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Design and Development of an Enlisted Force Management System for the Air Force

Warren E. Walker and
The Enlisted Force Management Project Team

PROJECT AIR FORCE

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A Project AIR FORCE Report
prepared for the
United States Air Force

RAND

PREFACE

This report summarizes the design of a new enlisted force management system (EFMS) for the Air Force and describes how that design is being turned into reality. It is the result of an effort begun in July 1981 at the request of the Directorate of Personnel Plans, Office of the Deputy Chief of Staff for Manpower and Personnel (DCS/MP), Headquarters, United States Air Force. At that time RAND was asked to perform a comprehensive review and analysis of the Air Force system for managing the enlisted force, to compare it with the systems used by the other armed services, and to recommend improvements to the Air Force system.

In March 1982, having completed their review and analysis, the RAND project team recommended that the Air Force develop a new, integrated, computer-based decision support system for managing the enlisted force. Subsequently, RAND and the Air Force jointly determined the scope and functions of the EFMS. Then a conceptual design was prepared for the proposed system[1] and a joint RAND/Air Force project, called the Enlisted Force Management Project (EFMP), was begun to build and implement the system. Implementation is still proceeding, but RAND's modeling and database creation activities are practically completed. This report shows how RAND and Air Force researchers on the team carried out the ideas in the conceptual design. It provides an overview of the conceptual design, the models specified, and the databases used by the researchers, and policy insights gained by RAND researchers using prototype versions of the models. It also provides references to other EFMP-produced documents that provide detailed information on these aspects of the project. However, since implementation is still underway, it does not comment on the actual model implementation, which differs from the published specifications in some cases, or on the performance of the system.

The report should be of interest to members of the manpower and personnel communities in all of the military services, particularly their planners and programmers. Much of it will also be of interest to staff members in other government agencies and to those with an interest in the use of computers to support decisionmaking in the public sector.

RAND's work on the EFMP falls within the Resource Management and System Acquisition Program of Project AIR FORCE. The EFMP is part of a larger body of work in that program concerned with the effective utilization of human resources in the Air Force.

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[1]Carter et al. (1983).

SUMMARY

This report describes the concepts underlying the Air Force's Enlisted Force Management System (EFMS), briefly introduces the system's models and databases, and presents some policy insights gained by use of the models. It serves as an overview of RAND's work on the Enlisted Force Management Project (EFMP).

The Air Force's previous system for managing its enlisted force (TOPCAP) was adopted in 1971. At that time it was the most advanced and sophisticated system for managing the enlisted force of all the services. Although TOPCAP served the Air Force well, the environment in which it had to operate changed considerably. TOPCAP's models were not revised to keep pace with these changes, so many fell into disuse.

The overriding objectives in the design of the EFMS were to:

- Improve the effectiveness and efficiency of enlisted force management.
- Place the personnel and manpower managers in more direct control of the information and models.
- Coordinate, integrate, and unify the enlisted force planning and programming system.
- Make the system flexible, adaptable, and easy to maintain.

For purposes of describing the system and explaining its functions, we divide the constituent models in the EFMS into four major sets of computer programs according to their functions. Figure S.1 shows the four sets of models, their interrelationships, and their most important inputs and outputs. The sets are:

- Authorization projection.
- Grade allocation.
- Skills management.
- Aggregate planning, programming, and oversight.

The Authorization Projection Model (APM) is used to predict future enlisted personnel requirements.[1] In particular, it is designed to anticipate the enlisted manpower authorizations that Air Force Major Commands will designate in future years, subdivided by specialty, skill level, and pay grade.

The Grade Allocation Model (GAM) is designed to mediate the conflicting demands of mission requirements and personnel constraints. The personnel constraints are used to adjust the distribution of grades within manpower authorizations in order to produce more achievable targets for the programming activities of the Directorate of Personnel Programs.

The last two sets of computer programs constitute the bulk of the EFMS models and consumed the bulk of the EFMP's effort. The skills management models are concerned with supporting programming decisions related to individual specialties, primarily for a one- or two-year span, but in some cases extending to the last year covered by the Program Objective Memorandum (POM). The aggregate planning, programming, and oversight models are concerned with management of the overall force (usually distinguishing only pay grade and years of service).

These two sets of programs help planners evaluate alternative policies and personnel programmers meet grade plans and manpower targets as they select programs for recruitment,

[1] The Air Force recently changed the name of this model to Authorization Distribution Model (ADM), which better conveys the way it obtains its predictions.

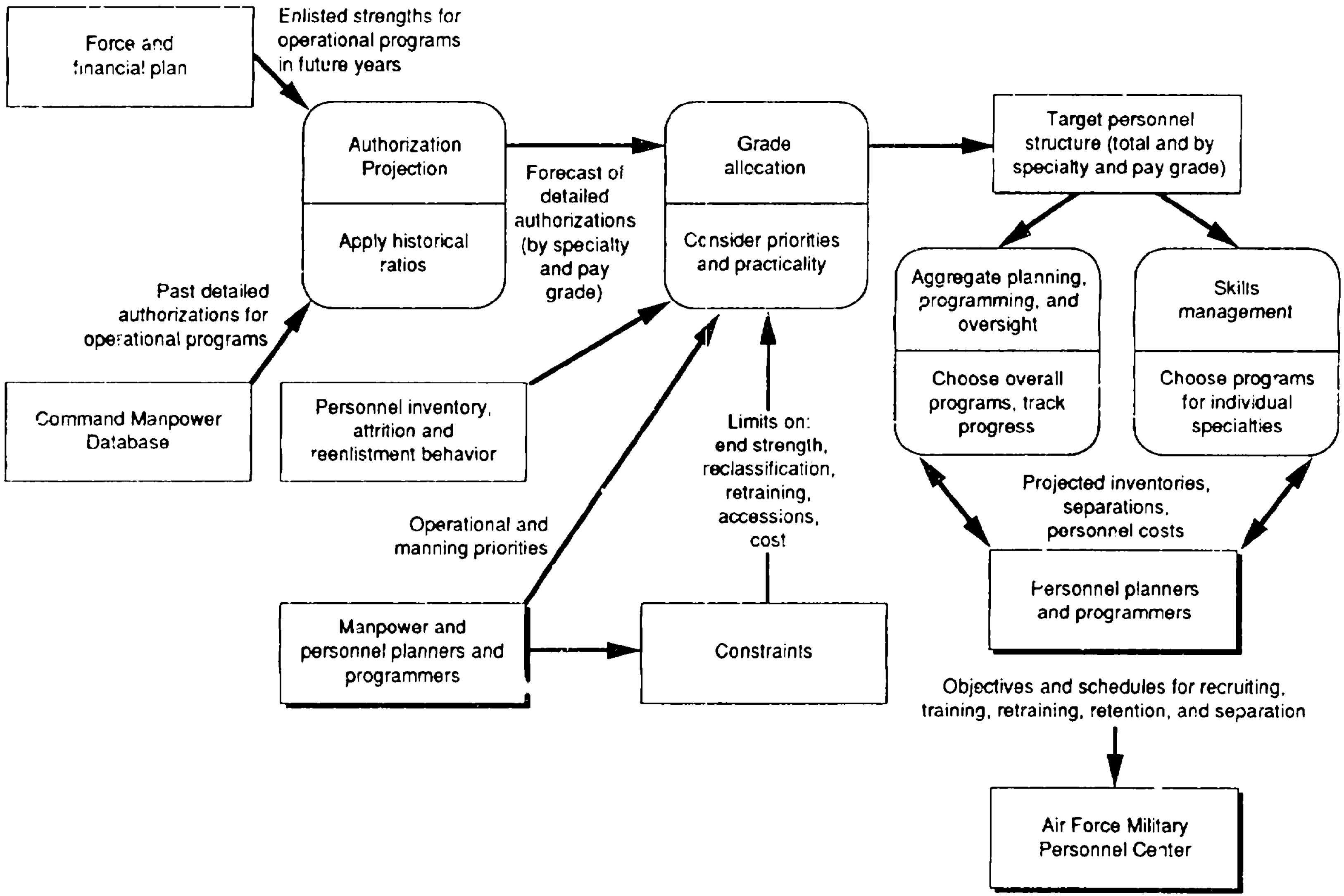

Fig. S.1—EFMS Model interrelationships, inputs, and outputs

training, crosstraining, retention, and separation. The skills management models help consider tradeoffs among various options for meeting targets for individual specialties. The aggregate planning, programming, and oversight models help set targets, track the progress being made toward established targets, warn of projected deviations, and help in choosing programs to correct projected deviations and meet overall grade plans, budgets, and manpower targets.

Each set of models (except the APM) includes at least one model that projects the enlisted inventory into the future. These models, which are called inventory projection models (IPMs), base their projections on predictions of losses of airmen from the force. In TOPCAP, loss predictions were based solely on losses from the enlisted force during the preceding years. The loss models in the EFMS produce loss estimates that depend on assumptions regarding external economic conditions (e.g., civilian unemployment rates), Air Force policies (e.g., changes in bonus levels), and the demographic characteristics of the force.

All of the EFMS models are able to be used in a "gaming" mode, which facilitates examining the effects of varying assumptions about policies, external economic conditions, and the future characteristics of the force. Some of the skills management models are difficult to use in this mode, however, because of the extensive computations and database preparation involved.

The EFMS is being developed and implemented by a joint project team using a staged development and implementation approach. (Staged implementation means that some models were specified and programmed in parallel with others and some were developed sequentially, in priority order.) The project team includes RAND and Air Force analysts directed by a steering committee composed of representatives from RAND and all of the affected Air Force directorates. Responsibility for specific project tasks was assigned to RAND or the Air Force based on comparative advantage. For the most part, RAND's role has been in concept development, model specification, prototype development, and the design and development of analysis databases. The Air Force's role has been in hardware and software procurement, system programming, model test and evaluation, and the design and development of operational databases. Use of a model began whenever a user felt comfortable trying it. At the present time (June 1991), some programs are operational, some have been programmed and are in various stages of test and evaluation, and some have only been specified mathematically and have yet to be programmed. Table S.1 shows the current status of the EFMS models.

The Air Force has established a System Management Office within the Air Force Military Personnel Center that is responsible for programming, documenting, and testing the models, creating and maintaining the database, procuring hardware and software, and supporting the user community.

Table S.1

STATUS OF EFMS MODELS
(June 1991)

Model	Status		
	Specified	Programmed	In Use
Loss Models			
Middle term	x	x	x
Short term	x	x	x
Authorization Management			
Authorization Projection Model	x	x	x
Grade Allocation Model	x		
Skills Management			
Disaggregate Middle-Term IPM	x	x	x
Part-of-the-Force Model	x		
Year-of-Service Target Generator	x	x	x
Bonus Effects Model	x	x	x
Aggregate Lifecycle Effectiveness and Cost Model (ALEC)	x	x	
Systematic Method of Analyzing Retention Tradeoffs Using ALEC	x	x	
Aggregate Planning, Programming, and Oversight			
Short-Term Aggregate IPM	x	x	x
Middle-Term Aggregate IPM	x	x	x
Retirement Policy Analysis Model	x	x	
Aggregate Dynamic Analysis Model (ADAM)	x	x	
Systematic Method of Analyzing Retention Tradeoffs using ADAM	x	x	

ACKNOWLEDGMENTS

The design, development, and implementation of the Enlisted Force Management System (EFMS) has been a joint effort between RAND and the United States Air Force over a ten-year period. At least 100 persons have been directly involved in this effort. In addition, many others in the Air Force and at the Defense Manpower Data Center supplied data, programming support, advice, and information. It is impossible to acknowledge them all, but we would like to acknowledge the major contributions to the effort.

This report was written by only a small subset of the contributors to the project, but many others have made intellectual contributions. Thus, the authors of the report can be said to include all of the persons listed below. These are the members of the Enlisted Force Management Project (EFMP) who have made substantive contributions to the conceptual design of the EFMS, the specification of its models, the development of the databases used to fit the models, and the test and evaluation of its prototype models.

Several of these people also served on the steering committee for the project. In this capacity, they provided guidance and support to the effort and had a major influence on how the EFMS design was turned into reality. Those who were on the steering committee at some time during the course of the project are identified with an asterisk.

In addition to those listed, we would like to thank other RAND colleagues. Project AIR FORCE Program Managers Michael Rich and Charles Kelley provided unwavering support over the years, and Craig Moore and Adele Palmer gave many helpful comments on an earlier draft of this report.

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ACRONYMS

ADAM	Aggregate Dynamic Analysis Model
ADM	Authorization Distribution Model
AFHRL	Air Force Human Resources Laboratory
AFMEA	Air Force Management Engineering Agency
AFMPC	Air Force Military Personnel Center
AFQT	Armed Forces Qualification Test
AFS	Air Force Specialty
AFSC	Air Force Specialty Code
AGL	Airman Gain/Loss (file)
ALEC	Aggregate Lifecycle Effectiveness and Cost (model)
ALPS	Airman Loss Probability System
APM	Authorization Projection Model
ARIMA	Autoregressive Integrated Moving Average
ARL	Airman Reenlistment/Loss (file)
ASKIF	Airman Skill Force (model)
ATC	Air Training Command
BES	Budget Estimate Submission
BEM	Bonus Effects Model
BMT	Basic Military Training
BSP	Benchmark Separation Projection (model)
CAREERS	Career Airman Reenlistment Reservation System
CATENL	Category of Enlistment
CEMPG	Chief Enlisted Manager Progression Group
CFG	Career Field Group
CJR	Career Job Reservation
CMDB	Command Manpower Database (file)
CPG	Career Progression Group
CONUS	Continental United States
DoD	Department of Defense
DOS	Date of Separation
DMDC	Defense Manpower Data Center
DMI	Disaggregate Middle-Term Inventory (Projection Model)
DPP	Directorate of Personnel Programs
DPMDW	Washington Area Personnel Systems Division of MPC
DPX	Directorate of Personnel Plans
DRM	Dynamic Retention Model
EAGL	Enriched Airman Gain/Loss (file)
EFMS	Enlisted Force Management System
ESO	Equal Selection Opportunity
ETS	Expiration of Term of Service
F&FP	Force and Financial Plan (file)

FY	Fiscal Year
FYDP	Future Year Defense Program
GAM	Grade Allocation Model
HYT	High Year of Tenure
IPM	Inventory Projection Model
MAJCOM	Major Command
MAR	Month-at-Risk (computer program)
MDB	Mainframe Data Base (programming language)
MOS	Months Of Service
MPA	Military Personnel Account (costs)
MPC	Military Personnel Center
MTA	Middle-Term Aggregate (inventory projection model)
NCO	Non-commissioned officer
NPS	Non-Prior Service (accession)
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PACE	Processing and Classification of Enlistees (file)
PDGL	Personnel Data Gain/Loss (file)
PE	Prediction error
PEC	Program element code
PEPNR	Prediction error as percent of number at risk
PETS	Prior to Expiration of Term of Service
PMS	Pipeline Management System
POF	Part-Of-the-Force (Inventory Projection Model)
POM	Program Objective Memorandum
PPBS	Planning, Programming, and Budgeting System
PRE	Percent relative error
PRM	Directorate of Manpower and Organization
PROMIS	Procurement Management Information System
PS	Prior Service (accession)
RPAM	Retirement Policy Analysis Model
RTS	Retirement/Separation (date)
SAM	Short-term Aggregate (Inventory Projection) Model
SAS	Statistical Analysis System
SMART-ALEC	Systematic Method for Analyzing Retention Tradeoffs using ALEC (model)
SMO	System Management Office
SPE	Standardized prediction error
SPM	Skills Projection Model
SRB	Selective Reenlistment Bonus
TAFMS	Total Active Federal Military Service
T&E	Test and Evaluation

TFMS	Total Federal Military Service
TIG	Time in Grade
TOE	Term of Enlistment
TOPCAP	Total Objective Plan for Career Airman Personnel
TPR	Trained Personnel Requirements
UAR	Uniform Airman Record (file)
WTPY	Weighted trained-person years
YAR	Year-at-Risk (file)
YETS	Years to expiration of term of service
YOS	Years of Service
YOSTG	Year of Service Target Generator

I. OVERVIEW

ENLISTED FORCE MANAGEMENT

Effective management of its enlisted force is of increasing importance to the Air Force as it tries to carry out its mission in the face of higher costs and constrained budgets. The enlisted component of approximately 415,000 airmen spread over 369 occupations and nine pay grades constitutes over 80 percent of the Air Force's active-duty manpower and accounts for expenditures of more than $13 billion per year. It is a monumental task of planning, programming, budgeting, and managing these resources to provide enough of the right kinds of people in the right grades and occupations in the right places at the right times to carry out the Air Force's missions. Responsibility for this task is shared by the Deputy Chief of Staff for Personnel (AF/DP) and the Deputy Chief of Staff for Programs and Resources (AF/PR), both at Headquarters, United States Air Force.[1]

Management of the enlisted force involves making decisions about force structure, promotion policies, and the procurement, assignment, training, compensation, separation, and retirement of personnel. In 1981, when the Enlisted Force Management Project (EFMP) began, these decisions were being made using tools that had both conceptual and operational shortcomings. The set of models being used was called TOPCAP (Total Objective Plan for Career Airman Personnel). TOPCAP and its shortcomings are discussed further below.

For simplicity, enlisted force management activities can be viewed as beginning with the determination of the manpower ("spaces") needed to accomplish the service's missions and ending with the assignment of personnel to each of the positions ("matching faces to spaces"). Broadly categorized, six sets of activities are included:

- Requirements determination—Determining the numbers and types of manpower most appropriate for carrying out mission objectives, for several years into the future, unconstrained by either manpower budget or the personnel inventory.
- Authorization management—Determining targets for personnel planning, programming, and assignment based on applying constraints (on end strength and budget) to the unconstrained manpower requirements.
- Personnel planning—Determining the policies under which the enlisted force will be recruited, trained, promoted, and separated.
- Personnel programming—Determining the quantity of and schedule for accessions, technical training, reclassification, retraining, bonuses, promotions, reenlistments, and separations. We divide these activities into two groups:
  1. Skills management, focusing on individual specialties.
  2. Aggregate programming and oversight, treating the active duty enlisted force as a whole.
- Personnel requisition, assignment, and training—Recruiting and enlisting airmen, training them for their jobs, and assigning them to authorized positions. These management tasks deal with individual enlisted members rather than with aggregates.

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[1]The names and symbols of the offices involved in enlisted force management that are used in this report are those that were in effect during most of the life of the Enlisted Force Management Project. Recent reorganizations of the Air Staff have changed these names and symbols. However, the functions described are still being carried out.

- Total force planning—Planning for the entire enlisted force, including the Reserves and Air National Guard, as well as for the active force.

The EFMS supports management activities in authorization management, personnel planning, and personnel programming. Although it is technically feasible to develop an integrated system to support all six areas, it is not necessarily worthwhile. Among the many reasons for not including some of these activities within the scope of the Air Force's new EFMS are that some of them are already well supported by existing systems (e.g., personnel requisition and assignment) and the well-known problems of developing and implementing large, multifunction, multiuser distributed data processing systems.

To assure that enlisted force management activities are carried out in a unified and consistent manner, the EFMS includes manual and computer interfaces with other enlisted force management activities. For example, manpower authorizations are one of the system's inputs, trained personnel requirements are an output supplied to the Air Force Military Personnel Center's (AFMPC's) Pipeline Management System, and the AFMPC supplies the system's input that describes the current inventory.

We summarize each of the included activities below and explain how the EFMS supports them. An overview of the major activities involved in enlisted force management, as they were carried out in 1980, is given by Armstrong and Moore (1980). Figure 1 is a summary overview of the enlisted manpower, personnel, and training system.

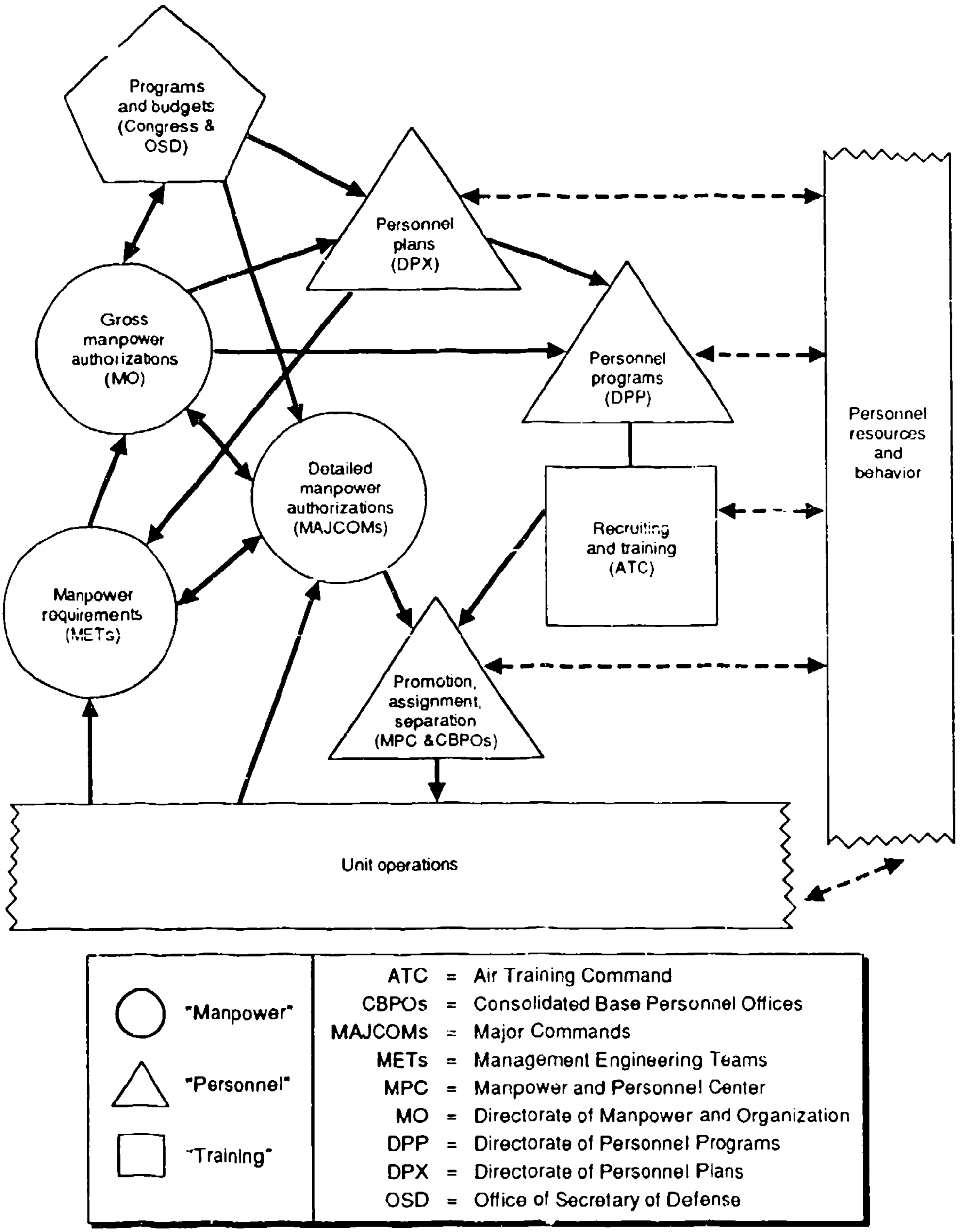
Authorization Management

Authorizations—which result from applying constraints derived from funding, end strength, and grade strength ceilings to the unconstrained manpower requirements—ultimately specify the allocation of manpower at the level of command, base, unit, occupational specialty, skill level, and pay grade. They are the targets for the personnel planning, programming, and assignment systems.

During the Planning, Programming, and Budgeting (PPB) process, the unconstrained manpower requirements are constrained to fit within fiscal and end-strength limits placed on the Air Force by Congress, the Office of the Secretary of Defense (OSD), and the Office of Management and Budget (OMB). Among the outputs from this process are the funded levels of manpower authorized by command, program element, and labor type (officers, enlisteds, and civilians). The detailed distribution of funded manpower to units by Air Force Specialty Code (AFSC) and grade is determined by the major commands (MAJCOMs) under broad allocation constraints determined by AF/PRM. The EFMS uses an Authorization Projection Model (APM) to give personnel planners and programmers information about expected skill and grade allocations by AFSC before MAJCOM decisions are available. The Air Force (not RAND) specified and developed the APM. Therefore, it is described in less detail than other models in this report.[2]

The Air Force does not routinely consider the personnel inventory when setting authorizations. Therefore, authorizations in some specialties have had grade structures that could never be realized without crosstraining persons from other specialties. The Air Force Directorate of Manpower Plans and Programs performs a "grade allocation" that develops a distribution of grades for each specialty annually. MAJCOMs use these allocations in setting grades on their authorizations. This effort is designed to decrease the amount of crosstraining required to fill the authorizations and to increase the experience and skills of the resulting

[2]Further information on the APM is available in Air Force Military Personnel Center (1987).



SOURCE: Based on Armstrong and Moore (1980).

Fig. 1—Summary: USAF enlisted manpower, personnel, and training system

inventory. The EFMS includes a set of modules that supports this effort and improves on the way it had been done previously.

