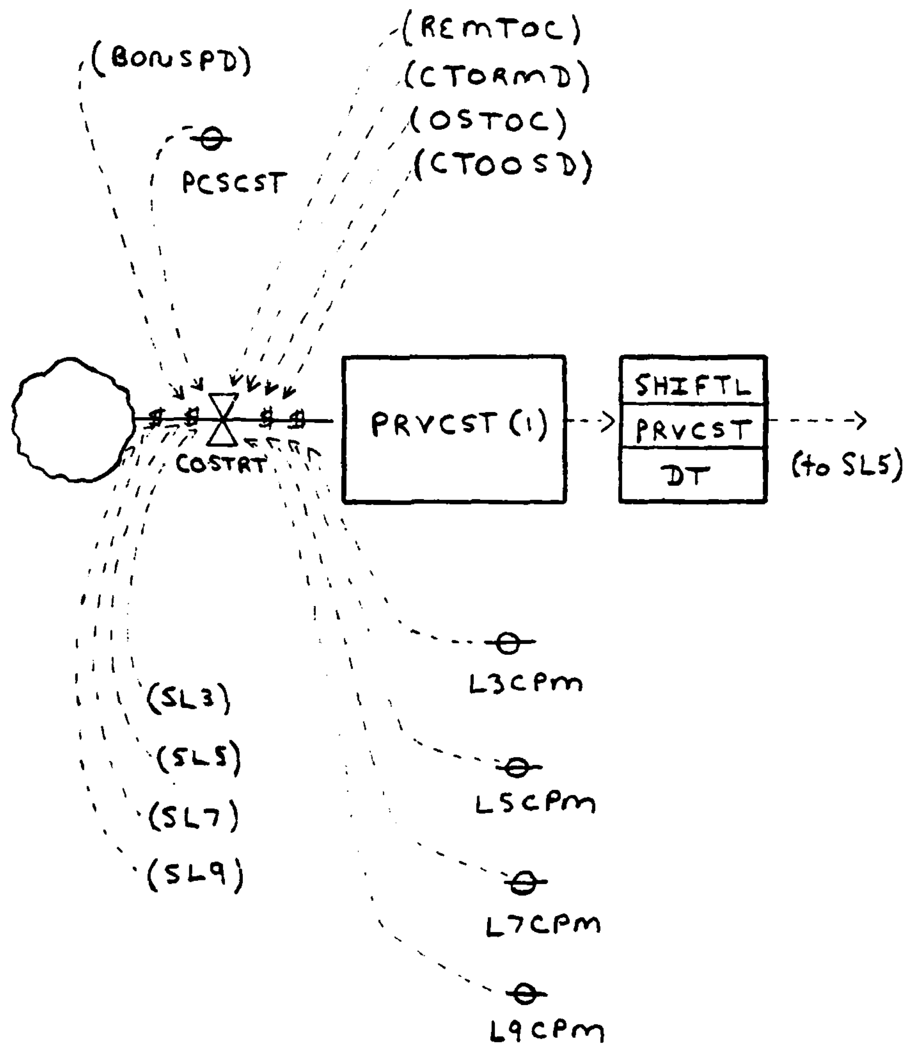



**Figure 3.21. Flow Diagram for Cost**

This is then multiplied by SRBM (value of SRB multiplier 1) which is in terms of thousands of dollars per man-year. BONSPD is a dimensionless number that is equal to the SRB multiplier.

```
R COSTRT.KL=L3CPM*SL3.K+(L5CPM+(3*BONSPD.K/2)*SRBM/4)
            *SL5.K+L7CPM*SL7.K+L9CPM*SL9.K+
            PCSCST*(REMTOC.JK+CTORMD.JK+OSTOC.JK+
            CTOOSD.JK)                                R11
S COST.K=COSTRT.JK*DT                                 R12
L PRVCST.K(1)=PRVCST.J(1)+DT*COSTRT.JK                R13

COSTRT=Cost Rate (thousands of dollars/year)
COST=Cost (thousands of dollars)
PRVCST=Previous Cost (thousands of dollars)
```

The number that is generated by the sums of products above is considered a rate, COSTRT. A rate is used because the cost from time period to time period is required, and the mechanism by which period values are tracked (SHIFTL) requires a level equation for the two word array and therefore a rate. The actual current period cost is calculated as COST, the product of the COSTRT ($000/time) times DT (time), resulting in thousands of dollars. The SHIFTL procedure is applied as before to track values, adding the rate times DT to a zero value and storing the current cost in PRVCST for use in the next time period as the previous cost.

Dissatisfaction Due to Rotation. Remaining in this discussion are levels and information flows associated with the system measures of effectiveness (MOE) used to calculate the dissatisfaction due to rotation (DISSAT) that is used in the Personnel Fill sector. The MOEs are:

1. average remote and overseas time per man per career in years (AROSPM),

2. average number of remote assignments per man per career (AVGREM), and

3. average time spent in the CONUS between remote and overseas assignments in years (CTBROS).

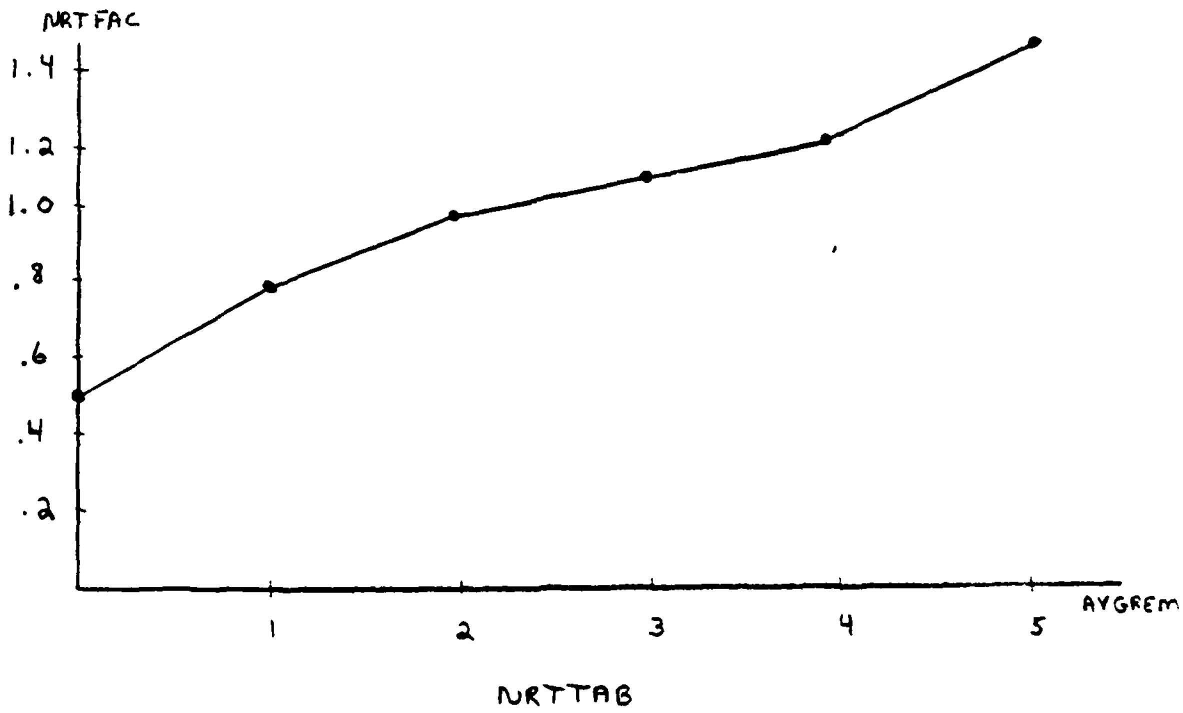
AROSPM is calculated as the ratio of the cumulative time spent remote and overseas (CUMROS) to the cumulative force strength over time (CUMTF). CUMROS is in units of man-years. CUMTF is in units of men. CUMROS is calculated as a level which is incremented by the cumulative rate of people being added to remote and overseas assignments (CUMRAT). CUMRAT is the sum of the people in the two levels at the current simulation time in units of men. By multiplying by DT, a value in terms of man-years spent in remote and overseas assignments is obtained and added to the level to accumulate CUMROS. CUMTF is calculated as a level of people who have entered the system. L3ARD is the rate at which people are realized into the system. CUMTF is initialized with the number of people starting in the system, then at each time step the level is incremented by L3ARD*DT. This level is never decremented. It tracks all the people who have entered the system since start up.

AVGREM is a function of CUMTF (explained above) and

CUMREM. CUMREM is the cumulative number of people that have been remote up until that point. CUMREM is in terms of number of tours and is calculated by DT*CTORMD, or the time by the number of remotes per time, which gives units of number of remotes. AVGREM is CUMREM (number of people in the CONUS and the average transition rate out of the CONUS (ACRM—Average CONUS to OS and REMOTE rate). ACRM is obtained by adding the smoothed CTOOS and CTOREM rate. The smoothing constants are policy variables. The smoothed value for CTOOS is ACOS (average CONUS to OS rate). The smoothed value for CTOREM is ACRM (average CONUS to REMOTE rate). CONUS is divided by ACRM to produce CTBROS. CONUS is in terms of men, and ACRM is in terms of average number of men transferred per unit time, or men/(men/time), which results in units of time.

This completes the discussion of the three minor levels of this sector, how they are used to calculate the three measures of effectiveness, and what actually makes up the MOEs. The flows and levels for the above processes are depicted in the consolidated flow diagram at the end of this section (see figure 3.25).

The MOEs are used as more than indicators of system performance. They also contribute towards calculation of the measure of the individual service person's dissatisfaction with the service (DISSAT). Each of the MOEs is converted to a multiplier by a table (see figures



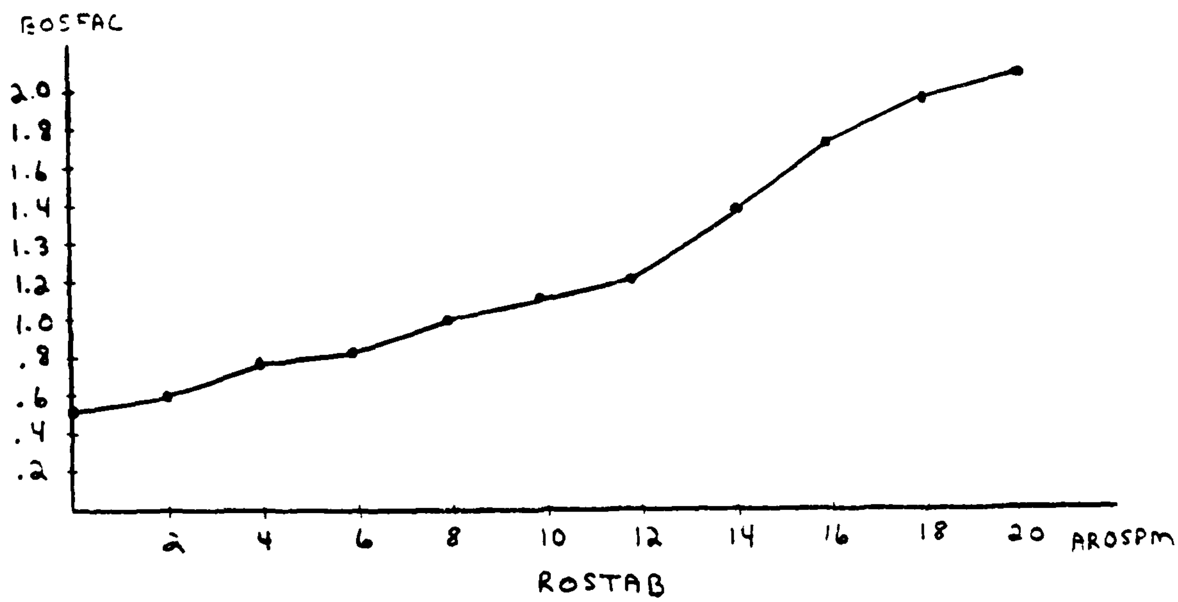




**Figure 3.22. Factors for Number of Remote Tours and Time Remote and Overseas per Career**

3.22 and 3.23):

1. AVGREM to NRTFAC (number of remotes factor) through NRTTAB,

2. AROSPM to ROSFAC (remote and overseas time factor) through ROSTAB,

3. CTBROS to CTBFAC (CONUS time between non-CONUS assignments factor) through CTBTAB.

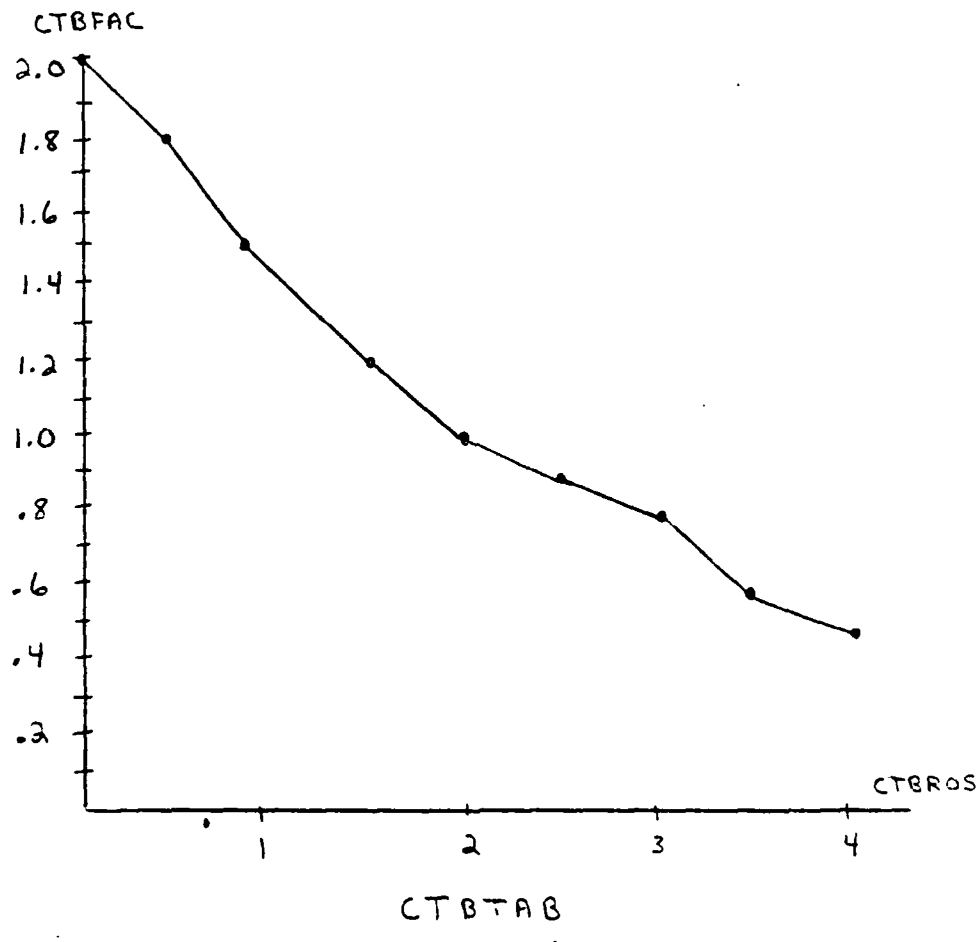



Figure 3.23. Factor for CONUS Time between Remote and Overseas

These multipliers are set to one if, based on the input to the table, the individual is neither particularly satisfied nor dissatisfied. The multiplier becomes greater than one as the input reflects conditions worse than desirable, for example, two weeks between remote assignments. Conversely, the dissatisfaction multiplier diminishes to near zero as the inputs become extreme in the opposite direction, for example, time between remotes of 18 years. The formulation of these tables was based on the input of personnel who were interviewed during this research. No "hard data" could be found that gives functional relationships between the three MOEs and dissatisfaction or between dissatisfaction and retention rates. Chow and Polich (Ref 11) attempted to control for rotation effects in determining the contribution to retention due to other factors. Chow and Polich (Ref 11), in discussing bonuses, asserted that it is difficult to control for "outside" factors such as job opportunities, the nature of the job, and economic conditions when attempting to establish a relationship between retention rates and bonuses. The same difficulties would arise in determining the effect of rotation dissatisfaction on retention rates. As with other tables, the sensitivity of model results to these formulations is addressed in Chapter Four.

These three multipliers are multiplied together to form DISSAT (see figure 3.24). DISSAT itself is a multiplier which is applied to the normal skill level separation rates in the Personnel Fill sector.

Rotation Sector Summary. The three major levels of the Rotation sector are CONUS, REMOTE, and OS. These levels, together with the associated rates and flows, are depicted in the consolidated flow diagram of the Rotation sector (see figure 3.25). The rotation from CONUS to OS or REMOTE are computed as functions of the level of personnel OS or REMOTE, the expected vacancies, and the expected arrivals. The expected vacancies are estimated through a one-year exponential smooth departure rate to CONUS. The expected arrivals are obtained from the pipeline quantities in DELAYP. Departure rates to CONUS are functions of the level of personnel OS or REMOTE and the respective tour lengths.

The MOEs computed in the Rotation sector correspond to the rotation indicators listed in AFR 26-1 (Ref 6). The MOEs determine how the airman assignment and rotation system is performing in relationship to its rotational objectives. They also are used in the formulation of the variable DISSAT that is used in the Personnel Fill sector to affect separation rates.

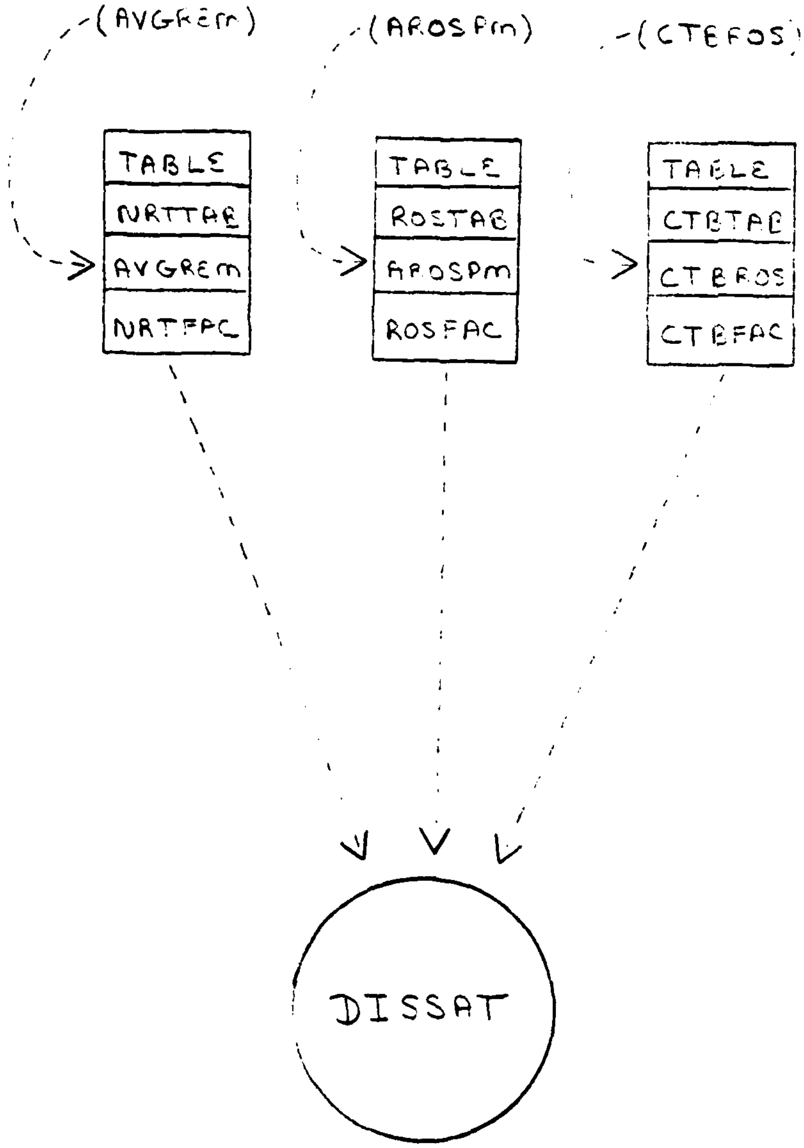



**Figure 3.24. Flow Diagram for Dissatisfaction**

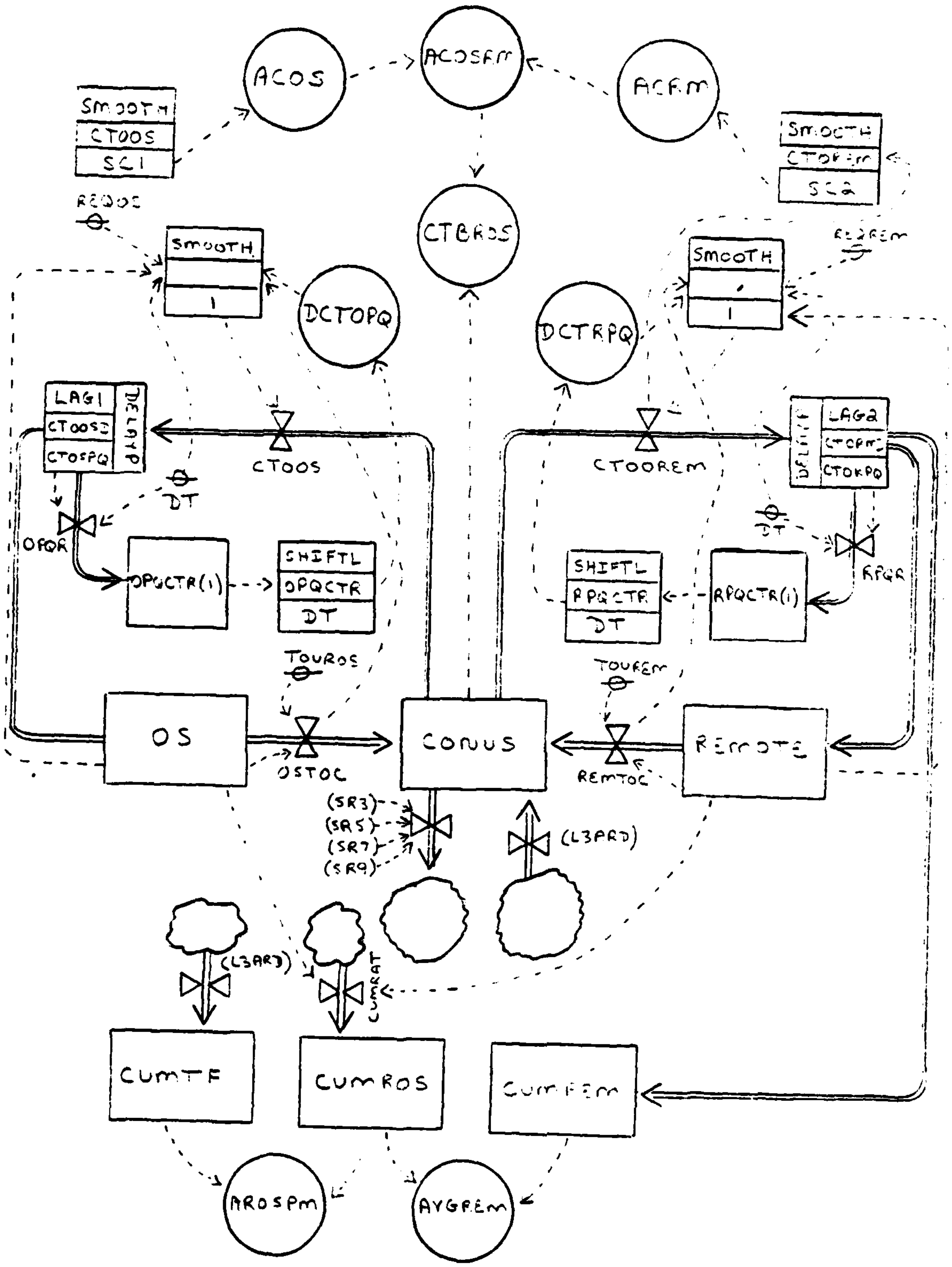



**Figure 3.25. Flow Diagram for Rotation Sector**

## Chapter Summary

Chapter Three has presented the conceptual and formal model of the airman assignment system. The model was divided into three sectors with one sector considered to be exogenous to the other two. The formulation of the two interacting sectors was presented. Chapter Four presents the model verification and validation which was performed to gain confidence in the use of the model.

## IV Model Verification and Validation

### Introduction

A model becomes more useful as it becomes strong in theory, data, and methodology. The confidence that one has in a model comes directly from these strengths. The issue of confidence building in a model can be addressed through the steps of verification and validation.

Verification is a test or series of tests to determine whether or not the model is faithful to its conception; that is, "whether the model has been synthesized exactly as intended" (Ref 18:70). Validation is "a test of whether the model is an adequate representation of the elements and relationships of the reference system that are important to experiments planned with the model" (Ref 18:70). Neither verification nor validation can be seen as "stamps of approval" for the models, but both steps are crucial to the modeling process. It is through these tests that confidence is gained, and the model is ultimately used.

Forrester and Senge (Ref 17) defined model testing as "the comparison of a model to empirical reality for the purpose of corroborating or refuting the model" (Ref 17:210). In this case, empirical information may include numerical statistics, descriptive knowledge of "real-system structure," and observed system behavior.

Model results should "make sense" to both the modeler and the client.

Forrester and Senge (Ref 17) described seventeen tests of structure and behavior suitable for system dynamics models (see Table 4.1). Identified from these seventeen tests was a set of ten "core tests for system dynamics" (Ref 17:226). In this chapter, the core tests of model structure and model behavior are presented. Tests of policy implications are presented in Chapter Five.

---

Tests of Model Structure
- a 1. Structure Verification
- a 2. Parameter Verification
- a 3. Extreme Conditions
- a 4. Boundary Adequacy
- a 5. Dimensional Consistency

Tests of Model Behavior
- a 1. Behavior Reproduction (symptom generation, frequency generation, relative phasing, multiple mode, behavior characteristic)
- a 2. Behavior Prediction (pattern prediction, event prediction, shifting mode prediction)
- a 3. Behavior Anomaly
-   4. Family Member
-   5. Surprise Behavior
-   6. Extreme Policy
-   7. Boundary Adequancy
- a 8. Behavior Sensitivity

Test of Policy Implications
-   1. System Improvement
- a 2. Changed-Behavior
-   3. Boundary Adequacy
- a 4. Policy Sensitivity

a = Core Tests

Table 4.1. Confidence Building Tests (Ref 17:227)

---

## Tests of Model Structure

The tests of model structure "assess structure and parameters directly without examining relationships between structure and behavior" (Ref 17:211-212). These tests were performed continuously throughout the developement of the model.

Structure Verification. Verifying structure consists of "comparing structure of a model directly with structure of the real system that the model represents" (Ref 17:212). The literature review and interviews conducted during the early stages of model development helped to formulate the "mental model" of the airman assignment and rotation system. The mental model was then formalized into a mathematical model of the system. The goals, major assumptions, and interrelationships that were presented in Chapter Three were discussed again with individuals working within the system. This second round of interviews resulted in a general acceptance of:

1. the system goals and prioritization,
2. the movement of personnel into and out of the major levels in the Personnel Fill sector and the Rotation sector, and
3. the calculation of dissatisfaction due to rotation indicators and the effect of dissatisfaction on separation rates.

The second round of interviews also resulted in a reformulation of:

1. bonus payment calculation,

2. effect of bonus payments on the Separation Rate from Level 3 (SR3), and the Separation Rate from Level 5 (SR5), and

3. CONUS to Overseas rate (CTOOS) and CONUS to Remote rate (CTOREM).

All of the new formulations were presented in Chapter Three. The bonus formulation currently reflects the SRB system and the general guideline for awarding specific SRB multiples. The effect of bonus payments on separation rates now correlates closely with the data presented in Table 3.6 and Table 3.7. CTOOS and CTOREM currently are functions of a one-year history of arrivals, departures, and shortages. The references for these formulations were given in Chapter Three.

There was some concern that the detail of the model structure was not sufficient to answer certain questions that might be asked in relation to the airman assignment and rotation system (Ref 8 and Ref 37). For example, the model does not consider individual bases within the three levels CONUS, OS, and REMOTE. Specific questions regarding the effect of changing the tour length of one remote base cannot be addressed, although the effect of changing the average tour length for all remote bases could be addressed. General agreement was reached that the model structure does exist within the airman assignment and rotation system. This structure was also regarded as an appropriate one for addressing the research problem outlined in Chapter One (Ref 25).

Parameter Verification. The parameter verification test involves the comparison of model constants "against observation of real life" (Ref 17:212). Some of the data used for this test has been presented in Chapter Three. Other data obtained from AFMPC (Ref 3 and Ref 4), AFCC Headquarters (Ref 1 and Ref 2), and Bolling AFB (Ref 5) was used in the model initialization (Appendix E). The constants used for normal separation rates (NL3SR, NL7SR, and NL9SR) were extracted from the data. Individuals at AFMPC and Air Force Headquarters (Ref 8, Ref 49, and Ref 27) corroborated these values. In the interview, a range that represented a considered analysis was given. The midpoint of these ranges was selected and the sensitivity of the model to these values is examined later in this chapter.

Extreme Conditions. "Structure in a system dynamics model should permit combinations of level (state variables) in the system being represented" (Ref 17:213). The extreme conditions test involves examining each rate equation in the model. The plausibility of the resulting rate equation is determined when imaginary maximum or minimum values of the level variables are employed (Ref

17:214). This test was accomplished for each rate equation in the model. For example, consider the following equation:

R OSTOC.KL=OS.K/TOUROS

OSTOC=Overseas to Conus rate (people/year)
OS=Overseas Level (people)
TOUROS=Overseas Tour length (years)

TOUROS is a constant. OS is formulated so that its value must be greater than or equal to zero. If OS=0, then OSTOC=0. If OS approaches positive infinity, then OSTOC also approaches positive infinity. As another example, this test was used to reformulate the separation rate and promotion rate equations. The SR3 equation is now:

R SR3.KL=MIN(SL3.K,NL3SR*DISSAT.k*L3CFAC.K*L5BFAC.K)

SR3=Separation Rate from SL3 (people/year)
SL3=Skill Level 3 (people)
NL3SR=Normal Level 3 Separation Rate
DISSAt=Dissatisfaction due to Rotation Indicators
L3CFAC=Level 3 Compensation Factor
L3BFAC=Level 5 Bonus Factor

Without the MIN function, it would be possible (under extreme values of the multipliers on the right hand side of the equation) for more people to separate from SL3 than were initially there. Thus, to avoid getting negative levels, the MIN function was used in this manner for separation and promotion rates.