Personnel Planning

We define personnel planning as the set of activities that determines the policies under which the enlisted force will be recruited, trained, promoted, and separated. Our distinction between personnel planning and personnel programming relates primarily to the level of detail of policy specification rather than to organizational arrangement.[3]

One of the major tasks of personnel planning is to choose a target force structure, including its composition by grade, year of service, and (sometimes) occupational specialty. (The target may vary over time.) Personnel programmers then use this target force to choose time-phased programs to control flows into, within, and out of the personnel inventory. The EFMS was to have included a planning model called the "Grade Profile Generator" to help the personnel planners establish force structure targets. However, the Air Force requested that development of this model be delayed until higher priority portions of the EFMS were completed. The EFMS includes several models that can be used to evaluate target force structures. But the target force to be used by programmers is initially being built by DPMDW using the APM and the Year-of-Service Target Generator.

Personnel Programming

We define personnel programming[4] as the set of activities that determine the quantities of and schedules for:

1. Accessions (which include non-prior service (NPS) and prior service (PS)).
2. Initial training (which includes Basic Military Training (BMT) and technical training).
3. Reclassification (of occupational specialty).
4. Retraining (from one occupational specialty to another).
5. Bonuses.
6. Promotions.
7. Reenlistments.
8. Separations (including retirements).

Except for technical training, these need to be determined for each grade and year of service within each occupational specialty. The models for personnel programming are the key components of the EFMS.

Planning and programming overlap somewhat in the realm of decisions regarding accessions, promotions, reenlistments, and separations. Part of our distinction between planning and programming lies in the responsibility of programmers for occupational specialty detail. The rest lies in the time frame and in the specificity of particular numbers.

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[3]In particular, it does not perfectly match the activities carried out by the Air Force Directorate of Personnel Plans (DPX). In our definition, *planning* is responsible for policy guidance (usually at the total force level—e.g., prescribing objectives for the experience mix and overall promotion opportunity), and *programming* is responsible for the translation of the guidance into detailed personnel programs and schedules (e.g., concerning recruiting and retention) for each occupational field and grade. Planning is usually concerned with a longer time frame than programming.

[4]The Air Force defines personnel programming more broadly as the projection and management of enlisted force structure and costs in accordance with law, Congressional guidance, and policies of the Air Force, OSD, and the President.

Detailed inventory projection models (both aggregate and disaggregate) are at the heart of the personnel programming portion of the EFMS. The gap between the total number of enlisted personnel in the projected inventory and in either the authorizations or target force helps to define goals for gaining and losing personnel. At the occupation-specific level, a comparison of projected inventories with targets may show the need to change bonus levels or retrain part of the force.

The inventory projection models depend on predictions of reenlistment and loss rates, which are subject to considerable uncertainty (see, for example, Hall and Moore, 1982). As inventory is monitored during the year, the original projections inevitably turn out to be somewhat wrong, and adjustments in personnel programs (e.g., for early outs or accessions) must be made during the operating year. Because the programmer's options are limited by the short time horizon, the final program decisions may be inefficient compared with the decisions that would have been made if more accurate loss predictions had been available. The EFMP devoted considerable effort to developing models that produced good predictions of reenlistments and losses. The models include the effects of changes in the environment (such as different bonus levels), so users can evaluate the effect of programs under different assumptions about the future.

Many of the inventory control mechanisms used by personnel programmers have similar purposes and can be considered as tradeoffs (although the Air Force rarely performs such tradeoff analyses). For example, one could increase the number of trained personnel that will be available a year from now in a particular specialty by increasing the reenlistment bonus, by retraining people from other specialties, or by recruiting civilians who have prior military experience in the specialty (PS accessions). Because these programs have different costs and effects, there may be an opportunity to find a better way to meet inventory targets. Several EFMS models facilitate such analyses.

THE LIFE CYCLE OF AN AIRMAN

In order to understand the structure, concepts, and models of the EFMS, it is helpful to have a general knowledge of the life cycle of an airman, from when he enters the force until he retires. The following is a broad overview, which is true for most but not all airmen.

Non-prior service accessions sign an enlistment contract of four, five, or six years, which defines their first term of service. Their expiration of term of service (ETS) is the date they report for duty plus the length of their enlistment contract. Virtually all NPS accessions go through basic military training (BMT), which lasts about six weeks. (The exceptions are reservists who enlist in the active force.) Formal technical training follows BMT. Some skills receive no technical training (they are trained on the job), while the technical training for others takes more than a year.

Each enlistee has a five-digit Air Force Specialty Code (AFSC), which designates the job the airman is trained to do, with the fourth digit representing the skill level (1, 3, 5, 7, 9, and 0). An airman's pay is based on his grade. The grades are E-1 through E-9, with E-5 through E-9 being non-commissioned officer (NCO) grades.

For promotion to any NCO grade, a minimum time in service (TIS) and time in grade (TIG) are required. For every grade there is also a maximum time in service, called the high year of tenure (HYT). The range between the minimum and maximum TIS is called the promotion zone.

Airmen who leave the service before their ETS are classified under the general categories of attrition losses or early releases. Attrition includes such separation reasons as disability, hardship (including pregnancy), quality (e.g., poor performance in BMT), and death.

Three Air Force personnel programs release airmen before the end of their obligated term of service:

- Palace Chase: early release for the purpose of joining the Air Reserve Force.
- Early Out: early release during a fiscal year of airmen who otherwise would have left the next fiscal year, for the purpose of reducing the earlier year's end strength.
- Rollup: early release during a fiscal year of people who otherwise would have left in a later month during the same fiscal year, for the purpose of reducing total personnel costs in the year.

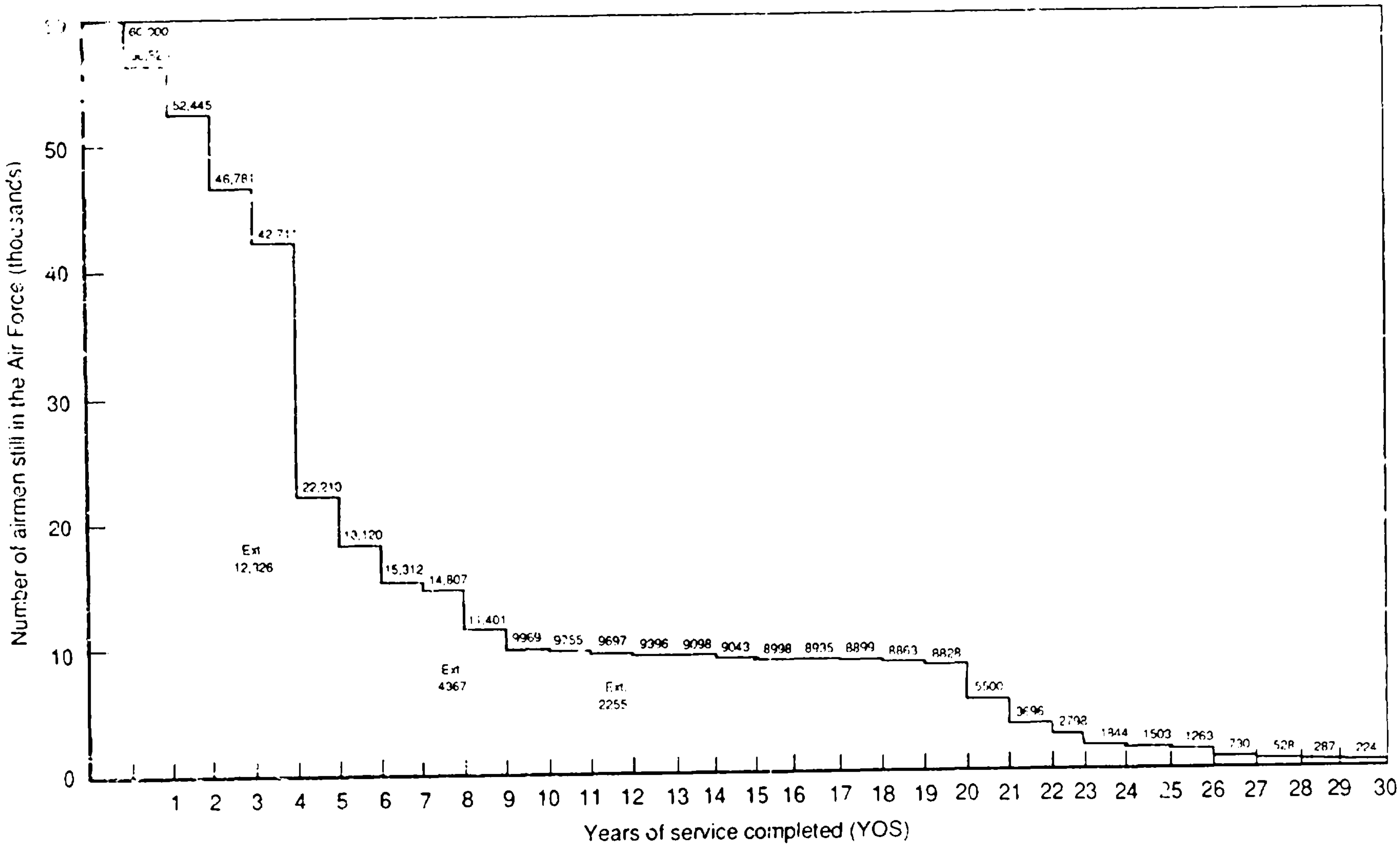
As an airman approaches his ETS, he has several choices. He can choose to leave the service. (This is a loss to the Air Force called an ETS loss.) He may ask to extend his term of service. Airmen are permitted to extend for a variety of reasons. Most extensions are made to increase retainability, to permit the airman to retrain (into a new AFSC), accept a Permanent Change of Station (PCS) move, or assume a grade of E-7 or higher. Airmen are sometimes allowed to extend for personal reasons, although the Air Force has tightened or loosened this policy to adjust to changing retention rates. When an airman extends, his new decision point changes from the ETS date to a date of separation (DOS), which is calculated from the length of his extension.

An airman can also ask to reenlist. This request is routinely granted to airmen in their second and later terms of service. However, the Air Force has quotas (called Career Job Reservations or CJRs) for first termers who wish to reenlist in a given AFSC. If a CJR is not available in his specialty, the airman might be allowed (or even encouraged) to retrain into a specialty for which a CJR is available and for which he qualifies. The CJR system gives enlisted force managers a way to shape the force or to meet end strength or budget constraints.

To stay in the force, airmen must continue the process of extending their contracts and/or reenlisting. In the EFMS, the force is divided into four categories of enlistment:

- First term.
- Second term (reenlisted once).
- Career (reenlisted more than once but is not yet eligible for retirement).
- Retirement eligible (airmen are eligible to retire and receive retirement benefits after 20 years of service).

To summarize the life cycle behaviors suggested above, Fig. 2 shows the pattern of losses for a representative cohort of 60,000 four-year enlistees who enter the service together. The abscissa of the figure is the number of full years of service (YOS) an airman in the cohort has already completed in the Air Force. Thus, an airman's first year of service is YOS 0, his second year of service is YOS 1, etc. For simplicity, the figure assumes that all reenlistments are for four-year terms, which include as part of the four years any period of extended service in the previous term. Nearly three-quarters of the airmen leave the service before the end of their second term, and more than half of these losses occur right at the end of the first term. In relative terms, losses at the end of the second term and at the 20-year point (first opportunity for retirement) are also especially large, with nearly a third of the airmen reaching each of these decision points choosing to leave the service.



SOURCE: Carter et al., 1987.

Fig. 2—Progression of a representative cohort of 60,000 four-year enlistees

TOTAL OBJECTIVE PLAN FOR CAREER AIRMAN PERSONNEL (TOPCAP)

TOPCAP, approved by OSD in May 1971, was the first comprehensive computerized system for supporting enlisted force planning and programming activities of any of the uniformed services. TOPCAP is both a management philosophy and a set of computerized management models translating that philosophy into practice. Under the EFMS, most elements of the TOPCAP philosophy remain, but the models are changed.

One of the key elements of the TOPCAP philosophy is a visible, stable career progression system. Until 1981 the system provided for equal selection opportunity (ESO) in all specialties. That is, the probability of being promoted out of a given grade would be identical in all specialties and independent of the grade authorizations in individual specialties. Promotion zones were established for each grade, and promotion rates were calculated and published. An HYT policy (specifying the last year of service an airman is permitted to remain on active duty in a grade) was established for grades E-5 and higher. In October 1981, ESO was modified to allow faster promotion rates in some critical skills—a "two-tier" promotion policy (because different ESO objectives were established for two subdivisions of all specialties).

TOPCAP includes two mechanisms for controlling the workforce structure across occupations: quotas for entering the career force (consisting of airmen beyond their first reenlistment) in each specialty, and centralized retraining. In the early years of TOPCAP, retraining was voluntary. But different specialties have developed overages and shortages over time, requiring implementation of more aggressive retraining programs.

TOPCAP was designed for conditions of stability, but the environment in which it had to operate changed considerably after its implementation in 1971. The political environment saw a change from Air Force enlistments in the face of conscription for the Army to enlistments into an All Volunteer Force for all the services. The previously stable economic environment was rocked by wide variations in unemployment rates and inflation. The technological environment saw spectacular gains in raw computing power and the widespread introduction of microcomputers.

The TOPCAP models and their operational environment did not change with the times, leading to the need for a new system of models. For example, our examination of the system as it was operating in 1982 revealed the following problems:

- *Multiple Computers.* The TOPCAP models were spread over three geographically dispersed computer systems,[5] with no direct (computer-to-computer) links. This led to time delays and database management problems.
- *Lack of System Integration and Consistency.* The data and assumptions were different in the different models.
- *Time Delays.* The information flows and data management procedures in TOPCAP often resulted in long time delays.
- *Focus on Career Force.* TOPCAP was essentially a plan for management of the career enlisted force. It was designed primarily to maintain promotion flow in grades E-4 through E-9. However, many personnel plans, policies, and problems center around the initial procurement and management of the first-term force, and individuals in this category make up almost half of the total force.

[5] The computers were located in the Pentagon, at Randolph Air Force Base (San Antonio, Texas), and at the San Antonio Data Services Center (San Antonio, Texas).

- *Inadequate Attention to Personnel Costs.* Practically none of the TOPCAP models considered personnel costs.
- *Focus on Steady State "Objective" Force.* The TOPCAP models supported the design of policies and programs to sustain an objective (long-run target) force and ignored dynamic changes in the short and middle term.
- *Future Loss Rates Based Solely on Past Rates.* The TOPCAP models implicitly assumed that future loss patterns would be the same as the patterns during the past few years. The system included no routinely used models for predicting the effects of policy changes or the effect of external conditions on loss rates. Loss rates depend on such things as basic compensation, bonuses, promotion opportunities, retirement options, and civilian opportunities. The TOPCAP models could not help the analyst assess, for example, the effects of a change in bonuses on loss rates
- *Little Documentation and Maintenance.* Documentation of the TOPCAP models was largely absent; no central group was responsible for maintaining all of the models. As a result, the models were rarely updated to reflect changed situations, and their users poorly understood them.
- *Limited Gaming Capabilities.* One of the most important activities of personnel planners and programmers is to examine the implications of alternative parameters and policies. However, many of the TOPCAP models were difficult to use in this manner.

In 1981, the Air Force's Deputy Chief of Staff for Manpower and Personnel asked RAND to take a fresh look at the Air Force's approach to enlisted force management and to provide a conceptual and mathematical design for a new Enlisted Force Management System that would overcome the deficiencies and enhance the capabilities of TOPCAP.

THE ENLISTED FORCE MANAGEMENT PROJECT

Between 1981 and 1983, RAND worked jointly with the Air Staff to determine the scope and functions that should be included in a new Enlisted Force Management System. The approach to this task involved the following steps:

- Specifying all activities related to management of the enlisted force.
- Reviewing the methods used by the various armed services to accomplish these activities.
- Identifying the scope of activities that the EFMS would support.
- Developing the conceptual design for an EFMS (presented in Carter et al., 1983).

The Air Force approved the conceptual design for the EFMS in 1983. A joint RAND/Air Force effort to develop the system was then begun. In addition to RAND staff, the project team has included Air Force analysts from DPP, DPX, DPMDW, DPMYA, and PRM.[6]

Overall control and direction of the project was provided by a steering committee composed of representatives from the participating organizations. The steering committee included the two team leaders. Meetings of the steering committee were generally held quarterly.

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[6]The RAND project team was led by Warren Walker. The Air Force project team was led by COL Robert Walker (until July 1988) and COL James Sampson (after July 1988)

Although work was often performed jointly, there was a clear division of responsibility and differentiation of roles between RAND and the Air Force. Tasks were assigned to one or the other based on comparative advantage. In most cases, responsibility for a task was assigned to one of the two partners, but the other partner provided assistance in carrying out the task. In general, RAND was responsible for developing the conceptual and mathematical specification for the system's modules, and the Air Force was responsible for transforming those specifications into operational programs, validating the models, and implementing and maintaining them.

In particular, RAND's major roles and responsibilities were to:

- Develop a conceptual design for the EFMS.
- Develop the mathematical specification of the models.
- Create data files to facilitate designing, building, and testing the models.
- Refine the mathematical specification of the models as needed during the testing and implementation phases.
- Provide system programmers with advice on input formats and output reports.
- Provide advice on desirable hardware capabilities.
- Help the Air Force to implement the system and set up procedures for operating and maintaining it.

The roles and responsibilities of the Air Force were to:

- Identify the specific needs of the various users of the system.
- Choose the system's hardware and software.
- Provide advice on the mathematical specification of the models.
- Help design the input and output screens for the models.
- Supply source data to RAND for building analysis files.
- Program the system's models.
- Build the system's database.
- Test, evaluate, and validate the models.
- Document the system's programs.
- Train the system's users.
- Maintain and update the system.

Figure 3 traces the history of the EFMP from FY 1981 through FY 1989. It highlights how the composition of the joint project team changed over time. The early years (1981-1985) were primarily devoted to conceptual design and model development. RAND expended considerably more manpower resources than the Air Force during these years. In 1986, the emphasis shifted toward implementation, and the Air Force began to expend considerably more manpower resources than RAND (implementation is very labor-intensive).

THE ENLISTED FORCE MANAGEMENT SYSTEM

The EFMS is a computer-based system whose purpose is to improve the effectiveness and efficiency of the efforts of the Air Staff members engaged in managing the enlisted force in carrying out their decisionmaking and information processing responsibilities. The objective in managing the enlisted force is to provide a group of airmen that is best able to support Air Force missions and operational programs within fiscal and end strength constraints. This is an

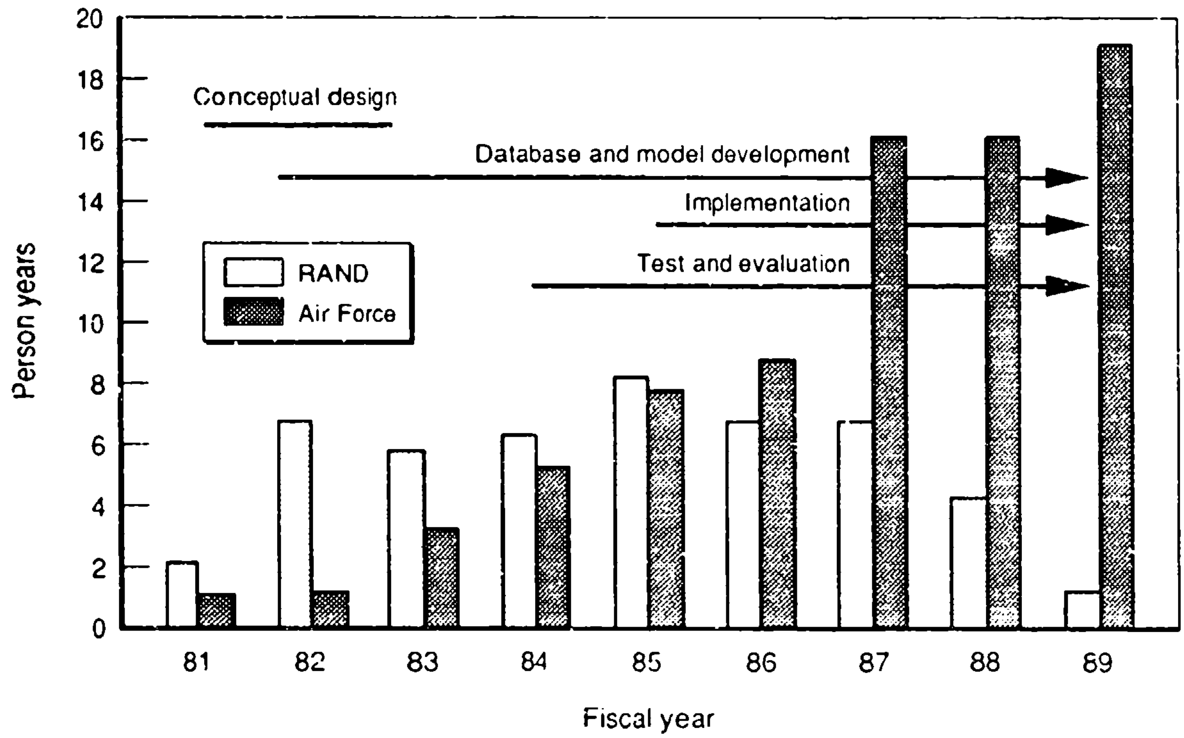


Fig. 3—Size of the EFMP team over time

iterative, continuous task, since the Air Force's needs and resources change in response to Congressional, Presidential, and OSD decisions, decisions by the Air Force, and exogenous labor market forces. The task is becoming increasingly difficult as the technology of weapon systems becomes more sophisticated and as budget pressures force the Air Force to a smaller enlisted force.

The Air Force breaks the tasks related to enlisted force management into three functional areas: *manpower*, associated with determining manpower requirements and allocating the authorizations funded through the PPBS process; *personnel*, associated with managing personnel in the organization; and *training*, associated with properly training (or retraining) Air Force personnel. The manpower functions at the Air Staff level are the responsibility of the Directorate of Manpower and Organization (PRM). Policymaking with respect to personnel planning and programming is carried out by both the Directorate of Personnel Plans (DPX) and the Directorate of Personnel Programs (DPP). Implementation of these plans and programs is the responsibility of the Air Force Military Personnel Center (AFMPC). Most of the formal military and technical training is provided by the Air Training Command (ATC). The roles and interactions among these organizations, as they existed in 1980, are documented in Armstrong and Moore (1980). The current roles and interactions under the EFMS were summarized in Fig. 1.

The EFMS is designed to support many of the functions related to the enlisted force that are carried out by PRM, DPX, and DPP. Data exchanges between the EFMS and the computer systems used by PRM, AFMPC, and ATC permit the EFMS to obtain inputs from these systems and to supply information to them.

Figure 4 is a simplified flowchart showing the four major sets of models in the EFMS, their interrelationships, and their most important inputs and outputs. The sets are:

- Authorization projection.
- Grade allocation.
- Aggregrate planning, programming, and oversight.
- Skills management.

The Authorization Projection Model is used to predict future enlisted personnel requirements. In particular, it is designed to anticipate the enlisted manpower authorizations that Air Force Major Commands will designate in future years, subdivided by specialty, skill level, and pay grade.

The Grade Allocation Model is designed to mediate the conflicting demands of mission requirements and personnel constraints. The personnel constraints are used to adjust the distribution of grades within manpower authorizations in order to produce more achievable targets for the programming activities of the Directorate of Personnel Programs.

The last two sets of computer programs constitute the bulk of the EFMS models and consumed the bulk of the EFMP's effort. The models in each of these sets can be divided into two categories: screening and impact assessment. Screening models are generally designed for rapid comparison of many alternative plans or programs using summary or approximate measures of performance. Impact assessment models are used when more detailed or more accurate calculations are required. The impact assessment models form the core of the current implementation of the EFMS. These models reside on the EFMS's mainframe and workstation computers. Their databases reside on the mainframe computers. Most are programmed in the system's DSS Generator language EXPRESS. Users at microcomputer workstations have access to these models and their databases, but they are often run on the mainframe. Output reports are displayed at the user's workstation. The databases are centrally updated and maintained by the System Management Office (SMO) at Bolling Air Force Base.

Most of the screening models are microcomputer models that are installed on the microcomputer workstations of their users. They do not reside on the mainframe computer and many are not programmed in EXPRESS.

Figure 5 shows the skills management models in the EFMS, and their most important inputs and outputs. The models are:

Impact Assessment

- Disaggregate Middle-Term Inventory Projection Model (DMI).
- Part-of-the-Force Inventory Projection Model (POF).
- Year-of-Service Target Generator (YOSTG).

Screening

- Bonus Effects Model (BEM).
- Aggregate Lifecycle Effectiveness and Cost Model (ALEC).
- Systematic Method of Analyzing Retention Tradeoffs using ALEC model (SMART-ALEC).

Figure 6 shows the aggregate planning, programming, and oversight models in the EFMS, and their most important inputs and outputs. The models are:

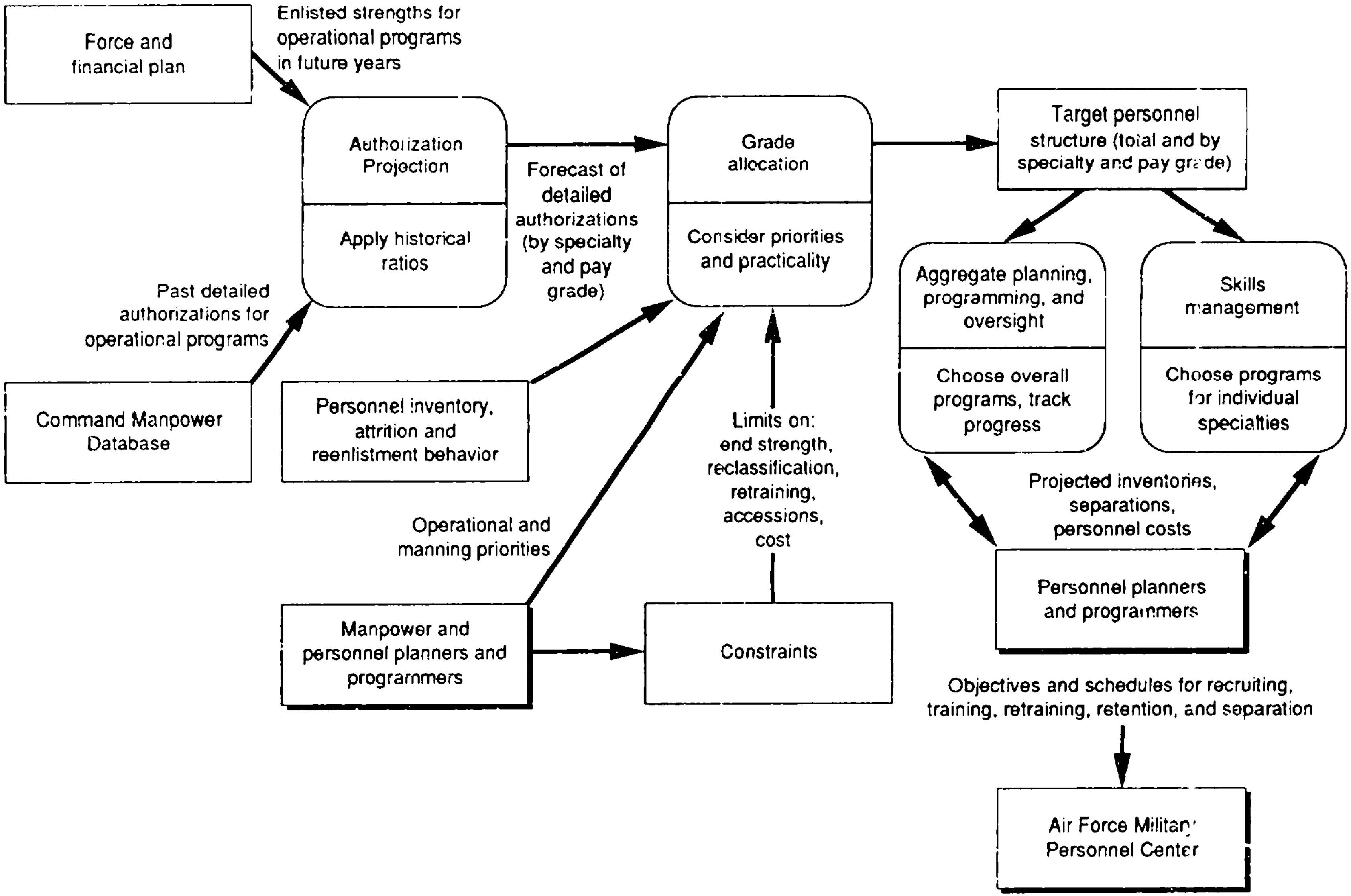
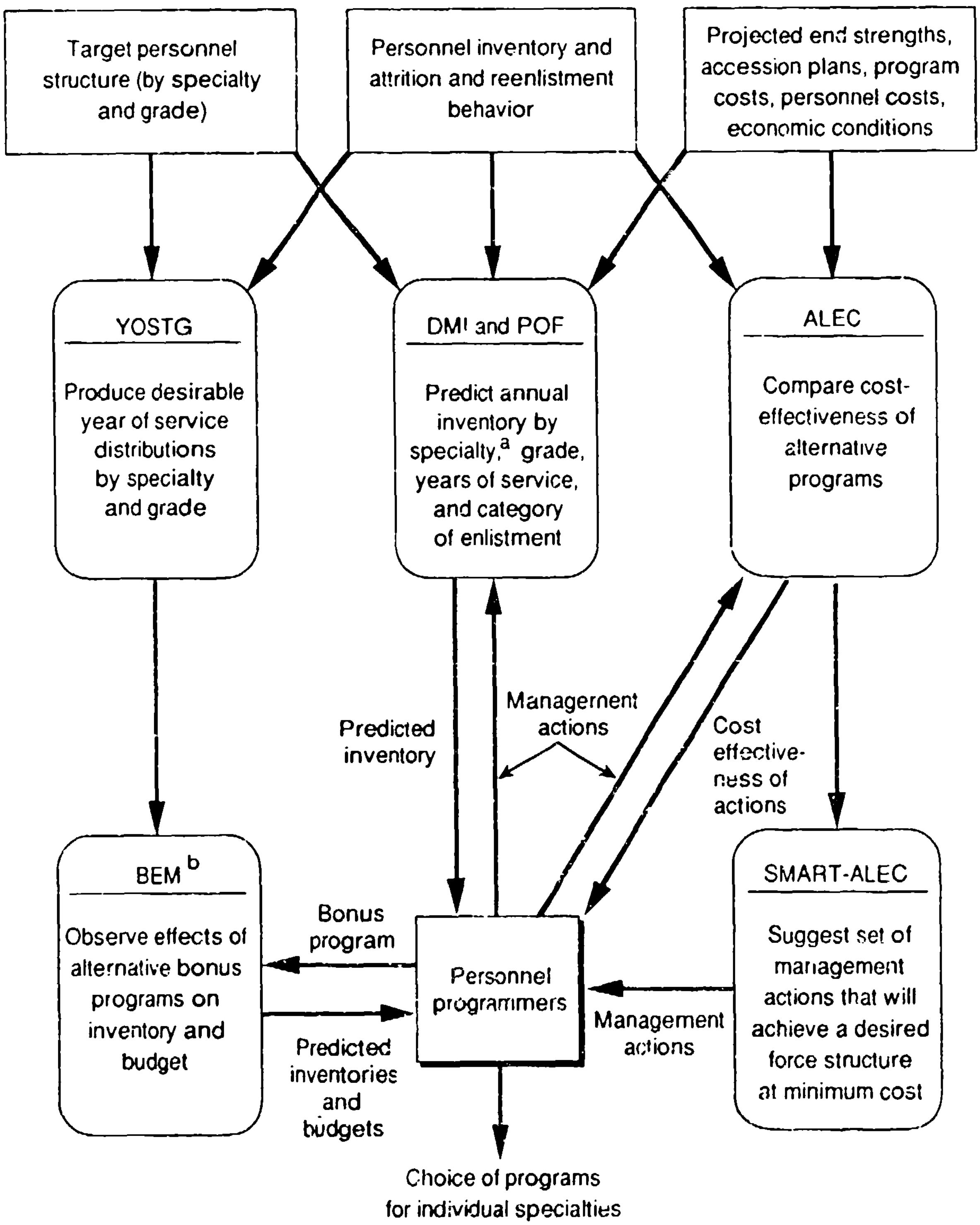
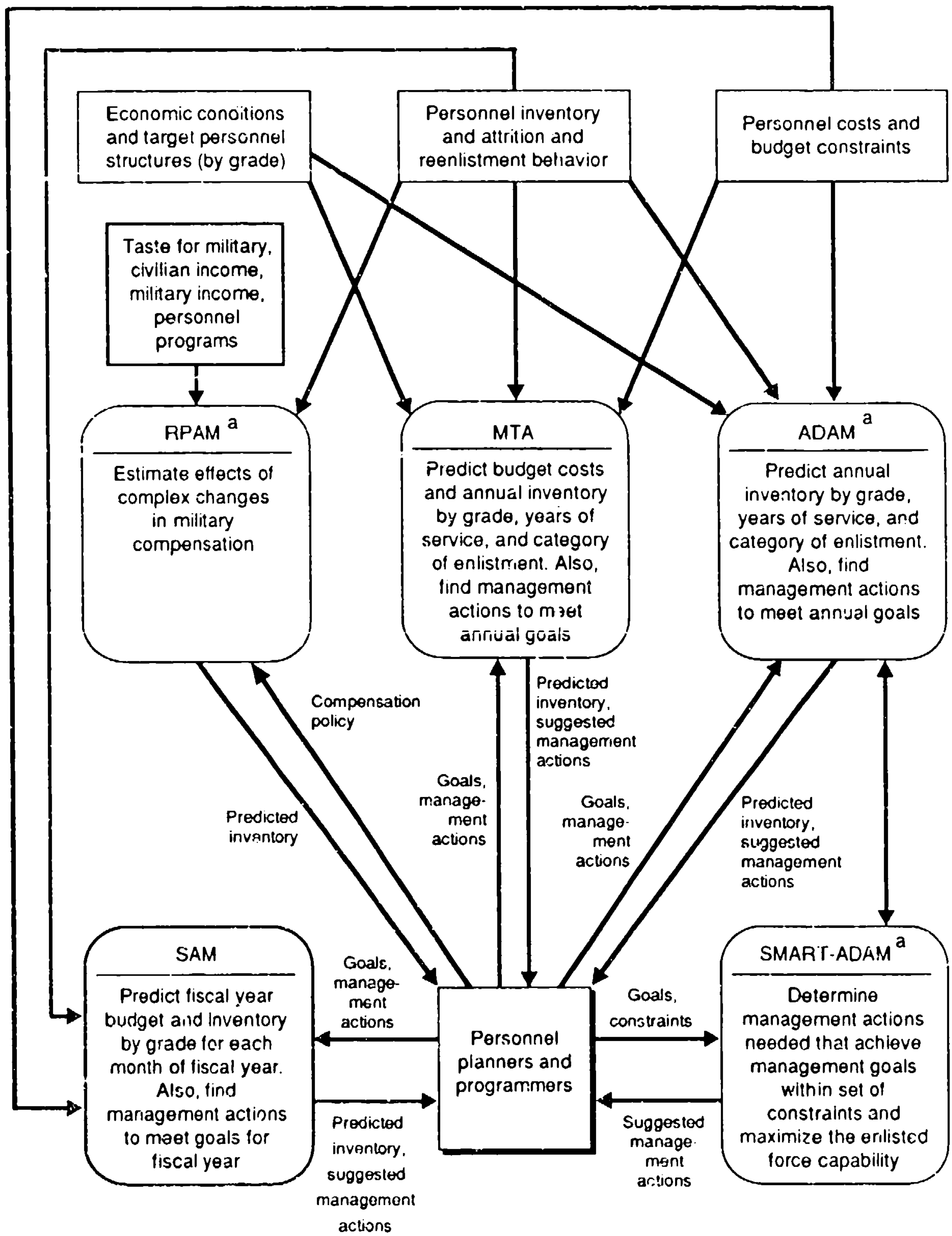


Fig. 4—EFMS Model interrelationships, inputs, and outputs



[a] The POF predicts the inventory for a group of specialties.
[b] Screening model.

Fig. 5—Skills management models in the EFMS



[a] Screening model.

Fig. 6—Aggregate planning, programming, and oversight models in the EFMS

Impact Assessment

- Short-Term Aggregate Inventory Projection Model (SAM).
- Middle-Term Aggregate Inventory Projection Model (MTA).

Screening

- Retirement Policy Analysis Model (RPAM).
- Aggregate Dynamic Analysis Model (ADAM).
- Systematic Method of Analyzing Retention Tradeoffs using ADAM model (SMART-ADAM).

The data files for the models include three types of data:

- Output from another EFMS model (e.g. output from the APM is one of the inputs to the GAM).
- Data supplied by other Air Force functions (e.g., information on the current airman inventory comes from MPC).
- External data (e.g. projected unemployment rates).

The major set of inputs to the system are projected end strengths and counts of funded authorizations distinguished by AFSC and required grade (called "authorizations unconstrained by grade") for Y years into the future (usually for the operating year, budget year, and the six years of the POM).[7] Another major set of inputs is a description of the current inventory (extracted from the Uniform Airman Records maintained by AFMPC) and recent actual experience (e.g., personnel loss and reenlistment rates). Other inputs needed by one or more of the system's models include program costs (e.g., training costs), manpower cost factors, and budget and end-strength constraints.

The appendix provides some illustrative examples of policy analyses that have been performed by RAND and by the Air Force using some of the models.

[7]Manpower requirements are generated by the MAJCOMs using engineered standards, statistical standards, and guides developed by the Air Force Management Engineering Agency (AFMEA). These requirements aggregrated over all AFSCs usually fail to meet the Air Force's grade-strength ceilings. Thus, although the grades in these authorizations are called "required," they have not yet been subjected to grade-strength constraints. The Air Force uses a process called "grade restructuring" to develop a constrained distribution of grades for each specialty.

II. PRINCIPLES FOR DESIGN AND DEVELOPMENT OF THE EFMS

DESIGN PRINCIPLES

Four overall principles guided the design of the EFMS:

1. Improve the effectiveness and efficiency of enlisted force management.
2. Place the personnel and manpower managers in more direct control of the information and models.
3. Coordinate, integrate, and unify the enlisted force planning and programming system.
4. Make the system flexible, adaptable, easy to build, and easy to maintain.

One way to operationalize these principles was to make the EFMS a decision support system (DSS) (Turban, 1988) and to base its design and development on principles that have appeared in the DSS literature (see, for example, Sprague and Carlson, 1982). In fact, we extended these principles to cover a new type of DSS, which has come to be called an organizational decision support system (ODSS).

Although there is no agreement on the definition of an ODSS, we use the term to refer to a DSS that is used by persons at several workstations in more than one organizational unit who make varied (interrelated but independent) decisions using a common set of tools. (See Walker, 1989, for a description of ODSSs and how they differ from traditional DSSs.) The basic paradigm for an ODSS includes four major components:

- Model base (and model management system).
- Database (and database management system).
- User interface (a dialog system that manages the interaction between the user and the previous two components).
- Interactive computer workstations.

The relationships among these four components in the context of the EFMS are depicted in Fig. 7. The remainder of this subsection provides an overview of the system's conceptual design. (See Carter et al., 1983, for further details.) As happens in translating concepts into real-world systems, various aspects of the conceptual design have been changed. Some of the changes were made to improve the system, some were forced by technological developments, and some were forced by resource and time constraints.

The EFMS was designed around the enlisted force managers and analysts in the manpower and personnel community, and it was designed to be responsive to their needs. As shown in Fig. 7, the end user, not personnel in a management information system support function, was to be at the controls of the EFMS. The design specified that, through a command language, the user would interact with both the database and the system's models. The command language would provide a common interface for all of the system's elements; that is, dialogs would be managed in a uniform fashion regardless of the model being run. Of course,

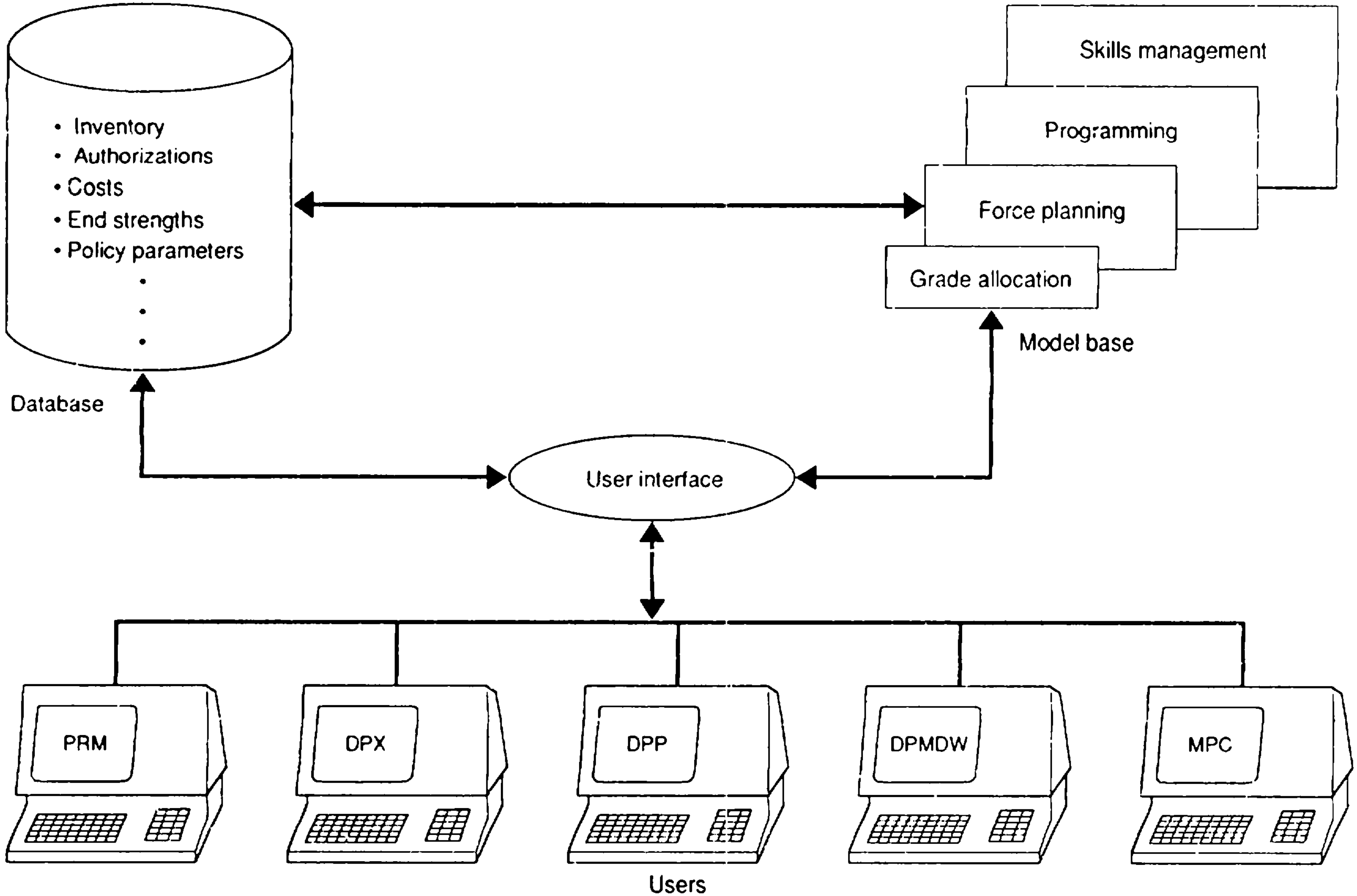


Fig. 7—Major elements of the EFMS

each model would have different specific input and output screens, but each would enable the user to do the same types of things in the same ways. Because the user is typically not a computer programmer, the command language was to be human-oriented instead of computer-oriented. It was also to be menu-driven and easy to use. Depending on the user and the model, the system was to allow the user to:

- Change information in the database.
- Specify parameters and input data for a model.
- Run a model.
- Specify output requirements (e.g., level of aggregation, time period covered).

In this man-machine system, the machine was to act as man's servant. If the user did not desire to adjust parameter values or specify new input data, the system would supply default values. However, the user could override many of the default values. In addition to the official common database, each user was to have his own working storage area in which he could store test data, data that reflect hypothetical situations, or data that refer to policies being evaluated. The design of the system was to include security and monitoring procedures to insure the integrity of the database, prevent users from making unauthorized changes, and allow specific users to have access to appropriate portions of the database.

The database was to retain all relevant information for reports, inquiries, and input to models in an organized, systematic manner. This would facilitate coordination and help provide consistency throughout the system. Information generated by one model would be able to be made instantly available to other models requiring that information. Data both internal (e.g., the inventory of airmen) and external (e.g., data on the U.S. economy) to the Air Force were to be included. The system did not need to have a single, unified, integrated database. But database administration was to be centralized, and the responsibility for updating and maintaining each item of information was to be assigned.

Each of the models of the EFMS was to be designed for a fairly narrow purpose. This modular approach to modeling is attractive for a variety of reasons. In addition to reducing the problems and risks inherent in building a single large model, it provides flexibility and convenience. It also makes it quite easy to adapt to a wide variety of circumstances, availability of data, and types of analyses without having to incur large amounts of time, skill, and confusion in reprogramming. The models were to be designed to be flexible (easy for the system programmers to change and revise) and dynamic (amenable to revision in response to changes in the data on which they are based).

The design criteria presented above led to a decision to use a fourth generation programming language (EXPRESS) as a "DSS Generator" (Sprague and Carlson, 1982) for the EFMS. EXPRESS and its replacement software, pcEXPRESS/MDB, are the main languages that the Air Force used to program the EFMS models and to create its databases. They were also used to create the menus and other facilities that constitute the user interface. (Only sophisticated users will use the languages directly.)

The general design principles also led to the choice of the hardware configuration. Each user sits at a microcomputer workstation. The workstations are linked with each other and with two large mainframe computers, one in the Pentagon and one at the Military Personnel Center in San Antonio, Texas (see Fig. 26 below).

DEVELOPMENT PRINCIPLES

Two general principles guided the building of the EFMS:

1. A single group within the Air Force should be responsible for overseeing the development, implementation, and operation of the system. (In the following discussion we call this group the System Management Office or SMO.)
2. Implementation should be performed in stages.

The SMO has a different set of responsibilities during the development and implementation of the EFMS and afterward. During development and implementation of the system, the SMO must:

- Procure the hardware and software.
- Prepare the computer facility and set up the workstations.
- Devise suitable data structures for implementing the models.
- Program the models.
- Test and evaluate the models.
- Create the databases for the models.
- Develop procedures for users, for database management, and for program maintenance.
- Develop standards for documentation.
- Develop training materials.
- Keep potential users informed of implementation status.
- Document the computer programs and the databases.

After implementation, the SMO must:

- Maintain the databases.
- Maintain the models, including
  - Refitting econometric equations.
  - Reestimating the equations when the environment changes.
  - Modifying programs in response to changing user needs.
  - Modifying programs in response to changes in Air Force policies and procedures.
  - Changing output reports in response to changes in reporting requirements.
- Distribute hard-copy reports produced by the system.
- Train users.
- Update documentation.

The models of the EFMS were to be developed and implemented using staged implementation, in which some models are programmed in parallel with others, and some are programmed sequentially in priority order. Use of a model can begin whenever a user feels comfortable trying it. In addition to the implementation of models one at a time, the implementation of each model is an interactive process that includes some or all of the following:

- Identifying user requirements.
- Preliminary mathematical specification.
  - Choice of model form.
  - Estimation of parameters of model.
- Building a stand-alone prototype.
- Test and evaluation.
- Revision.
  - Modification of mathematical specification.
  - Addition of features.
- Installation and integration.
  - Reprogramming.
  - Building database.
  - Integration into system.

Not all of these steps would necessarily be carried out for each model, and the implementation of each model would not necessarily involve carrying out the steps sequentially. There would be a lot of iteration and feedback among the steps. For example, testing of the prototype might reveal problems that would return implementation of the model to any of the previous steps (even rethinking the conceptual design).

Prototypes generally include some, but not all, of the features of the final versions of the models. In most cases, the inputs, outputs, and user interactions of a prototype are different from those in the final version. However, there are several good reasons for using the model in an early version:

- Support for some management areas can be obtained early in the system development process (e.g., a prototype supplied early support for bonus management).
- Problems with a model can be identified and corrected early in the process.
- Users can gradually become familiar with the concepts, procedures, and models of the EFMS.
- The SMO can gradually build up its organization and procedures.

Most of the design and development principles described above have been and are being applied in the development and implementation of the EFMS (see Sec. VIII). The SMO is the Washington Area Personnel Systems Division, Air Force Military Personnel Center (AFMPC/DPMDW), located at Bolling Air Force Base, Washington, D.C.

III. DATA FOR ANALYSIS AND MODEL BUILDING

PRINCIPLES FOR CREATING AND USING LARGE DATA FILES

The EFMP created and used several large data files. For example, its primary source data file, the Enriched Airman Gain/Loss (EAGL) file, consisted of approximately 300 items of data on each of the more than 1.5 million airmen who were on active duty in the Air Force between 1971 and 1988. In general, there are four primary uses of data in a policy analysis study:

- To understand or define the problem situation being addressed.
- To estimate a model.
- To test and evaluate a model.
- To run a model (input to the model).

Data were used for each of these purposes on the EFMP. Each use requires different types of data, and the data are used in different ways in each case.

Most of the information RAND used fell into the first two categories. Most of the information used by the Air Force fell into the second two categories. In this report, we restrict our attention to the databases used by RAND to understand enlisted force management problems and to estimate EFMS models. We call these types of data files "analysis files," since they are primarily used by analysts engaged in defining and building models.