Boundary Adeqaucy. The boundary adequacy (structure) test "asks whether or not model aggregation is appropriate and if a model includes all relevant structure" (Ref

17:215). The purpose of this research was to provide a dynamic policy model that could be used to study the effects of policies and environmental changes on the airman assignment and rotation system. Table 4.2 summarizes the levels of aggregation employed in the model.

| Entity | Represented |
|---|---|
| -- Skill Levels | Yes |
| -- Individual Enlisted Grades | No |
| -- Individual OS Bases | No |
| -- Overseas (Long/Short) | Yes |
| -- Individual CONUS Bases | No |
| -- CONUS Rotation Base | Yes |
| -- Volunteers/Non-volunteers | No |

Table 4.2. Summary of Levels of Aggregation Used in the Model

For the stated purpose of this research, the structure of the system is believed to be represented at the proper level of aggregation. Individuals at AFCC Headquarters, where the model is intended to be eventually used, agree that the level of aggregation is appropriate (Ref 25). Disaggregation of the model structure would be a simple matter by employing the array capability of DYNAMO (refer to Ref 39:374-381 for an example).

<u>Dimensional Consistency</u>. "The dimensional consistency test entails dimensional analysis of a model's rate equations" (Ref 17:215). The dimensions of the

variables used in each rate equation formulation were listed as the equations were developed. To pass this test, the dimensions on the right-hand side of the equation must match the dimensions on the left-hand side. This test was performed and passed for each rate equation as well as for the level and auxiliary equations.

Tests of Model Behavior

"Tests of model behavior evaluate adequacy of model structure through analysis of behavior generated by the structure" (Ref 17:217). The following tests of model behavior were performed and are presented here: (1) behavior reproduction, (2) behavior anomally, (3) surprise behavior, (4) extreme policy, and (5) behavior sensitivity.

Behavior Reproduction. Forrester and Senge (Ref 17) discussed five types of behavior reproduction tests: (1) symptom generation, (2) frequency generation, (3) relative phasing, (4) multiple mode, and (5) behavior characteristic (Ref 17:217-224). The behavior reproduction tests performed on the model that are discussed here include symptom generation and frequency generation.

"The symptom generation test examines whether or not a model recreates the symptoms of difficulty that motivated construction of the model" (Ref 17:217). The symptoms that motivated this research include:

1. simultaneous overmanning of Skill Level 3 (SL3) and undermanning of Skill Level 5 (SL5),

2. "overshooting" the total manning level for a given year following a total manning shortage in the previous years,

3. constant manning percentages for Overseas (OS) and Remote (REMOTE) bases but a varying total manning percentage for CONUS bases,

4. first-term reenlistment rates of approximately 40% and second-term reenlistment rates of approximately 60% to 70%, and

5. CONUS/OS imbalance that causes the Air Force rotation objectives to not be achieved (Ref 8, Ref 25, and Ref 49).

The model was initialized with AFSC 306X2 (Telecommunications System and Equipment Maintenance Specialist) FY82 data (Ref 1). The simulation was run for fifteen years of simulation time. All of the major level and rate variables were defined for model output so the behavior of the skill levels, the rotation levels (CONUS, OS, and REMOTE), and the promotion and separation rates could be observed. This base run sets the Total Force Weight (TFWT) to one and the Level 3 Weight (L3WT) to zero, reflecting what is believed to be the current policy of attaining a total manning percentage that is as close as possible to 100% without regard for the overmanning of

Skill Level 3. The rationale for this formulation was discussed in Chapter Three, The Model. Additionally, the AFSC is on the Unsatisfactory Rotational Index list and the Critical Military Skills list. It has approximately a 1:1 CONUS to overseas authorization ratio with 1000 total billets. The total force manning percentage is 97%. The skill level 3 manning percentage is 147%, while skill levels 5, 7, and 9 are undermanned.

Tour length for overseas (long) and remote tours are three years and one year, respectively. DT, the DYNAMO integration time interval, was chosen as 1/6 of the shortest third order delay or 0.4277 years. The inputs for the base run initialization are contained in Appendix E.

At the start of the simulation, there is an initial force shortage of 20 people. This shortage is quickly made up by increasing the Level 3 Accession Rate. Due to the delay of this rate, the increase in the rate has the effect of increasing the number of people in the pipeline. By the time this bulge of people begin to arrive in skill level 3, the total force shortage has already been alleviated. The level 3 manning is initially 147%, which includes 372 people in SL3 and 24 people in the promotion pipeline. During the first year of simulation time, a portion of the SL5 shortage is made up while the level 3 manning rises to 151% of its desired value (see figure

4.1). The total manning level rises from 981 people (20 people short) at the start of the simulation to 1072 people at the end of the first year of simulation. AFCC data showed the current (June 82) and projected (1 year into the future) manning levels (Ref 1). The total force manning for AFSC 306X2 goes from 97% to 105% while the skill level 3 manning goes from 147% to 160%. This tendency to "overshoot" both skill level 3 manning and total force manning seems to stem from a low estimate of the separation rates from skill level 3 and skill level 5. In both the model and the actual system, the historical separation rates were higher than those that transpired in the initial year. Thus, the new people accessed into the system more than replaced those who left.

Figure 4.1 depicts the individual skill manning levels juxtaposed with the required manning levels. The representations of the variables and corresponding ranges are summarized in Table 4.3. The key for these codes also appears at the top of the DYNAMO output (see figure 4.1). The variable ranges appear just below the key on the top horizontal axis. Note that the required levels and actual population levels have the same range, while the ranges differ from one major level to another. "Time" is given at the left vertical axis. In figure 4.1, "time" ranges from zero to fifteen years. All of the output given in this chapter and in the next chapter can be read and

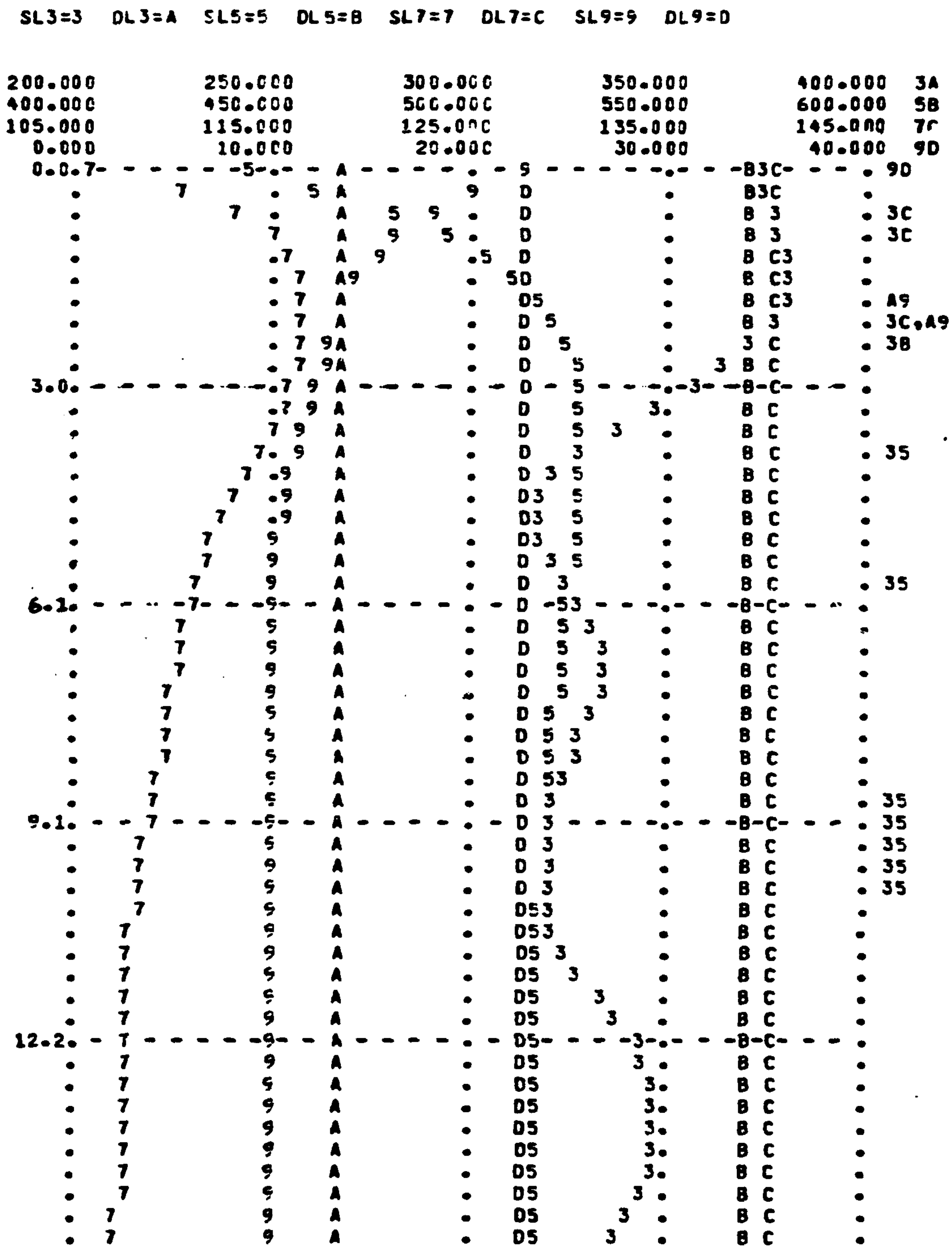



Figure 4.1. Base Run: Personnel Fill Sector Levels

interpreted in a similar manner.

| Range | Variable/Symbol |
| --- | --- |
| 200-400 | SL3/"3" |
| | DL3/"A" |
| 400-600 | SL5/"5" |
| | DL5/"B" |
| 105-145 | SL7/"7" |
| | DL7/"C" |
| 0-40 | SL9/"9" |
| | DL9/"D" |

Table 4.3. Variables and Symbols for DYNAMO Skill Level Output

From figure 4.1, it can be seen that SL3 remains overmanned throughout the simulation; however, the amount of overmanning varies. This variation is probably due to two factors:

1. L3AR is the only means through which total manning shortage can be alleviated without significantly altering separation rates; thus, the L3AR "value" tends to open and close relative to the total manning shortage.

2. L3AR is decreased through the economic multiplier, PNLM (Perceived National Labor Market). In the model, the recruiting quota is only met during slow economic years. As mentioned in Chapter Three, experience has revealed that this phenomenon also occurs in the airman assignment and rotation system (Ref 8 and Ref 37).

Figure 4.2 depicts the three major levels in the rotation sector: (1) OS, (2) REMOTE, and (3) CONUS. The symbols used to represent the levels appear at the top of figure 4.2. After the first two years of simulation time, the non-CONUS levels (REMOTE and OS) settle down to fairly constant values. CONUS has a larger initial reaction to the total manning "overshoot" of the Personnel Fill sector and continues to vary throughout the simulation. The model reflects the prioritization of REMOTE and OS tours over CONUS tours much the same as the airman assignment and rotation system for AFSC 306X2.

Figure 4.3 depicts the separation and promotion rates for the four skill levels in the model. The key for the symbols used are given at the top portion of the figure. Table 3.6, Chapter Three, shows the retention rate data for FY80, FY81, and FY82-3. At the 4-year point in the simulation, the retention rates for skill level 3 and skill level 5 are 44% and 63%, respectively. This compares favorably with the range of retention rates for first term and second term of AFSC 306X2 as shown in Table 3.6. This behavior reproduction may indicate that the factors chosen in the model to affect separation rates are adequate for skill levels 3 and 5, the levels given the most consideration by military manpower planners (Ref 27).

Throughout the simulation, an approximate CONUS-to-overseas (long and short tours) ratio of 1:1 is maintained. The imbalance is maintained primarily due to

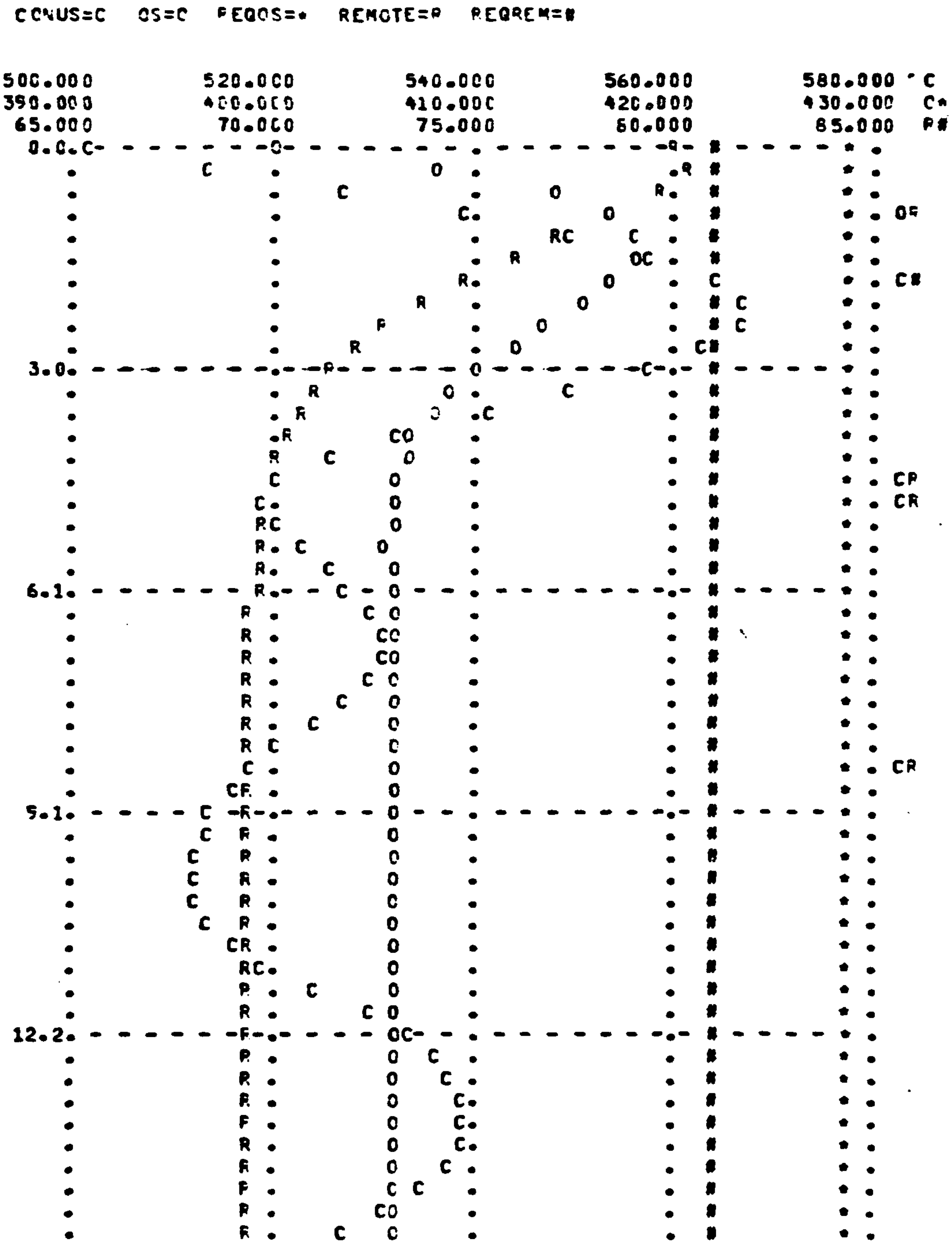



**Figure 4.2. Base Run: Rotation Sector Levels**

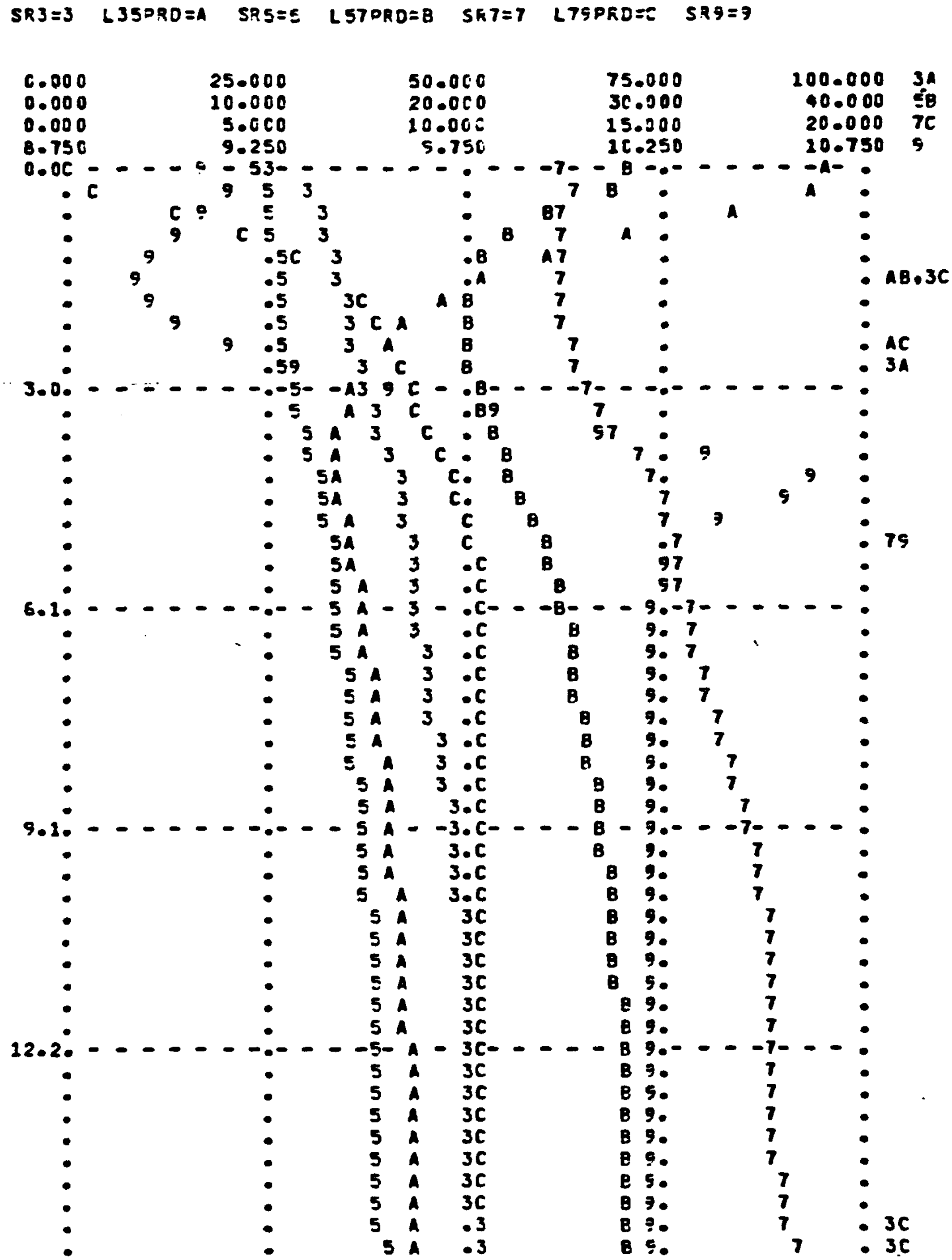



Figure 4.3. Base Run: Promotion and Separation Rates

the number of long overseas tours relative to the number of CONUS tours. Since there are never more than 82 remote tours, the number of remote tours per career does not exceed two. However, the output does indicate, as would be expected, that the CONUS time between involuntary overseas and amount of time spent overseas exceeds the Air Force objectives. This indicates that, with no policy changes, the AFSC would continue to remain on the Unsatisfactory Rotation List.

The frequency-generation test examines the periodicities of variables in the model. In general, the level variables REMOTE and OS stabilize at a value slightly below the desired levels, while CONUS reflects a wave behavior with peaks five to six years apart (see figure 4.2). These trends "make sense" in that the overseas assignments need to have a consistent level of manpower, particularly in a Critical Military Skills AFSC such as 306X2. CONUS can "absorb" gains or losses in manning levels more easily than OS or REMOTE.

The wave nature of SL3, in comparison to the fairly consistent level of SL5, SL7, and SL9, can be seen in figure 4.1. As in the reference system (airman assignment and rotation system), the SL3 level in the model is more subject to national economic variations and manning level shortages than are the other skill levels. SL5, SL7, and SL9 maintain at a level slightly below the desired levels, with manning percentages of approximately 90%, 77%, and 50%, respectively. The model's manning percentges for SL9 is slightly low, but the long-term percentages for SL5 and SL7 compare favorably with expected pecentages (Ref 25).

Behavior Anomally. The behavior anomally tests used extensively in the reformulation of rates during model development. The CTOOS and CTOREM rates originally considered only the current shortage. This resulted in an overreaction to initial shortages that was not characteristic of the reference system. Both rates were reformulated to be a function of historical and current shortages and historical rates of rotation back to CONUS. The L3AR rate did not originally account for the separation rate and promotion rate from SL3. Over the long-term, too few people were supplied to SL3. To more accurately reflect the behavior of the reference system, historical loss rates from SL3 were used in conjunction with shortages.

Surprise Behavior. The amount of "overshoot" in the total manning level during the first two years of simulation was not an expected result. A review of the data revealed the tendency to "overshoot" the total manning percentage for AFSC 306X2 as well as three of the AFCC imbalanced AFSCs. The causes for this overshoot were hypothesized earlier in this chapter. Those causes are believed to be the same in both the model and the reference system.

*Extreme Policy*. "The extreme-policy test involves altering a policy statement (rate equation) in an extreme way and running the model to determine dynamic consequences" (Ref 17:221). The model was developed so that this test could be performed using the previously explained DYNAMO RERUN option. The extreme-policy tests performed involved altering nine tables (refer to Appendix B for a sample of the re-run files used for these tests). Five different policies that were tested under extreme conditions are now presented.

*Case 1*. To investigate the reaction of the model to extreme effects due to national economy, the table for the Technical School Multiplier (TSCHM) was altered. TSCHM, the fraction of total desired recruits that could be obtained, varies from a value of 1 during low points of the economy to a value of 0.8 during high points of the economy. A change in the formulation of TSCHM will cause a change in L3AR, since the L3AR is the product of TSCHM and TEMPRT (the desired recruiting total). The Technical School Multiplier Table (TSCHMT) was reformulated with four different ranges of values:

1. all values of 1,
2. 1 to 0.5,
3. all values of 0.5, and
4. 1 to 0.1.

The output reporting the CONUS, REMOTE, and OS levels is shown in figures 4.4 to 4.7. If the economy had no effect on the L3AR (all values of 1), REMOTE and OS would be the same as in the base run, whereas CONUS reaches a value that is roughly the mean of the values of CONUS in the base run (see figure 4.4). With a variation in TSCHM of 1 to 0.5, REMOTE and OS are still roughly the same as in the base run, while CONUS has a larger amplitude than in the base run (see figure 4.5). With all TSCHM value of 0.5, REMOTE and OS reach their usual values, while CONUS drops to 70 people below its starting value (see figure 4.6). Finally, an extremely wide variation in the efects of the economy on recruiting (TSCHM values from 1 to 0.1) causes CONUS to vary with a large amplitude but has no effect on REMOTE and OS (see figure 4.7). In the Personnel Fill sector, most of the varying effects of these table reformulations were absorbed by SL3. The model reacts to these extreme changes as one would expect the reference system to react.

Case 2. Separation rates from SL3 and SL5 are, in part, functions of the Perceived Need to Pay Bonuses (PNTPB). PNTPB is the product of the two factors PNTPB1 and PNTPB2, which were defined in Chapter Three. The factor PNTPB1 is a function of the SL5 manning percentage. The factor PNTPB2 is a "pressure" variable based on the assumption that as the cost of operating the airman

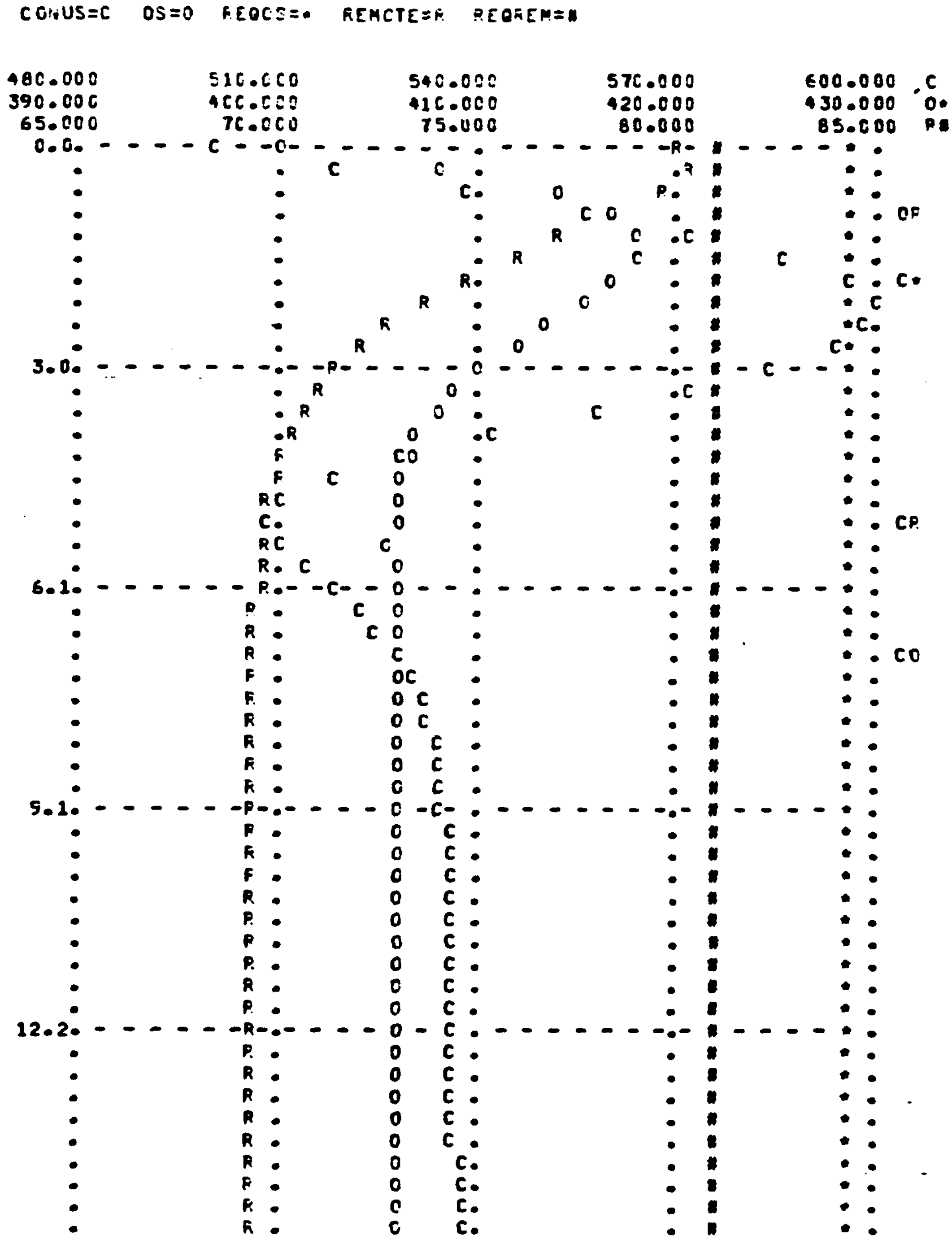



Figure 4.4. Case 1: Condition 1

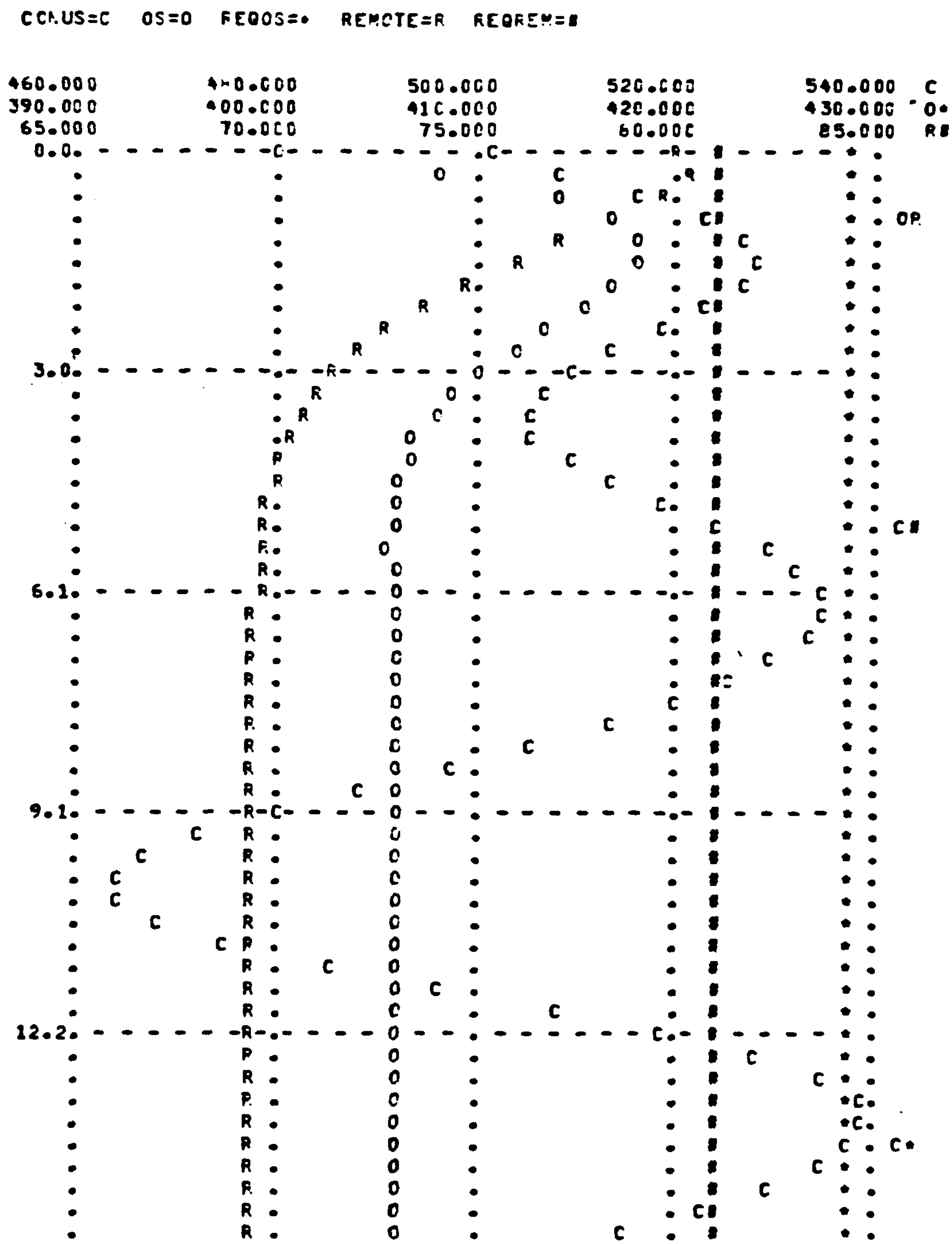



Figure 4.5. Case 1: Condition 2

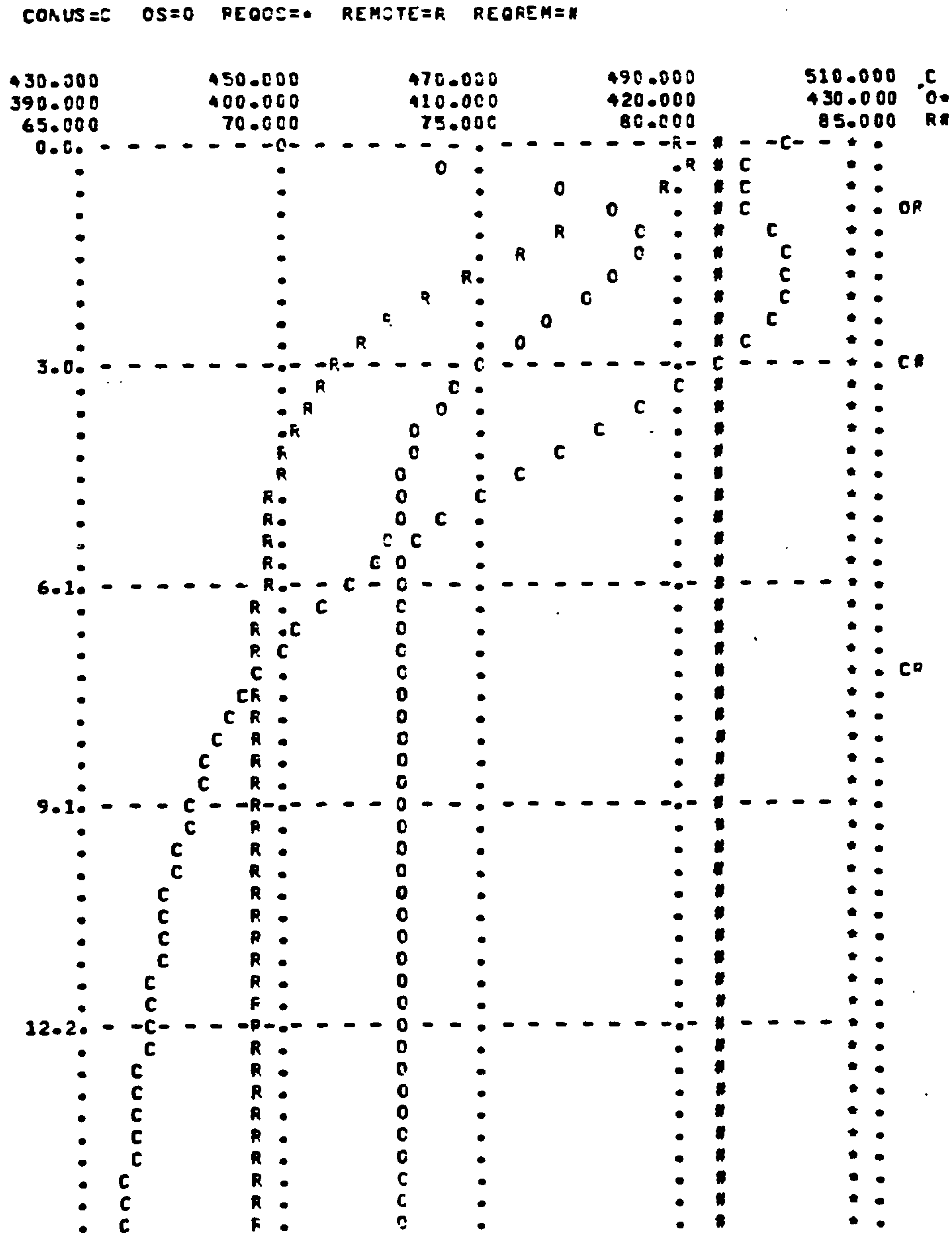



Figure 4.6. Case 1: Condition 3

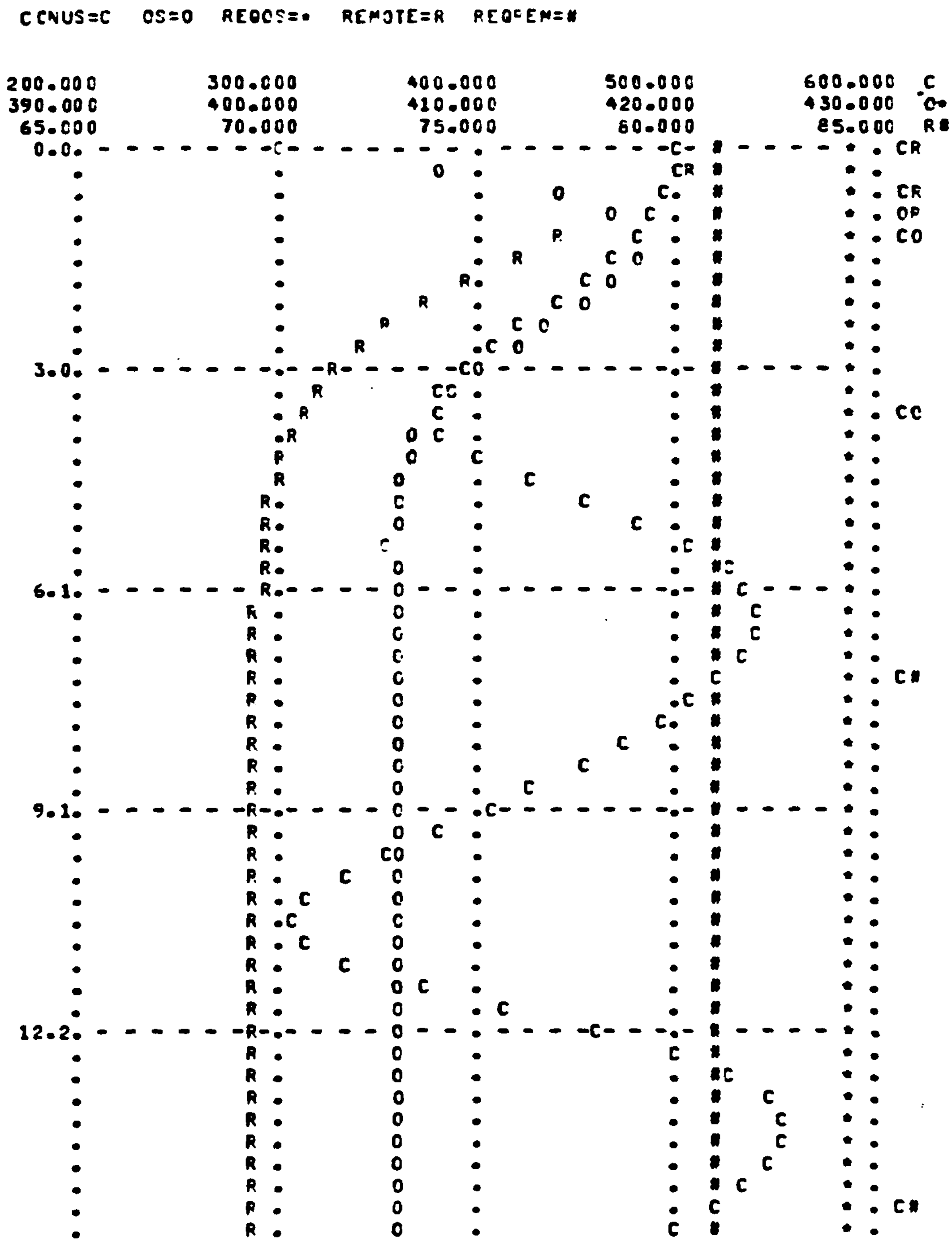



Figure 4.7. Case 1: Condition 4

assignment and rotation system goes up, the pressure to increase bonus payments goes down (see figure 4.8). COSTAB, the table used in the formulation of PNTPB2, was modified to reflect two situations:

1. regardless of system cost, there is no pressure to decrease the bonuses paid, and

2. regardless of system cost, there is significant pressure to decrease the bonuses paid.


Figure 4.8. Linkage Relating System Cost to PNTPB2

Situation 1 in the preceeding paragraph is modeled by setting all of the table values in COSTAB to 1. Situation 2 is modeled by setting all of the values in COSTAB to 0.5. In the base run of the model, the value of PNTPB2 ranged from 0.75 to 0.80. Consequently, the outside pressure to decrease bonus payments was fairly low (a value of 1 is interpreted as no pressure) under the original formulation of COSTAB, as was intended.

Under both situation 1 and situation 2, the model results are very similar to the results of the base run. There are very minor differences in the separation rates from SL3 and SL5 and consequently only minor differences in the levels. The reason for these similar results lies in the formulation of PNTPB2. PNTPB1 remains low throughout the simulation. Under situation 1, the value of PNTPB1 is used as the value for PNTPB. However, the increased value of PNTPB remains fairly low and generates only slightly more bonus payments than under the base run. Under situation 2, slightly less bonus payments are generated.

With more critial manning shortages or with a reformulation of PNTPB1, the extreme policies of this case would have more effect. However, the current policy for PNTPB1 is to consider 90% manning of SL5 to be adequate (and therefore worthy of only small bonus payments). Under this policy for PNTPB1, the extreme policies applied in this case to PNTPB2 have little effect. Under these circumstances, the reference system would be expected to behave similarly.

Case 3. In another extreme-policy test, the model was exercised under the following set of assumptions:

1. the effect of the bonus payments on separation rates (SR3 and SR5) is:

   a. more extreme than originally hypothesized, or

   b. less extreme than originally hypothesized.

2. regardless of manning considerations or cost considerations, either:

   a. no bonuses will be paid, or

b. the maximum bonus will be paid.

Under assumption 1-a, individuals in the system would react very strongly to the level of bonuses being paid. Under assumption 1-b, the level of bonuses paid would have no effect on the separation rates. To represent these two situations, the Level 5 Bonus Factor Table (L5BFT) was reformulated to range from 2 down to 0.2 under assumption 1-a, and to contain all values of 1 under assumption 1-b. Figures 4.9, 4.10, and 4.11 depict the output under assumption 1-a. From figure 4.9, the retention rate for SL3 can be computed to be approximately 37% at the 10-year point, whereas the retention rate in the base run at the same point in time was approximately 46%. SL5 retention rates decrease to a lesser degree under assumption 1-a. As a result of the higher loss-rates, the Level 3 Accession Rate (L3AR) increases by about 150%. This leads to greater amplitudes in both the SL3 population (see figure 4.10) and the CONUS population (see figure 4.11). This phenomenon of "higher peaks" and "lower valleys" is characteristic of personnel systems with high turnover-rates (Ref 45). Situation 1-b resulted in very little change in the model results. The base case represents only a small, incremental increase in bonus payments relative to situation 1-b. This incremental policy change has little effect on model results. In both situation 1-a and 1-b, the model seems to react as the

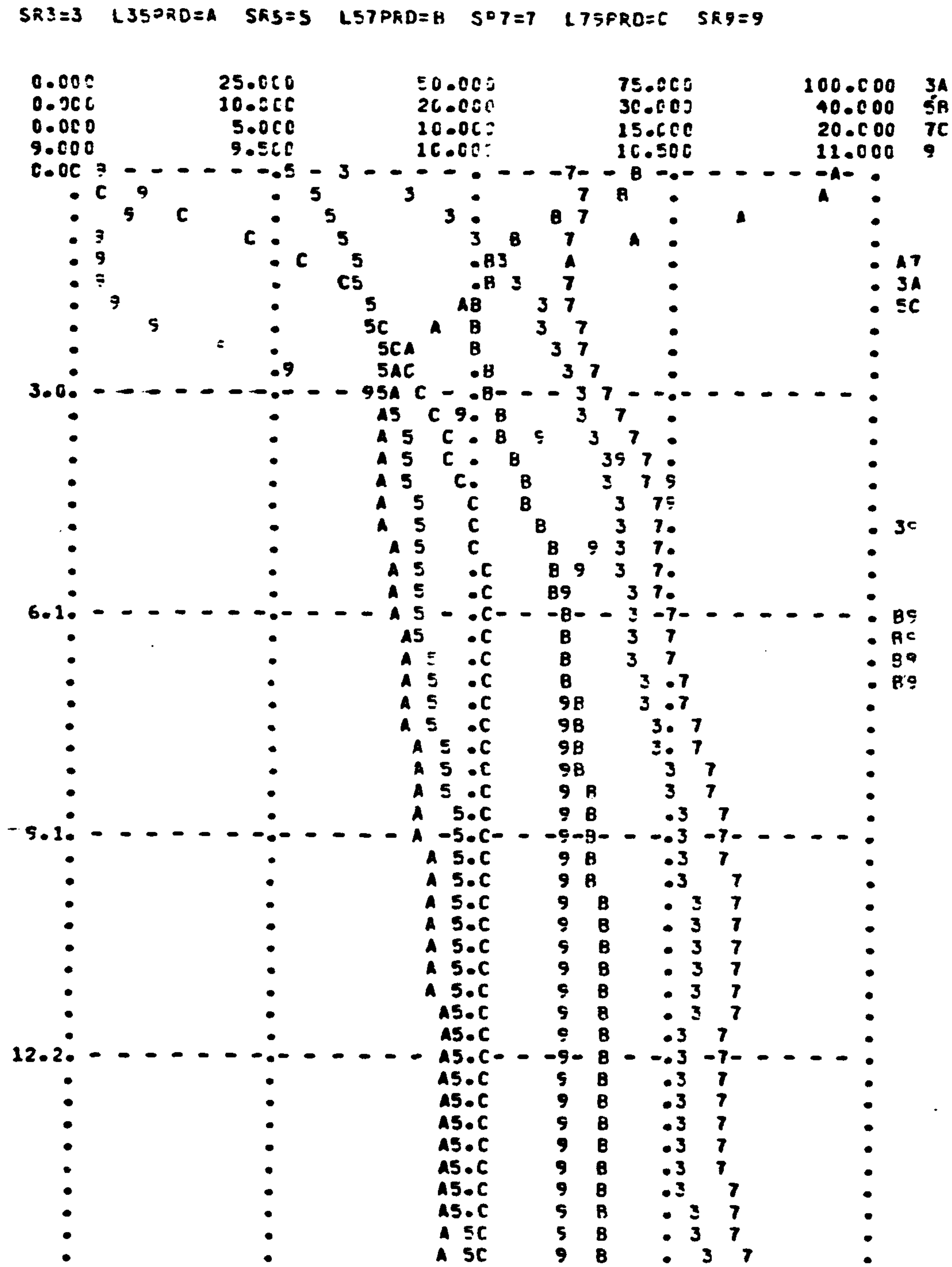



Figure 4.9. Assumption 1-a: Rates

SL3=3 DL3=A SL5=5 DL5=B SL7=7 DL7=C SL9=9 DL9=D

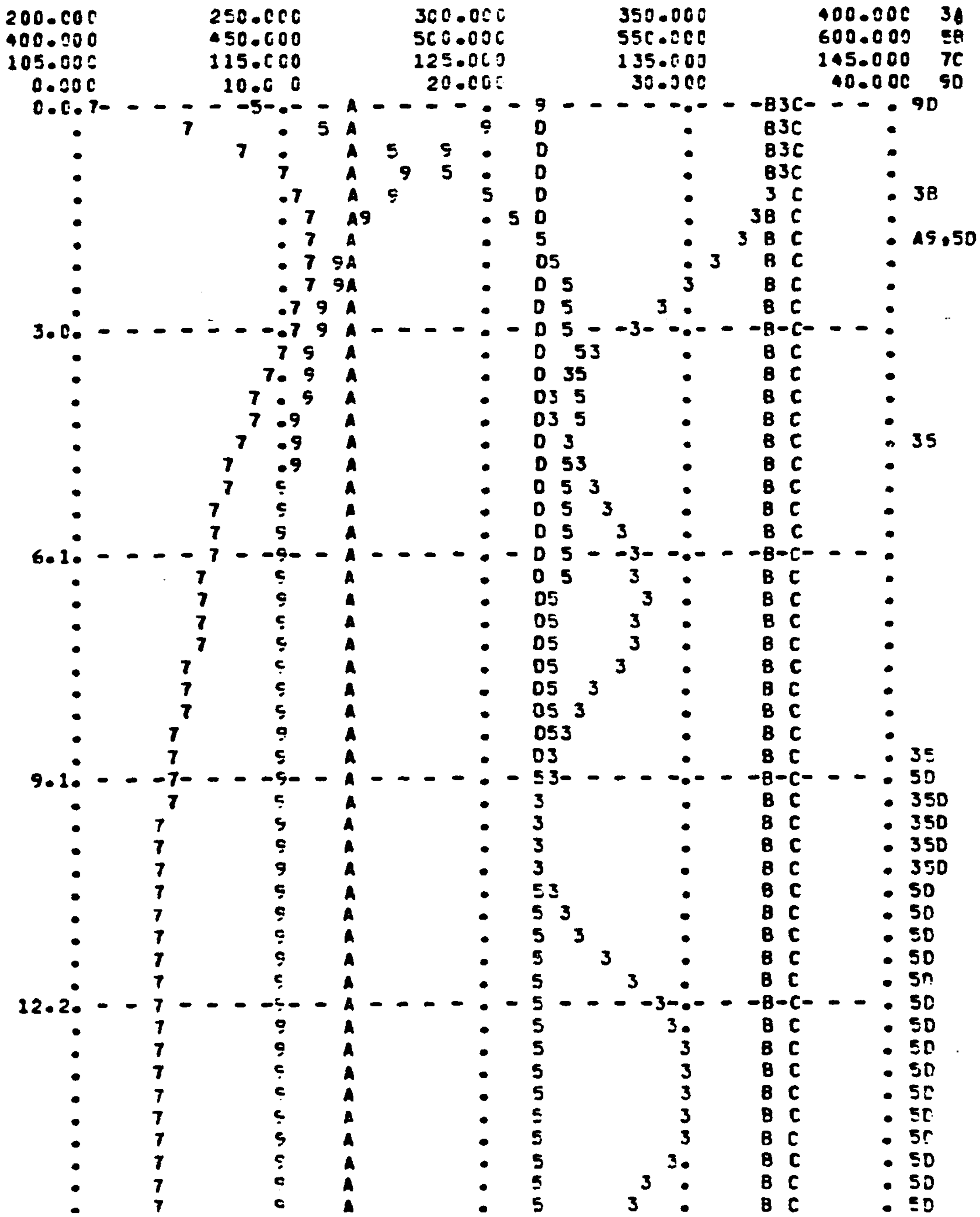



Figure 4.10. Assumption 1-a: Skill Levels

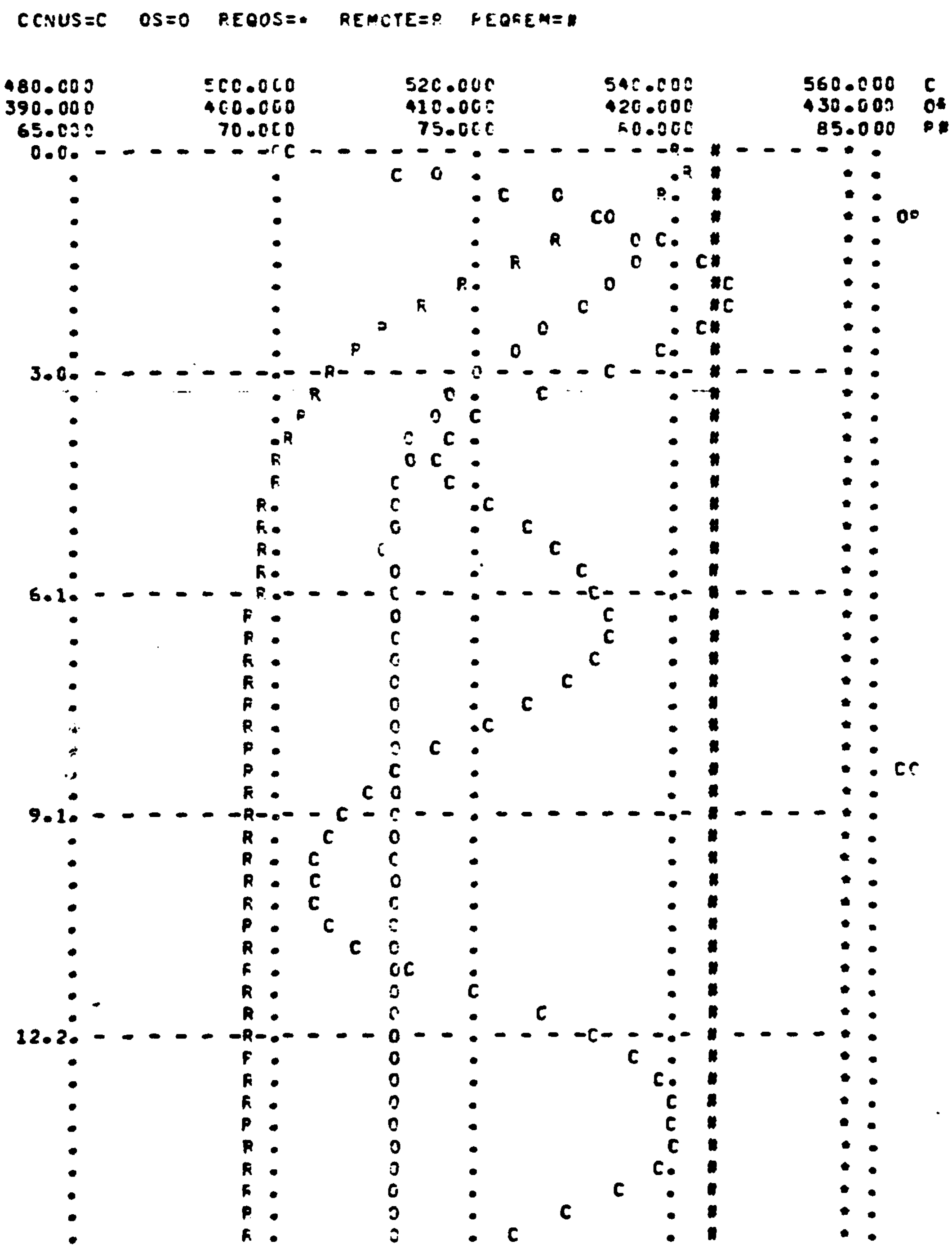



Figure 4.11. Assumption 1-a: Rotation Levels

system would under similar situations.

Under assumption 2-a, individuals are paid no bonuses. The model results under this assumption are very similar to the model results under the base case. This similarity is due to the low level of bonuses being paid in the base run of the model. Under assumption 2-b, individuals are paid the maximum bonus regardless of the situation. Consequently, the separation rates decrease and the population levels "smooth out", as would be expected. The value of L3AR is much less than in the base case, causing the turnover-rate of personnel to lessen. Figure 4.12 shows the resulting decrease in SR3 and SR5, while figures 4.13 and 4.14 depict the smaller amplitude in the population levels SL3 and CONUS, respectively. Again, the model reacts as one would expect the reference system to react.

Case 4. The separation rates from each skill level in the Personnel Fill sector is, in part, a function of the reaction of personnel to the level of pay and compensation. The hypothesized reaction to varying levels of pay and compensation for a given skill level is modeled through the use of a table function for each skill level. For example, the Level 3 Compensation Factor (L3CFAC) is obtained through a table (L3CTAB) and is a function of the Level 3 Cost Per Man (L3CPM). There is a similar compensation-factor variable for each skill level.

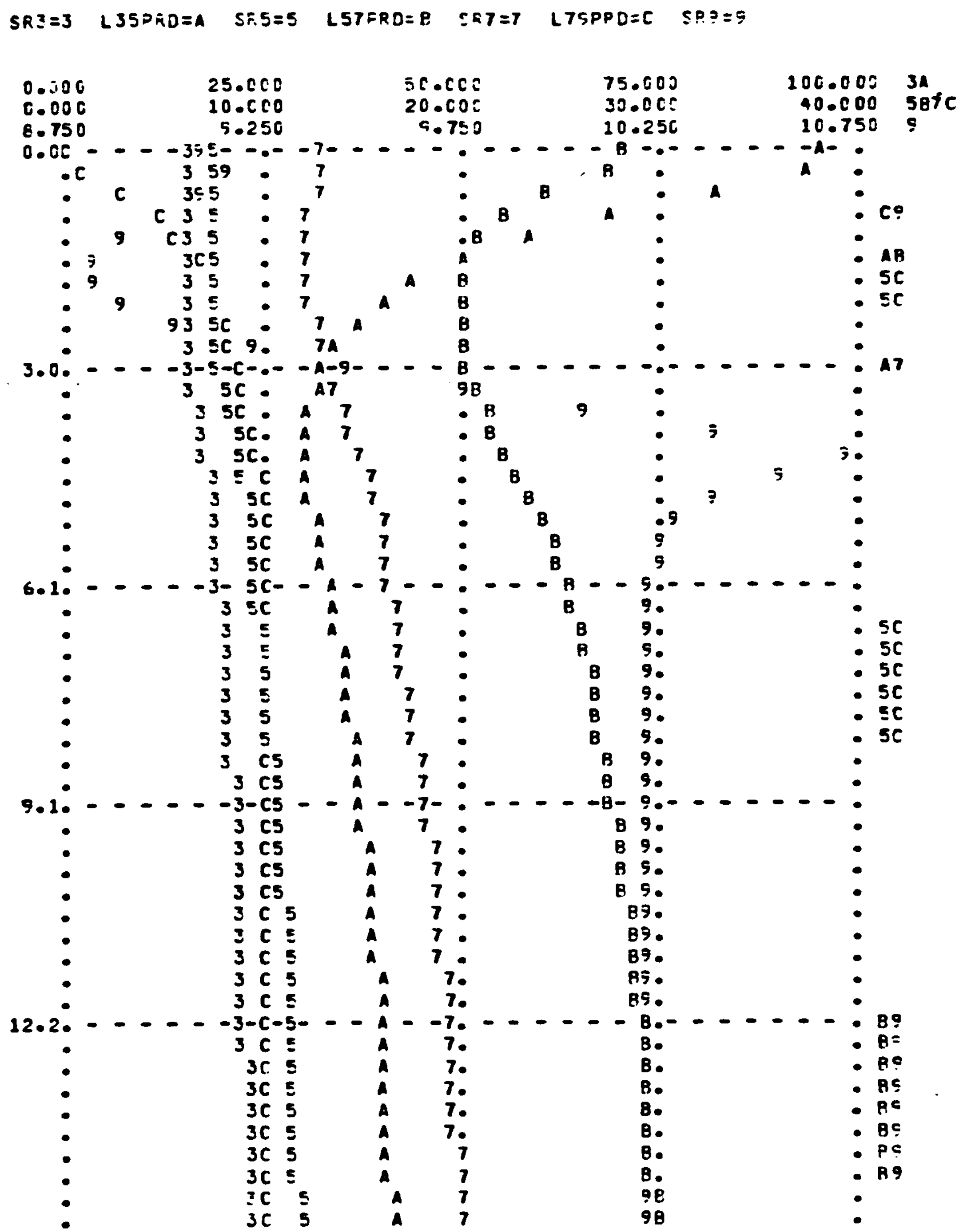



Figure 4.12. Assumption 2-b: Rates

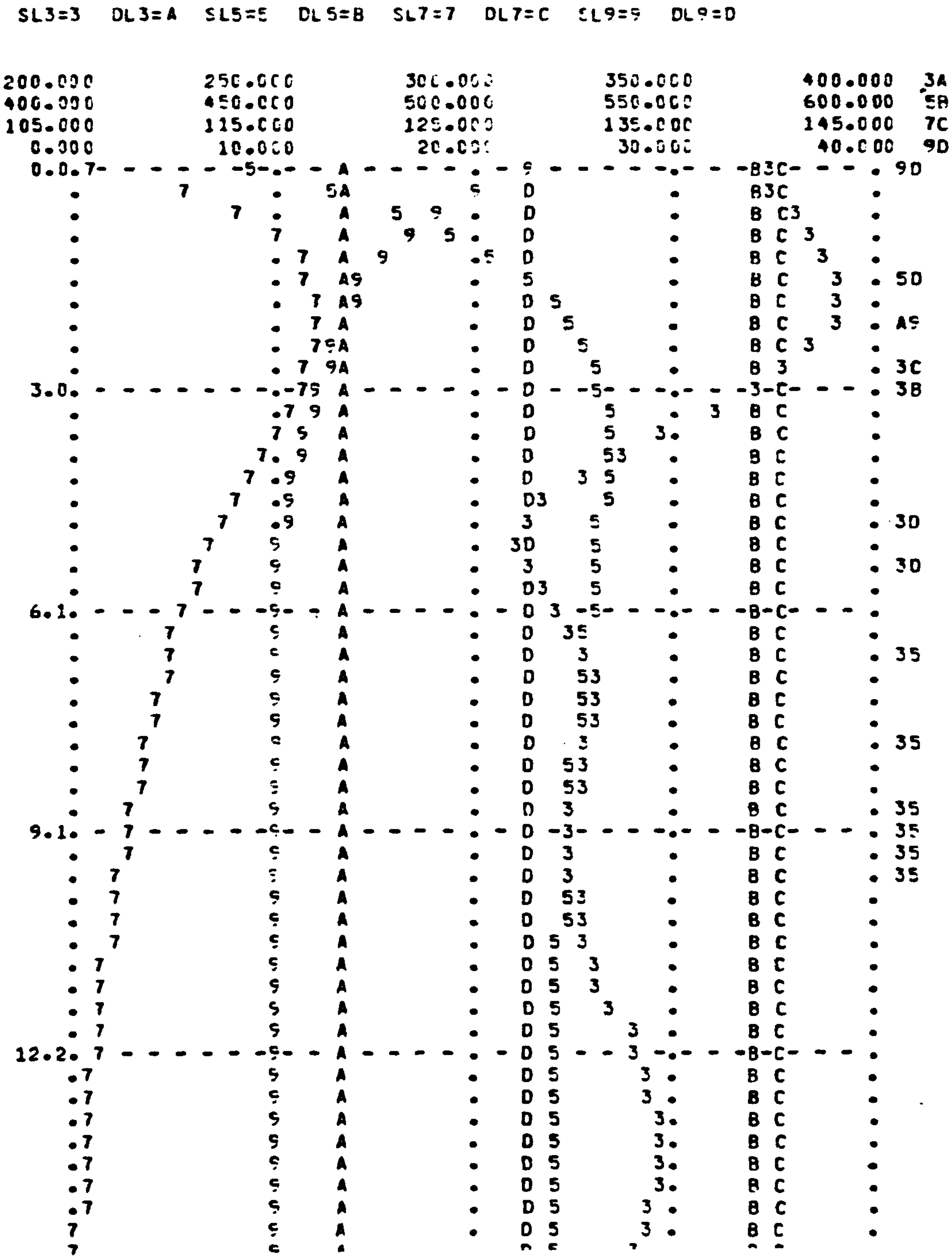



Figure 4.13. Assumption 2-b: Skill Levels

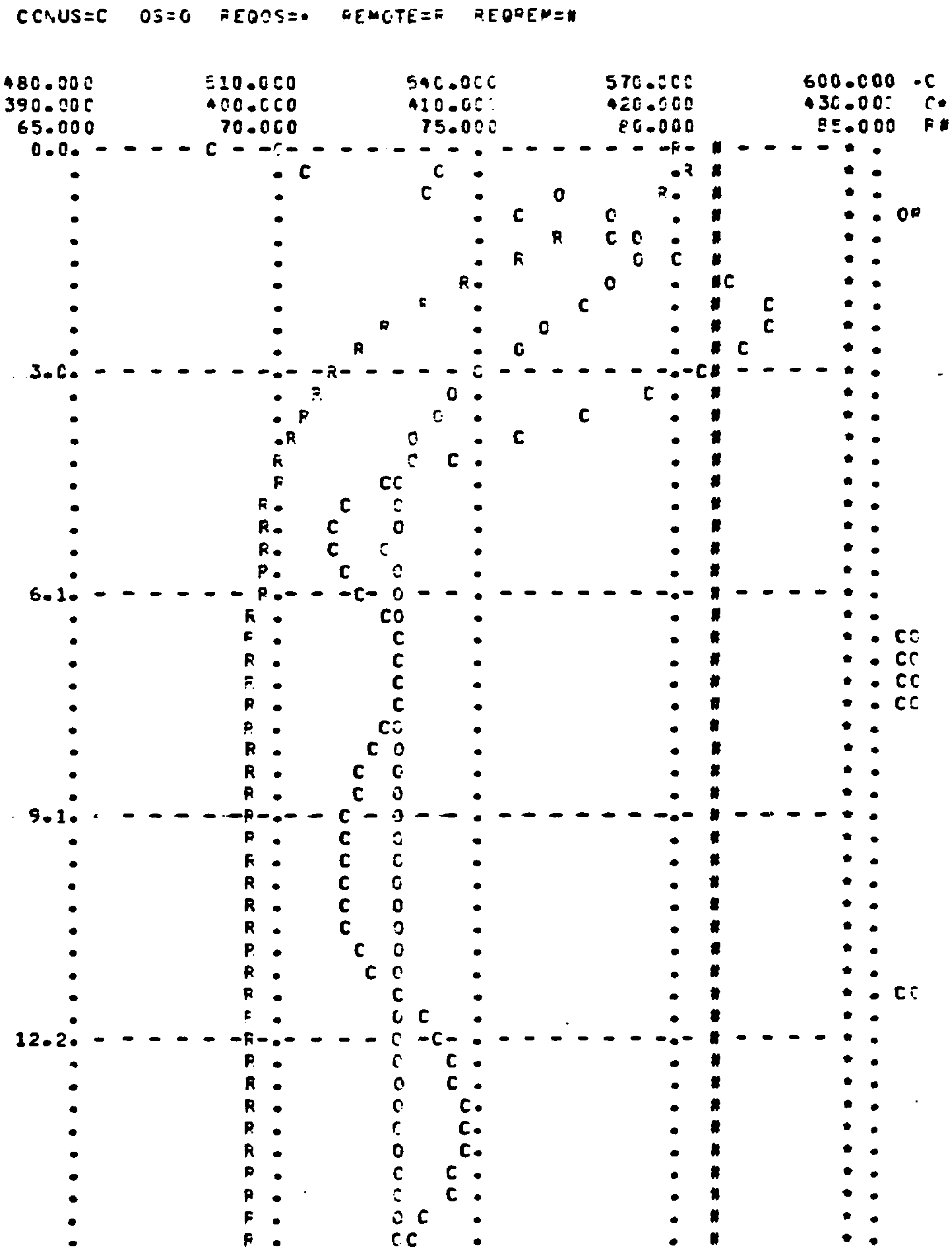



Figure 4.14. Assumption 2-b: Rotation Levels

The extreme-policy tests used to test the effects of unexpected or unusual formulations of the above compensation factors examined three situations:

1. compensation has no effect on separation rates, regardless of the compensation level (all table values set to 1),

2. compensation has a pronounced, positive effect on separation rates (all table values set to 0.5), and

3. compensation has a pronounced, negative effect on separation rates (all table values set to 2).