Managers of projects that make extensive use of large data files usually underestimate the amount of effort required to create useful analytical databases. About a third of RAND's effort on the EFMP was devoted to collecting, examining, cleaning, and structuring data to create useful analysis files.

Our first task was to define the data to be included in the analysis files. We identified the need for four types of data: demographic profiles of individual airmen, complete military histories of individual airmen, Air Force personnel policies over time, and economic conditions pertinent to separation/reenlistment decisions. A key requirement was the need to blend frequent, regular observations on an airman's status with inherently infrequent, episodic separation/reenlistment transactions. These needs led to the creation of the files described below.

In the remainder of this subsection we present principles for creating and using large data files that we applied to our work on the EFMP. The principles are based on studies by Relles (1986) and Arguden (1988), two of the RAND members of the project. Creating and using large data files pose many challenges. Errors are hard to catch but may be very costly if not caught early, and they may undermine the scientific quality of the research if they remain undetected. Thus, error is more than a risk; it is a problem that must be addressed systematically as part of the research process. We devoted a great deal of effort to developing "clean" data files.

The EFMP used two types of data files: (1) source data, and (2) analysis files, which were created from the source data. The source data consisted almost entirely of secondary data—data collected by others for purposes different from those of the EFMP. Our second task (once the source data files had been defined and test versions had been created) was to understand these data, clean them, and use them to define other variables that were more useful for EFMP purposes.

Several special challenges face researchers using large source data files such as these. Among them are:

- The large number of observations precludes spotting errors by visual scanning.
- The large number of data items per observation requires the analyst to absorb and check out numerous facts about the items and their interrelationships.
- Decisions made at the data-cleaning stage can distort or restrict what the analysis produces.

The relationship between data and modeling can be divided into two phases: the audit phase (which embraces all steps in cleaning the data and increasing the researcher's understanding of the data) and the analysis phase (which includes data analysis and model fitting). Several aspects of the audit phase require careful attention:

- Examining the frequencies with which the data items take on each value. Frequency distributions provide the basic information with which to judge data quality and the data's consistency with its documentation. They disclose undocumented codes and gaps between data values that signal potential outlier problems.
- Listing a number of complete records from the file. Listings supplement frequency distributions, enabling analysts to examine relationships among variables.
- Constructing new variables for analysis from one or more source variables. Rules for constructing variables must resolve numerous details, translating codes that may be arbitrary or inconsistent over time into variables about which analytical assumptions will be made. The rules have to deal with aggregation, including what to do when data items are missing.
- The unit of observation must also be defined at this stage. For example, are we analyzing a person, a person-year of service, or a year within a term of service?

We used the following two techniques when we examined the data during the audit phase:

- We looked at the frequencies of the variables. Not only did this help the analysts to understand the data, it indicated values that rarely appeared, which revealed some miscodings.
- We looked at partial listings of the data. These are listings of a small subset of the records in a file. Examination of such listings improved the analysts' understanding of the files by revealing relationships among variables within a given observation. They also contributed to understanding the units of measurement, completeness of the information about a variable, and whether the definitions in the documentation were accurate.
- We looked at totals for key variables for time periods (e.g., years) that could be checked against published Air Force data.

In creating analysis files, we generally used the following principles:

- Observations containing missing values for some variables were not excluded from the files, to avoid selection bias.
- Rules for recoding each new variable were kept separate (e.g., in different subroutines), to avoid confusion and facilitate modifications.
- All new variables were defined directly from the source data rather than from other new variables, to make the definitions clear and easy to find.

- The rules for selecting the observations from the source files that were included in the analysis files were specified clearly in the code that created the analysis files.

We devoted a great deal of effort to the audit phase. Relles (1986) says that projects involving the analysis of large data sets usually allocate about 60 percent of their resources to the analysis phase and only 40 percent to the audit phase. He suggests that it would be more efficient and effective to allocate about 65 percent of the project's resources to the audit phase, including more time from the project leader and a senior programmer.

Another fundamental concern about secondary source data, such as that used in the EFMP, is how reliable and meaningful the data are. Some questions that we tried to answer before using the data included:

- *Do the data measure objective conditions?* An airman's sex and date of birth are well defined, whereas his reason for separating from the Air Force is less well defined (the personnel office can choose from over 400 "reason codes," some of which are very similar to others).
- *Are all events fully reported?* For example, changes in an airman's date of separation and category of enlistment are always reported, while changes in marital status and education are not.
- *With what frequency are the events reported?* In the EFMP's analysis files, information on changes in grade is available at only one point during a year, while changes in category of enlistment are available at the time of the enlistment or reenlistment.
- *To what extent are the data artificially affected by changes in policy?* For example, fewer airmen will have left the service in one fiscal year if a large number of them were permitted, encouraged, or even required to leave the service early during the previous fiscal year.
- *Are the reporting categories stable?* Occupational specialties are defined by Air Force Specialty Codes, but the list of specialty codes is modified at least twice a year.

We tried to get answers to all of these questions before we even specified the source data files we wanted for the EFMP. However, some questions could only be answered after we examined the source data in the audit phase, and others only suggested themselves in the analysis phase.

The source data files described below were all tailored specifically to the needs of the EFMP. Before the files were created, we expended considerable time and effort to make sure that the structure and content of the files would facilitate estimation of the loss (and other) models of the EFMS and could be maintained and updated. (One of the design principles that guided work on the EFMP was that the input data should be routinely collected by the Air Force or some stable external source, such as the Department of Labor.)

SOURCE DATA

The Enriched Airman Gain/Loss File

The primary source data for the EFMP come from the Enriched Airman Gain/Loss (EAGL) file, containing longitudinal information about individual airmen's careers. For each airman, the file contains demographic information, annual snapshot information, and transactional information about reenlistments, extensions, and separations. The file is updated every year. The latest version of the file (EAGL8) contains data about each enlisted person who was on regular active duty in the Air Force any time between June 30, 1971 and June 30, 1990. The EAGL file is composed of data from three separate files: the Airman Reenlistment/Loss (ARL) file and Airman Gain/Loss (AGL) file, both maintained by the Air Force Human Resources Laboratory (AFHRL), and the Active Duty Master files maintained by the Defense Manpower Data Center (DMDC).[1]

For each airman, the AGL file provides (1) background information collected before, during, or shortly after Basic Military Training (information drawn from the Processing and Classification of Enlistees or PACE file); and (2) information at the time of every reenlistment, extension, and loss transaction during his career. The AGL file does not include any airmen who enlisted before January 1, 1956, the inception date of the PACE file. The ARL file provides similar information for airmen who enlisted before that date.

The DMDC master files provide annual "snapshots" of each airman in the Air Force, detailing personal traits and military circumstances as of June 30.

For each airman, the EAGL file combines a subset of his PACE data with a series of annual segments, one for each year that the airman was in the force during the sample period. Each annual segment has two parts:

- Snapshots from the DMDC active duty master files: a subset of the information on the airman contained in the June DMDC master file for that year.
- Transactions from the AGL or ARL file: a subset of the data on the airman's enlistment, extension, and separation transactions (if any) during the following year (July 1 to June 30).

Brauner et al. (1989) describe each variable in the EAGL file and the meanings of each of their codes.

Supplementary Historical Data Files

To build the EFMS models (e.g., models to predict airman losses) analysts needed two types of longitudinal data in addition to the EAGL file's data on individual airmen:

- Data describing Air Force policies (e.g., the bonus program).
- Data describing the economic environment outside the Air Force (e.g., unemployment rates).

Several data files were created to supplement the data in the EAGL file, including longitudinal data on:

- *Unemployment rates:* Monthly annual unemployment rates by age and average annual unemployment rates by age for the preceding 12 months.
- *Military compensation:* Monthly basic military compensation, basic pay, and basic pay plus basic allowance for quarters, by grade and years of service.
- *Selective reenlistment bonuses:* Bonus levels by AFSC and zone.
- *AFSC conversions:* Changes in AFSC designations over time.

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[1] To free the SMO from dependency on outside sources of information, new versions of the EAGL file update previous versions using data from two files maintained by the Air Force Military Personnel Center—the Promotion/Demotion Gain/Loss (PDGL) file and the Uniform Airman Record (UAR) file—instead of the AFHRL and DMDC files.

- *Non-CONUS Personnel Accounting Symbol Numbers:* Identification numbers for units stationed overseas.
- *Military/civilian wage ratio:* A comparison of military pay with pay levels in the private sector.
- *Separation program designator codes:* Codes used to categorize airman transactions related to gains, losses, reenlistments, and extensions.

Details of the contents of these files are provided by Walker and McGary (1989). Data from these files were combined with data from the EAGL file to produce the project's principal analysis file—the Year-at Risk (YAR) file.

THE YEAR-AT-RISK FILE

The YAR file is a longitudinal file containing information about individual airmen. It combines the demographic, snapshot, and transaction data from the EAGL file with the supplementary historical data mentioned above. The file contains one record for each "year at risk" in an airman's career.

The YAR structure was designed to facilitate analyses of yearly losses in the EFMS's middle-term loss models. A YAR is essentially a year in an airman's term of service. A new YAR begins on the anniversary of the start of the term. Whenever an airman enlists for a new term, he begins a new YAR. (Thus, some periods of an airman's career will be covered by two YARs, one for each term.) Figure 8 illustrates the definitions of anniversary and year at risk. The airman in this figure experienced seven anniversaries and seven years at risk. There was one period when two years at risk overlapped, because he reenlisted for a second term before his first term expired. Also, for the last part of his last year at risk he was no longer in the service.

The record (which is of variable length) for each airman consists of five kinds of data:

- *PACE data.* Primarily demographic data from the PACE file, these reflect the airman's situation when he joined the Air Force.
- *Snapshot data.* These data come from the DMDC master files. They provide annual "snapshots" of the airman on every June 30 he was in the Air Force, detailing the individual's personal traits and military circumstances on that date.

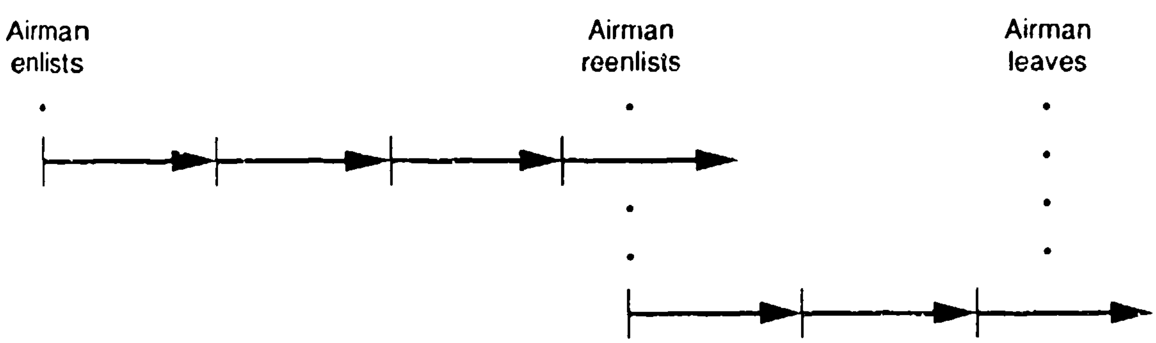

Fig. 8—Hypothetical airman career

- *YAR data.* These data characterize a specific year at risk for the airman.
- *Data on the term of the YAR.* These variables characterize the term of service the airman was in at the beginning of a specific YAR.
- *Variables for the end of the term of the YAR.* These variables characterize the airman's military circumstances at the end of the term of service the airman was in at the beginning of the YAR.

A complete description of the YAR file is provided in Murray et al. (1989).

IV. LOSS MODELS

THE NEED FOR LOSS MODELS

One of the most critical needs of enlisted force managers is accurate projections of the inventory of airmen. These inventory projections drive decisions in such key areas as recruiting, training, and bonus management. Sometimes the need is for detailed forecasts over a short period—e.g., for the number of airmen in each pay grade and year of service for each month remaining in the current fiscal year. Other times, projections might be needed by specialty or for a longer time horizon.

Formal models for making the inventory forecasts are called Inventory Projection Models (IPMs). Such models begin with an initial actual or hypothesized inventory of airmen and "age" it to predict what the inventory will look like in the future. No single IPM can serve all users equally well; the needs of users are simply too varied. Planning for meeting end strength, predicting the effects of a new bonus policy, and investigating alternative work force structures require different degrees of detail and different time horizons. Thus, the EFMS includes several IPMs.

IPMs are categorized according to their level of aggregation and their time horizon. Aggregate IPMs project the number of airmen by grade, length of service, and category of enlistment (first term, second term, career, and retirement eligible). Disaggregate IPMs include occupational specialty (AFSCs or groups of AFSCs. Short-term IPMs forecast inventories by month, from the present to the end of the current fiscal year. Middle-term IPMs forecast inventories by year for several years into the future.

Every IPM contains a loss model that predicts how many members of the current inventory will leave the Air Force or reenlist in each time step of the IPM. The "heart" of any IPM is its loss model. In fact, any IPM can be viewed as a system of models for forecasting changes in the enlisted inventory with an embedded loss model that supplies the predicted loss rates needed to update the system. The loss model for each IPM matches the IPM's level of aggregation and time horizon.

The short-term loss models are based on historical behavior and recent trends. The middle-term models also include demographic factors and the effects of expected changes in external economic conditions and military compensation. These models are described below.

MIDDLE-TERM LOSS MODELS

Overview

The EFMS uses two sets of middle-term loss models: aggregate and disaggregate. The aggregate models support planning and reporting activities. They do not distinguish airmen by occupational specialty, but they do provide demographic detail as well as loss rates by year of service and grade. The disaggregate models chiefly support personnel programming activities, such as bonus management. They include AFSC detail. Avoiding biases in the estimation of key policy parameters, such as bonus and pay effects, required the estimation of a single set of statistical loss models that embraced the detail of both the aggregate and disaggregate models.

The middle-term loss equations have simple structures. Most represent the probability of the outcome from an airman's stay/leave decision as a linear function of the airman's traits, circumstances, and economic opportunities. The parameters of the linear equations were estimated using ordinary least squares regression. All the loss models use one year in the career of an individual airman as the unit of analysis (with data from the YAR file). Thus, they are "cohort" models. The loss equations give the probability that an airman will leave the Air Force on or before the end of the next year of his term.

Different equations are used to describe the loss probabilities at different career points. Loss rates are subdivided according to the type of airman: (1) first termers, (2) second termers, (3) those who have completed at least two terms but are not yet eligible for retirement (whom we call "career airmen"), and (4) those who are eligible for retirement. The first three groups of loss rates are further subdivided into three subgroups based on the relationship between the year of the term under consideration and when the term was first scheduled to be completed (called the original expiration of term of service, or original ETS), either (1) the last year of the enlistment contract (i.e., the year that ends at the original ETS); (2) the years preceding the year of the original ETS, for which the major cause of loss is attrition; or (3) each year beyond the original ETS in which the airman remains in extended status and has not yet reenlisted.

This produced ten decision groups for which we modeled loss behavior. A total of 18 models were estimated, at least one for each decision group. The independent variables for the models are airmen's demographic traits (e.g., sex, race, education), Air Force circumstances (e.g., occupation, years of service, grade), and economic opportunities (e.g., unemployment rate, an index of the ratio of military wages to civilian wages). Not all variables are included in all models (because their effects in some cases were not significant enough to include). The ten decision groups and 18 models are:

1. First-term attrition (three equations: Basic Military Training (BMT), rest of first year, rest of first term).
2. Second-term attrition (one equation).
3. Career attrition (one equation).
4. First-term ETS (two equations: whether to leave by original ETS and whether to extend or reenlist given decision to stay).
5. Second-term ETS (two equations: whether to leave by original ETS and whether to extend or reenlist given decision to stay).
6. Career ETS (two equations: whether to leave by original ETS and whether to extend or reenlist given decision to stay).
7. First-term extension (two equations: one for decisionmakers, one for nondecisionmakers).[1]
8. Second-term extension (two equations: one for decisionmakers, one for nondecisionmakers).
9. Career extension (two equations: one for decisionmakers, one for nondecisionmakers).
10. Retirement (one equation).

[1]Airmen whose Date of Separation (DOS) falls sometime within the year for which losses are being predicted are called decisionmakers, since they must make a decision to stay or leave at some time during the year. Airmen whose DOS is beyond the current year are called nondecisionmakers.

Below we discuss the initial set of specifications for the 18 equations, which are based on data through June 30, 1983. Since their publication in 1987, the specifications have been modified (where tests showed they performed poorly) and updated (using more recent data). We discuss these specifications in general terms by providing information on the independent variables that are included in each equation. The influences of the three types of independent variables (demographic traits, Air Force circumstances, and economic opportunities) are discussed in separate subsections. These descriptions apply to the equations as they existed in December 1987, which are based on data through June 30, 1983. Complete specifications for these versions of the middle-term loss models are given in Carter et al. (1987). The equations are being updated and revised every year, as new data are added to the database.

Specifications

Demographic Correlates of Loss Behavior. Table 1 displays the demographic variables that appear in the middle-term loss equations. As the table makes clear, demographic influences are found in only eight of the 18 loss models, and they lessen as an airman is in the force longer. The demographic effects in the equations conform closely to those that have been found by previous researchers. The only differences are the persistence of sex, race, and marital status effects through the second-term ETS decision, and a more refined treatment of the stay/leave decision process that allows us to distinguish, for example, three first-term attrition effects (for three periods) for each demographic variable.

Demographic effects are most varied in the first-term attrition equations. Attrition decreases with more education and better test scores. Those who join the Air Force before

Table 1

DEMOGRAPHICS IN THE MIDDLE-TERM LOSS AND EXTENSION EQUATIONS

	Model							
	First-Term Attrition			First-Term ETS		Second Term ETS		
Characteristic	Basic Training	Months 3-12	YOS ≥ 1	Loss	Extend Given Stay	Loss	Extend Given Stay	Retire
Older than 18	+	+	−					
Younger than 18	+	+	+					
Age × term length	x		x					
Black	−	−	x	−		−		
Female	+	+	x	−	x		+	
Single	−	+	+	+	+	+	+	
Dependents > 1		+	+					
Sex × marital status				x	x			
Female black		−	x					
Sex × occupation			x					
High school graduate	−	−	−		+			−
Some college						+	+	−
High intelligence	−	−	−		+			

NOTES: + = higher loss or extension rates for the group; − = lower loss or extension rates for the group; x = a statistically significant effect whose sign for the group may depend on other interactions in the equation.

they are 18 leave at a higher rate than others throughout the first term. Those who join the Air Force after they are 18 leave at a slightly higher rate during their first year of service (YOS) than those who join at exactly 18, but this effect reverses during the remainder of the term. Six-year enlistees who join the Air Force before age 18 leave at a slightly higher rate during their first YOS and at a slightly lower rate in later YOS during the first term than would be predicted by the separate effects of term of enlistment, age, and other demographic effects.

Those who were married but without children when they entered the service have modestly lower attrition rates after BMT than singles or persons with more than one dependent. Married recruits appear to have a slightly harder time getting through BMT.

Most previous studies of attrition in the Air Force found either no difference or only small differences due to race. We found that the first-term attrition rate is much higher for white women than for black women, but the difference in attrition rates between black men and white men is very small. The similarity in the rates for men and the preponderance of men in the Air Force means that the average rate does not differ much by race.

Demographic effects are simpler in the first-term ETS model than in the first-term attrition model. We found no effect of Armed Forces Qualification Test (AFQT) score on the stay/leave decision in the first term, but we did find that graduates and persons without low AFQT scores are more likely to extend than to immediately reenlist. The first-term reenlistment rate is lower for single than for married persons, but marital status is a much more important determinant of the first-term ETS decision for men than it is for women.

The total first-term reenlistment rate is higher for women than for men. Thus gender, in addition to education and AFQT score, has an effect on the first-term ETS decision that is opposite in sign from its effect on attrition. Like other researchers, we found that blacks are less likely than whites to leave at ETS.

The demographic effects on second-term reenlistment decisions are even simpler than those at first-term ETS. The only important effects, as shown in Table 1, are race, gender, marital status, and whether the airman has ever attended college.

After the second-term ETS, demographics play no discernible role in airmen's decision-making until they reach retirement eligibility. Airmen with some college training are significantly less likely to leave the Air Force during the retirement years than those with only a high school diploma or those who never completed high school.

Air Force Circumstances. Table 2 reports the variables pertaining to an airman's circumstances in the Air Force that appear in the middle-term loss equations. The importance of these circumstances does not diminish with length of service as demographic effects do. Behavioral differences across occupations do become less for airmen beyond the second term, but the effects of grade, and particularly of years of service, become greater over an airman's career. The estimated effects of term of enlistment (TOE), grade, and years of service conform in general to those that previous researchers have found. The chief difference lies in the richer structure of stay/leave decisions incorporated in our models.

We found that from the beginning of the second term through 29 years of service, airmen in lower grades are more likely to leave the service than are airmen in higher grades. There is so little variation in grade at the first-term ETS decision that the effect of grade is indiscernible. The strongest effects of grade are in the retirement years, where high year of tenure (HYT) rules force the retirement of a large proportion of airmen.

Airmen in the first and second terms leave less frequently as their years of service (and years served within the term) increase. In the career years, attrition declines as years of

Table 2

AIRMEN'S CIRCUMSTANCES IN THE MIDDLE-TERM LOSS EQUATIONS

Characteristic	First-Term Attrition: Months 3–12	First-Term Attrition: YOS ≥ 1	First-Term ETS: Loss	First-Term ETS: Extend Given Stay	First-Term Extension: Nondecision-makers	First-Term Extension: Decision-makers	Second-Term Attrition: All Years	Second-Term ETS: Loss	Second-Term ETS: Extend Given Stay
Lower grade							+	+	+
More years of service		x					+	–	–
Six-year enlistees	+	+	x	–					
TOE × demographics	x	x							
TOE × grade								x	
TOE × pay			x						
Air Force Specialty Code			x	x				x	x
Career field		x					x		
Careen field group					x	x			
Career field group × demographics		x							

Characteristic	Second-Term Extension: Nondecision-makers	Second-Term Extension: Decision-makers	Career Attrition: All Years	Career ETS: Loss	Career ETS: Extend Given Stay	Career Extension: Nondecision-makers	Career Extension: Decision-makers	Retirement: All Years
Lower grade			+	+				x
More years of service			–	–	x			x
Term of enlistment			+					
TOE × YOS			x					
Career field								x
Career field group	x	x	x	x		x	x	
Career field group × YOS				x				
Grade × YOS			x	x				
High year of tenure								x
Year in grade								x

NOTES: (1) + = higher loss rates for the group; – = lower loss rates for the group; x = a statistically significant effect whose sign for the group may depend on other interactions in the equation, or may vary across subgroups, or is not monotonic.

service increase but increases as the years served within the term increase. Nonattrition losses decrease as years of service increase in the first, second, and career terms.

The effect of year of service in the retirement years is dominated by the high year of tenure rules. Excluding cases for which HYT is effective, retirement losses are highest at 20 years of service, fall slightly from years 21-25, and generally rise thereafter.

An airman's term of enlistment is correlated with his loss behavior. In the first term, annual attrition losses for six-year enlistees are higher than those for four-year enlistees. Second-term attrition is not measurably influenced by term of enlistment. In the career terms, annual attrition losses are again found to be higher for six-year enlistees.

Of special importance to the EFMS is the ability of the middle-term loss models to forecast occupation-specific loss rates. In the first and second terms, occupations are distinguished by AFSC (for AFSCs with many personnel). In later terms, more aggregate depictions of occupation suffice.

Estimated first-term annual attrition rates for years beyond the first vary by as much as 23 percent across AFSCs, although variations of 3 percent are most common. By the second term, the magnitudes of the occupational effects on attrition are quite small, with only a few career fields differing much from the norm. The attrition effects are clustered so that the fields with higher attrition rates contain either administrative personnel or craftsmen. In the career years, occupational differences in attrition are even smaller.

The effect of occupation on ETS losses is quite different from its effect on attrition losses. When AFSC effects are averaged across AFSCs in each of four broad occupational categories (which we called Career Field Groups or CFGs),[2] we found that skilled technicians had the highest loss rates and the greatest propensities to extend rather than reenlist at the end of both the first and second terms. These data are consistent with our a priori expectations that skilled technicians have better civilian career opportunities than other airmen and that civilian opportunities play a large part in end of term decisions.

Early in the career years, loss rates among CFGs differ in an absolutely small but measurable degree. Airmen in the skilled technician CFG leave the service most often, while airmen in the functional support and administration CFG and in the craftsmen, service, and supply handlers CFG leave least often. Beyond 12 years of service, however, the differences among the CFGs become inconsequential.

Occupational effects return during the retirement years. Separate effects for each career field could be discerned and were estimated. The pattern of effects is not as strongly related to CFGs as in the first- and second-term models.

Economic Conditions and Incentives. Economic variables appear in all but the attrition equations (see Table 3). Unemployment appears in all nonattrition equations except the first-term and career extend-given-stay equations. The military/civilian pay ratio appears in all nonattrition equations except the extension and retirement loss models and the first-term and career extend-given-stay models. There are no economic effects in the attrition equations.