The model was run under each of the above assumptions. Under assumption 1, the effects due to compensation were neutralized. The results indicate a significantly higher retention rate and consequently a larger number of people retained in each skill level (see figures 4.15 and 4.16). This more stable force in the Personnel Fill sector naturally results in a more stable rotation base (the CONUS level) in the Rotation sector (see figure 4.17). The percentage manning at SL5 is greater than it was in the base run. Thus, the overmanning at SL3 is not as great as it was in the base run. Under assumption 2, the model results indicate a fairly stable force. Under assumption 3, the force tends to be very unstable. Figures 4.18 and 4.19 depict the levels of the Rotation sector under assumptions 2 and 3, respectively. As one would expect, separation rates

```
 SR3=3  L35PRD=A  SR5=5  L57PRD=B  SR7=7  L79PRD=C  SR9=9

0.000         25.000        50.000        75.000        100.000  3A
0.000         10.000        20.000        30.000         40.000  5B
0.000          5.000        10.000        15.000         20.000  7C
8.750          9.250         9.750        10.250         10.750  9
0.CC - - - -53 - -.- - - - - - - .7- - - - - B -.- - - - - -A- . 39
   . C       553  .              .7        B    .          A   .
   .       C95  3 .              .7   B         .   A          .
   .      9  5  3 .              .B          A  .              . B7,3C
   .   9     5  3 . C           B7   A          .              .
   .  9      5  3 .    C       BA7              .              .
   .  9      5   3.     C    AB  7              .              .
   .    9    5   3.       A   B  .7             .              . AC
   .        9 5  3.     A  C  B  .7             .              .
   .          5  3.    A    C B  . 7            .              . 39
3.0. - - - - -5- -3- A -9- -C- B . 7 - - - - - -.- - - - - - - .
   .          5   3  A       C B 9  7           .              .
   .           5  .3A         C B.   7     9    .              .
   .           5  .3A          CB.     7        .   9          .
   .            5 .3A          C B      7       .            9 .
   .            5 . 3           C.B      7      .        9     . 3A
   .            5 . 3            CB      7      .   9          . 3A
   .            5 . A3           C B      7     .9             .
   .             5.   3          .C B      7    9              . 3A
   .             5.   3          .C B      7    9              . 3A
6.1. - - - - - - 5.- 3 - - - - - .C- B - - 7 - 9.- - - - - - - . 3A
   .             5.   3          .C   B     7  9.              . 3A
   .             5.   3A         .C    B    7  9.              .
   .             5.    3         .C    B    7  9.              . 3A
   .             5.    3         .C    B     7 9.              . 3A
   .             5.    3         .C    B     7 9.              . 3A
   .              5    3         .C     B    79.               . 3A
   .              5    3A        .C     B    79.               .
   .              5     3        .C     B     7.               . 3A,79
   .              5     3        .C     B     7.               . 3A,79
9.1. - - - - - - -5- - 3 - - - - .C- - -B- - - 97- - - - - - - . 3A
   .              5     3        .C      B     97              . 3A
   .             .5     3        .C      B     97              . 3A
   .             .5      3       .C      B     9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
   .             .5      3       .C       B    9.7             . 3A
12.2. - - - - - - -.5 - -3- - - .C- - - B - - 9.-7- - - - - - . 3A
   .             .5      3A      .C       B    9. 7            .
   .             .5      3A      .C       B    9. 7            .
   .             .5      3A      .C       B    9. 7            .
   .             .5      3A      .C       B    9. 7            .
   .             .5      3A      .C       B    9. 7            .
   .             .5      3A      .C       B    5.  7           .
   .             . 5      3      .C        B   9.  7           . 3A
   .             . 5      3      .C        B   9.   7          . 3A
   .             . 5      3      .C        B   9.   7          . 3A
```

Figure 4.15.  Assumption 1: Rates

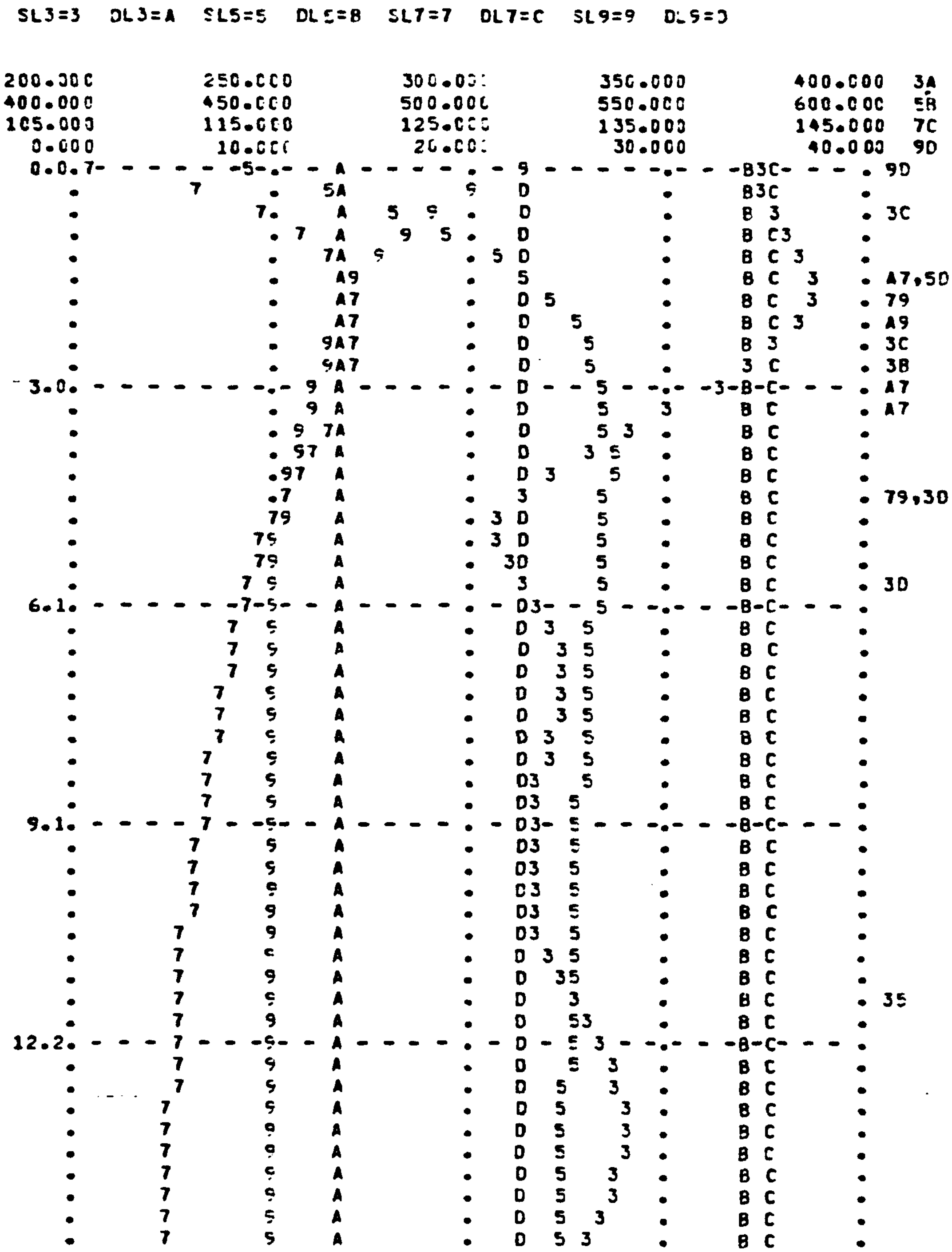



Figure 4.16. Assumption 1: Skill Levels

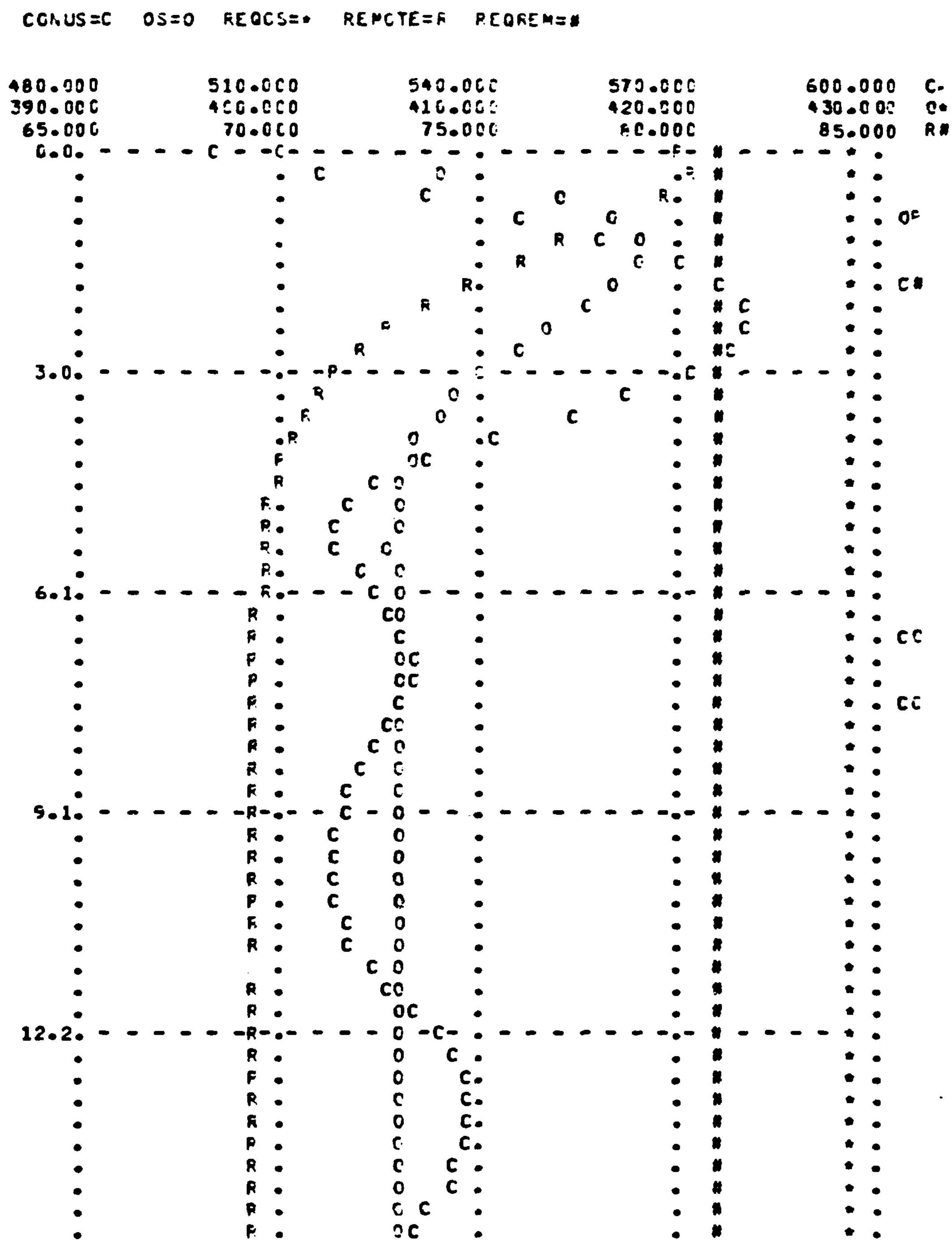



Figure 4.17. Assumption 1: Rotation Levels

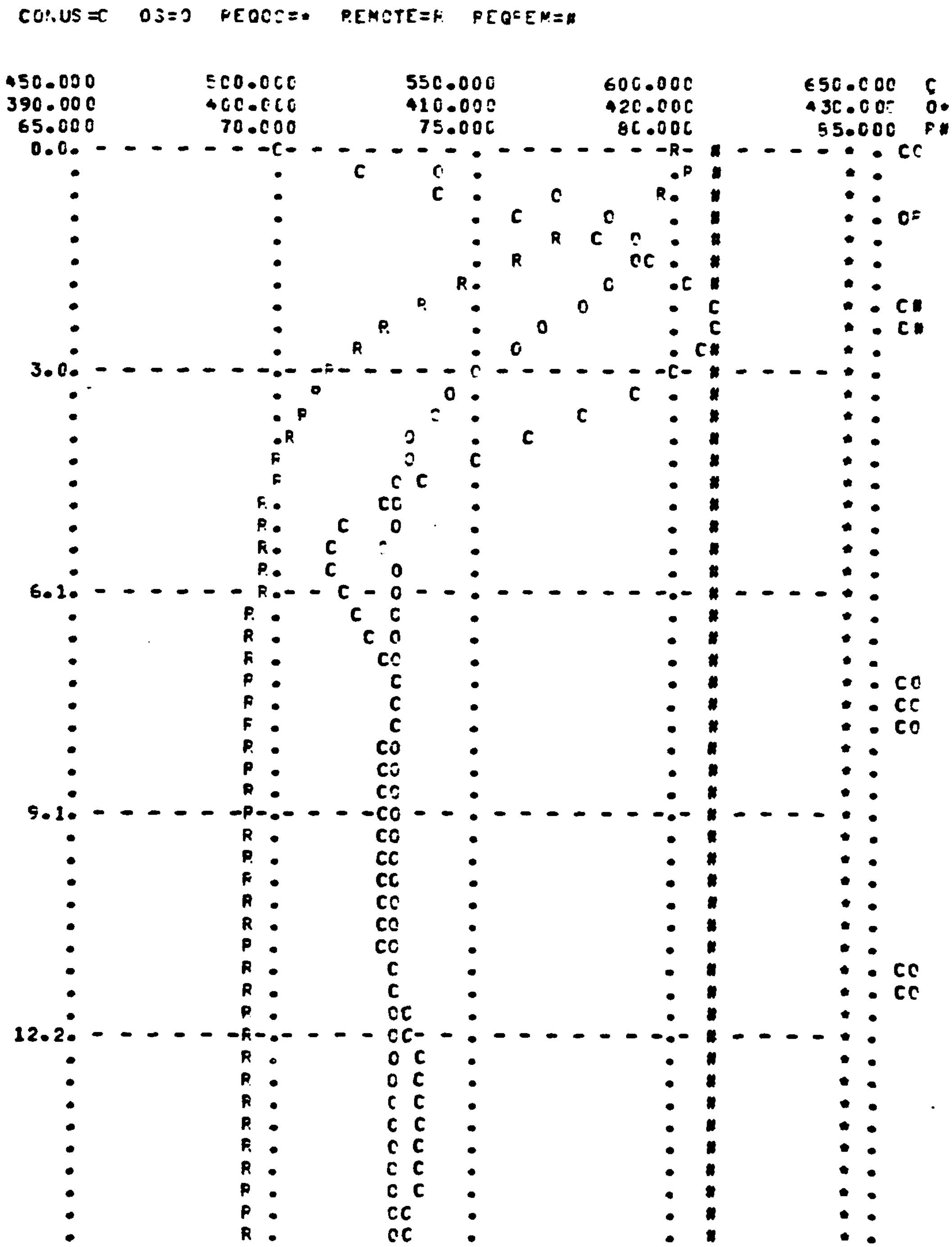



Figure 4.18. Assumption 2: Rotation Levels

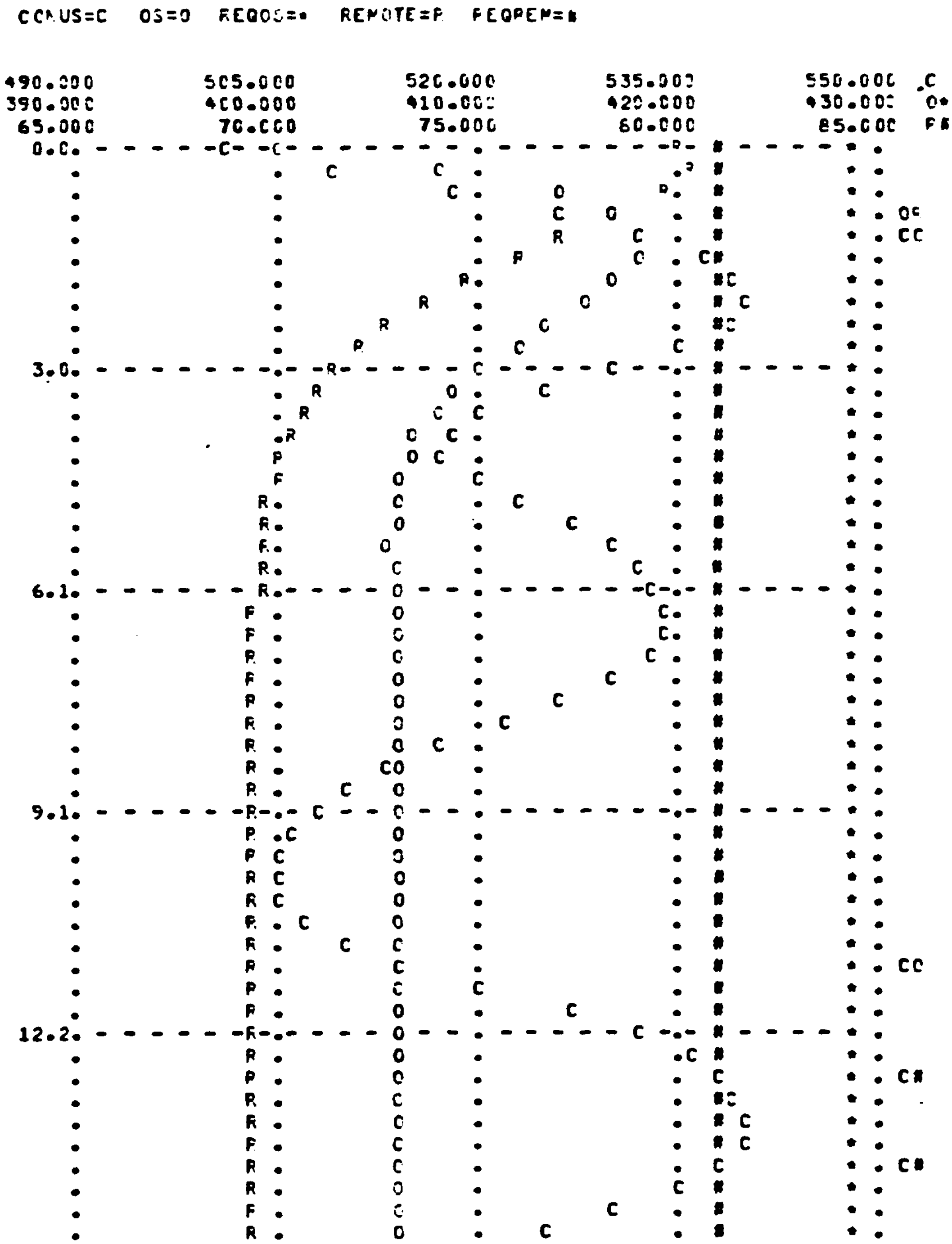



Figure 4.19. Assumption 3: Rotation Levels

decrease significantly under assumption 2, consequently removing much of the variation in the CONUS rotation base. Significant increases in separation rates occur under assumption 3, causing instability in the CONUS rotation base.

Case 5. A final example of an extreme-policy test involves the three rotation tables: NRTTAB, ROSTAB, and CTBTAB. These three tables are used in obtaining factors for the rotation indicators mentioned previously in Chapter One and Chapter Three. The product of these three factors forms the variable DISSAT, which in turn affects the separation rates for the skill levels. To represent more negative effects of rotational indicators, the above table values were all set to 2. Under the improved-effect formulation, the model results in a stable rotation base (see figure 4.20). An unstable rotation base results under the negative-effect formulation (see figure 4.21). Under each of these extreme effects, the model behavior is quite realistic.

Behavior Sensitivity. Model parameters can be adjusted to examine the sensitivity of model behavior to the changes. The behavior-sensitivity test is performed by changing the values of many constants in the model. In general, the basic goal-seeking behavior of the model is not altered, even though the manner in which that behavior progresses does change. For example, figure 4.22

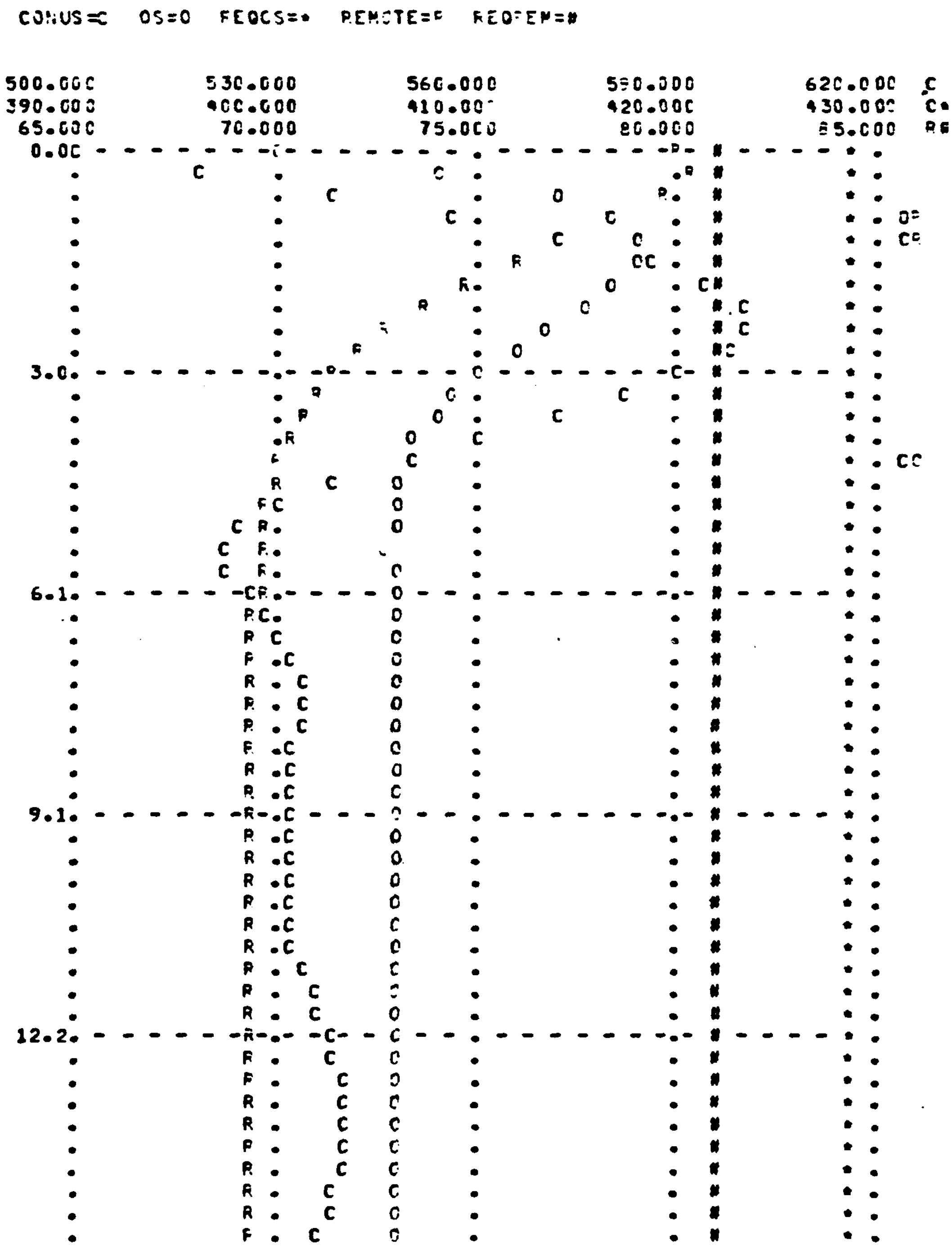


Figure 4.20. Improved Rotation Effect: Rotation Levels

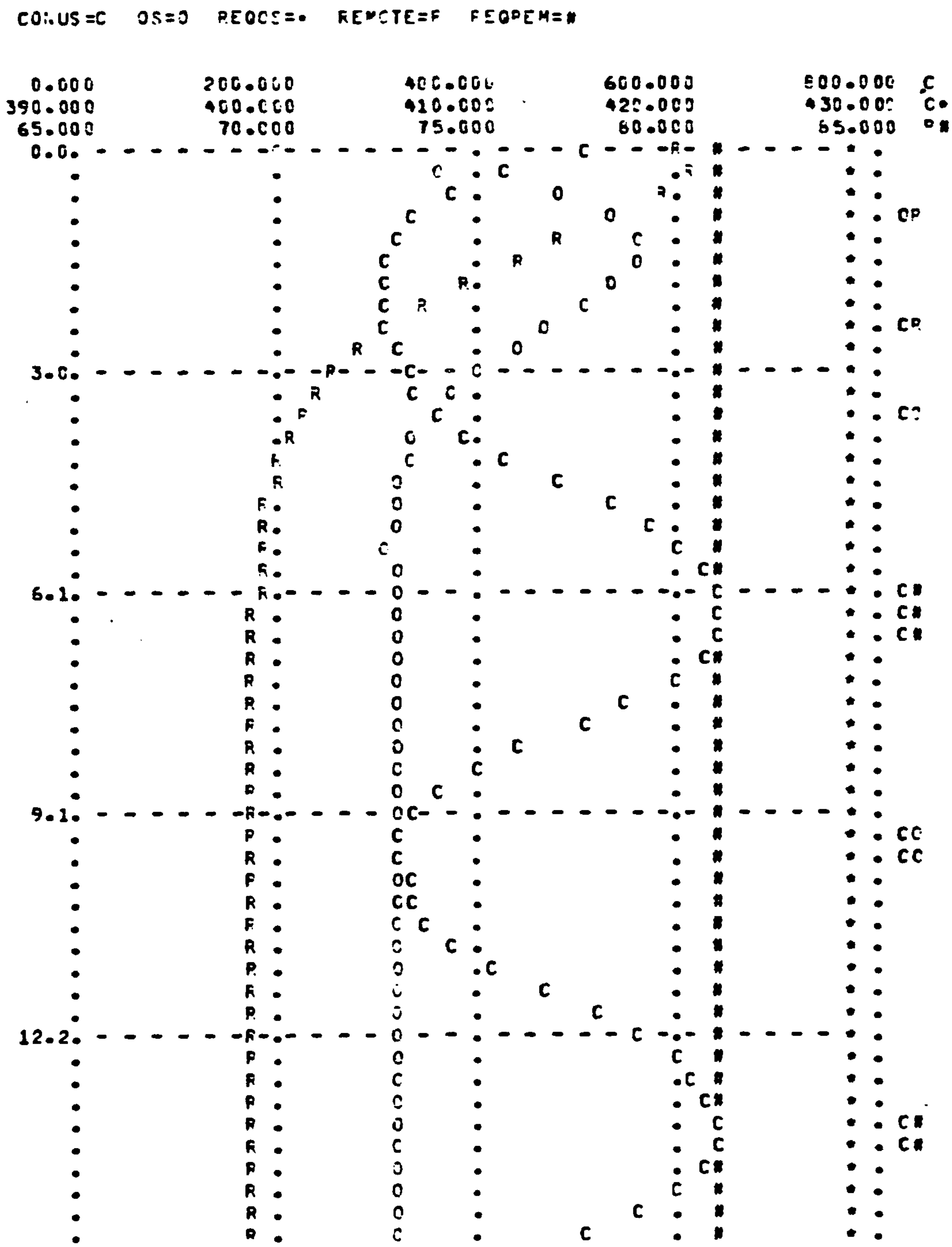



**Figure 4.21. Decreased Rotation Effect: Rotation Levels**

illustrates the Rotation sector levels under increased required levels of OS and REMOTE. Personnel are drawn from the CONUS level to increase the REMOTE and OS levels. Simultaneously, the increase in dissatisfaction due to rotation causes continued instability in the CONUS level. When the desired levels of OS and REMOTE are decreased with no change in the total personnel in the AFSC, the OS and REMOTE levels decline to slightly below their new required values, while the CONUS level becomes much larger than in the base run (see figure 4.23). Additionally, the decrease in dissatisfaction due to rotation results in more stability in the CONUS rotation base.