In all cases, the signs of the coefficients are consistent with expectations based on economic theory. Losses increase and reenlistments decrease with decreases in unemployment, decreases in military wages relative to civilian wages, and decreases in the bonus amount.

Bonuses appear in the first- and second-term nonattrition equations, except the one for extension decisionmakers. We found that in the first term the first bonus multiple increases the fraction of airmen in a typical AFSC who stay past ETS by about 3.4 percentage points.

[2] The CFGs are (1) skilled technicians; (2) electrical/mechanical equipment repairmen; (3) functional support and administrative personnel; and (4) craftsmen, service, and supply handlers.

Table 3

ECONOMIC CONDITIONS IN THE MIDDLE-TERM LOSS EQUATIONS

	Unemployment	Military/ Civilian Pay Ratio	Bonus Multiple	Cross Bonus Average	Received Bonus at First Reenlistment
First term					
ETS loss	−	−	−	−	
ETS extend given stay			−		
Extension decisionmakers	−				
Second term					
ETS loss	−	−	−		+
ETS extend given stay	−	−	−		
Extension decisionmakers	−				
Career					
ETS loss	−	−			
ETS extend given stay					
Extension decisionmakers	−				
Retirement	−				

NOTE: + = higher loss rates for the group; − = lower loss rates for the group.

However, it also increases the fraction of airmen who immediately reenlist out of those who stay past ETS by 3.8 percentage points. Each subsequent bonus multiple decreases the ETS loss rate by 1.3 percentage points and increases the immediate reenlistment rate by 3.8 percentage points. Thus, the bonus has a larger effect on immediate reenlistments than it has on immediate losses. Since many of those who extend leave during the next year or two, the full effect of a bonus on retention is not visible until the cohort is at least two years past ETS.

In the second term, as in the first, we found that the bonus has a larger effect on the immediate reenlistment rate than it does on the immediate loss rate. We also found that second-term loss rates are higher the greater the proportion of the second-termers who received bonuses at the end of their first term.

Test and Evaluation

According to the principles of prototyping and staged implementation described in Sec. II, the models developed by Carter et al. (1987) were subjected to a thorough test and evaluation (T&E). The T&E included efforts by both RAND analysts and the Air Force implementation team. The RAND effort (Abrahamse, 1988) compared the loss and extension rates predicted by models with actual loss and extension rates for three fiscal years. The Air Force effort (Air Force Military Personnel Center, 1987-1988) compared the inventory projections derived using the middle-term disaggregate models in the Disaggregate Middle-term Inventory Projection Model to actual inventory levels for one fiscal year. As a result of these efforts, the original model was modified and improved. Some coefficients were changed, and some of the equations were respecified.

Abrahamse (1988) compared the loss predictions from the models with the actual losses for airmen who were in each of the ten decision groups at the beginning of fiscal years 1983, 1984, and 1985. He used four measures of fit:

- *Prediction error (PE):* the number of predicted losses minus the number of actual losses.
- *Percent relative error (PRE):* the prediction error divided by the number of actual losses, times 100.
- *Prediction error as percent of number at risk (PEPNR):* the prediction error divided by the number of airmen at risk, times 100.
- *Standardized prediction error (SPE):* the prediction error divided by an estimate of the variance of the number of losses in a decision group under the assumptions that the population in the group is homogeneous and that airmen in the group act independently. (These assumptions enable the probability of observing a given prediction error to be estimated from tables of the standard normal distribution.)

The test and evaluation process showed that the loss models reported in Carter et al. (1987) were good enough to be encouraging, but not good enough to be satisfying. Few of the models were actually validated,[3] but in general they performed at least as well as the loss models used in the Airman Loss Probability System (ALPS) (Miller and Golenski, 1984), the source of the loss rates in the Air Force's existing system. For example, Fig. 9 shows the cumulative absolute error over AFSCs plotted against the fraction of the force covered by the sum for the EFMS models and ALPS for FY 1984. A perfect model would have absolute errors equal to zero for each AFSC, so its curve would lie flat along the x-axis. The closer the graph of a model lies to this axis, the better it is. As can be seen, the EFMS shows a superior

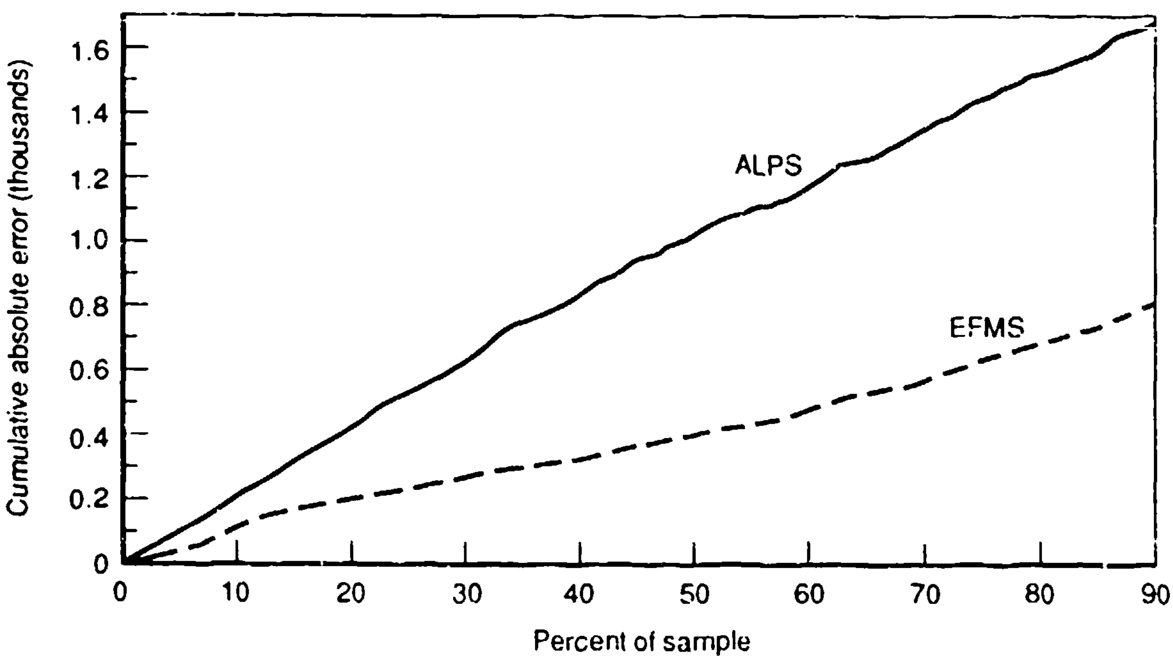

Fig 9—Comparing cumulative absolute errors, FY 84

[3]Here we use *test and evaluate* to refer to the process of comparing a model's performance with that of the real world. We use *validate* to mean that the model is found to be accurate enough to be used for its designed purpose.

performance, especially for the larger AFSCs. The results of this test and evaluation led to reestimation and refitting (with more recent data) of several of the component EFMS models.

Updating

The world is constantly changing, and airmen change with it. One of the reasons the TOPCAP system of models for managing the enlisted force fell into disuse was that the models were not updated to account for changes in the environment. The EFMS models will be updated regularly, particularly the loss models. It is expected that the middle-term loss models will be updated once a year, after the end of a fiscal year.

Updating the middle-term loss models involves four activities:

1. Adding data to the files used to estimate the equations.
2. Reestimating the existing specifications of the equations.
3. Exploring possible respecifications of the equations to exploit the additional data or to accommodate new EFMS needs.
4. Testing and evaluating new versions of the equations.

The files that need to be updated are the EAGL file (Brauner et al., 1989), the supplementary historical data files (Walker and McGary, 1989), the YAR file (Murray et al., 1989), and the analysis files drawn from the YAR file that are used as direct inputs to the model estimation programs. Adding data also requires understanding the programs that create the YAR and the analysis files.

Reestimating the existing specifications of the loss equations requires understanding only the programs that calculate the estimates. Exploring possible respecifications is more demanding. It requires understanding (1) the statistical strategy underlying the estimation procedures, (2) the perils for estimation inherent in the available data, (3) the uses to which the loss equations will be put, (4) the programs for calculating estimates, and (5) how to adapt the equations in response to information from the testing and evaluation exercise.

Testing and evaluating the new versions of the loss equations requires understanding (1) the testing programs, (2) the performance criteria used to evaluate the performance of the loss equations, (3) the purposes to which the loss equations will be put, and (4) the "blending" process by which loss estimates for individuals in a given year at risk are transformed into estimates of loss rates for the Air Force in a given fiscal year (see below).

Murray (1989) provides information on the first three activities to guide the analysts who will update the middle-term loss equations. Abrahamse (1988) provides information on the test and evaluation activity.

Blending

The middle-term loss models specified by Carter et al. (1987) estimate loss rates for an airman's cohort year, where a cohort year is defined as a year at risk for an airman in a given decision group. Such loss rates by themselves are not particularly useful. Enlisted force managers need to predict loss rates for a fiscal year, and a fiscal year coincides with the year at risk for only a small fraction of the Air Force. During a fiscal year, two or three different loss models may be needed to calculate the probability that some particular airman will be lost during that fiscal year. The technique of combining the loss rates from the cohort models to obtain fiscal year loss rates we call blending.

More specifically, to use the middle-term disaggregate loss models in the Disaggregate Middle-term IPM (DMI), there is a need to transform the cohort year loss and extension rates into fiscal year loss and extension rates that can then be applied to the inventory at the start of a fiscal year. Blending cohort year loss and extension rates into fiscal year rates requires seven steps. The first two assemble inputs, the middle four do intermediate calculations, and the final one produces the outputs.

Step 1: Input cohort year loss and extension rates.

Step 2: Input the proportions of cohort year losses and reenlistments that occur at the end of the cohort year, as opposed to continuously during the cohort year.

Step 3: Construct six detailed cohort year rates that recognize the distinction between events during a cohort year and events at the end of the cohort year and that recognize the link between events in a given cohort year and the next cohort year.

Step 4: Construct nine components of fiscal year rates that assemble fiscal year results by three stages: during the cohort year in which personnel are found at the start of the fiscal year, at the end of that cohort year, and during the portion of the next cohort year that is in the fiscal year being analyzed.

Step 5: Determine the proportion of each monthly cohort in the inventory at the start of the fiscal year.

Step 6: Average the nine components of fiscal year rates over all monthly cohorts, weighting by the proportions determined in the previous step.

Step 7: Output fiscal year loss and extension rates.

Unpublished RAND research by Rydell and others describes the computer program that produces fiscal year loss and extension rates for the DMI. It also provides the theory of blending that forms the basis for the program.

The Middle-Term Aggregate IPM (MTA) also needs blended loss and extension rates. For efficiency, the blending in this model is done within the program and not outside it, as is done for the DMI. The blending procedure for the MTA is described by Rydell and Mickelson (1990).

SHORT-TERM AGGREGATE LOSS MODELS

Overview

The Short-term Aggregate Inventory Projection Model (SAM) is the component of the EFMS that supports aggregate planning within a fiscal year (see Sec. VII). SAM provides one- to 12-month projections for the aggregate force (across all AFSCs). It consists of five modules. One of them (called SAM1) estimates for each month how many airmen will reenlist, be lost, become retirement-eligible, or simply continue in their terms. It divides losses into three types: attrition, ETS, and retirement. The ETS loss projections are "policy-free"—i.e., the ETS losses that would occur if there were no early release programs.[4]

SAM1 begins any given month with the inventory in each of a large number of airman classes (the actual number and their defining attributes depending on the loss model being used). It then estimates the number of each type of transition that will occur within each class. The classes were chosen to be roughly homogeneous groups of airmen within which we

[4]Three programs release airmen before the end of their obligated term of service: Palace Chase, in which the airmen join the Air Reserve Forces; Early Out, which releases airmen who would otherwise have left next fiscal year; and Rollup, which releases airmen who would otherwise have left later during the same fiscal year.

expect fairly consistent loss and reenlistment behavior. Among the attributes used to define classes are:

- Category of enlistment (first term, second term, career, retirement-eligible).
- Term of enlistment (four or six years, defined only for first term airmen).
- Months of service (1, 2, 3, . . .).
- Months to ETS or months to date of separation (DOS).

Transitions in a class can be one of four types:

- Loss to attrition.
- Loss to ETS.
- Retirement.
- Reenlistment.
- Simple aging into the next class.

Given these transition estimates, SAM1 updates the size and composition of the airman classes for each projection month. Output from SAM1 becomes input to the next module of SAM (see Sec. VII).

Given a starting inventory, if the transition probabilities were known, the size of the force could be projected perfectly. In fact, these transition probabilities are not known but have to be estimated. To find a modeling approach that would produce good predictions, we evaluated models developed using three different approaches:

- *Time series forecasting:* autoregressive, constant rate, regression, and straight line running average models, based on time series analysis of loss and reenlistment rates in the period 1973–1983.
- *Robust separation projection:* loss and reenlistment rate projections based on the techniques of trend and seasonal fitting of time series.
- *Benchmark separation projection:* loss and reenlistment rates based on various combinations and weights of historical rates for the same cohorts.

The time series models are fully documented by Brauner, Lawson, and Mickelson (1991). The robust method is described by Brauner and Relles (1991). The benchmark separation projection (BSP) method is documented by Rydell and Lawson (1991a).

We originally believed that the first set of time series models would predict losses and reenlistments for SAM1. But we determined that their implementation would be far more complex than expected. The set includes many Box-Jenkins forecasting model, which are the most sophisticated forecasting models in use today. The benchmark separation models are among the simplest forecasting models. Robust models are in between.

Below we provide summary descriptions of these modeling approaches, together with brief statements of their strengths and weaknesses. The Air Force is using these approaches as a basis for developing an appropriate method for producing the monthly separations required from SAM1.

Time Series Forecasting

Most of the models used in this approach are of the general form known as autoregressive integrated moving average (ARIMA) models. In such models, the time dependency in successive observations is inferred from plots of autocorrelation and partial autocorrelation functions, then parameters are fitted (often by regression methods) to summarize the functional form of these dependencies.

The models that we fitted are a large collection of different models for the different phases of an airman's career. For example, there are different models for each of the first three months of the first term, a model for months 4 through 12, a model for first-term airmen on short extensions who are six months or less past their original ETS, a model for retirement-eligible airmen who are in grade E-8 and have between 265 and 275 months of service, etc.

Box-Jenkins models are widely used. Software is also readily available; for example, the Statistical Analysis System (SAS) contains procedures to fit this type of model. But Box-Jenkins models have many problems. They are not adaptive, requiring separate computer programs outside the IPM to estimate new parameters. They are not easy to fit, requiring several stages of expert examination of autocorrelation and partial autocorrelation plots to identify lag terms. The fitted coefficients are highly sensitive to outliers, and there are many outliers in the EFMP data. The models do not adapt to changes in the underlying process, so they would need to be continually refitted. (For example, at one time, first-term reenlistments could occur at any time in the ETS year, whereas now they can only occur in the last three months of the ETS year. This change would require refitting of the first-term ETS loss models.) Finally, the data requirements of Box-Jenkins models during execution of SAM are high. Some models need lagged values of loss or reenlistment rates as far back as 12 months, which would have to be maintained by SAM1 in memory when the IPM was running.

Robust Separation Projection

The robust separation projection method uses data on past losses and reenlistments to estimate separation rates for a model that predicts loss and reenlistment flows one month at a time for each of a mutually exclusive set of about 500 cohorts. After these flows are predicted for a projection month, the inventory is updated and the models are applied to the updated inventories to predict the flows for the following month. This process is repeated until the inventory for the last month of the fiscal year is projected. Thus, it applies separation rates to a series of different inventories.

The robust models obtain a prediction of a loss or reenlistment rate as the sum of three components: a trend, a seasonal effect, and a residual. A particular model is obtained by subjecting the time series data to several "filters," each of which operates on a moving window of points. The filters are robust in the sense that they are not greatly affected by one or two outliers. The estimation procedure involves the following nine steps:

1. Smooth the data with 12-month moving medians. (The 12-month window is wide enough to avoid seasonal effects, and the medians are insensitive to outliers.)
2. Smooth the moving medians with moving averages. (Since the effects of outliers were eliminated in Step 1, using moving averages does not cause a problem here.)
3. Compute the residuals of the raw data with respect to the moving average fit from Step 2.

4. Group the residuals by month of year.
5. Find the median for each month.
6. Estimate a monthly effect by smoothing the monthly medians using averages over adjacent months.
7. Deseasonalize the data by subtracting the monthly effect from the original series.
8. Extrapolate the deseasonalized data forward and backward to their original endpoints using robust regression.
9. Project the last fitted trend point forward, and add the estimated monthly effects to extrapolate to future months.

This process produces estimates that capture long-term trends and seasonal behavior in a way that is adaptive and is not unduly influenced by outliers in the historical data. The models are simple, but they require at least three years of data to get the estimation process started, and they require more effort to maintain and update the data files than is required by the BSP approach. They are based on the ideas in a procedure called SABL (Cleveland et al., 1979).

Benchmark Separation Projection

The BSP method uses data on past years' losses and reenlistments to estimate a set of separation rates for each month of the next fiscal year for a mutually exclusive set of about 280 "decision groups." Those separation rates are then applied to the current inventory to predict monthly loss and reenlistment flows for the rest of the fiscal year. Thus, the BSP method applies different sets of separation rates to a single inventory. (That single inventory is the inventory at the start of the projection period.)

The inventory categories that are used by the BSP method are designed to track groups approaching a decision point. The categorization includes months to DOS, high year of tenure, and first opportunity to retire. The BSP method also includes "months to retirement/separation (RTS) date" as a categorization variable. Decisions to leave the Air Force must be communicated to, and approved by, the Air Force Military Personnel Center (AFMPC) at least three months before the departure date for retirements and generally at least four months before the departure date for first termers who are not eligible to reenlist. Once this happens, the information is recorded as the RTS date in the airman's personnel record. Its existence is a good indicator that the airman will leave. That is why the BSP method uses the RTS date when it exists. Otherwise, it uses the airman's date of separation (DOS), which is the date on which the airman has to leave if he has not reenlisted or extended.

The BSP approach is simple, intuitive, and adaptive. The data requirements are modest. It improves on simpler running average models by automatically capturing seasonal behavior and by taking advantage of the information contained in the RTS. But it ignores long-term behavior, being dependent on behavior during the last year. It may also be extremely sensitive to outliers. If one of the months last year had an unusually high or unusually low value, then the forecast for the same month this year will be perturbed by this outlier. This type of model performs best on time series that are stable over time. It is also intuitive and provides a good benchmark against which to compare other approaches. In fact, the method was originally developed to serve as a standard of comparison for the accuracy, reliability, and runtime of other alternative methods for SAM1. During the development of the method, however, it became an attractive alternative in its own right.

V. AUTHORIZATION MANAGEMENT

AUTHORIZATION PROJECTION MODEL

Enlisted force management requires two types of projections for each category of enlisted manpower: (1) how many funded authorizations will exist at each designated future time, and (2) among those airmen in the force now, how many will remain at each designated future time. The difference determines, for each category, how many additional airmen must be provided through accessions, training, and other personnel programs. Section IV focused on the second issue. This section focuses on the first.

The TOPCAP system of models included one called the Skills Projection Model (SPM) for making the first type of projection. In the late 1970s the SPM's projections came under criticism for their volatility and inaccuracy. The model was also complex to operate and "unfriendly" to its users. It fell into disuse. Its replacement in the EFMS is called the Authorization Projection Model (APM).[1] It was designed, developed, and implemented by the Air Force and is documented in Air Force Military Personnel Center (1987).

It will be important in reading this and the next subsection to recall the distinction between manpower requirements and funded authorizations (see Sec. I). Manpower requirements are the number and mix of jobs specified in Air Force manpower standards and guides as needed to carry out the Air Force's mission objectives. Manpower requirements depend not only on the mission, but also on the weapon systems that will be available to carry out the mission. They are used to analyze alternatives during development of the Future Year Defense Program and the budget but are unconstrained by the budget. Funded authorizations result from applying constraints derived from funding decisions to the unconstrained manpower requirements.

Because budgets are limited, authorizations frequently fall short of requirements. Fewer positions may be authorized than are required and/or positions are authorized with lower pay grades (or skill levels) than are required. (The latter issue is addressed in the next subsection.)

The APM is the EFMS model that has been designed to provide enlisted force planners and programmers with authorization projections for the years covered by the Future Year Defense Program (FYDP). Each time a PPBS cycle ends[2] a new budget and FYDP are established. The total number of positions that can then be funded for each Air Force program at each Major Command (MAJCOM) in each of the years covered by the FYDP is entered into the Force and Financial Plan (F&FP) data file. These aggregate authorizations are then forwarded to the MAJCOMs, which break them into authorizations by AFSC, grade, base, operating unit, etc. The resulting authorizations are stored in the Command Manpower Database (CMDB). Ideally they would become the targets for the personnel programmers and be used by MPC for making assignments of airmen.

The problem with this process is that the MAJCOMs take several months to specify the detailed authorizations corresponding to a new set of aggregate authorizations. The APM was developed to anticipate the outcome of this process. It uses both the new F&FP data and the latest CMDB to produce its projections. Thus, it combines the currency of the FYDP with the

[1]The Air Force recently changed the name of this model to Authorization Distribution Model (ADM), which better conveys the way it obtains its predictions.

[2]This occurs three times per year: in the spring with the Program Objective Memorandum, in the fall with the Budget Estimate Submission, and in the winter with the President's Budget. Because budgets are first developed nearly two years in advance, the FYDP sometimes actually looks almost seven years into the future.

detail of the CMDB. It estimates information that will shortly become firmed up, after which its estimates are no longer needed. The process described above is depicted in Fig. 10.

Both files are organized by PEC and MAJCOM.[3] The APM uses (1) the total enlisted manpower allocated to a MAJCOM for a PEC for each time period (from the F&FP) and (2) the most recent distribution of enlisted manpower associated with that MAJCOM and PEC (from the CMDB). It "scales" each future allocation by applying a factor (the ratio of F&FP to CMDB authorizations for a given MAJCOM/PEC combination) to the CMDB authorizations, and sums Air-Force-wide to obtain projected authorizations by grade and AFSC. (The scaling applies the same ratio to each AFSC found in the PEC and MAJCOM.)

This is an intuitively appealing procedure, which is basically the same as the one used in the SPM. The major problem in practice is that, because of uncertainties and variabilities in the economic and political environment, the program-based AFSC targets the Air Force tries to hit change from month to month and year to year. Thus, there are considerable problems in building a model that would be accurate in projecting future authorizations.

The Air Force analyzed prediction errors of authorizations at the AFSC level for FY 1988 (the end of FY authorizations projected at the beginning of the FY). They found, for example, only 57 percent of the AFSCs had less than a 5 percent error in prediction of authorizations, even over one fiscal year, and 29 percent of the AFSCs were in error by more than 10 percent over the same time period.[4] Prediction errors over longer time periods are likely to be even greater.

The APM cannot solve this dilemma, but it deals with it by allowing for interactive pre- and post-processing by the user. The interactive capabilities allow the user to adjust the data to late-breaking budget changes, to correct discrepancies between the two base files, to target increases or decreases to selected skills, and to selectively adjust authorization levels to projected end strength figures.

The APM includes an interactive "what if" facility that allows users to evaluate alternative strategies for responding to changes in end strength. They can input a projected end strength, propose a strategy for targeting cuts or increases to match that end strength, and see how their strategy affects authorizations at the AFSC level. The user may evaluate several strategies (e.g., specifying ceiling levels, and shielding programs, MAJCOMs, or AFSCs from changes) without changing the data in the main file. Once the user has selected a strategy, he asks for it to be implemented, and the authorization projections are changed.

The APM is implemented as a set of 13 batch and interactive SAS computer programs. The F&FP and CMDB data files are supplied to the system by the Directorate of Manpower and Organization (AF/PRM). The SMO runs most of the programs, which produce the authorization projections that are passed on to the Grade Allocation Model (GAM) or to the other EFMS modules before the GAM is completed. Figure 11 shows the major steps and data flows that make up the APM.

GRADE ALLOCATION MODEL

The authorizations generated by the MAJCOMs or projected by the APM include "required grades," but these grade requirements do not generally meet overall grade-strength ceilings. (They usually specify more high-grade airmen and fewer low-grade airmen than are

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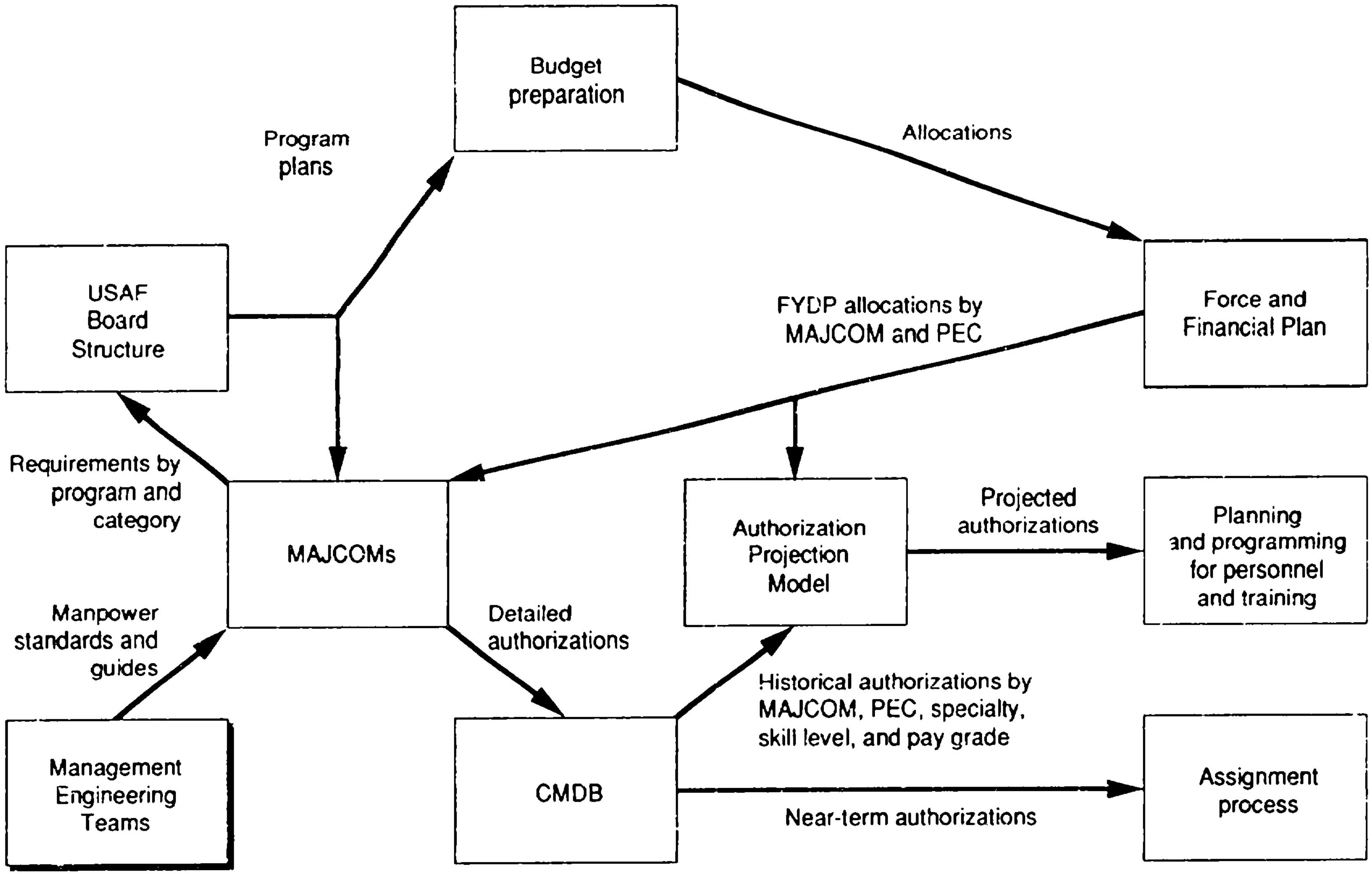
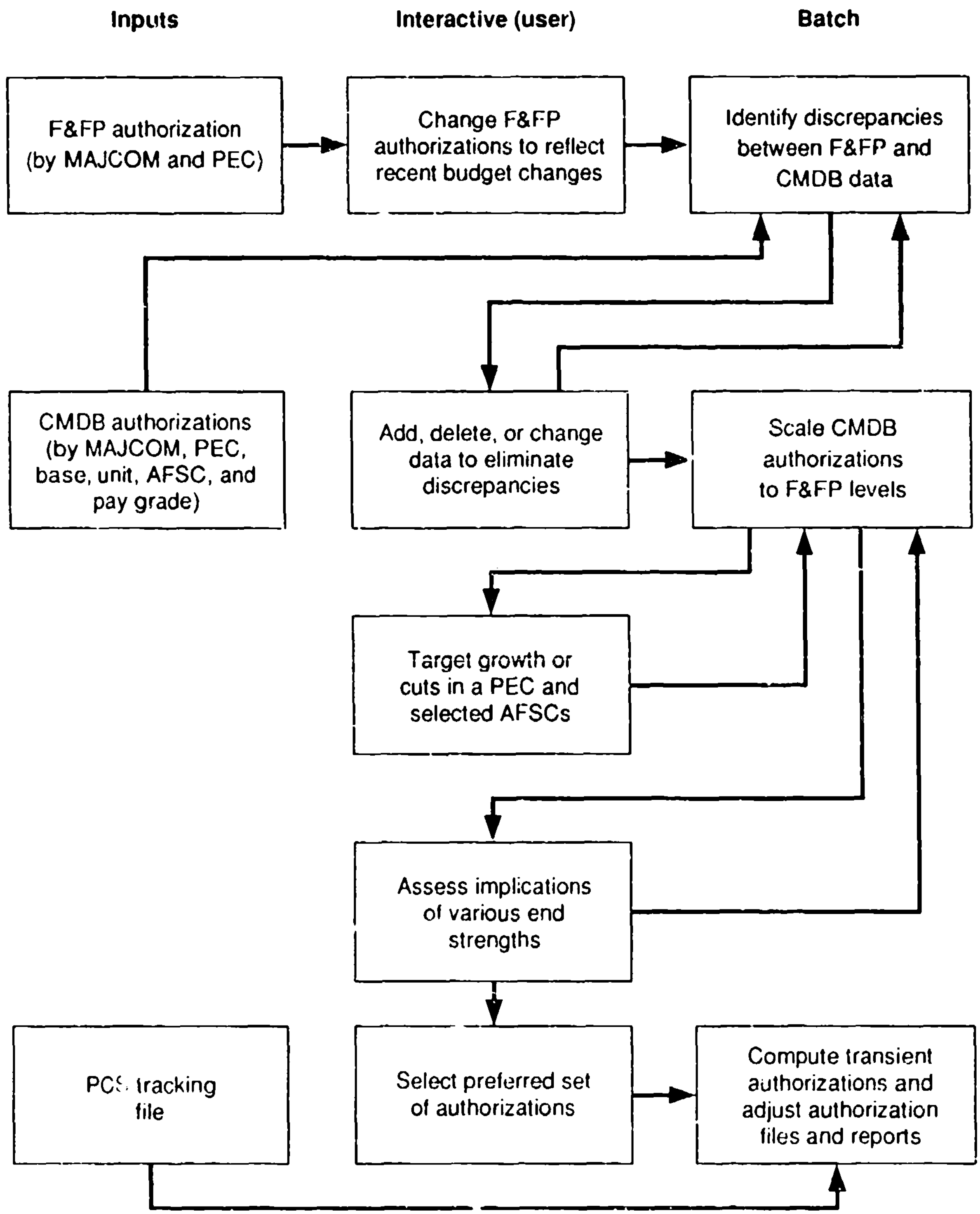
[3] A program element is a subclass within one of the Air Force's Major Force Programs. The Air Force uses this categorization in submitting its FYDP data.

[4] The prediction error for an AFSC was defined as |(authorizations projected on 1 October 1987) − (actual authorizations on 30 September 1988)|/(actual authorizations on 30 September 1988)*100.



SOURCE: Adapted from S. C. Moore et al., 1983.

Fig. 10—Data flows surrounding the Authorization Projection Model



SOURCE: Adapted from DFMDW, 1987, p. 43.

Fig. 11—Authorization Projection Model flowchart

allowed.) They also sometimes require a grade structure within an AFSC that is inconsistent with the constraints inherent in the personnel structure of the Air Force, such as the need for a visible and equitable promotion policy in each AFSC. The GAM helps enlisted force managers assign grades to the authorizations in a manner that satisfies overall grade-strength ceilings, equity considerations, and personnel constraints. The resulting set of authorizations aggregated to the level of specialty and grade become the targets for the personnel programmers. Specifications for the model have been proposed by Mickelson in unpublished RAND research, but the model has not yet been developed, even as a prototype.

Current Procedure

The GAM is based on the current procedure used by enlisted force managers in AF/PRM to allocate grades. The process starts with total funded authorizations unconstrained by grade and proceeds through the following steps:

1. The total number of grades available to be allocated (excluding fixed grades) is calculated. These are called the factored grades.[5]
2. The factored grades are divided among CPGs so that each CPG gets its "fair share" of the total.[6] This process ensures each agency of receiving a share of grades that takes into account the differing mission requirements among MAJCOMs, as reflected in the required grades (certain missions require more experienced personnel).
3. Manpower analysts and functional managers meet to manually modify this allocation for each CPG. They try to reach a compromise between the "fair share" allocation and the authorizations based on required grade. We call this the "target" grade structure. (It becomes the target for the personnel programmers.)
4. The target grade structure by CPG is allocated to the MAJCOMs.[7]

Grade Allocation Model

We found no reason to change Step 1 or Step 2 of the current procedure (determining fixed grades and fair shares). However, the GAM provides a new way of performing Step 3 (determining a target grade structure) that automates the process, provides improved algorithms, and expands the information provided to the enlisted force managers, while retaining the attributes of fairness and flexibility that are present in the current system.

The GAM enables personnel planners and programmers to generate and evaluate alternative enlisted force grade structures (targets by grade and occupation) that provide a good fit to the fair share of grades within each specialty and that are feasible. A grade structure is considered feasible if acceptable personnel actions (e.g., bonus multiples, promotions) can create a steady-state force that matches this structure.

Use of a steady-state work force means that the tradeoffs considered by the model in assessing the goodness of a grade structure will not be a completely accurate representation of the potential tradeoffs among personnel management actions in the real world. To get a more

[5]Some grades are for fixed positions that are not identified in the CMDB, such as students and patients. These positions are not available to be allocated, so they are subtracted from overall grade ceilings. The rest of the fixed grades are for positions that are included in the CMDB but must be fully funded (e.g., instructors and recruiters). These are also subtracted from the overall grade ceilings. The remainder to be distributed are the factored grades.

[6]CPGs are groupings of occupations based on the first three digits of the AFSC.

[7]The allocations to the MAJCOMs are only recommendations; the MAJCOMs retain the right to set their own targets by grade and occupation within their total grade allocation.

realistic representation of those tradeoffs, the model would have to use data on the current inventory. However, the existing inventory contains within it the results of many past personnel policy decisions; it was decided that it was inappropriate to constrain the target of the personnel system by decisions made in the past (although, of course, the actual results will be so constrained).

Different personnel actions have different effects on personnel flows and would lead to different feasible grade structures that would fit more or less closely to authorizations. The different personnel actions also lead to different amounts of specialty reclassification, cost to retrain personnel, and level of experience within occupations. The GAM helps the user to systematically examine tradeoffs between the fit of a grade structure and the resulting turmoil (e.g., reclassification) required to achieve that structure.

The proposed GAM has five modules (see Fig. 12), each with its own user interface (input and output mechanism). The modules are:

1. *Data Preparation and Fair Share Calculator.* This module assembles the requirements data (by MAJCOM, occupation, and grade) and the data needed to generate the theoretical force inventory (e.g., AFSC-specific loss and reenlistment rates). All calculations that are "one time only" are performed in this module. For example, Module 1 calculates and reports the fair share grade allocation, which forms a basis for comparing alternative grade structures.

2. *Steady-state Inventory Generator.* The purpose of Module 2 is to generate survival probabilities by AFSC and grade based on a given theoretical steady-state enlisted inventory. The probabilities are conditional on a user-specified bonus plan and promotion rates, as well as EFMS-supplied separation rates. The survival probabilities are supplied to the optimization modules (Modules 3 and 4).

3. *Grade Structure Designer.* Module 3 determines a grade structure for each occupation and grade using a piecewise linear optimization procedure. The model minimizes the sum of the weighted deviations between required grades and the grade structure. The model is essentially a transportation model[8] with constraints dictated by end strength, amount of grade reclassification (deviation from required grades within a specialty), and the amount and cost of retraining (movement between occupations). The model is piecewise linear because different weights are assigned to different sized deviations from the required grades. To speed computation, this module allows for optimization over user-specified parts of the force. Statistics are calculated that indicate the amount of reclassification required to support the grade structure, and the expected cost of retraining. The various grade structures and results are saved for use in Module 5.

4. *Grade Structure Evaluator.* The objective function and constraints from Module 3 may not be sufficient to determine a unique optimal grade structure. Module 4 identifies a good structure from within the set of alternative optima by using the "shadow prices" on the allowable amounts of retraining and grade reclassification that are generated in Module 3. The results of Module 4 can be used in Module 3 to revise the reclassification and retraining constraints.

5. *Tradeoff Mediator.* Modules 3 and 4 may produce several acceptable grade structures. This module assists the user in choosing among these structures by allowing him to

[8]Transportation models are described by Hillier and Lieberman (1990, Sec. 7.1).

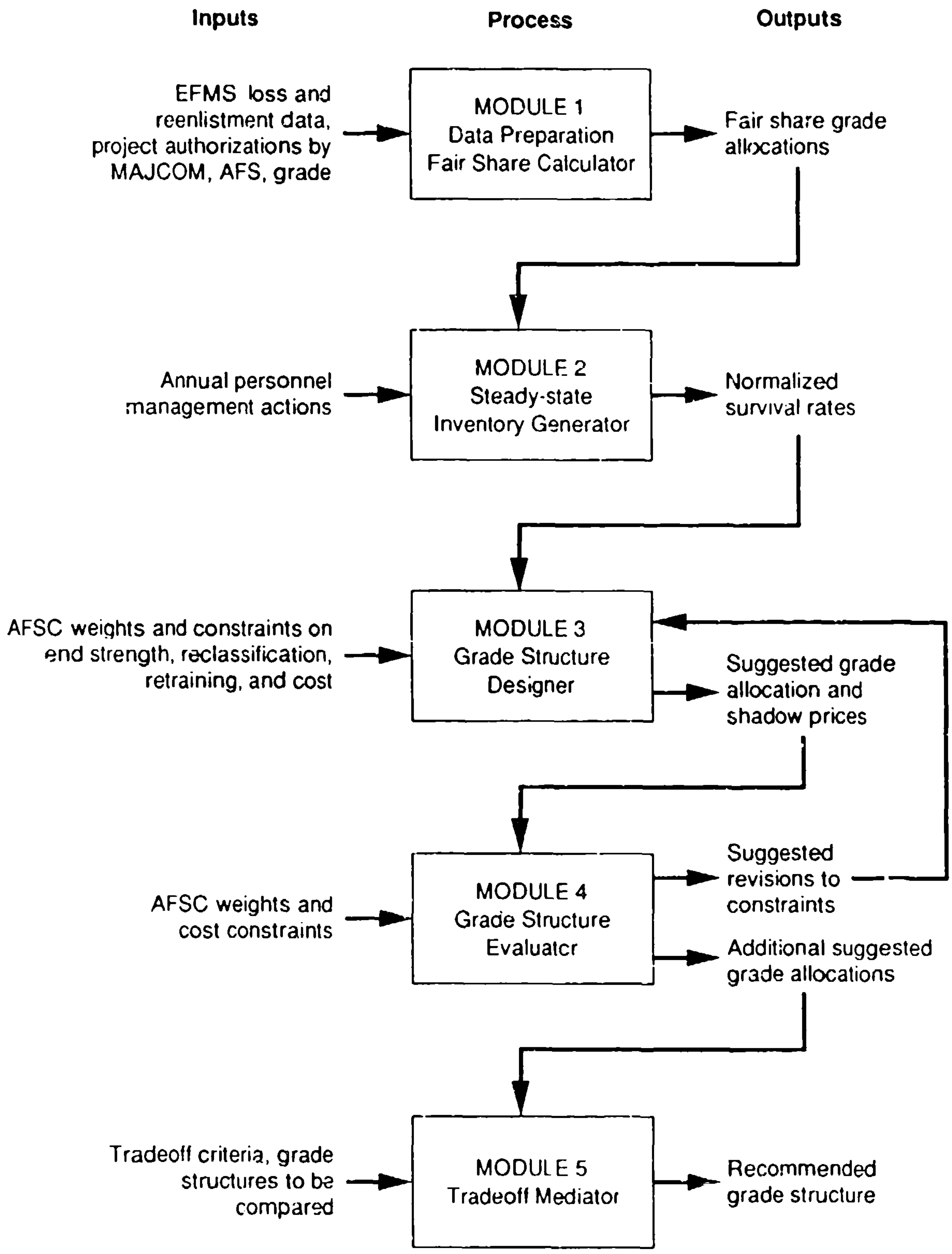


Fig. 12—Modular design of the Grade Allocation Model

trade off fit to requirements with amount of reclassification, taking into account levels of experience and costs. This module functions only on the grade structures generated and saved in Modules 3 and 4. It consists of two components—one to examine aggregate statistics and another to compare the alternative grade structures at a more detailed level. The user has the options of using these components sequentially or separately:

a. A "scorecard" is created for comparative purposes.[9] The scorecard consists of aggregate statistics on goodness of fit, reclassifications, and costs for each grade structure. The user has several interactive tools at his disposal to examine the aggregate statistics and assess the alternative grade structures. This component allows the user to narrow the field of competing grade structures to a small list that can be compared in greater detail by the second component.

b. Two grade structures are compared for a user-specified collection of specialties and levels of aggregation. The most disaggregate level is by pay grade within specialty. The required grades and fair share grades form the basis for comparison of the two grade structures.

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[9]For a discussion of scorecards, see Miser and Quade, 1985, pp. 96-99.

VI. SKILLS MANAGEMENT

OVERVIEW

The objective of the Force Programs Division of the Personnel Programs Directorate (DPPP) is to produce an inventory that matches the authorization target in each occupational specialty while remaining within constraints imposed by the budget and by personnel policies. Aggregate management, to remain within budget and end-strength constraints, is discussed in Sec. VII. This section deals with the effort to meet authorization targets by specialty, which we refer to as "skills management."

Enlisted force programmers have many management levers available for moving the force toward its target, such as bonuses and training. The purpose of the skills management modules of the EFMS is to provide DPPP with the information necessary for making decisions on how and when to apply each such management action. The necessary information includes the effects the action will have on the inventory and the costs associated with the action.

The skills management models (and the aggregate planning, programming, and oversight models) can be divided into two categories: screening and impact assessment. Screening models are generally designed for rapid comparison of many alternative plans or programs using summary or approximate measures of performance. Impact assessment models are used when more detailed or more accurate calculations are required. Since the primary criteria used to evaluate alternative plans and programs are related to their effect on the inventory of airmen, most of the skills management and aggregate programming models are inventory projection models (IPMs) or include IPMs as subprograms.

INVENTORY PROJECTION MODELS

As noted earlier, IPMs take an initial actual or hypothesized inventory of airmen and "age" it to predict what the inventory will look like in the future. The complexity of an IPM depends largely on the accuracy and detail with which one wishes to describe future inventories. In designing the EFMS we realized that no single IPM would be able to serve all users equally well; the needs are simply too varied. Planning for meeting end strength, predicting the effects of different bonus plans, analyzing alternative force structures, etc. require different degrees of detail and different time horizons. We decided that tailoring individual IPMs to specific needs would provide better and simpler service to each user. Thus, the EFMS includes several IPMs.

The major distinctions among the IPMs involve two dimensions: (1) time horizon and (2) level of aggregation. Short-term IPMs focus on monthly projections, primarily for the remaining months of the current fiscal year; middle-term IPMs focus on annual projections and are designed to provide projections from one to six years into the future. Disaggregate models can be used to analyze separate job specialties; aggregate models project total personnel across all job specialties. Underpinning each of the IPMs is a loss model that shares the IPM's time horizon and level of aggregation (see Sec. IV).

IMPACT ASSESSMENT MODELS

The Disaggregate Middle-Term Inventory Projection Model

The Disaggregate Middle-Term Inventory Projection Model (DMI) makes annual predictions of Air Force enlisted force levels by AFSC for one to six years into the future. The predictions are conditional on specific management policies (for example, reenlistment bonuses) and on economic conditions (such as unemployment rates). Losses and extensions in the DMI are predicted using the middle-term disaggregate models described in Sec. IV.

The primary purpose of the DMI is to help managers match the personnel inventory to manpower authorizations (e.g., those produced by the Authorization Projection Model) or to the manpower targets produced by the Grade Allocation Model. The authorizations or targets are specified by time (end of fiscal year), job (AFSC), and grade (E-3 or lower, E-4, E-5, . . . E-9). If the model is run with existing policies and plans, its projections will warn of future mismatches between inventory and authorizations (or targets). Then additional runs can be made using alternative management programs to test ways to reduce the mismatches. The model also establishes training requirements used by the Air Training Command and accession requirements used by Air Force recruiters.

In addition to a beginning inventory, the authorizations or targets, projected economic variables, and variables describing various management actions, the inputs to the DMI include a number of tables (e.g., all AFSCs, AFSCs to be given a higher promotion rate, career flow relationships among AFSCs) and the values of various parameters (e.g., proportion of NPS accessions with a six year term of enlistment).

The inventory is divided into four category of enlistment (CATENL) groups: CATENL=1 represents first-term airmen by AFSC, grade, YOS, and years to expiration of term of service (YETS); CATENL=2 represents second-term airmen by AFSC, grade, YOS, and YETS; CATENL=3 represents career airmen who are not eligible for retirement by AFSC, grade, YOS, and YETS; and CATENL=4 represents retirement-eligible airmen by AFSC, grade, and YOS. Authorizations or targets are specified by AFSC and grade for each year of the inventory projection.

The process of projecting any start-of-the-year inventory one year into the future is divided into five steps. (Each step has been coded as a separate module of the operational version of the DMI.) As shown in Fig. 13, these steps are:

1. *"Survive" the Force.* Blended loss rates from the middle-term disaggregate models (see Sec. IV) are applied to the start-of-the-year inventory. High-year-of-tenure rules are applied to eliminate those in the inventory whose YOS exceed the maximum allowed for persons in their grade.
2. *Age the Force.* Extension rates from the middle-term disaggregate models (see Sec. IV) are applied to the "survived" inventory. Reenlistments are estimated as a residual (airmen who neither leave nor extend are assumed to reenlist). The TOE for those who reenlist is determined using a model specified by Carter and Hackett in unpublished research. End-of-year values for YOS and YETS are assigned to the survived inventory.
3. *Promote the Force.* Information on grade strength ceilings, promotion eligibility, and historical promotion rates is used to estimate promotions. End-of-year values for grade and time in grade (TIG) are assigned to the survived inventory.

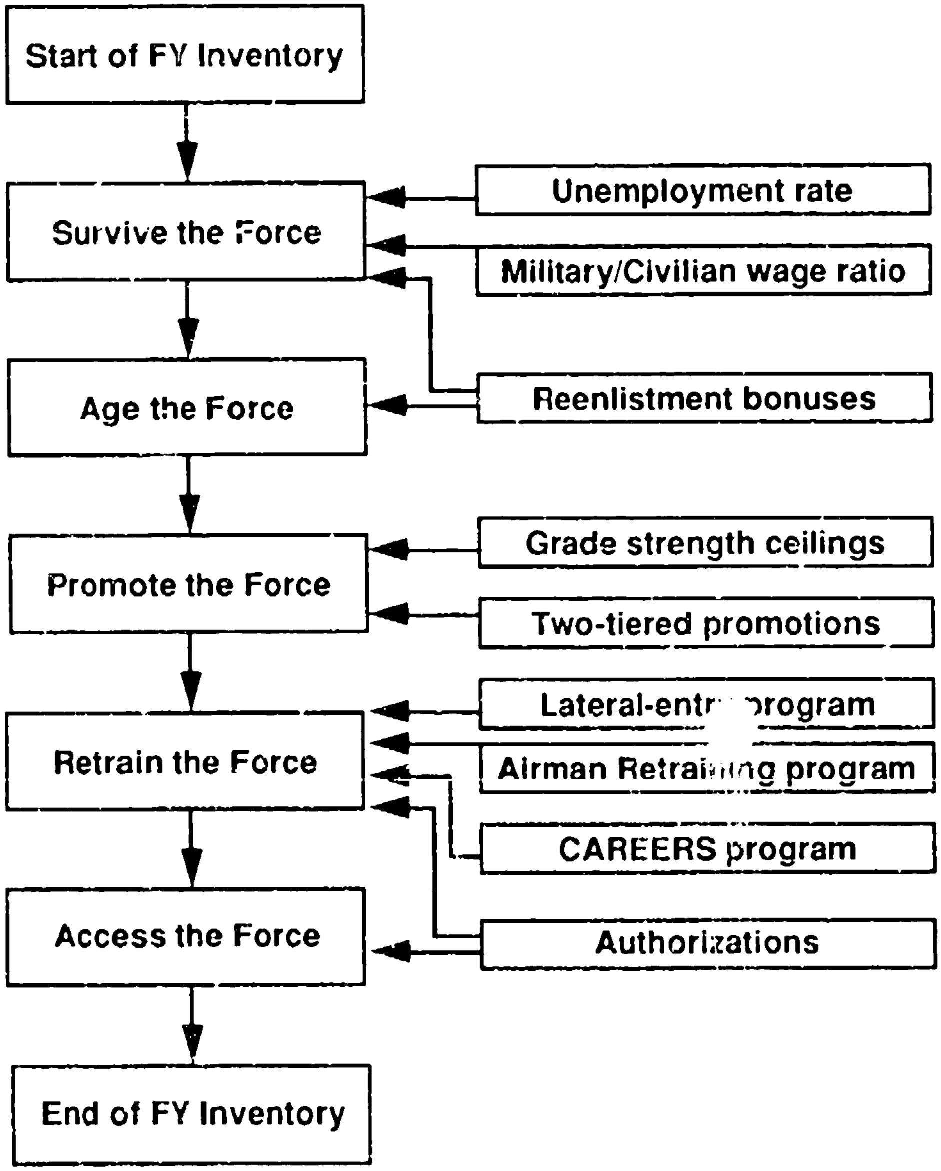


Fig. 13—Annual inventory projection in the DMI

4. *Retrain the Force.* The values of the end-of-year AFSCs for airmen who remain in the force are assigned in this step. Some AFSCs are changed according to predetermined natural career progressions called career ladders. Others are changed based on voluntary or forced retraining programs (called Airman Retraining[1] and CAREERS[2]). Details of the planned Palace Balance program are provided to the DMT as input data. A mathematical model is used to predict the number of airmen who will join the CAREERS program each year, the distribution of occupations from which they will come, and the distribution of occupations which they will enter. This model is described by Carter in unpublished research.
5. *Access the Force.* Prior service accessions are added to the end-of-year inventory. based on user inputs.[3] Nonprior service accessions are determined based on the difference between authorizations and the projected inventory. (As of now, the inventory in the DMI is the trained inventory, so all airmen have an AFSC assigned and none are in basic training. Unpublished RAND research by Dowling proposed a way of adding the training pipeline to the DMI.)