## Summary

Chapter Four has described confidence-building tests for system dynamics models and how they were applied to the model of the airman assignment and rotation system. Specifically, five tests of model structure and six tests of model behavior were successfully accomplished. Shannon (Ref 43) stated that we need to be "concerned with the internal consistency of the model, its correspondence with the real system, and the correct interpretation of the resulting data" (Ref 43:210). The concern of this chapter has been with the first two issues: internal consistency (verification) and correspondence of the model to the real system (validation). Chapter Five is concerned with the

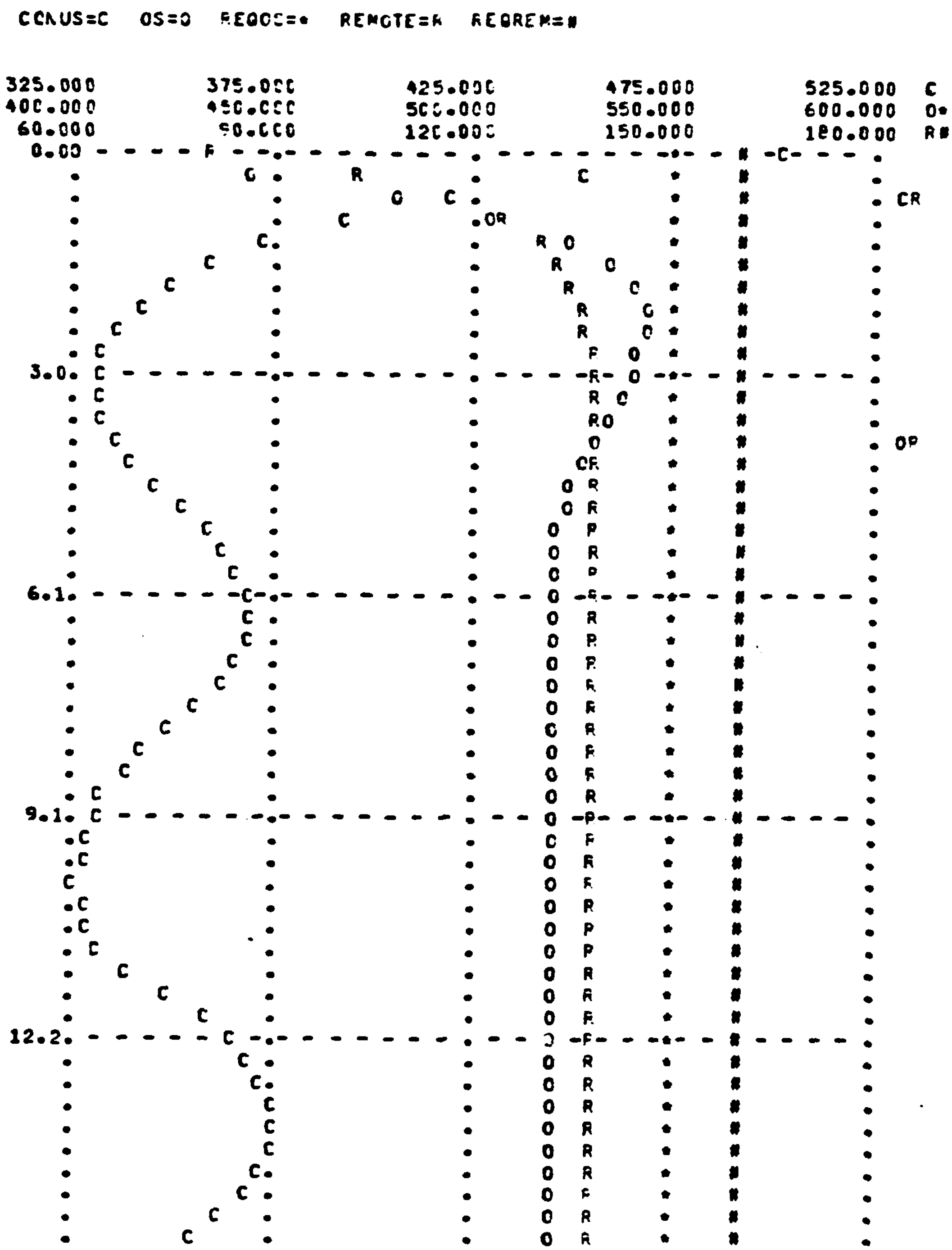



Figure 4.22. Increased Required OS and REMOTE Levels: Rotation Levels

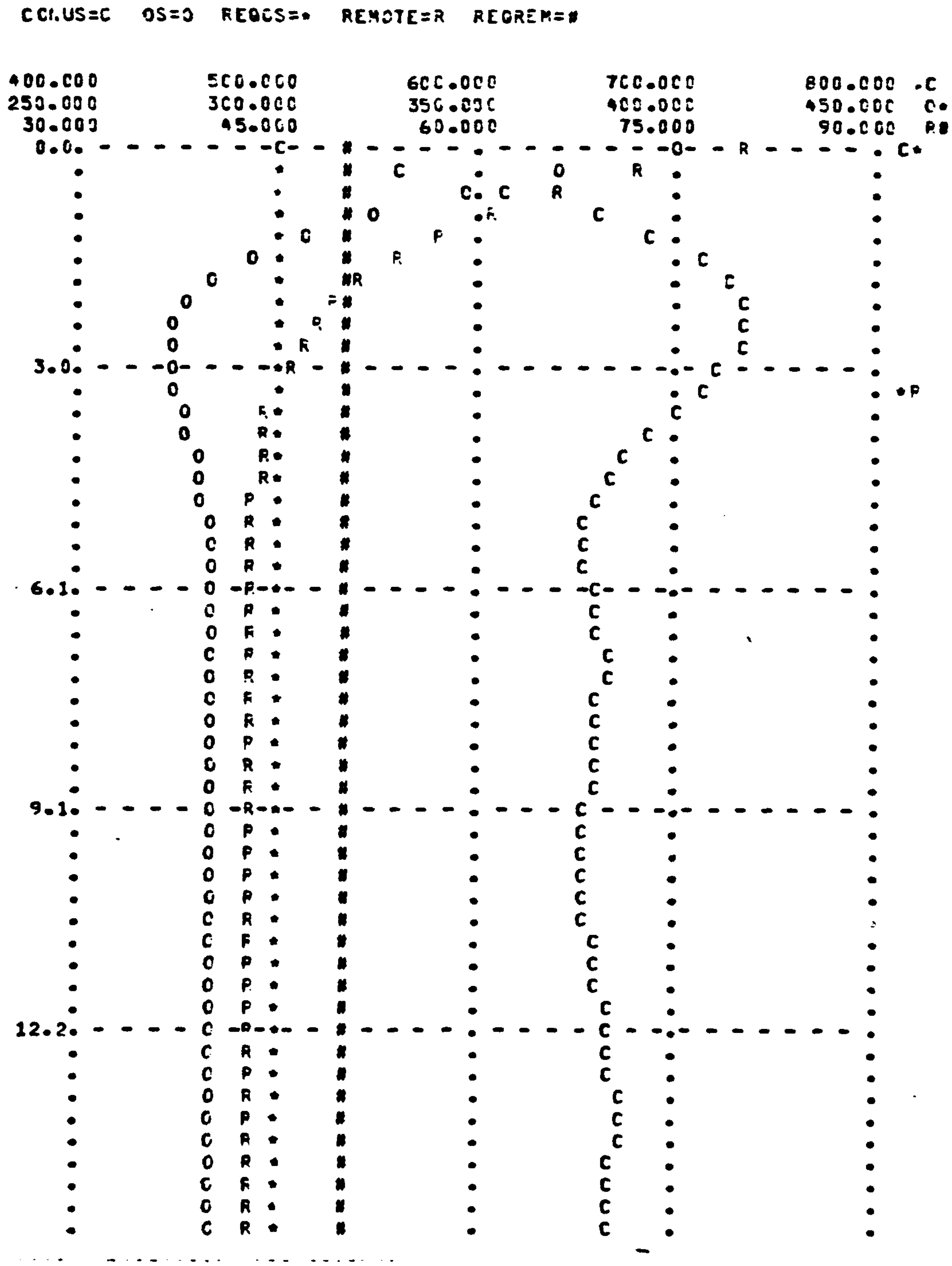



Figure 4.23. Increased CONUS Level: Rotation Levels

correct interpretation of the model results. Included in the next chapter are tests of policy implications and examples of policy experimentation.

# V Policy Experimentation

## Introduction

Policy analysis can only proceed under the assumption that useful policy models can be developed and validated with respect to the assumptions upon which their development was based (Ref 28:13). The issues of model verification and validation were addressed in Chapter Four to build confidence in the model's implications. This chapter will focus on two areas that explicitly examine policy changes:

1. changed-behavior-prediction tests, and
2. policy-sensitivity tests.

Both of the above are tests of policy implications that were presented by Forrester and Senge (Ref 17:224-226).

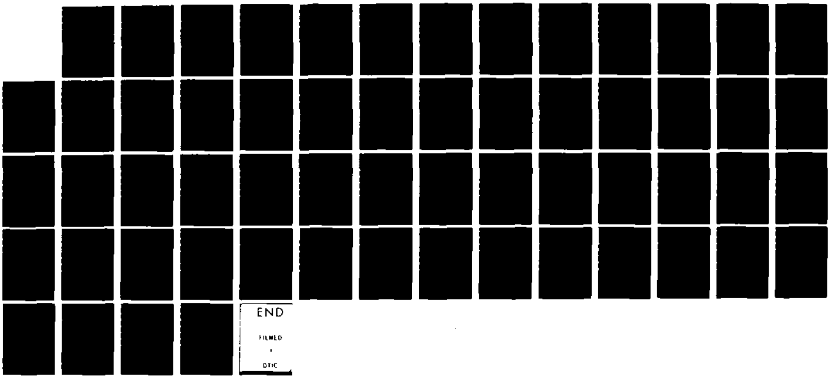
## Tests of Policy Implications

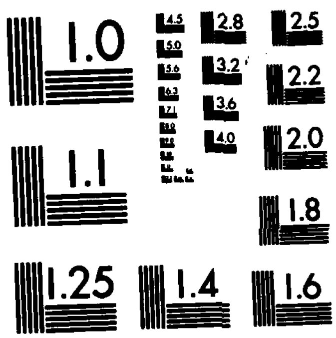
Policy implementation tests are the third broad category of confidence building tests (see Table 4.1). "Policy implication tests attempt to verify that response of a real system to a policy change would correspond to the response predicted by a model" (Ref 17:224). There is, of course, some degree of overlap between the tests of model behavior presented in Chapter Four and the tests of policy implications presented here.

The testing in this area was not as extensive as in

AD-A124 779 THE ROTATION/ASSIGNMENT SYSTEM OF IMBALANCED AIR FORCE SPECIALTY CODES NI..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. K L LAWSON 3/3

UNCLASSIFIED DEC 82 AFIT/GOR/OS/82D-8 F/G 5/9 NL






MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

# V Policy Experimentation

## Introduction

Policy analysis can only proceed under the assumption that useful policy models can be developed and validated with respect to the assumptions upon which their development was based (Ref 28:13). The issues of model verification and validation were addressed in Chapter Four to build confidence in the model's implications. This chapter will focus on two areas that explicitly examine policy changes:

1. changed-behavior-prediction tests, and
2. policy-sensitivity tests.

Both of the above are tests of policy implications that were presented by Forrester and Senge (Ref 17:224-226).

## Tests of Policy Implications

Policy implementation tests are the third broad category of confidence building tests (see Table 4.1). "Policy implication tests attempt to verify that response of a real system to a policy change would correspond to the response predicted by a model" (Ref 17:224). There is, of course, some degree of overlap between the tests of model behavior presented in Chapter Four and the tests of policy implications presented here.

The testing in this area was not as extensive as in the areas of model structure and model behavior. The changed-behavior-prediction test and policy-sensitivity test are now presented.

Changed-Behavior-Prediction Test. The changed-behavior-prediction test examines the plausibility of model results if a governing policy is changed. Another form of this test involves examining the "response of a model to policies which have been pursued in the real system to see if the model responds to a policy change as the real system responded" (Ref 17:225). Several examples of this test using the plausibility method of assessment will be presented.

In the formulation of this model, the system goals were enumerated and listed in order of priority. A consensus on this sequencing was reached by individuals working within the system. It was agreed that the total manning percentage recieved more importance than individual skill level manning percentages, even though the two goals are very difficult to separate. To allow flexibility in altering this priority listing, a set of relative weights was incorporated into the structure. This admittedly simple scheme allows the user to place less emphasis on managing by the Total Force Shortage (TFS) than was the case for the base run.

In the base run, the Total Force Weight (TFWT) was set to one and the Level 3 Weight (L3WT) was set to zero.

Two policies were tested using an alternative formulation of these weights:

1. equal emphasis was placed on the Level 3 Shortage (L3SHRT) and the Total Force Shortage (TFS), and

2. TFS shortage was ignored while the emphasis was placed on L3SHRT (L3WT=1 and TFWT=0).

Under the first situation, the two weights were both set to 0.5. As one would expect, the SL3 draws down to a lower level of manning than in the base run (see figure 5.1). Due to the lower value of SL3, there is a shortage in the total force. The population of SL5 stays at approximately 90% of its desired value, since bonuses are paid if it drops very far below that level. A somewhat unexpected result is the greater oscillation in SL3. This result is plausible, however, since the TFS becomes large relative to the TFS in the base run, especially during years in which the economy is good. Consequently, a relatively large number of new SL3 people must be brought in when the economy is poor. This cycle results in force-instability that carries over into the CONUS level (rotation base) of the Rotation sector (see figure 5.2).

Figures 5.3 and 5.4 depict the model results when the AFSC is managed entirely through the shortage in Level 3. SL3 falls far below the Desired Level 3 (DL3) before building again (see figure 5.3). The delay in obtaining SL3 personnel causes the lag in correcting for the SL3

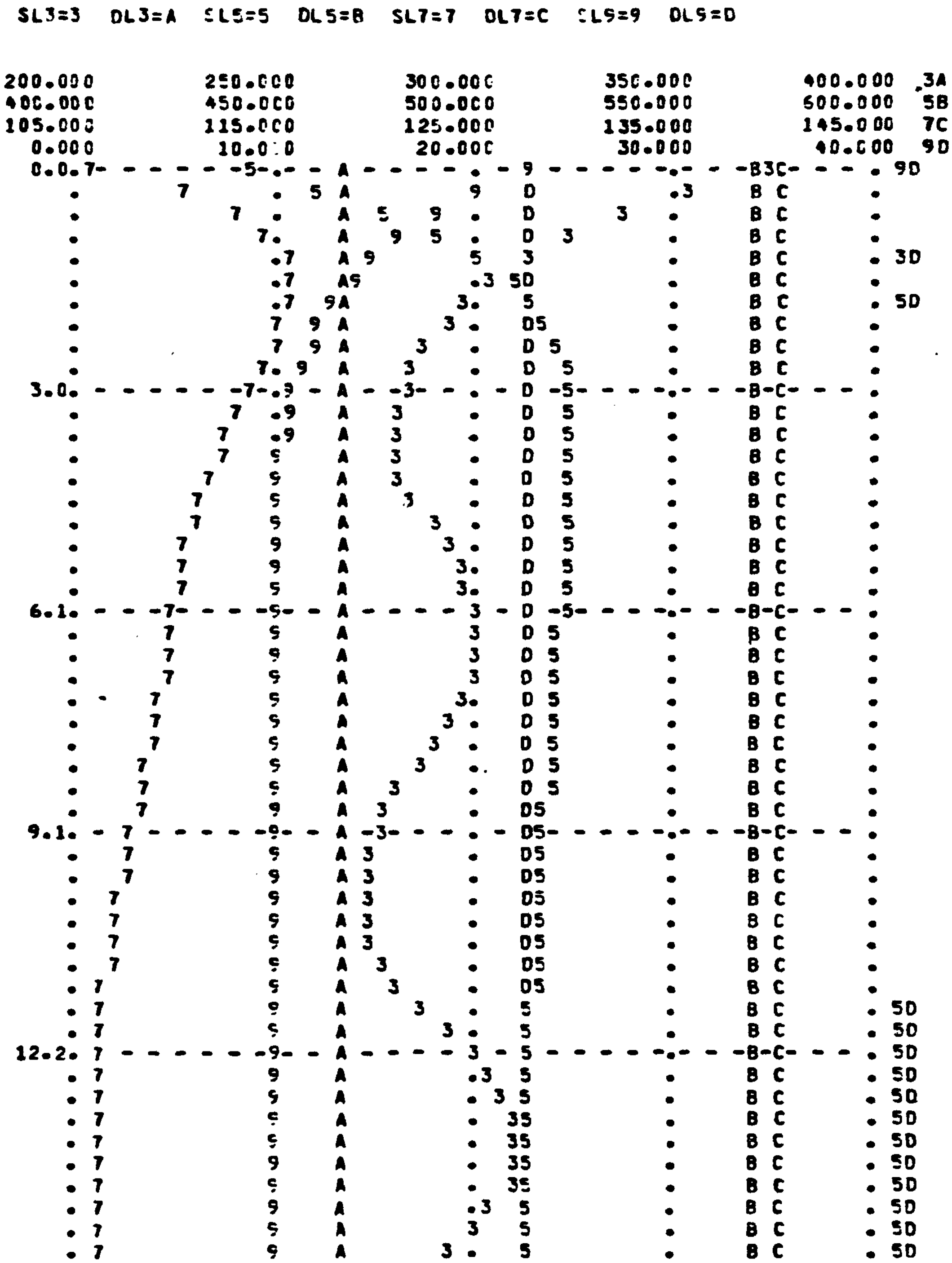



**Figure 5.1. Level 3 and Total Force Weights Set to 0.5: Skill Levels**

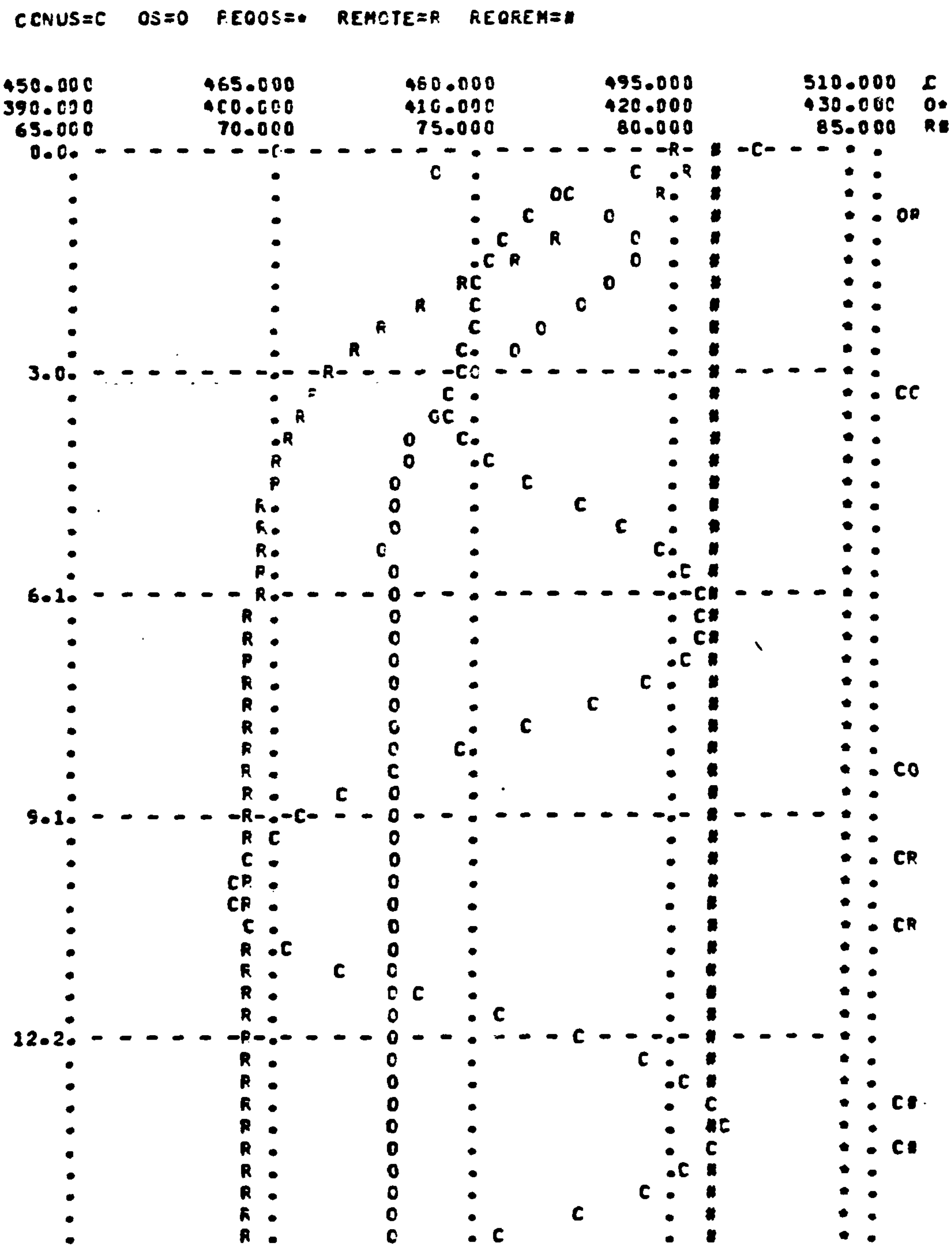



Figure 5.2. Level 3 and Total Force Weights Set to 0.5: Rotation Levels

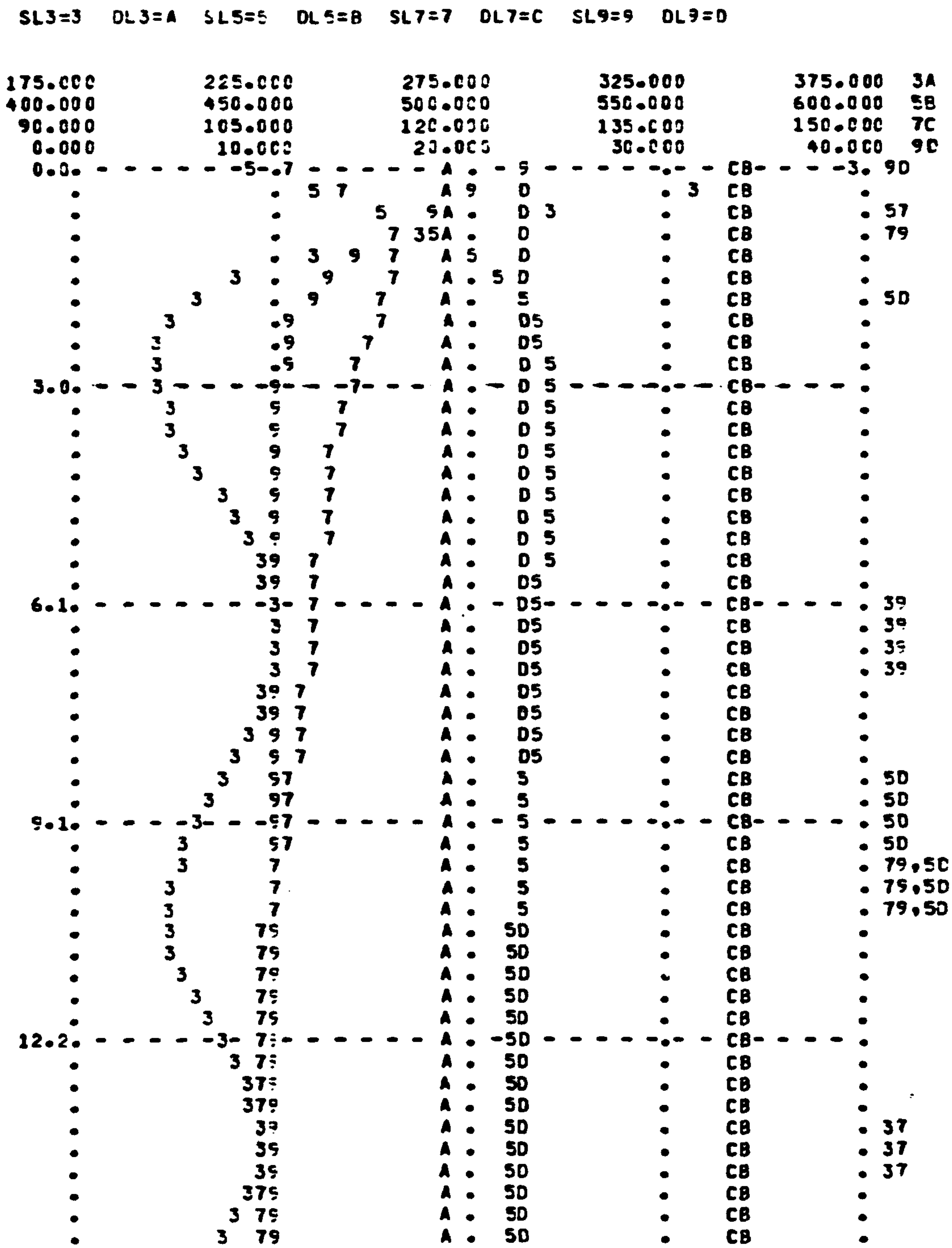



Figure 5.3. Level 3 Weight Set to 1: Skill Levels

manning deficiency. The SL3 "draw-down" also results in the eventual lowering of SL5 and SL7. This result seems reasonable since the Separation Rate from Level 3 (SR3) is such that a large SL3 population is required to maintain an adequate population in the higher skill levels. Even though more bonus payments are generated, the separation rates do not improve enough to prevent the depletion of the higher skill levels. In the Rotation sector, the CONUS level absorbs the loss to the AFSC (see figure 5.4). Given the policy changes, the model results appear to be credible and explainable. Of course, if more emphasis were actually given to skill level shortages, there would need to be weights for each skill level shortage. Additionally, a different bonus policy would probably be implemented to reflect the altered system goals. However, under the current model structure, the model responds in a plausible manner.