The models used in Step 2 to assign a TOE to airmen who reenlist are regression models that relate the number of years in the reenlistment contract to characteristics of the airman and his service environment—particularly Selective Reenlistment Bonuses (SRBs). Unpublished RAND research by Carter and Hackett showed that size of the SRB offered in the reenlistee's specialty is one of the strongest determinants of TOE. (Almost 90 percent of airmen who are not offered a bonus choose a 4-year term, but less than 32 percent of those offered a bonus choose such a short term.) Other determinants of TOE include the length of time the reenlistee has already served in the Air Force, his occupation, and his demographic characteristics.

Calculations in the CAREERS model, which is used in Step 4 to predict the occupational choice decisions of first-term reenlistees, are divided into three parts: (1) predict the number of persons who will join the program in a given year, (2) predict the distribution of occupations from which the airmen will come, (3) predict the distribution of occupations they will enter. Unpublished RAND research by Carter showed the importance of the CAREERS program. In recent years, between 1700 and 3600 airmen have retrained annually through the program. The vast majority who reenlisted completed their second term, and most went on to serve a full 20-year career. Thus, the program is potentially very important in determining the occupational makeup of the cohorts of experienced airmen who costitute the career force. Because it allows airmen to choose their AFSC from among those with projected vacancies, it probably contributes to higher morale and to a better match of personnel to job categories than would occur if the decisions were imposed by the Air Force.

Between 1987 and 1989 the Air Force carried out a careful, comprehensive test and evaluation of the DMI (Air Force Military Personnel Center, 1987, 1988). Individual submodules were tested on artificial data, inventory projections from the DMI were compared with

[1]Under the Airman Retraining program, airmen in grades E-5 to E-7 in specialties whose inventories are over target levels are retrained into specialties where they are needed.

[2]First-term reenlistment is limited by occupation through the Career Airman Reenlistment Reservation System (CAREERS). A first-term airman who wishes to reenlist must first obtain a career job reservation (CJR). Quotas are set in some specialties. If the quota in his chosen specialty has been exhausted, the airman is provided with a list of other specialties in which there are openings and for which he is qualified. The airman may remain on the waiting list for a CJR in his original career field, or apply for retraining. If he agrees to retrain, he is provided a CJR.

[3]Persons already trained by the military who have left the service can be enlisted to help meet the need for experienced personnel in a particular AFSC. These are called prior service (PS) accessions.

projections made using existing IPMs, and losses and inventory projections from the DMI were compared with actual losses and end-of-year inventories. As an example of the results of the last test, Fig. 14 shows the distribution of the percentage difference between DMI predictions one year in advance and the actual ending inventories for FY 1988 for the 217 AFSCs that had inventories of more than 50 airmen and no unpredicted changes in management practice (e.g., changes in SRB levels). The DMI inventory predictions for 54 percent of the 217 AFSCs were within 3 percent of the actuals, and the DMI's predictions were within 10 percent of the actuals for 88 percent of the AFSCs. The DMI has begun to be used on a regular basis by personnel programmers in DPPP.

Part-of-the-Force Inventory Projection Model

The DMI is a large, complex model that requires long execution times. The main reason that its execution time is so long is that it has to project the inventory (by at least grade and YOS) for about 400 AFSCs. The Middle-Term Aggregate IPM (see Sec. VII) is a much faster model, primarily because it does not include the AFSC dimension. The Part-of-the-Force Inventory Projection Model (POF) was added to the EFMS (it was not in the original conceptual design) to give skills managers the capability of evaluating alternative ways of correcting manning imbalances in individual specialties without paying the computational cost of tracking changes in the entire enlisted force.

The POF, which was specified in unpublished RAND research by Mickelson, is based on, functions like, and is designed to be used in conjunction with the DMI. The POF models

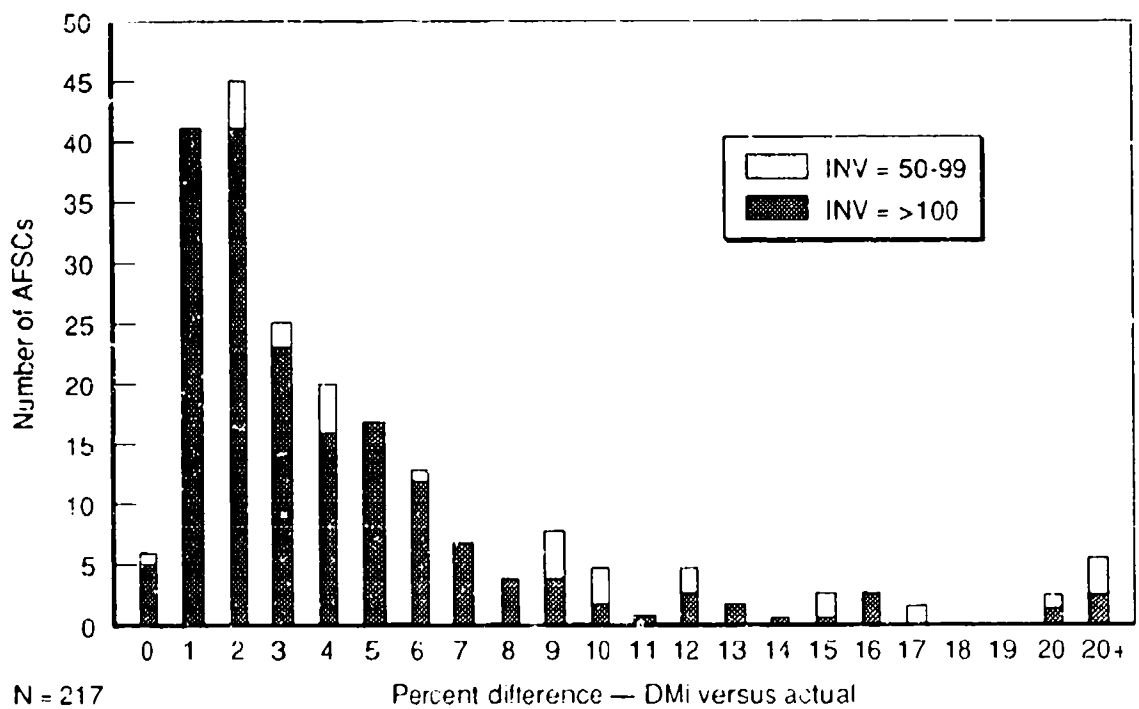


Fig. 14—Test and evaluation of DMI: Percentage differences for all AFSCs with inventories > 50

subsets of AFSCs in isolation. The subsets it models are called Chief Enlisted Manager Progression Groups (CEMPGs).

A CEMPG is defined to be the set of all AFSCs whose career ladder culminates in the same Chief Enlisted Manager level capper AFSC (skill level 0). The set of all CEMPGs forms a natural and complete decomposition of the enlisted force. That is, every AFSC is contained in only one CEMPG. There are just over 100 CEMPGs. Almost two-thirds of these consist of a single AFSC ladder. However, the other CEMPGs contain over two-thirds of all AFSCs.

The POF projects the inventory for a single CEMPG, the rest of the force, and the dynamic interaction (personnel flows) between the two. The following is the procedure that is likely to be used to evaluate alternative program options using the POF (see Fig. 15):

1. Run DMI to establish a base case. This will set the management actions for the rest of the force.
2. Identify the CEMPG to be analyzed (for example, a CEMPG whose authorizations and projected inventory differ substantially in the DMI results).
3. Accept force-wide programs for promotions, CAREERS, and retraining flows.
4. Identify policies for the CEMPG (for example, accessions, bonuses, inclusion in top promotion tier).
5. Run POF, producing accessions, losses, reenlistments, promotions, CAREERS, and retraining flows within the CEMPG.
6. Output performance measures.
7. Compare outputs from several runs of the POF to select the most promising programs for that CEMPG.
8. Perform Steps 2-7 for other CEMPGs.
9. Rerun DMI using selected program choices.

The DMI divides its calculations into five modules (see Fig. 13). To maintain consistency, the specifications for the POF use the same five modules and suggest using a modification of the same code. The POF has yet to be programmed, even as a prototype.

Year-of-Service Target Generator

The Year-of-Service Target Generator (YOSTG), specified by Carter (1991a and 1991b), provides targets that add a YOS dimension to authorizations (or to the targets produced by the GAM). The YOSTG produces desirable year-of-service distributions (for each AFSC) that are designed to meet mission needs as reflected in authorizations and to be attainable with current personnel policies. The need for the YOSTG arises from two considerations. First, some personnel programs increase or decrease the number of personnel in specific year groups. To decide how to manage these programs, it is necessary to know how many people one wants in each occupation and year group—to have YOS targets. Second, authorizations are created without explicit attention to feasibility. It may be that, given personnel constraints, it is impossible to meet both this year's authorizations and future years' authorizations in both grade and AFSC detail. Thus, personnel managers must trade off today's overages and shortages against future overages and shortages. The YOSTG calculates the optimal tradeoff point, given the user's time preferences.

For each AFSC, the YOSTG determines the distribution of airmen by YOS that will have a grade distribution as close to the authorization targets as is possible given constraints on how the inventory can change from year to year (loss rates from attrition, length of time in BMT,

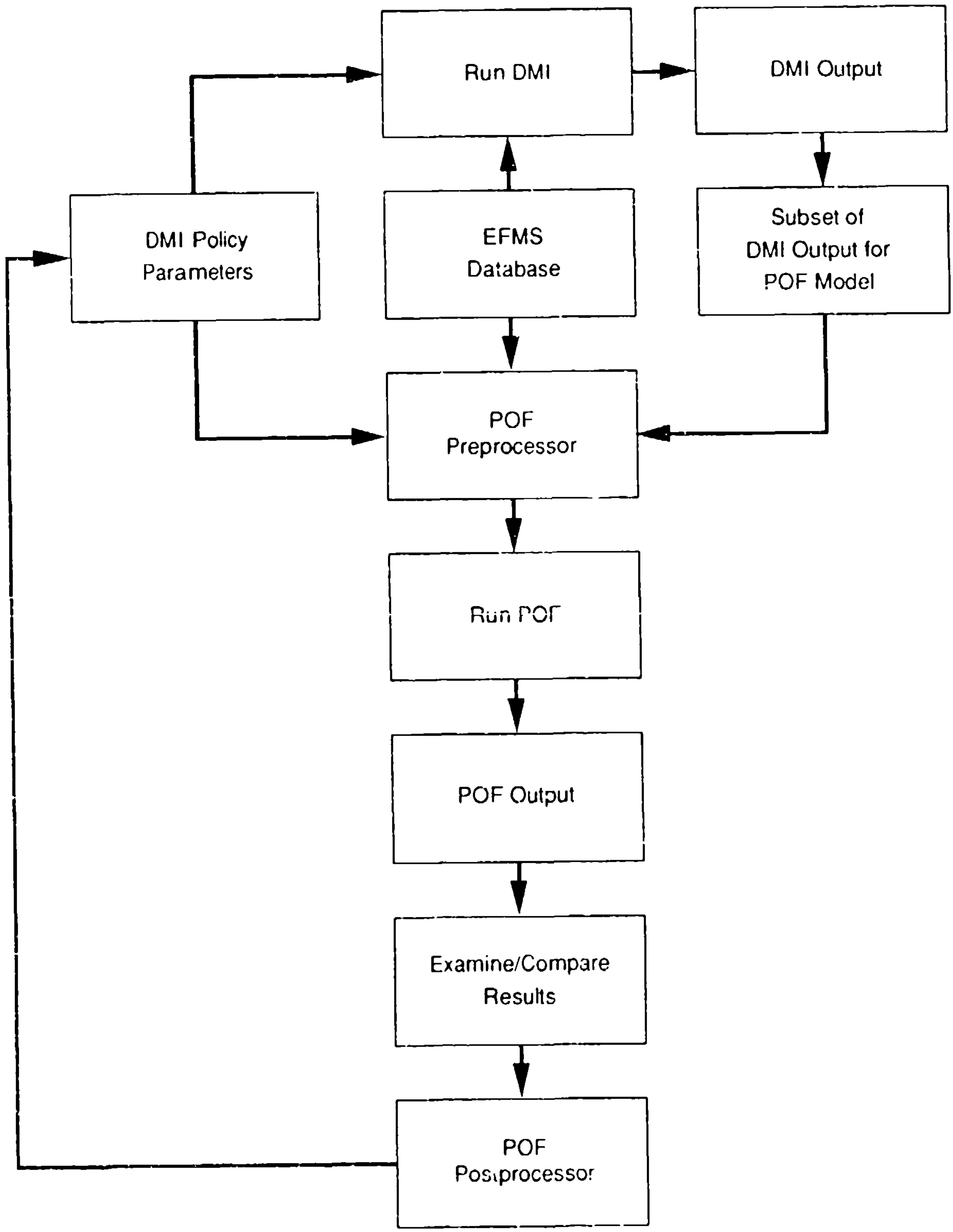


Fig. 15—Structure of Part-of-the Force model application

etc.). It does so by repeatedly projecting the inventory, using alternative loss and reenlistment rates for persons in YOS 3–14. Given a fixed promotion rate and end strength for the AFSC, if retention is increased, then the number of persons in higher grades in future years will increase. If retention is decreased, then accessions must be increased to maintain end strength. Thus, there will be an increase in the number of persons in lower grades in the AFSC.

The model uses a "penalty function" to measure how well the inventories match the authorizations in each future year. This function includes a discount rate to lower the importance of a future discrepancy between authorizations and inventory compared with the importance of an earlier year's discrepancy.

The model produces a steady-state target and a target for each year of a finite planning horizon. The dimensions of each target include AFSC, CATENL, YOS, grade, and YETS. The steady-state target is the best possible fit to a single year's authorizations—usually authorizations for the last year of the planning horizon—and can be of interest as a measure of what one would eventually like the inventory in the AFSC to look like.

The model includes an accurate representation of all major personnel management actions. To make it compatible with the DMI, the data structure for the inventory was chosen to have the same dimensions, and many of the inputs are the same as those used by the DMI. The inputs include authorizations by AFSC and grade in each future year, blended loss and reenlistment rates (from the middle-term disaggregate models described in Sec. IV), a beginning inventory, and parameters describing personnel programs, including annual promotion rates for each grade, the size of the retraining program, and relationships among AFSCs. Output from the YOSTG has the same data structure as is used with the DMI. This facilitates creation of routines to compare inventory and targets and to examine targets.

The YOSTG consists of five modules, as shown in Fig. 16. The first module prepares the data that will be used by the other modules. The second module produces a steady-state target for each of the model's occupational groups (which are called "self-sustaining ladders"). This steady-state target is part of the input to the third module, the dynamic optimizer, which iteratively projects the inventory and chooses improved values for the decision variables. The final step is the allocation of the targets for the self-sustaining ladders to individual AFSCs. The fourth module allocates both the steady-state target and the dynamic targets to individual AFSCs.

Use of the YOSTG, with its inherent concern for the future distribution of the force, should enable the process of managing AFSCs to become more efficient. It should eliminate personnel programs that overcorrect shortages and overages. Also, it can be used to point out which specialties have authorizations that cannot be filled (because their profiles cannot be produced under existing personnel guidelines). This can initiate a dialogue aimed at creating more sustainable authorizations.

A prototype version of the YOSTG (written in the PL/1 programming language) has been operating as part of the EFMS since 1986. An output file created by the YOSTG is input to another EFMS model, the Bonus Effects Model, which is used to manage the Air Force's Selective Reenlistment Bonus Program. The YOSTG is also being used to help manage career force entry and other year-group programs. The EFMS's operational version of the YOSTG has been programmed using the conceptual design given in Carter (1991a) and the mathematical specifications given in Carter (1991b).

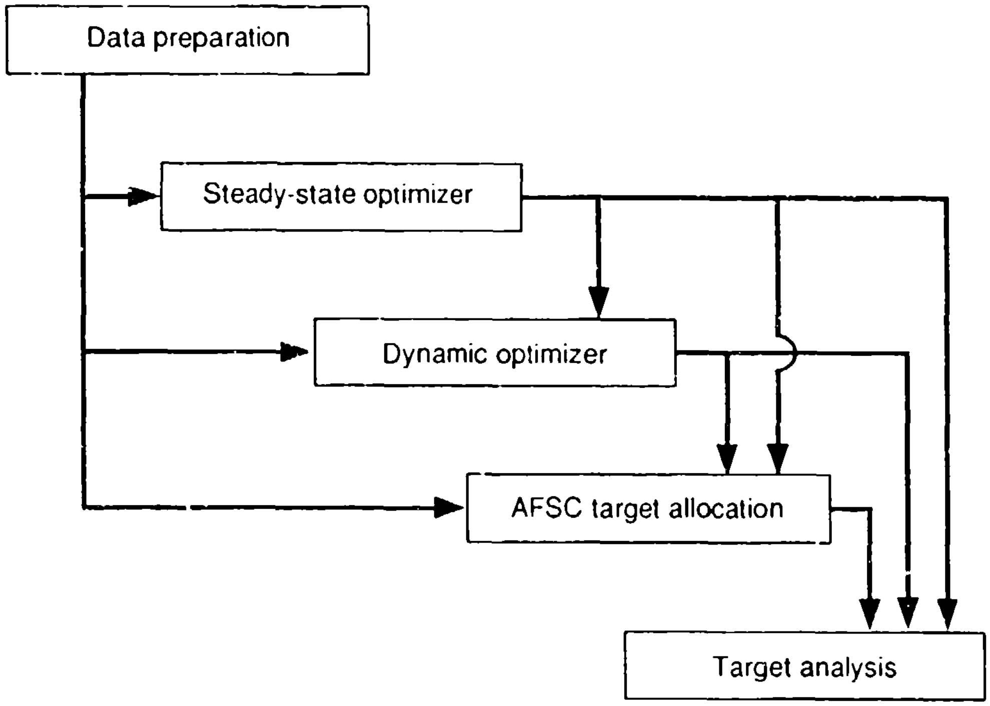


Fig. 16—Structure of the Year of Service Target Generator

SCREENING MODELS

Bonus Effects Model

One of the tools that personnel officers can use to encourage retention of skilled personnel and help guide the force toward authorization targets is the Selective Reenlistment Bonus (SRB) program. SRBs are offered to members of selected AFSCs on the condition that they reenlist or extend for 23 months. The bonus amount can vary by YOS as well as by AFSC. Currently, there are three YOS groups that can be offered a bonus: zone A (3-6 years), zone B (6-10 years), and zone C (10-14 years). The bonus amount is determined by multiplying the airman's monthly basic pay by the number of years of his additional obligated service, and by a bonus multiple that is specified according to his AFSC and zone.

Unpublished RAND research by Carter has shown that bonuses can have a large effect on the shape of the enlisted force (see appendix). Not only do they increase the number of reenlistments, they affect the term of enlistment and the career specialty choice. Because they affect the term of enlistment (causing many airmen to reenlist for six years rather than four), their effects persist many years after the bonus is offered. Carter has shown that offering a zone A bonus of multiple 1 instead of no bonus in an average AFSC increases the number of man-years obtained from a given cohort of airmen over the remainder of their enlisted careers by over 10 percent. The maximum effect is felt six years after the bonus is offered, when the cohort size is estimated to be almost 18 percent larger than it would have been at that point if a bonus had not been offered.

The Bonus Effects Model (BEM) is designed to help bonus managers develop the Air Force's SRB program. It provides the capability to examine the effects of alternative bonus program decisions on projected inventory and projected bonus expenditures. Bonus managers can quickly and easily obtain information about the influence of a variety of potential bonus plans on the decisions of individual airmen (e.g., reenlistment choice and occupational choice) as well as on the evolution of the force structure (e.g., projected aggregate force profiles and experience mixes within AFSCs). This information could be obtained from the DMI, but it would not be feasible to run the DMI to test a variety of bonus plans. The BEM was developed as a simplified analytical tool that retains the DMI features strongly affecting the accuracy of bonus effects (such as the number of airmen facing a reenlistment decision in each specialty and zone during each planning year) but eliminates second-order effects. The model facilitates the identification of good bonus plans. These (few) plans are then run through the DMI to obtain more accurate and detailed predictions of their performance.

Various EFMS models provide information to the BEM. It uses blended loss and extension rates from the middle-term disaggregate models described in Sec. IV. These models provide the BEM with information on retention and how expected reenlistment decisions change as a function of the bonus. A separate model, based on unpublished RAND research by Carter, predicts occupational choices in the CAREERS program and the probability that an airman entering the career force will decide to stay in the same AFSC or retrain, based in part on the bonuses offered in his and other AFSCs. The YOSTG (Carter, 1991a) is used to set year-of-service targets by AFSC and grade. This information helps the bonus manager decide on the desired number of reenlistments for each AFSC by zone. The BEM also requires information on the number of persons who will reach the end of their enlistment contracts during each year of the projection period. The DMI will eventually supply these counts. In the prototype version they are generated by an IPM based on the YOSTG.

The BEM is an interactive system of programs that interface with the user by means of a series of menus. The menus provide options that allow the user to display tables, construct a test bonus plan, and compare a test plan with the current actual plan. Its output includes screens that show, for a user-specified set of specialties and for each planning year: the reenlistments predicted to occur at each bonus level, the predicted bonus costs, the predicted inventory by year of service, and a comparison of both reenlistments and inventory with targets. It also provides summary tables, including inventory summaries across AFSCs, zones, and planning years. The program, its inputs, its outputs, and its user interface are documented in (Carter et al., 1988).

A prototype version of the BEM has been part of the EFMS since the middle of 1986. It has been used by bonus managers in DPPP to help develop the Air Force's SRB plan for every fiscal year since FY 1987. In its very first year of use, the BEM provided the bonus manager with information that led to decisions reducing the number of AFSCs receiving Zone C bonuses from 40 to 21. This change saved the Air Force $1.9 million per year.

Much of the data manipulation for the prototype is programmed in SAS, while the interactive capabilities and the final stages of data manipulation are written in EXPRESS. This division was based purely on EFMP staffing availabilities and does not fully exploit the unique capabilities of either language. Thus, the operational BEM is likely to be different from the prototype.

Some capabilities that are missing in the prototype might be added in future versions. These include (1) additional cost information (both training costs and life cycle costs) and (2) an allocation algorithm that will show the user how a fixed SRB budget can be allocated among specialties and zones so as to minimize the deviation between the inventory and its target.