Another example of the changed-behavior-prediction test is similar in nature to one of the extreme-policy tests of Chapter Four, in which the REMOTE and OS levels were altered. A subset of that test doubled all of the desired skill levels without altering the REMOTE and OS levels. To represent a more realistic policy change, the desired skill levels were increased slightly. Figure 5.5 shows the results of population levels in the skill levels in the Personnel Fill sector. SL5 increases and remains

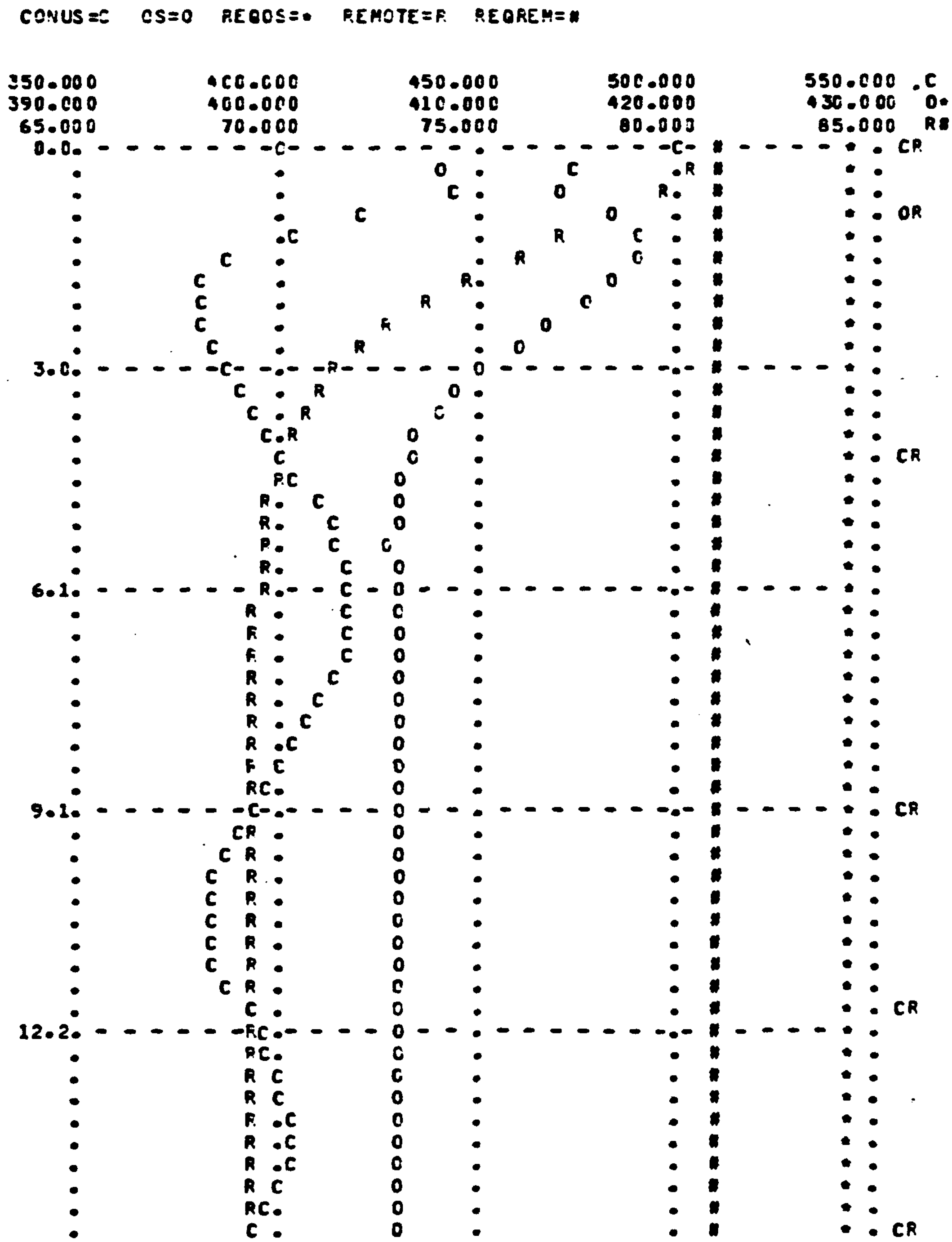



**Figure 5.4. Level 3 Weight Set to 1: Rotation Levels**

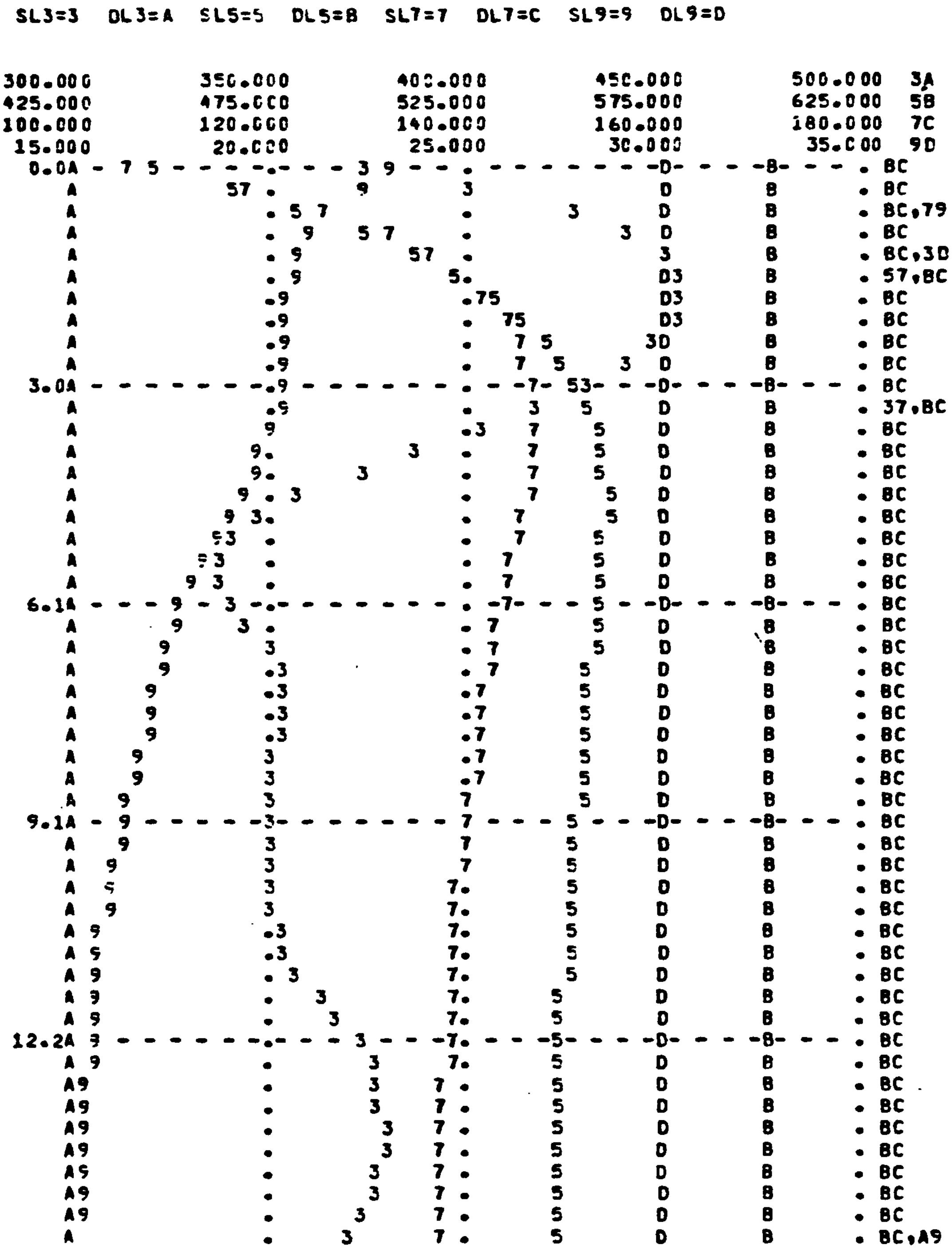



Figure 5.5. Increased Desired Number in Skill Levels: Skill Levels

high throughout much of the simulation. SL3 initially increases quite drastically to make up the shortage in total manning due to the additive increases in the desired values for each skill level. Because of the delay in acquiring SL3 personnel, an "overshoot" occurs at approximately 2 years of simulation time. Consequently, SL3 declines to correct for the overage in the total force. However, once the system stabilizes, the increased number of people leads to a decrease in dissatisfaction due to rotation indicators. The CONUS population therefore becomes more stable in the later years of the simulation (see figure 5.6). Again, the results are credible under the current model structure.

A last example of the changed-behavior-prediction test arises from a potential change in the number of remote authorizations relative to the number of overseas (long tour) authorizations. Currently, all of the AFSCs examined in this research have a relatively small number of remote authorizations. For example, AFSC 306X2 currently (October 1982) has 81 remote authorizations and 429 overseas authorizations. A change in mission or equipment may alter this relationship (Ref 25). To reflect such a change, the number of remote authorizations was set to a value of 200, while the number of overseas authorizations was set to 375. Since the increase in remote authorizations is greater than the decrease in

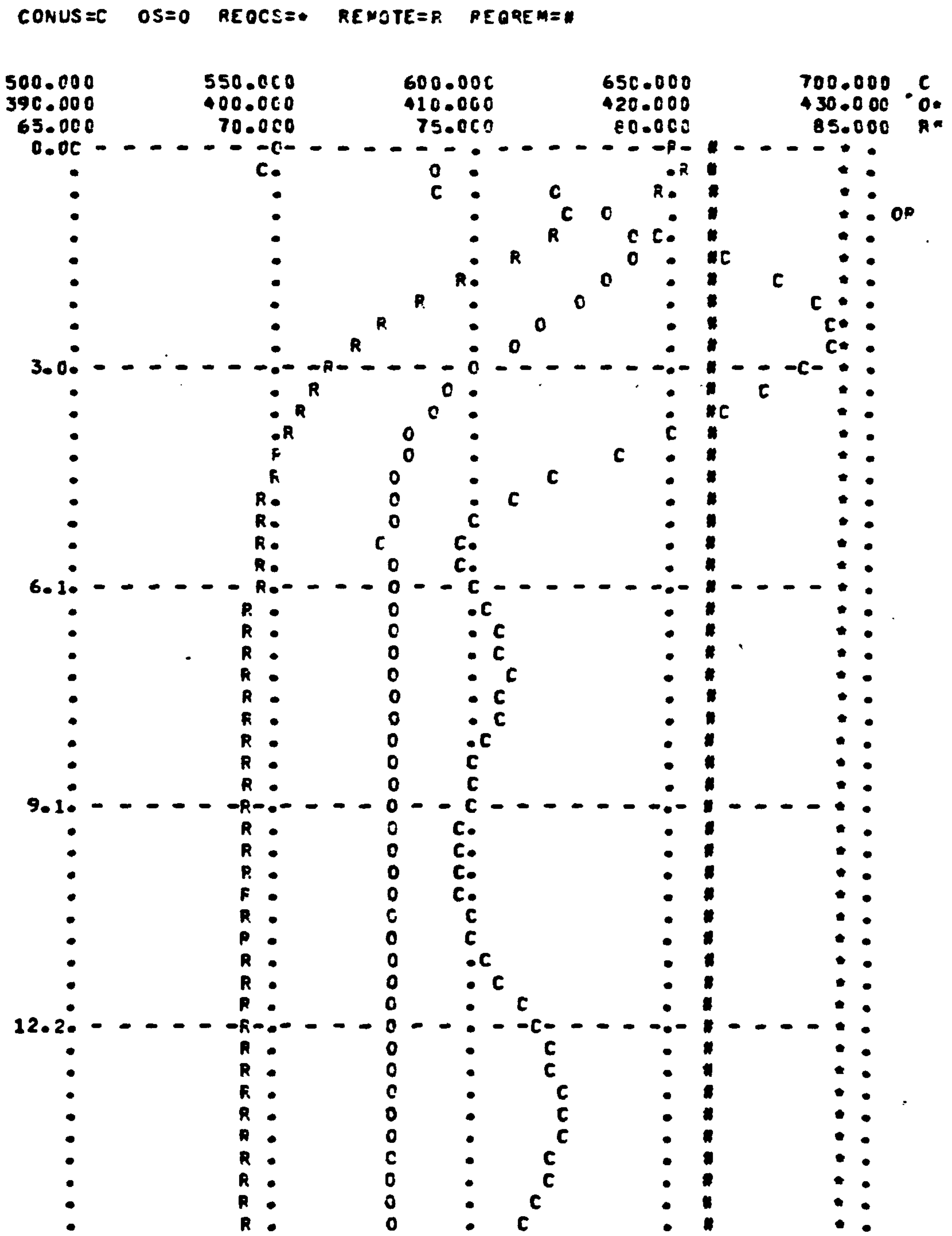



Figure 5.6. Increased Desired Number in Skill Levels: Rotation Levels

overseas authorizations, the difference must come from CONUS. (This assumes that no new 306X2 authorizations are made; the lost CONUS jobs can be filled by civilian workers.)

As one would expect, the increase in remote assignments causes an increase in the number of remote tours per career as well as a decrease in the amount of time spent in the CONUS between overseas or remote tours. Thus, the dissatisfaction due to rotation increases and causes a higher turnover in the force. The oscillation in SL3 becomes quite pronounced. SL5, SL7, and SL9 decrease more rapidly and SL3 reaches a very high level of over-manning (see figure 5.7). The high degree of instability that results in the CONUS level of the Rotation sector is not unexpected (see figure 5.8). More bonuses are paid, but the subsequent increase in retention rates is not enough to counteract the problems that arise from the increased rotation imbalance.

The results of each of the above changed-behavior-prediction tests were assessed in terms of their plausibility. After examining the cause and effect relationships of each problem and assessing the expected effect of the policy change on the reference system, each experimental result was determined to be plausible.

Policy-Sensitivity Test. One factor involved in the payment of bonuses is PNTPB1, originally formulated as a

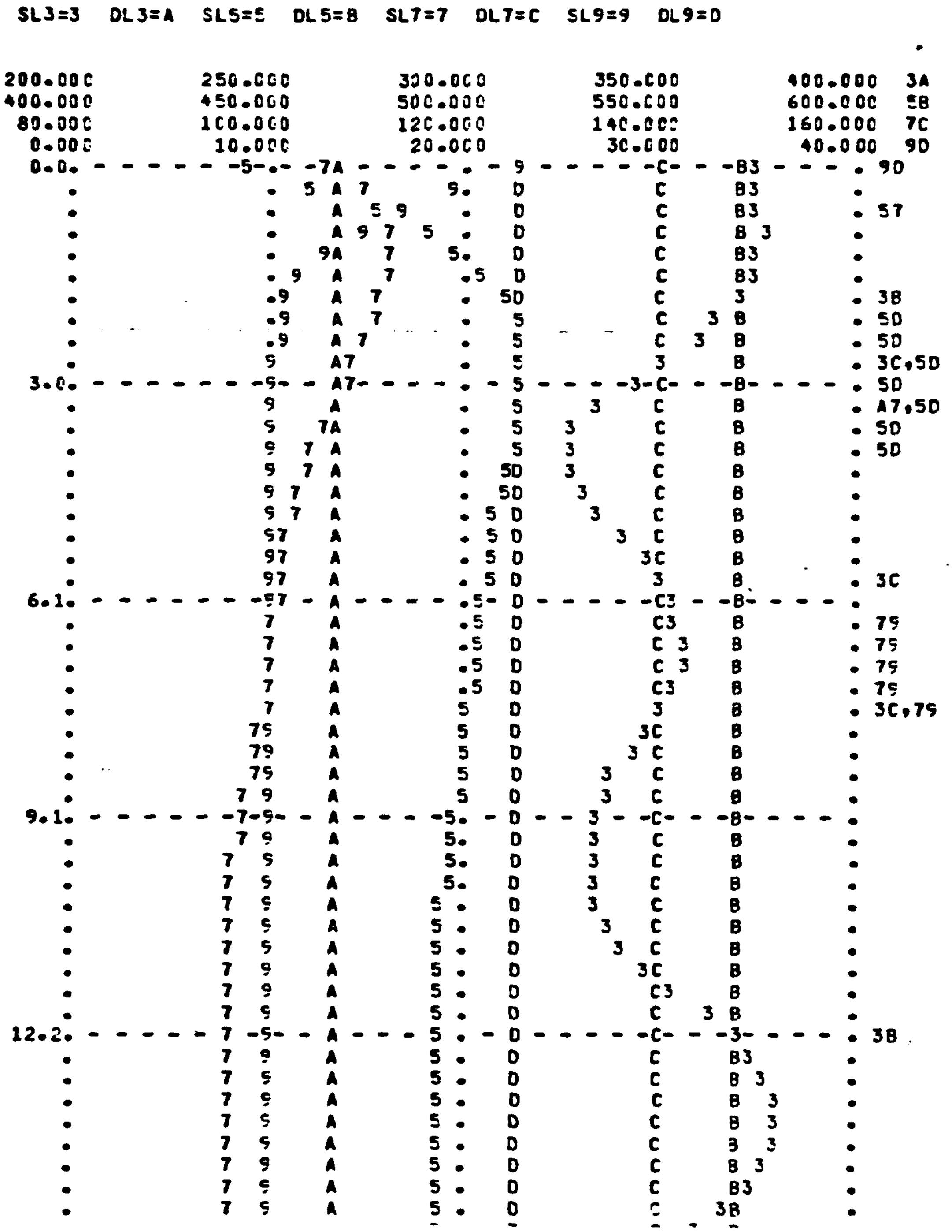



Figure 5.7. Changed Proportion of REMOTE to OS: Skill Levels

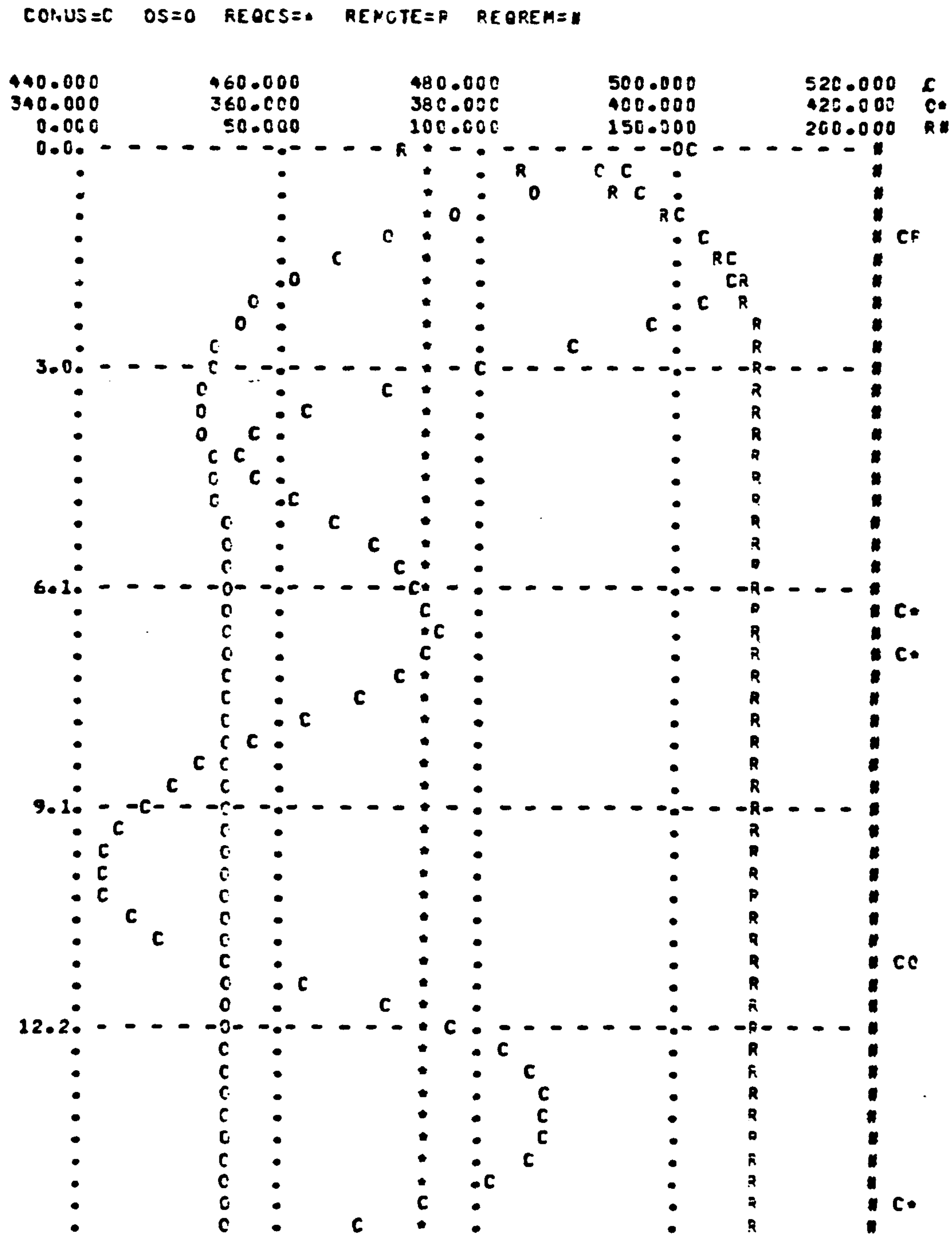



**Figure 5.8. Changed Proportion of REMOTE to OS: Rotation Levels**

function of the SL5 manning percentage. An alternative policy formulation would be to base bonuses on a one-year history of reenlistment rates (Ref 49 and Ref 27). This policy can be obtained from the OSD criteria for bonus awards outlined in Table 3.5. This alternative formulation involves the use of the following equations:

```
A KEEP.K=SMOOTH(L3L5PR.JK,1)/SMOOTH(SR3.JK+
        L3L5PR.JK,1)
N KEEP=.792
A PNTPB1.K=TABLE(L5BPTB,KEEP.K,0,1,.29
T L5BPTB=1/.8/.4/.4/0/0
```

KEEP=Keep rate for SL3
L3L5PR=Level 3 to Level 5 Promotion Rate
SR3=Separation Rate from Level 3
PNTPB1=Perceived Need to Pay Bonuses, Factor 1
L5BPTB=Level 5 Bonus Paid Table

This formulation was added to the model and simulated for 15 years. The model was rerun with the values of PNTPB2 ("pressure" factor due to cost) set to 1. Table 5.1 summarizes the resulting SRB multipliers for various KEEP rate values under this formulation for bonus payments. As with the original formulation based on SL5 manning percentages, the values were obtained through interviews (Ref 49 and Ref 27).

Figure 5.9 depicts the levels of the Rotation sector under the KEEP-rate formulation. The results are very similar to the base run of the model. Figure 5.10 shows a nearly identical pattern for the KEEP-rate formulation under an assumption of a neutral pressure-factor due to cost (values of PNTPB2 set to 1). There is a small

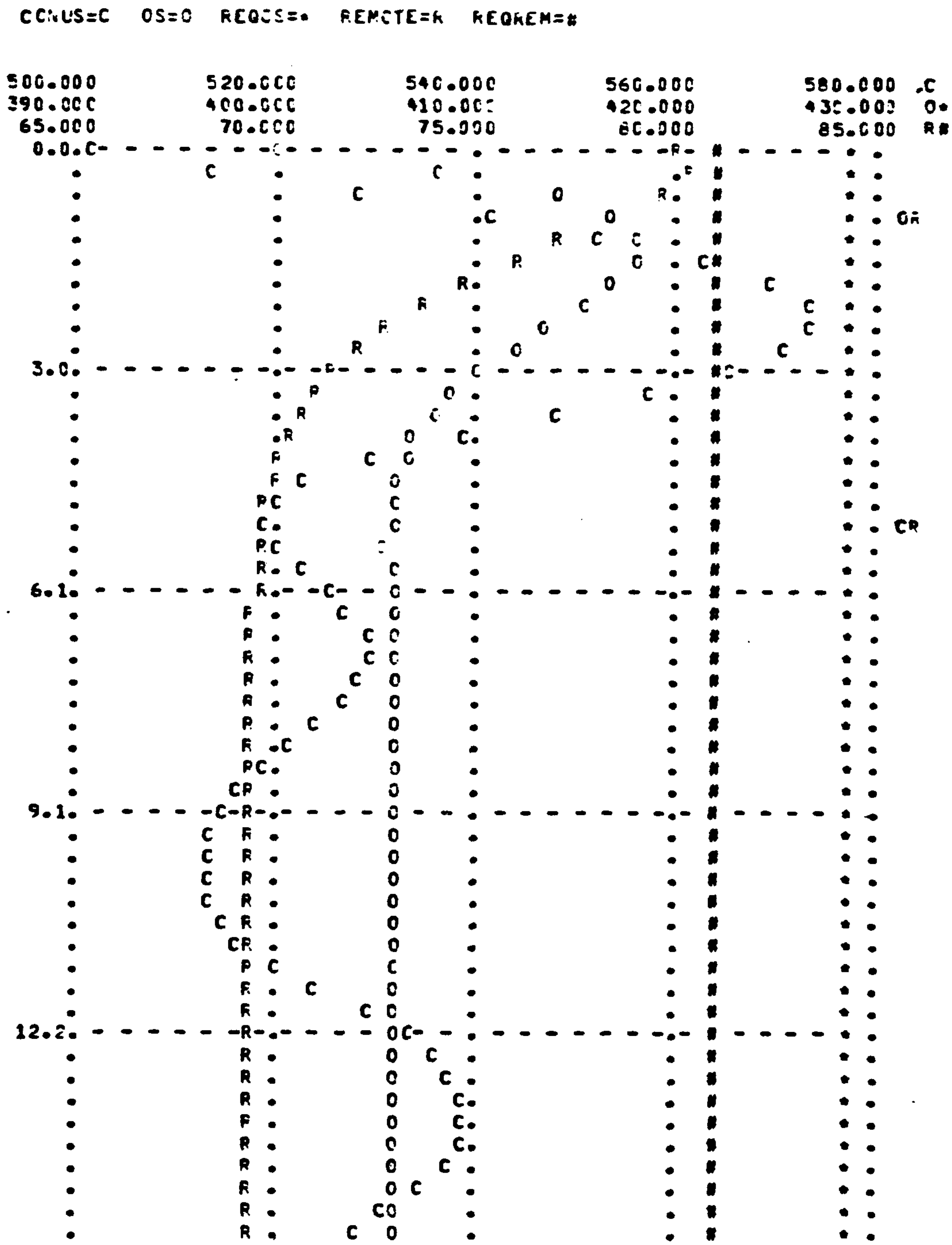



**Figure 5.9. Keep-Rate Formulation: Rotation Levels**

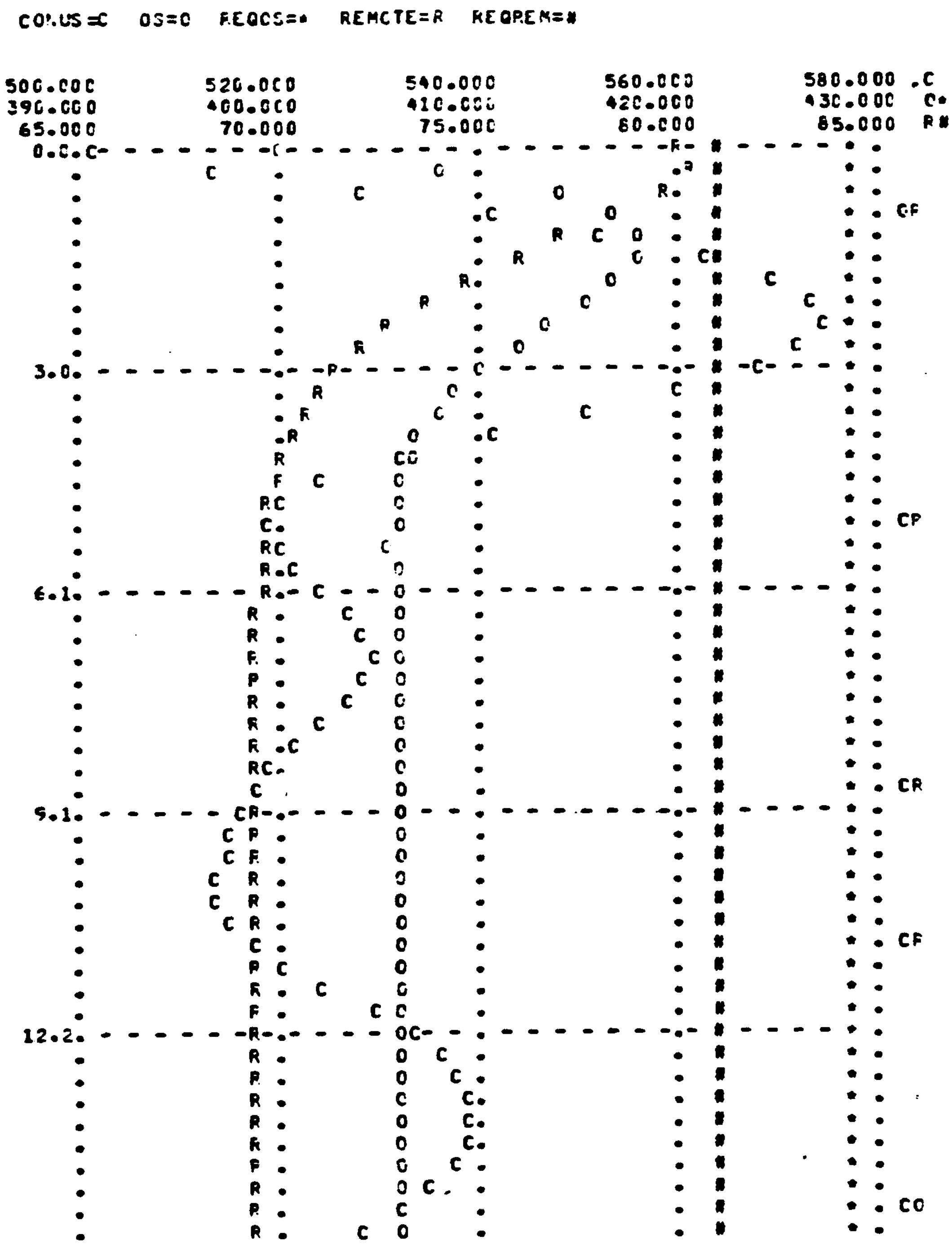



**Figure 5.10. Keep-Rate Formulation with Neutral Pressure Factor: Rotation Levels**

increase in bonuses paid and, therefore, minor changes in the CONUS level. The actual recommendation for bonuses paid is based on both the KEEP rate and the manning levels, as well as other inputs (Ref 49 and Ref 27). The above test indicates a high degree of robustness of model behavior with respect to the formulation for bonus payments.

| KEEP RATE as a Percentage | RESULTING SRB Multiplier |
|---|---|
| 0 | 4 |
| 20 | 3 |
| 40 | 1 |
| 60 | 1 |
| 80 | 0 |
| 100 | 0 |

Table 5.1. SRB Multipliers under the Keep Rate Formulation for Bonuses

## Summary

The purpose of this chapter on policy experimentation was two-fold. First, the value of the model as a policy analysis tool was demonstrated through the presentation of several policy tests. Second, one potential "high-leverage" policy was identified and its results demonstrated. This policy, described above, involved an increase in desired skill levels and a subsequent increase in the total manning level as well as the CONUS level.

More stability and less turnover were the obvious benefits. The decrease in dissatisfaction due to rotation was an implicit advantage. This policy is a "high-leverage" policy in the sense that it can help to reduce the problems which are present in the imbalanced AFSCs. Although there are probably other "high-leverage" policies that could be found, there are also a number of "low-leverage" policies that either do not correct the problems of the system or lead to an accentuation of the problem. Some of these "low-leverage" policies were identified and presented earlier.

Chapter Six presents a summary of the research effort, makes recommendations for further work in this area, and offers the conclusions of this research effort.

# VI Summary, Conclusions, and Recommendations

The primary research objective was to develop a dynamic policy model that could be used to evaluate alternative policies for the airman assignment and rotation system. This chapter will summarize the major accomplishments of this effort with respect to the stated objectives, give recommendations for extended research, and present the conclusions of this research effort.

## Summary and Conclusions

Six intermediate research objectives were outlined in Chapter One. These objectives included a review of manpower planning models, a conceptualization of the internal and external environment of the airman assignment and rotation system, the development of a formal policy model, verification and validation of the model, a demonstration of the use of the model as a policy analysis tool, and the identification of a policy that leads to improved behavior of the airman assignment and rotation system. Each of these areas will be addressed briefly and summarized.

Manpower Planning Models. In the literature relating to manpower planning models, three approaches dominate: (1) fractional-flow "Markov" modeling, (2) "isomorphic" simulation modeling, and (3) system dynamics modeling.

Markov modeling generally involves the computation of "optimal" flow rates and the use of static transition probabilities. Isomorphic modeling attempts to create a one-to-one correspondence between entities in the model and the reference system being modeled. System dynamics models are homomorphic, continuous, and prescriptive. The system dynamics approach employs a "wholeness of perspective" and concentrates on problems within closed-loop feedback systems. The system dynamics methodology was used for the development of the policy model of the airman assignment and rotation system.

Conceptualization. The goals of the airman assignment and rotation system were enumerated and prioritized. The highest system goal was determined to be the maximization of the total manning percentage (up to 100% manning). Although dissatisfaction due to rotation indicators did seem to be a consideration, other goals took precedence. The goals of the system were divided into three major sectors: (1) Personnel Fill, (2) Rotation, and (3) Manpower Authorization. The Manpower Authorization sector was assumed to be exogenous to the assignment and rotation process, since manpower requirements are generated through changes and requirements in the mission or the equipment being used.

The components of the Personnel Fill Sector interact with other components of the Personnel Fill sector and with some components of the Rotation sector. The major levels within the Personnel Fill sector are the people in skill levels. Personnel enter the system at a low skill level, can depart the system from any skill level, and can progress through the system by flowing from one skill to the next. Factors affecting these rates of flow include the level of pay and compensation, the amount of bonuses paid, the level of dissatisfaction due to rotation indicators, and the perceived national labor market.

The major levels of the Rotation sector are the CONUS population, the overseas (long tour) population, and the remote (short tour) population. This level of aggregation allowed for basic trend analysis with respect to these major levels and the rates of flow from level to level. From this sector, the dissatisfaction due to rotation and the cost due to the frequency of PCS moves are computed. The values of these components affected the computation of components within the Personnel Fill sector.

The Formal Model. In formalizing the model, a structure was developed to capture many "intangible" system components. DYNAMO TABLE functions were used extensively for this process. The effect on separation due to bonus payments, level of pay, and rotational indicators is an important part of the system. These effects were not incorporated in previously developed rotation models that used Markov modeling or isomorphic modeling techniques. Interviews with personnel within the system and data analysis of retention factors found in the literature were the main tools employed in the formulation of these relationships. Management concepts that incorporated historical loss rates, historical shortages, and pipeline values (personnel who have been assigned but have not yet arrived) were implemented in the formal model.

Verification and Validation. The formal, mathematical model was written in the DYNAMO computer simulation language. The model was subjected to numerous structural verification tests throughout its development. Specifically, each of the five tests of model structure proposed by Forrester and Senge (Ref 17) were successfully accomplished. These tests are intended to aid in building confidence in the model. Model validation consisted of performing more confidence-building tests. Six of the eight tests of model behavior proposed by Forrester and Senge (Ref 17) were successfully accomplished. The behavior of the model replicated the general behavior of the airman assignment and rotation system. Data from AFSC 306X2, one of the imbalanced AFSCs within Air Force Communications Command (AFCC), was used to formulate the model input. The investigation into the model's ability to react to potential system changes and to "extreme" conditions indicated that the model was valid in the sense that it reproduced expected system behavior for the values of the input variables chosen.

Policy Tests. Implementation of the model involves the testing of alternative policy formulations. Policy tests presented in this report included increases, decreases, and redistribution of required manning levels. The changed behavior that resulted from the alternate policy formulations was compared to the expected response of the system. The changed model behavior was determined to be plausible by tracing through the cause-and-effect relationships involved in the response to the altered policies.

There are three distinctive conclusions that can be drawn from the policy implementation tests:

1. system behavior is fairly insensitive to small changes in bonus payments,

2. system behavior improves when the number of people in the skill levels is increased with no change in the overseas and remote requirements, and

3. system behavior worsens when the required overseas and remote levels are increased with no change in the skill level populations.

These results imply that a "high-leverage" policy should involve increasing the CONUS rotation base. The model results indicate that even small increases (on the order of 15% to 25%) in the rotation base will result in lower turnover rates which in turn lead to a more stable CONUS population level, a decrease in the dissatisfaction due to rotation, and a decrease in the frequency of PCS moves.

## Recommendations

This research effort concentrated on building a sound and verifiable model structure and incorporating that structure into a dynamic policy model of the airman assignment and rotation system. The feedback structures centered around relationships found within the imbalanced AFSCs within AFCC. Policy experimentation involves primarily one AFSC at a time. Six areas in which extension of this research would be useful have been identified and are now presented.

Family Behavior. The family-member test of model behavior (refer to Table 4.1) can be performed for extended analysis of the airman assignment and rotation system. The input data for the validation and policy tests were taken from AFSC 306X2. This AFSC is a member of the class of imbalanced AFSCs within AFCC (see Appendix A). The model should take on the characteristics of different members of the class of imbalanced AFSCs when the policies are adapted to known decision-making differences between the members. In addition, the family-member test could be expanded to include imbalanced AFSCs in other than electronics or communications career fields. Special care would be needed to incorporate any inherent differences.

Expanded Bonus Formulations. The OSD criteria for bonus payments were general and multi-faceted. The current form of the model bases bonus payments on the manning percentage of skill level 5. An alternative formulation was tested that based bonus payments on the retention rate for skill level 3. In both formulations, a "pressure" factor based on total system cost could modify the bonus level paid. In the reference system being modeled, the above factors in addition to other information are employed in the decision process of paying bonuses. A more complicated formulation for the level of bonuses paid would be necessary to capture the full dimensions of system behavior.

The base run of the model was fairly insensitive to the bonus formulation, since the model operated with low values of bonuses paid (just as the reference system operates). A more complex formulation of the process of paying bonuses would be necessary if, for example, policies were tested that caused extreme instability in the AFSC after some large increase in the desired manning levels. In such a case, the shortage in skill level 5 might be very large, but bonuses normally would not be paid since the retention rates would still be acceptable. Some combination of the above factors in addition to other information would more easily handle these "special" situations.

Data Analysis Relating Rotation to Retention Rates. Model results were quite sensitive to changes in the formulation of dissatisfaction due to rotational indicators and to the effect of dissatisfaction on the separation rates in the Personnel Fill sector. This indicates that more firm relationships need to be established between the negative effects of rotation and separation rates for first-term and second-term enlisted personnel in the imbalanced AFSCs. This step of data gathering and analysis was "postponed" during model development so that the sensitivity of model results to dissatisfaction (due to rotation) could be investigated. The model is more sensitive in this area than in the bonus formulation, so further work should be sequenced accordingly.

Inclusion of Dynamic Manpower Authorizations. The Manpower Authorization sector was assumed to be constant throughout the initial development of the model. A more accurate approach would assume that manpower authorizations were exogenous to the Personnel Fill and Rotation sectors, but not necessarily constant. The formulation of manpower authorization as a function of time would allow for the testing of policies that involved the introduction of some new equipment or a new mission at some given point in time. This was done (to a small degree) by changing initial input values, but TABLE functions for desired manning levels versus time would allow for more thorough and realistic policy experimentation along these lines.

Validation. The family-member test is only one aspect of extended validation that is needed to continue building confidence in the model if wider ranges of policy experimentation are desired. Other tests of model behavior that should be performed include boundary-adequancy tests and more thorough behavior-prediction and behavior-reproduction tests. "The boundary adequancy (behavior) test considers whether or .ot a model includes the structure necessary to address the issues for which it was designed" (Ref 17:222). To perform this test, additional structure would need to be conceptualized and the analysis of model behavior with and without the additional model structure would be examined. More thorough testing of behavior reproduction and prediction would involve analyzing potential behaviorial aspects not yet tested.

Implementation. The system improvement test (Ref 17:224) is the ultimate policy test for a model. Once a model has led to the improvement of a system, the degree of confidence in using the model is very high and many more areas of model use are identified. This model was developed with the eventual implementation at AFCC Headquarters as a goal. As Forrester and Senge stated, "the ultimate test of a system dynamics model lies in identifying policies that lead to improved performance of the real system" (Ref 17:224). This research represents the initial step toward the achievement of this ultimate goal and initial results indicate a potential policy that should lead to an improvement in the behavior of the airman assignment and rotation system. The recommended areas for extended research represent steps that can allow the model to be used for various types of policy analysis within the rotation system.

## Conclusion

The objective of this research was accomplished. A dynamic policy model representative of the airman assignment and rotation system was develped, inital verification and validation of the model was performed, the model was employed to evaluate several hypothetical policy formulations, and a high-leverage policy that consists of expanding the rotation base was identified. The results of this research can be directly applied. In addition, the model can aid the policy maker in understanding the complex, feedback structure of the system, and the effect of various policy formulations on that system. The model can be employed to assist the policy maker in the evaluation of proposed policy changes. Recommendations for extended areas of research have been given. These recommendations are merely guidelines for further model use that will increase the utility of the model and the understanding of the airman assignment and rotation system. Additional areas for extended research may arise through the use of the model as a tool for policy analysis.

## Bibliography


1. AFCC Form 555s, Air Force Communications Command Manning Strength Reports, Scott AFB, Illinois, AFCC/MPXP, 30 June 1982.

2. AFCC Summary, Manpower and Personnel. Review of Retention Program, Critical Military Skills, and Manpower Standards. Scott AFB, Illinois, Cost and Management Analysis, 25 May 1982.

3. AFMPC Level Data of AFCC Imbalanced AFSCs . Breakdown of Manning Levels by Tour Length and Skill Level (FY80 to FY82-3), prepared by Lt. Cochran. Randolph AFB, AFMPCRAC2, October 1982.

4. AFMPC Rate Data, Retention Rates and SRB Multiples of AFCC Imbalanced AFSCs (FY80 to FY82-3), prepared by SSGT Schmidt, Randolph AFB, Texas, AFMPCHS, October 1982.

5. AF Retention Data, Loss Rates and Population Levels of AFCC Imbalanced AFSCs (FY80 and FY81), prepared by Lt. David B. Morrow, Bolling AFB, Washington, D.C., AFMPC/MPCDW, October 1982.

6. AFR 26-1 Vol. 1. Manpower Policies and Procedures: Cost Analysis. Department of the Air Force, Washington, D.C., 2 October 1981.

7. AFR 39-6 Vol. 2. Airman Classification: Enlisted Personnel. Department of the Air Force, Washington, D. C., 1 January 1982.

8. Almond, Daniel. Captain, USAF, MPCRA/AFMPC, Randolph AFB, Tx., Personal interview, 9 July 1982.

9. Armstrong, B.E., et al. Air Force Manpower Personnel, and Training System: Volumn II -- Analysis of the Enlisted Authorization/Assignment and Manpower Requirement Personnel Objectives Subsystems. N-1476-AF. Rand Corporation, Santa Monica, Ca., April 1982.

10. Bartholomew, D.J. and A.F. Forbes. Statistical Techniques for Manpower Planning, New York, John Wiley and Sons, 1979.

11. Chow, Winston K. and J. Michael Polich. Models of the First-Term Reenlistment Decision. R-2468-MRAL. Rand Corporation, Santa Monica Ca., September 1980.

12. Fekke, Peter L. Systems Dynamics Modeling Approach to Analysis of the USAF Pilot Production/Allocation System. Thesis. Air Force Institute of Technology, WPAFB, Ohio, December 1978.

13. Flynn, James. "Retaining Productive Units: A Dynamic Programming Model with a Stady State olution," Management Science, 21: 753-764.

14. Ford, Jeffrey D. and Slocum, John W. "Size, Technology, Environment and the Structure of Organization," paper presented at the Thirteenth Annual Eastern Academy of Management Meetings, George Washington University, Washington, D.C., May 1976.

15. Forrester, Jay W. "Changing Economic Patterns," Technology Review, 47-45 (August/September 1978).

16. Forrester, Jay W. Industrial Dynamics. Cambridge, Mass.: MIT Press, 1961.

17. Forrester, Jay w. and Peter M. Senge. "Tests for Building Confidence in System Dynamics Models," Studies in the Management Sciences, Volume 14, System Dynamics, edited by Augusto A. Legasto, jr., et al. Amsterdam and New York: North-Holland Publishing Company, 1980.

18. Greenberger, Martin, et al. Models in the Policy Process. New York, Russell Sage Foundation, 1976.

19. Grinold, Richard C. Manpower Planning with Uncertain Requirements. ORC 73-29. Berkely, University of California, December 1973. AD 773113.

20. Grinold, Richard c. and Marshall, Kneale T. Manpower Planning Models. New York: North-Holland Publishing Company, 1977.

21. Grinold, Richard C. and Stanford, Robert E. Optimal Control of a Graded Manpower System. ORC73-8. Berkely, University of California, April 1973. AD 759694.

22. Guinn, Nancy, et al. Reenlistee/Non-Reenlistee Profiles and Prediction of Reenlistment Potential. AFHRL-TR-77-24. Brooks AFB, Texas, Air Force Human Resources Laboratory, June 1977. AD A043198.

23. Haldeman, Joyce. Major, USAF, MPCYAC, Randolph AFB, Tx., Personal interview, 9 July 1982.

24. Hall, Gaineford J. and Craig S. Moore. Uncertainty in Personnel Force Modeling. N-1842-AF. Rand Corporation, Santa Monica, Ca., April 1982.

25. Hammel, Scott. Captain, USAF, AFCC/MPX, Scott AFB, Illinois, Telephone interviews, 20 July to 29 October 1982.

26. Herzberg, F., et al. The Motivation to Work, Second Edition. New York: John Wiley and Sons, Inc., 1959.

27. Hoffman, Michael. Major, USAF, HQ USAF/AFMPPP, Washington, D.C., Telephone interview, 1 November 1982.

28. House, Peter W. and John McLeod. Large Scale Models for Policy Evaluation. New York, John Wiley & Sons, Inc., 1977.

29. Jaquette, D.L. and Nelson, G.E. Optimal Wage Rates and Force Composition in Military Manpower Planning. Paper from the Rand Paper Series. Rand Corporation, Santa Monica, Ca., September 1974. AD A031664.

30. Kast, Fremont E. and Rosenzweig, James E. "Evolution of Organization and Management Theory," Contingency Views of Organization and Management, edited by Kast and Rosenzweig. Chicago: Science Research Associates, 1973.

31. Kast, Fremont E. and Rosenzweig, James E. "General Systems Theory: Applications for Organization and Management," Academy of Management Journal, 447-465 (December 1972).

32. Knight, John M. The Aggregate Pilot Pipeline Model. AFIT TR 78-6. WPAFB, Ohio Air Force Institute of Technology, November, 1978.

33. Landis, Fred. "A Dynamic Simulation Model of Engineering Manpower Needs," Engineering Education, 218-225 (December 1976).

34. Leupp, H.A. Navy Group VIII (SEABEE) Enlisted Personnel Simulation Model. Stinger System Tactical Memorandum No. 69-3. Port Hueneme, California, SEABEE Systems Engineering Office Systems Analysis Group, August 1969. AD 772083.

35. Looper, Larry. Career Area Rotation Model (CAROM): Historical Overview of Technique and Uttilization. AFHRL-TR-78-97. Brooks AFB, Texas, Air Force Human Resources Laboratory, September 1979.

36. Moore, Craig S. Demand and Supply Integration for Air Force Enlisted Work Force Planning: A Briefing. N-1724-AF. Rand Corporation, Santa Monica, Ca., April 1982.

37. Polk Stanley. Major, USAF, MPCHS, Randolph AFB, Personal and Telephone interviews, 9 July to 28 October 1982.

38. Pugh, Alexander L. III. DYNAMO User's Manual, Fifth Edition. Cambridge, Mass.: MIT Press, 1976.

39. Richardson, George P. and Pugh, Alexander L. III. Introduction to System Dynamics Modeling with DYNAMO. Cambridge, Mass.: MIT Press, 1981.

40. Roberts, Edward B. Managerial Applications of System Dynamics. Cambridge, Massachusetts: MIT Press, 1978.

41. Rueter, Frederick H., et al. Integrated Simulation Evaluation Model Prototype (ISEM-P) of the Air Force Manpower and Personnel System: Overview and Sensitivity Analysis. AFHRL-TR-81-15. Brooks AFB, Texas, Air Force Human Resources Laboratory, July 1981.

42. Schoderbek, Charles G., et al. Management Systems: Conceptual Considerations. Dallas, Texas: Business Publications, Inc., 1980.

43. Shannon, Robert E. Systems Simulation: the Art and Science. Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1975.

44. Sherman, Stuart H., Jr. Major General, USAF, Staff Director, 5th Quadrennial Review of Military Compensation, Skyline Place 3, Suite 1511, 5201 Leesburg Pike, Falls Church, VA., Personal interview, 20 July, 1982.

45. Shreckengost, R.C. and Gibson, S.P. An Introduction to Dynamic Simulation of Personnel Systems. Unpublished training guide, washington, D.C., Information Science Center, Office of Training, Central Intelligence Agency, June 1978.

46. Smith, Roberta J. A Description of the Enlisted Service Rotation System. N-1004-MRAL. Rand Corporation, Santa Monica, Ca., December 1979.

47. Steers, Richard M. "When is an Organization Effective? A Process Approach to Understanding Effectiveness," Organizational Dynamics, 50-63 (Autumn 1976).

48. Sweeny, Arthur B. and Tubbs, Ann V. Periodic Factors Involving Reenlistment Decisions: Measured by Social Indicators. Technical Report Number III, Wichita State University, Center for Human Appraisal, August 1977. AD A043229.

49. Unger, John. SMSGT, USAF, HQ USAF/MPPP, Washington, D.C., Personal interview, 30 October 1982.

50. Ward, Joe H., Jr. GS-14, Brooks AFB, Tx, Air Force Human Resources Laboratory, Personal interviews, 6 July to 29 October, 1982.

51. Whisman, Alan W. Optimal Accession Requirements (OAR) Model. NPRDC TR 80-33. San Diego, California, Navy Personnel Research and Development Center, September, 980. AD A089095.

52. Williams, Kenneth L. A System Dynamics Model for Assessing the Cost-Effectiveness of USAF Engineering Officer Compensation Policies. Thesis. Air Force Institute of Technology, WPAFB, Ohio, December, 1980.

53. Williams, Richard B. et al. Career Area Rotation Model. User's Manual. AFHRL-TR-73-49. Brooks AFB, Texas, Air Force Human Resources Laboratory, October 1973.

54. Wilson, E.B. and Griffin, B.S. Seeking the Minimum Cost Assignment Policy for Personnel Given a Geographical Distribution of Forces. Paper presented at the 27th Military Operations Research Society (MORS) Conference, Maxwell AFB, Alabama, June 1971.

55. Witt, Joanne M. and Narva, Adele P. SIMPO-I Dynamics Army Model (DYNAMOD). Research Study 70-2. Behavior and Systems Research Laboratory, U.S. Army, May 1970. AD A077745.

## Appendix A: Description of Imbalanced AFSCs

The purpose of this supplement is to provide a description of the imbalanced AFSCs within Air Force Communications Command (AFCC). The titles of the AFSCs were given in Chapter One. The duties and responsibilities are taken primarily from skill level 5. The skill level number is the fourth digit in the AFSC. An "X" will be substituted for the skill level number to denote a fairly general description. Skill levels 7 and 9 involve a greater amount of supervisory work than skill levels 3 and 5. All of the descriptions were obtained from AFR 39-1 (Ref 7).

### 293X3: Ground Radio Operator

Personnel operate radio transmitting and receiving equipment in ground radio stations to conduct point-to-point and ground-air-ground communications. Duties include (1) tuning receivers to prescribed frequencies and/or desired signals, (2) changing transmitter frequencies and making frequency measurements, (3) making adjustments on command and control communications equipment, and (4) reporting operational deficiencies and signal interference suspected to be from other than natural causes. Other responsibilities involve copying transmissions from aircraft and ground stations, encoding and decoding classified messages, and maintaining continuous watch on designated frequencies. The related DoD Occupational Subgroup is 201.

304X0: Wideband Communications Equipment Specialist

Personnel install, repair, modify, maintain, and operate fixed, mobile, and transportable wideband communications systems, including trapospheric scatter and line-of-sight radio, analog and digital multiplex, signaling and termination equipment, intrusion detection systems, and associated test equipment. Duties include tuning, testing, operating, and adjusting equipment. Other responsibilities involve: (1) inspection of tubes, connecting plugs, circuit wiring, and solid state and detection devices; (2) isolation of malfunctions and replacement of faulty electronic parts; and (3) inspection of all equipment to determine operational status. The related DoD Occupational Subgroup is 101.

304X6: Space Communications Systems Equipment Operator/ Specialist

Personnel analyze data to determine spacecraft communications transponder operational readiness. Duties include: (1) calculation of timing and orbital parameters for communications spacecraft acquisition and tracking, (2) establishment of a communications link with the distant earth terminal via the communications spacecraft,

(3) operating the earth terminal control console and monitoring the systems performance indicators, (4) performing detailed repair and modification of earth terminal operational directives. The related DoD Occupational Subgroup is 101.

306X1: Electronic-Mechanical Communications and Cryptographic Equipment Systems Specialist

Personnel install, maintain, inspect, repair, modify and safeguard electronic-mechanical communications and cryptographic equipment. Personnel must perform operational tests on equipment using oscilloscopes, multimeter, finely calibrated scales, gauges, stroboscopes, and other electrical and mechanical testing devices. Equipment is set for correct mode, rate, type of signal, and cryptologic function. Safeguarding duties include performing TEMPEST inspections, amending cryptographic equipment, and transporting and destroying cryptographic equipment and materials as authorized. The related DoD Occupational Subgroup is 160.

306X2: Telecommunications Systems/Equipment Maintenance Specialist

Personnel install, inspect, test, and maintain electronically and mechanically operated communications systems systems/equipment. Personnel must perform operational tests, observe equipment functioning, and make required adjustments, for proper operation. Other duties include performing preventive maintenance inspections, cleaning and lubricating parts, and bench checking and repairing electronically-mechanically operated telecommunications systems and equipment, crypto devices, and associated communication equipment. The related DoD Occupational Subgroup is 160.

307X0: Telecommunications Systems Control Specialist

Personnel monitor and analyze performance of telecommunications systems, including circuits, equipment, and transmission media. Personnel must make operational adjustments of communications-electronics equipment, circuits and subsystems. Other duties include (1) identification and initiation of action to correct conditions affecting circuit effectiveness, and (2) the coordination of operations with associated facilities and stations. The related DoD Occupational Subgroup is 101.

## Appendix B: Sample Rerun Files

The DYNAMO rerun option (Ref 38:47) can be used to make any number of runs of a model. Only constants and tables may be altered in a rerun. This option could be used in making the family-behavior tests mentioned in the recommendations for further research, since the model initialization (see Appendix D and Appendix E) is accomplished with constants and tables. Illustrated below are two sequences of rerun statements used in Chapter Four, Model Verification and Validation. The first sequence tests the sensitivity of the model to extreme values of the Technical School Multiplier Tale (TSHMT), while the second sequence tests the sensitivity of the model to extreme values of the Level 5 Bonus Factor Table (L5BFT) and the Level 5 Bonus Table (L5BONT).

```
T TSCHMT=1/1/1/1/1/1
RUN TS1's
T TSCHMT=.5/.5/.5/.5/.5/.5
RUN TS.5's
T TSCHMT=1/.8/.6/.4/.2/.1
RUN TS1-.1
QUIT
```

```
T L5BFT=2/1.5/1.0/.5/.2
RUN BF2-.2
T L5BFT=1/1/1/1/1
RUN BF1's
T L5BONT=0/0/0/0/0/0
RUN BONT0's
T L5BONT 4/4/4/4/4/4
RUN BONT4's
QUIT
```

# Appendix C: Variable Listing

## Personnel Fill Sector Variables

BDT=Bonus Delay Time (years)

BONSPD=Bonuses Paid Multiple (0 to 4)

COST=Cost (thousands of dollars)

COSTAB=Cost Table for PNTPB2

COSTRT=Cost Rate (thousands of dollars/year)

DL3=Desired Level 3 (people)

DL5=Desired Level 5 (people)

DL7=Desired Level 7 (people)

DL9=Desired Level 9 (people)

DPQ13=Dummy Pipeline Quantity for Level 1 to Level 3 (people)

DPQ35=Dummy Pipeline Quantity for Level 3 to Level 5 (people)

DPQ57=Dummy Pipeline Quantity for Level 5 to Level 7 (people)

DPQ79=Dummy Pipeline Quantity for Level 7 to Level 9 (people)

DTF=Desired Total Force (people)

INIT13=Initial Pipeline Quantity from Level 1 to Level 3 (2-word array of people)

INIT35=Initial Pipeline Quantity from Level 3 to Level 5 (2-word array of people)

INIT57=Initial Pipeline Quantity from Level 5 to Level 7 (2-word array of people)

INIT79=Initial Pipeline Quantity from Level 7 to Level 9 (2-word array of people)

ISL3=Initial Skill Level 3 (people)

ISL5=Initial Skill Level 5 (people)

ISL7=Initial Skill Level 7 (people)

ISL9=Initial Skill Level 9 (people)

L13PQ=Pipeline Quantity for Level 1 to Level 3 (people)

L35PQ=Pipeline Quantity for Level 3 to Level 5 (people)

L57PQ=Pipeline Quantity for Level 5 to Level 7 (people)

L79PQ=Pipeline Quantity for Level 7 to Level 9 (people)

L3AR=Level 3 Accession Rate (people/year)

L3ARD=Level 3 Accession Rate Delayed (people/year)

L3AT=Level 3 Adjustment Time (years)

L5AT=Level 5 Adjustment Time (years)

L7AT=Level 7 Adjustment Time (years)

L9AT=Level 9 Adjustment Time (years)

L5BF=Level 5 Bonus Factor

L5BFAC=Level 5 Bonus Factor (Delayed)

L5BFT=Level 5 Bonus Table

L5BONT=Level 5 Bonus Table for PNTPB1

L5BPTB=Level 5 Bonuses Paid Table

L3CFAC=Level 3 Compensation Factor

L5CFAC=Level 5 Compensation Factor

L7CFAC=Level 7 Compensation Factor

L9CFAC=Level 9 Compensation Factor

L3CPM=Level 3 Cost Per Man (thousands of dollars)

L5CPM=Level 5 Cost Per Man (thousands of dollars)

L7CPM=Level 7 Cost Per Man (thousands of dollars)

L9CPM=Level 9 Cost Per Man (thousands of dollars)

L3CTAB=Level 3 Compensation Table

L5CTAB=Level 5 Compensation Table

L7CTAB=Level 7 Compensation Table

L9CTAB=Level 9 Compensation Table

L3L5PR=Level 3 to Level 5 Promotion Rate (people/year)

L5L7PR=Level 5 to Level 7 Promotion Rate (people/year)

L7L9PR=Level 7 to Level 9 Promotion Rate (people/year)

L5MPCT=Level 5 Manning Percentage

L3SHRT=Level 3 Shortage (people)

L5SHRT=Level 5 Shortage (people)

L7SHRT=Level 7 Shortage (people)

L9SHRT=Level 9 Shortage (people)

L3WT=Level 3 Weight

NL3SR=Normal Level 3 Separation Rate (people/year)

NL5SR=Normal Level 5 Separation Rate (people/year)

NL7SR=Normal Level 7 Separation Rate (people/year)

NL9SR=Normal Level 9 Separation Rate (people/year)

PERIOD=Period of Perceived "Labor Cycle"

PNLM=Perceived National Labor Market

PNTPB=Perceived Need to Pay Bonuses

PNTPB1=Perceived Need to Pay Bonuses from L5MPCT

PNTPB2=Perceived Need to Pay Bonuses from COST

PQ13CT=Pipeline Quantity for Level 1 to Level 3 Counter (2-word array of people)

PQ35CT=Pipeline Quantity for Level 3 to Level 5 Counter (2-word array of people)

PQ57CT=Pipeline Quantity for Level 5 to Level 7 Counter (2-word array of people)

PQ79CT=Pipeline Quantity for Level 7 to Level 9 Counter (2-word array of people)

PQ13R=Pipeline Quantity Rate for Level 1 to Level 3 (people)

PQ35R=Pipeline Quantity Rate for Level 3 to Level 5 (people)

PQ57R=Pipeline Quantity Rate for Level 5 to Level 7 (people)

PQ79R=Pipeline Quantity Rate for Level 7 to Level 9 (people)

PRVCST=Previous Cost (thousands of dollars)

SL3=Skill Level 5 (people)

SL5=Skill Level 5 (people)

SL7=Skill Level 7 (people)

SL9=Skill Level 9 (people)

SR3=Separation Rate from SL3 (people/year)

SR5=Separation Rate from SL5 (people/year)

SR7=Separation Rate from SL7 (people/year)

SR9=Separation Rate from SL9 (people/year)

SRBM=SRB Multiplier (thousands of dollars)

TEMPRT=Temporary Rate for L3AR (people/year)

TF=Total Force (people)

TFS=Total Force Shortage (people)

TFWT=Total Force Weight

TSCHAR=Technical School Accession Rate (people/year)

TSCHM=Technical School Multiplier

TSCHMT=Technical School Multiplier Table

XTNGAR=Cross-Training Accession Rate (people/year)

XTNGFX=Cross-Training Fraction

<u>Rotation Sector Variables</u>

ACOS=Average CONUS to Overseas Rate (people/year)

ACOSRM=Average Rate from CONUS to Overseas and Remote (people/year)

ACRM=Average CONUS to Remote Rate (people/year)

AROSPM=Average Remote and Overseas Time Per Man (years)

AVGREM=Average Fraction of People in Remote Tours to the Total Force

CONUS=Continental United States (people)

CTBFAC=CONUS Time Between Overseas and Remote Factor

CTBROS=Average Time Spent CONUS Between Remote and Overseas Tours (years)

CTBTAB=CONUS Time Between Overseas and Remote Table

CTOOS=CONUS To Overseas Rate (people/year)
CTOOSD=CONUS To Overseas Rate Delayed (people/year)

CTOREM=CONUS To Remote Rate (people/year)

CTORMD=CONUS To Remote Rate Delayed (people/year)

CTORPQ=CONUS To Remote Pipeline Quantity (people)

CTOSPQ=CONUS to Overseas Pipeline Quantity (people)

CUMRAT=Rate for Calculation of CUMROS (people)

CUMREM=Cumulative People Remote (people)

CUMROS=Cumulative Time Remote and Overseas (people years)

CUMTF=Cumulative Total Force (people)

DCTOPQ=Dummy CONUS To Overseas Pipeline Quantity (people)

DCTRPQ=Dummy CONUS To Remote Pipeline Quantity (people)

DISSAT=Dissatisfaction due to Rotation

ICONUS=Initial Level Overseas (people)

INITRM=Initial Level Remote (people)

IREQOS=Initial Required Level Overseas (people)

IREQRM=Initial Required Level Remote (people)

LAG1=Delay Time for Rotation to Overseas (years)

LAG2=Delay Time for Rotation to Remote (years)

NRTFAC=Number of Remote tours Factor

NRTTAB=Number of Remote Tours Table

OPQCTR=Overseas Pipeline Quantity Counter

OPQR=Overseas Pipeline Quantity Rate (people/year)

OS=Overseas (people)

OSTOC=Overseas to CONUS Rate (people/year)

PCSCST=Permanent Change of Station Cost Per Man Per Move
(thousands of dollars)

REMOTE=Remote Level of Personnel (people)

REMTOC=Remote To CONUS Rate (people/year)

REQOS=Required Level of Overseas Personnel (people)

REQREM=Required Level of Remote Personnel (people)

ROSFAC=Remote and Overseas Time Factor

ROSTAB=Remote and Overseas Time Table

RPQCTR=Remote Pipeline Quantity Counter (people)

RPQR=Remote Pipeline Quantity Rate (people/year)

SC1=Smoothing Constant for ACOS (years)

SC2=Smoothing Constant for ACRM (years)

TOTFRC=Total Force from Rotation Sector Levels (people)

TOUREM=Remote Tourlength (years)

TOUROS=Overseas Tourlength (years)

## Appendix D: Documented DYNAMO Equations

```
* ASSIGNMENT/ROTATIC  - NOV6 FORM
 THE FIRST BLOCK INITIALIZES AND SETS CONSTANTS.
C      ISL3=372                     INITIAL NUMBER IN SKILL LEVELS
C      ISL5=444                     THE NUMBERS TAKE INTO ACCOUNT
C      ISL7=106                     THE PIPELINE QUANTITIES
C      ISL9=23
N      SL3=ISL3                      SKILL LEVELS ARE INITIALIZED
N      SL5=ISL5
N      SL7=ISL7
N      SL9=ISL9
N      TF=981                        INITIAL TOTAL FORCE
                                     SUM OF SKILL LEVELS PLUS PROM PQ'S
C      DL3=268                       DESIRED LEVELS IN SKILL LEVELS
C      DL5=570
C      DL7=140
C      DL9=23
A      DTF.K=DL3+DL5+DL7+DL9         DESIRED TOTAL FORCE
C      XTNGFX=.05                    AMT OF L3SHRT TO BE FILLED BY XTNG
C      PERIOD=7                      LENGTH OF NAT ECONOMY CYCLE
C      L3WT=0                        REL IMPORTANCE OF FILLING L3SHRT
C      TFWT=1                        REL IMPORTANCE OF FILLING TFSHRT
C      SC1=.25                       SMOOTHING CONSTANT FOR ACOS
C      SC2=.25                       SMOOTHING CONSTANT FOR ACRM
C      BDT=.25                       BONUS DELAY TIME
C      NL3SR=75                      NORMAL SEPARATION RATE, PER YEAR
C      NL5SR=25
C      NL7SR=40
C      NL9SR=20
C      L3CPM=7                       AVG COMPENSATION PER MAN, $000
C      L5CPM=10
C      L7CPM=13
C      L9CPM=16
C      SRBM=1                        SRB MULTIPLIER PER MAN
C      L3AT=.417                     LAG TIME BEFORE ENTERING LEVEL
C      L5AT=.25
C      L7AT=.1667
C      L9AT=.25
C      PCSCST=5                      AVG COST OF PCS, $000
N      OS=INITOS                     INITIAL OVERSEAS LEVEL
C      INITOS=400
N      REMOTE=INITRM                 INITIAL REMOTE LEVEL
C      INITRM=80
N      CONUS=ICONUS                  INITIAL CONUS MANNING LEVEL
C      ICONUS=501
A      REQREM.K=IREQRM               REQD/DESIRED REMOTE MANNING LEVEL
C      IREQRM=81
A      REQOS.K=IREQOS                REQD/DESIRED OS MANNING LEVEL
C      IREQOS=429
C      TOUROS=3                      OVERSEAS TOUR LENGTH; POLICY VARIABLE
C      TOUREM=1                      REMOTE TOUR LENGTH; POLICY VARIABLE
N      CUMTF=981                     INITIAL CUM TOTAL FORCE
N      CUMREM=INITRM                 INITIAL CUM # IN REMOTES
N      CUMROS=0                      INITIAL CUM # IN REMOTE & OS SLOTS
C      LAG1=.1677                    PIPE DELAY BETWEEN CONUS AND OS.
C      LAG2=.1677                    PIPE DELAY BETWEEN CONUS AND REMOTE.

  THE FOLLOWING SECTION INITIALIZES ARRAYS.
  ALL ARRAYS ARE TWO WORD, AND TRACK AUX VALUES FROM TIME J TO K.

FOR    M=1,2
N      PRVCST(M)=INIT(M)             CUMULATIVE TOTAL COST THRU LAST DT
                                       QTY IN PIPE FROM LEVEL 1 TO 3
```

```
N      PQ35CT(M)=INIT35(M)
N      PQ57CT(M)=INIT57(M)
N      PQ79CT(M)=INIT75(M)
N      OPQCTR(M)=INIT(M)              QTY IN PIPE FROM CONUS TO OS
N      RPQCTR(M)=INIT(M)              QTY IN PIPE FROM CONUS TO REMOTE.
T      INIT=0/0
T      INIT13=84/84
T      INIT35=31/31
T      INIT57=6/6
T      INIT79=0/0

  ROTATIONAL SECTOR

R      OSTOC.KL=OS.K/TOUROS           OS TO CONUS ROTATION RATE
A      DCTOPQ.K=SHIFTL(OPQCTR.K,DT)
                                      DUMMY CONUS TO OS PIPELINE QTY.
                                      SHIFTL GETS VALUE FROM TIME J.

R      CTOOS.KL=SMOOTH(OSTOC.JK+(REQOS.K-OS.K-DCTOPQ.K),1)
                                      RATE AT WHICH REPLACEMENTS
                                      LEAVE CONUS FOR OS SLOTS.
                                      RATE IS COMPOSED OF DESIRED LEVEL, MINUS
                                      THE ACTUAL LEVEL MINUS AMT IN PIPE.
R      CTOOSD.KL=DELAYP(CTOOS.JK,LAG1,CTOSPQ.K)   RATE AT WHICH
                                      REPLACEMENTS ACTUALLY ARRIVE OS.
                                      RATE IS DELAYED BY LAG1.
                                      CTOSPQ IS THE QTY IN PIPELINE.
R      OPQR.KL=CTOSPQ.K/DT            OPQR IS RATE AT WHICH OPQCTR
                                      WILL BE INCREASED.  CTOSPQ IS DIVIDED
                                      BY DT SO THAT WHEN THE RATE IS MULT
                                      BY DT, THE LEVEL WILL BE CORRECT.
L      OPQCTR.K(1)=OPQCTR.J(1)+DT*OPQR.JK
                                      THE VALUE AT TIME J IS ZERO.
                                      THE DT*RATE VALUE IS ADDED TO ZERO
                                      TO GET THE CURRENT PIPE QTY.

R      REMTOC.KL=REMOTE.K/TOUREM      REMOTE TO CONUS ROTATION RATE.
A      DCTRPQ.K=SHIFTL(RPQCTR.K,DT)
                                      DUMMY CONUS TO REMOTE PIPELINE QTY.
                                      THIS VALUE IS RETRIEVED FROM TIME J
                                      BY SHIFTL.  RPQCTR IS THE ARRAY
                                      WHICH HOLDS THE HISTORICAL DATA.
R      CTOREM.KL=SMOOTH(REMTOC.JK+(REQREM.K-REMOTE.K-DCTRPQ.K),1)
                                      RATE AT WHICH
                                      REPLACEMENTS LEAVE CONUS FOR REMOTES.
                                      RATE IS CALCULATED AS DIFF BETWEEN
                                      REQUIRED, ACTUAL AND PIPE QTY.
                                      THIS QTY IS IN PEOPLE, AND THEN
                                      DIVIDED BY TIME TO GIVE PEOPLE
                                      PER UNIT TIME.
R      CTORMD.KL=DELAYP(CTOREM.JK,LAG2,CTORPQ.K)  RATE AT WHICH
                                      REPLACEMENTS ACTUALLY ARRIVE REMOTE.
                                      RATE IS DELAYED BY LAG2.
                                      CTORPQ IS THE QTY IN PIPELINE.
R      RPQR.KL=CTORPQ.K/DT            REMOTE PIPELINE QTY RATE.
                                      THIS IS THE RATE WHICH WILL SET
                                      THE REMOTE PIPE QTY COUNTER FOR
                                      THE "LAST" TIME PERIOD.  IT IS
                                      DIVIDED BY DT, SO THAT WHEN THE
                                      RATE IS MULTIPLIED BY DT IN THE
                                      LEVEL EQUATION, THE UNITS ON THE
                                      NEW VALUE WILL BE CORRECT.
L      RPQCTR.K(1)=RPQCTR.J(1)+DT*RPQR.JK
                                      REMOTE PIPELINE QTY COUNTER.
                                      THE J VALUE IS ZERO, AND WHEN THE
                                      DT*RATE VALUE IS ADDED, THE RESULT
```

```
                                                   IS THE CURRENT PIPELINE QTY, SAVED
                                                   FOR NEXT PERIOD.

L      OS.K=OS.J+DT*(CTOCSD.JK-OSTOC.JK)
                                                   NUMBER PEOPLE OVERSEAS.
                                                   RATE IS THE FLOW DIFFERENCE
                                                   BETWEEN DELAYED ARRIVALS AND
                                                   DEPARTURES.
L      REMOTE.K=REMOTE.J+DT*(CTORMD.JK-REMTOC.JK)
                                                   NUMBER OF PEOPLE REMOTE.
L      CONUS.K=CONUS.J+DT*(L3ARD.JK-SR3.JK-SR5.JK-SR7.JK-
X        SR9.JK+OSTOC.JK-CTOOS.JK+REMTOC.JK-CTOREM.JK)
                                                   LEVEL OF PEOPLE STATIONED IN US.
                                                   RATE IS DIFFERENCE BETWEEN
                                                   ACCESSION RATES, SEPARATION
                                                   RATES, AND ASSIGNMENT LEVEL FLOWS.

S      TOTFRC.K=CONUS.K+REMOTE.K+OS.K+CTORPQ.K+CTOSPQ.K
                                                   TOTAL FORCE:  SUM OF CONUS, OS,
                                                   REMOTE, AND THE PIPELINE QTYS
                                                   BETWEEN CONUS, REMOTE, AND OS.
                                                   USED AS A CHECK ON TF.

R      CUMRAT.KL=OS.K+REMOTE.K             PSEUDO-RATE FOR CALC OF PSEUDO-LEV
                                                   CUMROS.  RATE IS IN PEOPLE.
L      CUMROS.K=CUMROS.J+DT*CUMRAT.JK
                                                   CUM TIME REM AND OS IN MAN YEARS.
A      AROSPM.K=CUMROS.K/CUMTF.K           AVG REM AND OS TIME PER MAN.
                                                   THIS IS ONE OF SYSTEM MOE'S.

L      CUMREM.K=CUMREM.J+DT*CTORMD.JK
                                                   CUM PEOPLE REMOTE.
L      CUMTF.K=CUMTF.J+DT*L3ARD.JK
                                                   CUMTF IS CUMULATIVE TOTAL FORCE.
                                                   SHIFTL GETS VALUE FROM TIME J.
                                                   ADDS CURRENT VALUE.
A      AVGREM.K=CUMREM.K/CUMTF.K           AVG NUMBER PEOPLE REMOTE.
                                                   THIS IS ONE OF SYSTEM MOE'S.

A      ACOS.K=SMOOTH(CTOOS.JK,SC1)         SMOOTH AVERAGES THE CTOOS RATES
                                                   FOR THE LAST SC1 TIME PERIODS.
                                                   THIS GIVES THE AVG CONUS TO OS RATE.
A      ACRM.K=SMOOTH(CTOREM.JK,SC2)        SMOOTH AVERAGES THE CTOREM RATES
                                                   FOR THE LAST SC2 TIME PERIODS.
                                                   THIS IS THE AVG CONUS TO REM RATE.
A      ACOSRM.K=ACOS.K+ACRM.K              ACOSRM IS THE AVG RATE OUT OF CONUS.
A      CTBROS.K=CONUS.K/ACOSRM.K           AVG TIME SPENT CONUS
                                                   BETWEEN REMOTE AND OS TOURS.
                                                   THIS IS ONE OF THE SYSTEM MOE'S.

   PERSONNEL FILL SECTOR

A      DPQ13.K=SHIFTL(PQ13CT.K,DT)         RETRIEVE LAST PERIOD'S PIPE QTYS.
A      DPQ35.K=SHIFTL(PQ35CT.K,DT)
A      DPQ57.K=SHIFTL(PQ57CT.K,DT)
A      DPQ79.K=SHIFTL(PQ79CT.K,DT)

A      TF.K=SL3.K+SL5.K+SL7.K+SL9.K+
X        DPQ35.K+DPQ57.K+DPQ79.K           TOOK OUT DPQ13
                                                   TOTAL FORCE.  SUM OF:
                                                   LEVELS AND PIPE QTYS.
A      TFS.K=MAX(0,DTF.K-TF.K)             TOTAL FORCE SHORTAGE.
                                                   MAX IS USED SO NO NEGATIVE SHORTAGE.
                                                   NEXT ARE LEVEL SHORTAGES.
A      L3SHRT.K=MAX(0,DL3-SL3.K-DPQ13.K)
```

```
A       L7SHRT.K=MAX(0,DL7-SL7.K-DPQ57.K)
A       L9SHRT.K=MAX(C,DL9-SL9.K-DPQ79.K)

A       XTNGAR.K=XTNGFX*(L3WT*L3SHRT.K+TFWT*TFS.K)
                                        CROSS TRAINING ACCESSION RATE.
                                        L3WT IS WEIGHT ASSIGNED TO THE
                                        IMPORTANCE OF FILLING SHORTAGES
                                        IN LEVEL 3.  TFWT IS WEIGHT ASSIGNED
                                        TO IMPORTANCE OF FILLING SHORTAGES
                                        IN THE TOTAL FORCE.
A       PNLM.K=SIN(6.283*TIME.K/PERIOD)
                                        PERCEIVED NATIONAL LABOR MARKET.
A       TSCHM.K=TABLE(TSCHMT,PNLM.K,-1,1,.4)
                                        TECH SCHOOL MULTIPLIER.
                                        TSCHM IS USED TO SCALE TSCHAR
                                        BASED ON FLUCTUATIONS IN ECONOMY.
T       TSCHMT=1/1/.9/.85/.8/.8
A       TSCHAR.K=(L3WT*L3SHRT.K+TFWT*TFS.K)*(1-XTNGFX)
                                        TECH SCHOOL ACCESSION RATE.
                                        1-XTNGFX INPLIES THAT THE PORTION OF
                                        THE FORCE SHORTAGE NOT MET BY CROSS
                                        TRAINING WILL BE SATISFIED BY TECH
                                        SCHOOL ACCESSIONS.
A       TEMPRT.K=XTNGAR.K+TSCHAR.K+SMOOTH(SR3.JK+L3L5PR.JK-
X       TFWT*(MAX(C,TF.K-DTF.K))-L3WT*(MAX(0,SL3.K+DPQ35.K-DL3)),1)
R       L3AR.KL=TEMPRT.K*TSCHM.K
                                        TEMPRT IS THE RATE WHICH
                                        WILL DETERMINE THE L3 ACCESSION
                                        RATE.  IT IS CALCULATED AS THE TECH
                                        SCHOOL ACCESSION RATE PLUS THE CROSS
                                        TRAINING ACCESSION RATE PLUS AN
                                        EXPONENTIALLY SMOOTHED VALUE WHICH
                                        REPRESENTS A FORECAST OF NEXT
                                        PERIOD'S ANTICIPATED SHORTAGE.
                                        L3AR IS L3 ACCESSION RATE, THE RATE
                                        AT WHICH PEOPLE ENTER THE AIR FORCE.
                                        L3AR AS A RATE IS DEFINED BY THE AUX
                                        TEMPRT.
                                        L3ARFS IS L3AR FOR SHIFTL.  TEMPRT
                                        IS DIVIDED BY DT SO THAT WHEN IT IS
                                        MULTIPLIED BY DT IN THE LEVEL EQN
                                        THE CORRECT VALUE WILL BE STORED
                                        FOR NEXT PERIOD.
R       L3ARD.KL=DELAYP(L3AR.JK,L3AT,L13PQ.K)
                                        RATE AT WHICH PEOPLE ACTUALLY
                                        ARRIVE INTO LEVEL 3.  DELAYED
                                        TO ACCOUNT FOR BASIC TRAINING,
                                        TECH SCHOOL TIME, ETC.
                                        THE DELAY IS BY DT, AND
                                        L13PQ IS THE AMT IN THE PIPELINE.
A       L5MPCT.K=SL5.K/DL5              LEV 5 MANNING PERCENTAGE.
A       PNTPB1.K=TABLE(L5BPTB,L5MPCT.K,0,1,.2)
T       L5BPTB=1/1/1/.6/.5/0
                                        PNTPB1-PERCEIVED NEED TO PAY BONUS,
                                        BASED ON LEVEL OF MANNING IN SL5.
A       PNTPB2.K=TABLE(COSTAB,SHIFTL(PRVCST.K,DT),0,1000,100)
T       COSTAB=1/.93/.86/.79/.72/.65/.55/.43/.2/.1/0
                                        PNTPB2-PERCEIVED NEED TO PAY BONUS,
                                        BASED ON CURRENT COSTS LEVELS.
                                        THIS ACTS COUNTER TO PNTPB2.
A       PNTPB.K=PNTPB1.K*PNTPB2.K
                                        OVERALL PERCEIVED NEED TO PAY BONUS.
                                        PRODUCT OF TWO PREVIOUS MULTIPLIERS.
                                        RESULT IS 0<PNTPB<1.
A       BONSPD.K=TABLE(L5BONT,PNTPB.K,0,1,.2)
T       L5BONT=0/0/1/2/3/4
```

```
A      L5BF.K=TABLE(L5BFT,BONSPD.K,0,4,1)
T      L5BFT=1.2/1.05/.8/.65/.5
A      L5BFAC.K=SMOOTH(L5BF.K,BDT)
                                          BONSPD IS AMT OF BONUSES PAID IN
                                          ANY TIME PERIOD AS A FUNCTION OF
                                          PNTPB ($000).
                                          L5BF IS THE LEVEL 5 BONUS FACTOR
                                          THAT IS MEASURES THE INCREASE OR
                                          DECREASE IN SEPARATION RATE DUE TO
                                          THE EXISTING LEVEL OF BONUS MONEY.
                                          L5BFAC IS THE AVERAGE VALUE OF THE
                                          BONUS FACTOR, SMOOTHED OVER BDT
                                          TIME PERIODS.  THE DELAY REFLECTS
                                          THE AMOUNT OF TIME IT TAKES FOR
                                          A BONUS TO BE REALIZED IN A MEMBERS
                                          PAYCHECK.

A      NRTFAC.K=TABLE(NRTTAB,AVGREM.K,0,5,1)
T      NRTTAB=.5/.8/1/1.1/1.2/1.5
A      ROSFAC.K=TABLE(ROSTAB,AROSPM.K,0,20,2)
T      ROSTAB=.5/.6/.7/.8/1/1.1/1.2/1.4/1.7/1.9/2
A      CTBFAC.K=TABLE(CTBTAB,CTBROS.K,0,4,.5)
T      CTBTAB=2/1.8/1.5/1.25/1/.9/.8/.7/.6
A      DISSAT.K=NRTFAC.K*ROSFAC.K*CTBFAC.K
                                          NRTFAC IS THE COMPONENT OF
                                          DISSATISFACTION BASED ON THE NUMBER
                                          OF REMOTE TOURS A MEMBER HAS HAD.
                                          ROSFAC IS THE COMPONENT OF DISSAT
                                          BASED ON THE REMOTE AND OVERSEAS
                                          TIME THAT A MEMBER HAS SERVED.
                                          CTBFAC IS THE COMPONENT OF DISSAT
                                          BASED ON THE CONUS TIME BETWEEN
                                          REMOTES AND OVERSEAS.
                                          DISSAT IS THE MEASURE OF THE
                                          LEVEL OF DISSATISFACTION.  THE
                                          THREE COMPONENT MULTIPLIERS OF
                                          DISSAT FORM AN AGGREGATE
                                          MULTIPLIER THAT AFFECTS SEPARATION
                                          RATES.  THE MULTIPLIER RANGES FROM
                                          .125 TO 6.

A      L3CFAC.K=TABLE(L3CTAB,L3CPM,5,15,2)
T      L3CTAB=2/1.5/1/.9/.8/.7
A      L5CFAC.K=TABLE(L5CTAB,L5CPM,8,16,2)
T      L5CTAB=2/1.5/1/.9/.8/.75
A      L7CFAC.K=TABLE(L7CTAB,L7CPM,10,18,2)
T      L7CTAB=1.7/1.4/1/.9/.6
A      L9CFAC.K=TABLE(L9CTAB,L9CPM,15,19,1)
T      L9CTAB=2/1.75/1.5/1.2/1
                                          THESE FOUR FACTORS REFLECT A MEMBERS
                                          INCREASED OR DECREASED INCLINATION
                                          TO SEPARATE BASED ON THE EQUITY HE
                                          OR SHE SEES IN PAY LEVEL COMPARED
                                          TO THE CIVILIAN SECTOR.
                                          NOTICE THAT THE INPUT TO THIS FACTOR
                                          IS CURRENTLY A CONSTANT.  THIS
                                          ALLOWS THE ANALYST TO ADJUST THE
                                          LEVELS OF PAY AND STUDY THEIR
                                          AFFECTS ON SEPARATION.  PAY LEVELS
                                          ARE NOT DYNAMICALLY RECOMPUTED.

R      SR3.KL=MIN(SL3.K,NL3SR*DISSAT.K*L3CFAC.K*L5BFAC.K)
R      SR5.KL=MIN(SL5.K,NL5SR*DISSAT.K*L5CFAC.K*(1+L5BFAC.K)*.5)
R      SR7.KL=MIN(SL7.K,NL7SR*DISSAT.K*L7CFAC.K)
R      SR9.KL=MIN(SL9.K,NL9SR*DISSAT.K*L9CFAC.K)
                                          THE SEPARATION RATES FOR EACH LEVEL
```

```
                                    ARE CALCULATED IN THIS SECTION.
                                    THE RATE IS BASED ON AN INCREASE
                                    OR DECREASE FROM AN INITIALLY
                                    DEFINED "NORMAL" SEPARATION RATE.
                                    THE FACTORS THAT ADJUST SEPARATION
                                    ARE THE DISSATISFACTION AND PAY
                                    MULTIPLIERS.  LEVEL 5 IS ALSO
                                    AFFECTED BY THE BONUS MULTIPLIER.

R     L3L5PR.KL=MIN(SL3.K,L5SHRT.K)          THESE ARE THE RATES THAT WILL B
R     L5L7PR.KL=MIN(SL5.K,L7SHRT.K)          USED TO CALCULATE THE DELAYED
R     L7L9PR.KL=MIN(SL7.K,L9SHRT.K)          PROMOTION RATES.  THEY ARE A DI
                                    FUNCTION OF THE SHORTAGES AT THE
                                    HIGHER LEVEL.  THIS CALCULATION OF
                                    RATE REFLECTS THE FACT THAT
                                    SHORTAGES AT HIGHER LEVELS CAUSE
                                    PROMOTION FROM BELOW--A SUCKING UP
                                    EFFECT.

R     L35PRD.KL=DELAYP(L3L5PR.JK,L5AT,L35PQ.K)
R     L57PRD.KL=DELAYP(L5L7PR.JK,L7AT,L57PQ.K)
R     L79PRD.KL=DELAYP(L7L9PR.JK,L9AT,L79PQ.K)
                                    THESE ARE THE DELAYED PROMOTION
                                    RATES.  THE QUANTITIES STILL IN THE
                                    PIPELINE BETWEEN LEVELS ARE LISTED
                                    AS THE FINAL PARAMETER IN THE DELAYP
                                    CALL.  THE DELAY TIMES BETWEEN
                                    LEVELS ARE THE SECOND PARAMETERS.

R     PQ13R.KL=L13PQ.K/DT           THESE ARE THE RATES THAT WILL BE
R     PQ35R.KL=L35PQ.K/DT           USED TO DEFINE THE PIPE QTY LEVEL
R     PQ57R.KL=L57PQ.K/DT           COUNTERS FOR TIME K TO TIME L
R     PQ79R.KL=L79PQ.K/DT           STORAGE.  DIVIDED BY DT SO THAT
                                    WHEN THE LEVEL IS CALCULATED BY
                                    MULTIPLYING DT*RATE, THE UNITS WILL
                                    BE CORRECT.

L     PQ13CT.K(1)=PQ13CT.J(1)+DT*PQ13R.JK
L     PQ35CT.K(1)=PQ35CT.J(1)+DT*PQ35R.JK
L     PQ57CT.K(1)=PQ57CT.J(1)+DT*PQ57R.JK
L     PQ79CT.K(1)=PQ79CT.J(1)+DT*PQ79R.JK
                                    ASSIGNMENT OF CURRENT PIPELINE QTY
                                    TO STORAGE FOR USE IN TIME K.  THE
                                    J VALUES ARE ALL ZERO.  THE VALUE
                                    THAT IS STORED IS THE QTY IN MEN.

L     SL3.K=SL3.J+DT*(L3ARD.JK-SR3.JK-L3L5PR.JK)
L     SL5.K=SL5.J+DT*(L35PRD.JK-SR5.JK-L5L7PR.JK)
L     SL7.K=SL7.J+DT*(L57PRD.JK-SR7.JK-L7L9PR.JK)
L     SL9.K=SL9.J+DT*(L79PRD.JK-SR9.JK)
                                    THE NEW SKILL LEVELS ARE CALCULATED.
                                    THE RATE IS THE DIFFERENCE BETWEEN
                                    DELAYED INFLOW RATES AND THE OUTFLOW
                                    RATES.

R     COSTRT.KL=L3CPM*SL3.K+(L5CPM+(3*BONSPD.K/2)*SRBM/4)*SL5.K+
X        L7CPM*SL7.K+L9CPM*SL9.K+PCSCST*
X        (REMTOC.JK+CTORMD.JK+OSTOC.JK+CTOOSD.JK)
S     COST.K=COSTRT.JK*DT
L     PRVCST.K(1)=PRVCST.J(1)+DT*COSTRT.JK
                                    COSTRT IS THE RATE AT WHICH THE COST
                                    COUNTER IS TO BE INCREMENTED.  THE
                                    UNITS ARE IN $000/TIME.  THE
                                    COMPONENTS ARE THE NUMBER OF MEN IN
                                    EACH LEVEL TIMES THE COST PER MAN
                                    PER UNIT TIME, PLUS THE FREQUENCY
```

```
                                      OF PCS PER MAN TIMES THE COST IN
                                      $000 PER PCS, AND THE COST OF
                                      BONUSES AWARDED TO THOSE IN SL5.
                                      THE SUPPLEMENTARY VARIABLE COST IS
                                      CALCULATED FOR PRINTOUT ONLY.
                                      PRVCST TRACKS THE COST FOR THE
                                      PREVIOUS PERIOD FOR USE IN THE
                                      PERCEIVED NEED TO PAY BONUS
                                      CALCULATIONS.
OPT RF
PRINT OS,REMOTE,CONUS,SR3,SR5,SR7,SR9,ACOSRM,CUMTF,CUMREM
PRINT OSTOC,REMTOC,XTNGAR,L3AR,L3L5PR,L5L7PR,L7L9PR,ACOS,CUMRAT,PNTPB1
PRINT DCTOPQ,DCTRPQ,TSCHAR,L3ARD,L35PRD,L57PRD,L79PRD,ACRM,CUMROS,PNTPB
PRINT CTOSPQ,CTCRPQ,TOTFRC,L13PQ,L35PQ,L57PQ,L79PQ,CTBROS,AROSPM,AVGREM
PRINT CTOOS,CTOREM,TFS,L3SHRT,L5SHRT,L7SHRT,L9SHRT,CTBFAC,ROSFAC,NRTFAC
PRINT CTOOSD,CTORMD,TF,SL3,SL5,SL7,SL9,DISSAT,BONSPD,COST
PRINT L13PQ,L35PQ,L57PQ,L79PQ
PLOT  CONUS=C/OS=O,REQOS=*/REMOTE=R,REQREM=#
PLOT  SL3=3,DL3=A/SL5=5,DL5=B/SL7=7,DL7=C/SL9=9,DL9=D
PLOT  SR3=3,L35PRD=A/SR5=5,L57PRD=B/SR7=7,L79PRD=C/SR9=9
PLOT  REMTOC=1,CTOREM=2,CTORMD=3
PLOT  OSTOC=1,CTOOS=2,CTOOSD=3
SPEC  LENGTH=15,PRTPER=3,PLTPER=.3,DT=.0277
RUN   BASE
```

## Appendix E: Model Initialization

The initialization of model levels must be performed when running the model with alternative AFSC data. The "N" equation is the actual initialization statement. In the documented DYNAMO equations (see Appendix D), the necessary N equations and corresponding constants and tables are listed prior to the first rate equation of the Rotation sector. The level variables for both sectors are discussed here in a general sense.

### Personnel Fill Variables

The actual number of prsonnel in each skill level and the number required in each skill level must be supplied. The variables used for this are SLX and DLX, respectively. (The letter "X" is used in place of skill levels 3, 5, 7, and 9.) The delay time for the third order delay rates from one skill level to the next is specified by LXAT. This "lag time" represents the amount of delay time in years before entering a level. DYNAMO initializes the number of people in the pipeline between levels by taking the product of the non-delayed promotion rate and the corresponding delay time. The user should account for the number in the pipeline by initially assigning a smaller number to the appropriate skill level and by assigning this number to the table variables INIT13, INIT35, INIT57, and INIT79. For example, if the initial number in Skill Level 3 (SL3) was 400, the Level 3 Accession Rate (L3AR) was 100 people per year, and the Level 3 Accession Time (L3AT) was .5, then the number that would be assigned to the pipeline value coming into SL3 would be 50, so INIT13 should also be assigned values of 50 in both positions of the two-word vector. The initial value for SL3 (ISL3) should be assigned the value 350. The total of the numbers assigned to the skill levels should match the total of the numbers assigned in the Rotation levels.

Other important variables that need to be initialized include (1) NLXSR, the normal separation rates in terms of number of people per year, (2) PERIOD, the period of the business cycle assumed (in years), (3) LXCPM, the cost per man for all skill levels in thousands of dollars per year per man for an SRB of 1, and (5) BDT, the Bonus Delay Time in years.

Rotation Variables

The actual number of people initially in the levels OS (overseas long), REMOTE (overseas short), and CONUS (Continental U.S.) must be initialized as well as the required number for REMOTE and OS (REQREM and REQOS,respectively). The tourlengths for overseas long and overseas short tours are assigned to TOUROS and TOUREM, respectively. The pipeline delay time for sending people to the levels OS and REMOTE are LAG1 and LAG2, respectively. These variables should be appropriately set. The number of people in the pipeline that are going to OS and REMOTE from CONUS must be considered in a manner similar to the number of people in the pipelines between levels in the Personnel Fill sector.

# VITA

Kevin Lee Lawson was born on 24 September, 1955 in Jamestown, New York. He graduated from high school in Falconer, New York in 1973 and enlisted in the USAF. He served in the 539 AF Band, Lackland AFB, Texas until entering Southwest Texas State University in August 1976. He received the degree of Bachelor of Science in Mathematics in August 1978. He received a commission in the USAF through the ROTC program in December 1978. He then served as a Laser Systems Analyst in the Air Force Weapons Laboratory, Kirtland AFB, New Mexico until entering the School of Engineering, Air Force Institute of Technology, in July 1981.

Permanent Address: 7200 W. Military Dr., Lot 64
San Antonio, Texas 78227

END