Aggregate Lifecycle Effectiveness and Cost Model

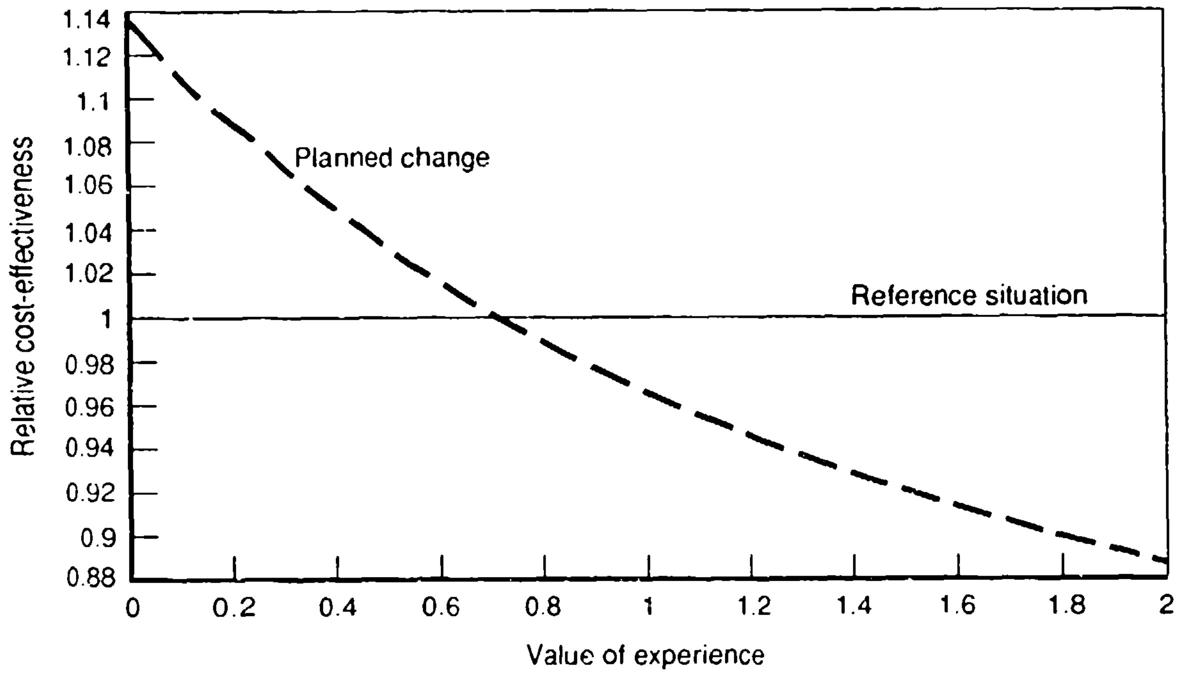
The Aggregate Lifecycle Effectiveness and Cost (ALEC) model, which was specified and implemented by Rydell (1987a, 1987b), estimates the cost-effectiveness of alternative skills management programs, including accessions, retraining, SRBs, early releases, and Career Job Reservations. It analyzes the lifecycle of a cohort of enlisted personnel from the time the cohort enters the Air Force until the last member of the cohort leaves the Air Force. The model tracks both the costs and the number of persons working during each year of the lifecycle and constructs the ratio of incremental cost caused by the action to the incremental effectiveness produced by the action. In the case of a plan that decreases force size, the ratio indicates the savings obtained per unit of effectiveness lost.

The effectiveness measures used in the model are based on the concept of a trained-person year, reflecting, roughly, the productive output contributed by an average person (in whatever specialty is being studied) who has just completed initial formal technical training. This fundamental unit of effectiveness is then adjusted to account for the fact that senior personnel contribute more to force effectiveness than do junior personnel. The adjustment values experience (the cumulative time spent in the enlisted force) in proportion to the pay for each level of experience. The model varies the proportionality constant from zero (indicating that all trained-person years in an occupation are of equal value), through one (indicating that effectiveness increases at the same rate that pay increases), to two (indicating that effectiveness increases with experience twice as fast as pay does). The user of the model must decide which part of the value of this range best reflects conditions in the specialty being analyzed. (Sometimes this judgment is not critical, since the decision among alternative actions often remains the same over a wide range of choices for this constant.) The "effectiveness" generated by any personnel cohort, then, is the sum of its "weighted trained-person years" (WTPY) over its entire life cycle, where the trained-person years obtained from the cohort in each year of its life cycle are weighted by the product of the proportionality constant and the average pay at that level of experience.

ALEC calculates the change in personnel costs and weighted trained-person years associated with changes in management actions (e.g., accession and bonus levels). It also divides the cost effects into several categories, including trained-person pay, support, training, retirement benefits, and reenlistment bonuses. It produces tabular output, but its primary output is graphical. Figure 17 illustrates one of the screens it produces. It shows the change in the relative cost-effectiveness of a planned policy change (in this case, a change in the zone A bonus in a highly skilled occupation)[4] as a function of the value of experience. In this case, unless the value of experience in the occupational group being examined is quite low, the planned change would be cost-effective. ALEC's inventory projections are based on the loss and extension rates produced by the middle-term models (see Sec. IV).

ALEC is a microcomputer model that was written using the Symphony integrated application package (a product of the Lotus Development Corporation). It was designed more for speed than for accuracy. Its purpose is to give insight into the expected performance of various

[4] A cost-effectiveness ratio less than 1.0 indicates that the planned change has better cost-effectiveness than the reference situation. For further details of this case, see Rydell (1987b), p. 10.



SOURCE: Rydell (1987b), p. 14.

Fig. 17—Change in relative cost-effectiveness of policy as a function of the value of experience

management actions. Two simplifications that were made to further this goal were (1) to omit the grade dimension and (2) to divide the force into Chief Enlisted Manager Progression Groups CEMPGs or sectors instead of individual AFSCs. The sectors were constructed by starting with the CEMPGs used in the POF, assigning each to either the support or operations category, then further categorizing each group by the duration of formal training. Runs can be made by CEMPG or by sector.

Because it is fast, easy to operate, and focuses on a small (user-selected) part of the force in any given run, the model enables enlisted force managers to quickly screen out unpromising management actions for achieving a particular force management objective, leaving a short list containing those that are most cost-effective. The actions in this short list can then be subjected to more detailed analysis using the appropriate impact assessment models.

Rydell (1987a) demonstrated the usefulness of the model by analyzing several management actions for achieving various objectives. For example, he showed that, regardless of the value of experience or the training requirements in a particular specialty, if an increase in the senior force relative to the junior force is desired, it would be best to:

- Use either prior-service accessions without retraining or retraining into a specialty from other specialties before using prior-service accessions that require retraining.
- Use prior-service accessions that require retraining before offering a zone A reenlistment bonus.

- Offer a zone A reenlistment bonus before offering a zone B bonus.
- Avoid using zone C reenlistment bonuses. (The force increases that they generate cost 1.5 to 3.0 times more than other alternatives.)

Complete documentation of ALEC and a user's guide are provided by Rydell (1987b). In addition to a diskette containing the ALEC model and the ALEC database, the model requires a microcomputer installation containing an IBM PC-compatible computer with 640K memory, a graphics card, a printer, and the Symphony spreadsheet program from the Lotus Development Corporation.

SMART-ALEC

The Systematic Method of Analyzing Retention Tradeoffs using ALEC (SMART-ALEC) model is a microcomputer screening model that can be used to suggest a set of management actions that will achieve a desired force structure at the minimum cost. The model is composed of two modules: (1) ALEC and (2) another Symphony-based spreadsheet model that has a linear programming add-on. Figure 18 shows the relationship between these two modules.

The user chooses the occupational group that he would like to examine (SMART-ALEC uses the same groupings as are used in ALEC). He then applies ALEC to this group to determine how personnel costs and the personnel inventory would change in response to each of a variety of management actions (accessions, bonuses, retraining in, and retraining out), generating a set of linear response functions. The coefficients of these response functions form the A-matrix (personnel responses by YOS group) and objective function (cost response) of the

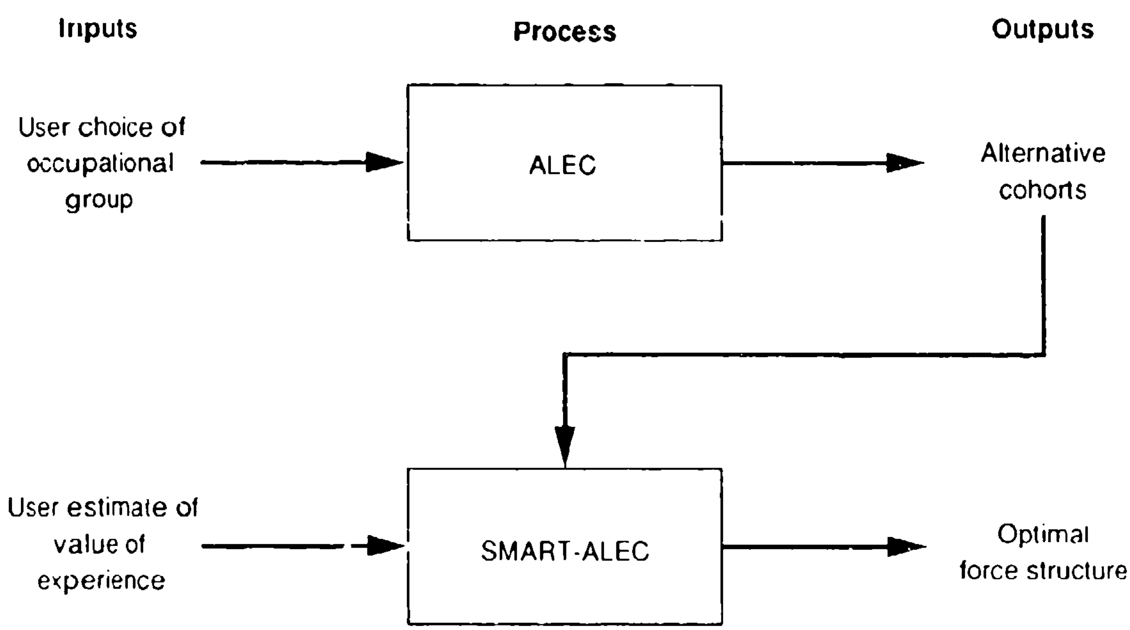


Fig. 18—Relationship between the ALEC and SMART-ALEC models

linear programming (LP) problem that is the heart of SMART-ALEC. The right-hand-side of the LP consists of the force targets (by YOS group) that the user would like to achieve.

SMART-ALEC requires a diskette with the ALEC model, the ALEC database, and the SMART-ALEC model. It also requires a microcomputer installation containing an IPM PC-compatible computer with 640K memory, a graphics card, a printer, the Symphony spreadsheet program from the Lotus Development Corporation, and the linear programming add-on to Symphony, called Optimal Solutions Plus.[5]

[5]Optimal Solutions Plus is a product of ENFIN Software Corporation, San Diego, California

VII. AGGREGATE PLANNING, PROGRAMMING, AND OVERSIGHT

This section deals with functions and models in which the occupation dimension is absent. Many enlisted force management functions are carried out at this more aggregate level. These include:

- Designing force structures that have desirable characteristics.
- Designing programs to meet end strength and budget targets.
- Examining nonskill-specific programs, such as accessions and promotions, to determine their implications for force size, grade distribution, and YOS composition.
- Monitoring the behavior of these programs, to make sure that whatever was expected from them is actually happening.
- Monitoring the behavior of the force, to detect new trends, developing problems, etc.

Several models are discussed, all of which are basically inventory projection models with different assumptions, management actions, and purposes.

IMPACT ASSESSMENT MODELS

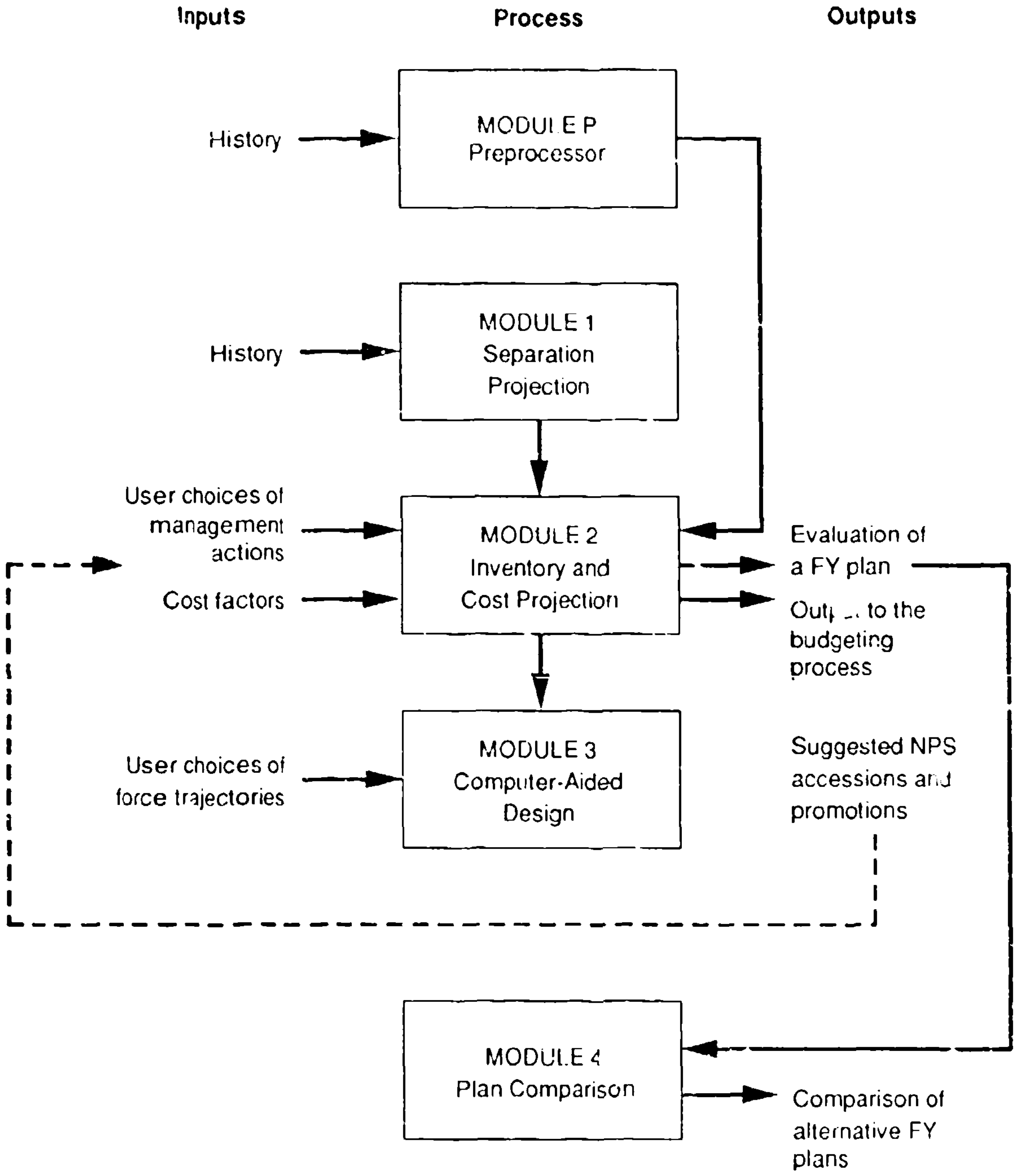
Short-Term Aggregate Inventory Projection Model

The Short Term Aggregate Inventory Projection Model (SAM) supports aggregate programming within a fiscal year. SAM can be used to analyze the size and grade composition of the enlisted force by month during a fiscal year and to estimate the budget cost of the force for the entire fiscal year. It also supports the determination of management actions that are designed to achieve fiscal-year goals for total force strength, force strength in the top five grades, and personnel cost.

Users can start the model during any month of the fiscal year. SAM will then incorporate actual events between October (the start of the fiscal year) and the start of the projection period, project future events for the remaining months of the fiscal year, accept inputs of possible management actions, and evaluate the ability of the management actions to achieve fiscal-year goals. If requested by the user, SAM will help revise a draft management plan to produce a plan that is expected to achieve inventory goals exactly. SAM can also be used to compare the projected results from alternative plans.

SAM consists of five modules (see Fig. 19):

- *SAMP (Preprocessor).* This module transforms information on past enlisted force behavior (e.g., events during the past 12 months, early release programs, losses from accessions) into variables that are needed in other modules.
- *SAM1 (Separation Projection).* This module forecasts attrition, ETS losses, retirements, reenlistments, and flows to retirement eligibility by grade, category of enlistment, and month, for up to 12 months into the future using a short-term aggregate loss model, such as those described in Sec. IV. It generates "policy-free" forecasts. (That is, if special programs were implemented to drive airmen out of the Air Force



SOURCE Rydell and Lawson, 1991

Fig. 19—Structure of Short-Term Aggregate Model for projecting Air Force enlisted personnel

early, the data are adjusted to reflect loss behavior as if the policy had not been in place; the module works off the adjusted data.)[1]

- *SAM2: (Inventory and Cost Projection).* This module projects (a) the inventory that results from user choices of management actions and (b) the costs that result from those actions. Among the management actions the user can manipulate are accessions (NPS and PS), Rollups, Early Outs, and promotions. SAM estimates the Military Personnel Account (MPA) cost of the enlisted force during the fiscal year, disaggregated into several categories (including basic pay, retired pay accrual, and incentive and special pay).
- *SAM3: (Computer-Aided Design).* This module helps users achieve end-strength and grade-strength goals. It accepts trajectories (monthly goals) chosen by the user for the number of airmen in the total force and in each of the top five grades. It then computes the monthly NPS accessions for the remainder of the fiscal year that will make the inventory follow the desired force trajectory, and it computes promotions that will make the inventory by pay grade follow the desired grade trajectories. The suggested NPS accessions and promotion policy, together with the management actions chosen in SAM2, constitute a fiscal-year plan that "exactly" achieves the inventory goals for the fiscal year. (Since the projected losses of personnel are subject to uncertainty, of course, the *actual* inventories cannot be expected to match the inventory goals exactly.)
- *SAM4: (Plan Comparison).* This module provides output that compares the projected results from two alternative plans for the same fiscal year. (If the plans were made in different months, then at least part of the comparison will involve comparing projections with actual events.)

Rydell and Lawson (1991b) provide a complete description of SAM plus specifications for SAMP, SAM2, SAM3, and SAM4. Some alternative specifications for SAM1 were described in Sec. IV. Figure 19 shows the relationships among the five submodules. Users operate SAM by moving back and forth among modules. The simplest monthly analysis sequence is to run SAMP, SAM1, SAM2, and SAM3, in that order, iterate between SAM2 and SAM3 until several plans have been constructed, and then run SAM4 to compare the alternative plans.

SAM is driven by user choices made in SAM2 and SAM3. In SAM2 the user chooses management actions. In SAM3 the user chooses force trajectories, and the computer designs short-term management actions that achieve those trajectories. If the user would like, SAM2 can use the short-term management actions designed in SAM3. This feedback flow is shown by a dotted line in Fig. 19 to indicate that users decide whether to implement the feedback. Moreover, SAM is flexible enough for users to adopt some of the suggested management actions and not others.

An operational version of SAM is up and running on the EFMS computer. SAM1 is programmed in FORTRAN (several versions are still undergoing test and evaluation—see Sec. IV). All other modules are programmed in EXPRESS.

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[1]The SAM1 module that uses robust separation projection is itself an IPM. This methodology is required since the "robust" method of loss estimation provides a forecast of separations one month into the future. Consequently, "forward chaining" of policy free inventories is necessary to get forecasts of separations farther into the future. The SAM1 module that uses the BSP approach provides these flows directly. This is because the BSP model calculates separations to the current inventory k months ahead (where k = 1, 2, . . . , 12).

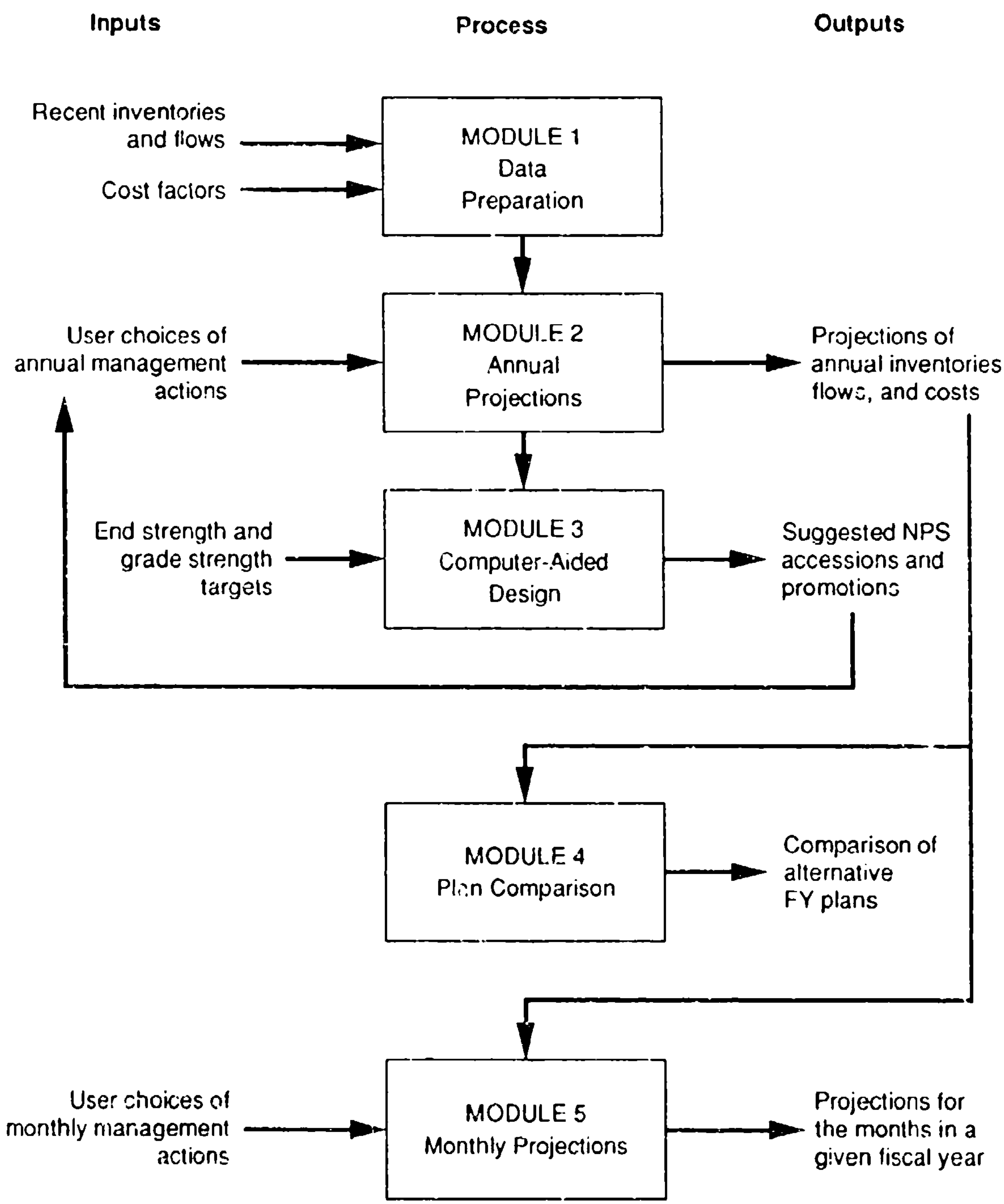
Middle-Term Aggregate Inventory Projection Model

The Middle-Term Aggregate Inventory Projection Model (MTA) projects the aggregate enlisted force (by category of enlistment, grade, and YOS) by year for up to nine fiscal years into the future. At the user's request, it can also make monthly projections within any specified fiscal year. The MTA can be used to analyze the structure and cost of the enlisted force that would result from the following types of management actions: accessions, reenlistment bonuses, early releases, and promotions. In addition to predicting the consequences of alternative management actions, the MTA can also be used to help design management actions. Users can specify targets for year-end force strengths by grade and the MTA will suggest accession and promotion schedules to achieve those targets.

To facilitate the selection of good management actions, the MTA also provides the capability to compare the detailed consequences of alternatives systematically. It also enables users to compare predictions with actual events, once those events become known. This should lead to the discovery of ways of improving both the model and management actions.

The MTA consists of five modules (see Fig. 20):

- *MTA1 (Data Preparation).* This module is a "preprocessor." It performs calculations that prepare the database for the rest of the modules. In particular, it obtains information on the current inventory and flow behavior from the EFMS database, and it blends cohort-year information on loss and reenlistment behavior (using the middle-term loss and reenlistment models described in Sec. IV) into fiscal year information.
- *MTA2 (Annual Projections):* This is the inventory projection module of the MTA. It accepts annual management actions and economic conditions as inputs and projects the annual inventories, flows, and costs that can be expected to result from those actions for up to nine fiscal years into the future. MTA2 performs three functions for each fiscal year: (1) aging the force (apply middle-term loss and extension rates to the beginning inventory and increment the YOS of the survivors by one); (2) promoting the force (which determines the final grade distribution) and adding NPS and PS accessions; and (3) entering the resulting information into output screens.
- *MTA3 (Computer-Aided Design of Management Actions):* This module determines the accession and promotion actions that will enable the inventory to achieve end-strength and grade-strength targets for each fiscal year. Interface menus enable the user to feed the recommended actions into MTA2 to get a complete report on the annual flows and inventories that would result from these actions.
- *MTA4 (Comparison of Alternative Plans):* This module compares the results from two alternative [illegible] The purpose of the comparison is to view the implications, over time, of alternative management actions, to assess the tradeoffs associated with these plans, and to obtain as much information as possible about why plans have to be revised to make better plans in the future.
- *MTA5 (Monthly Projections).* This module spreads the annual projections for any given fiscal year over the months of that year. It is run at user request. To run it, the user must provide additional inputs that specify the monthly pattern of management actions. The capability of obtaining monthly projections will be useful to programmers who want to do monthly planning for the next fiscal year while still only part way through the current fiscal year. This module is being built using SAM (see above). Thus, MTA5's input and output screens are identical to those that the user sees when using SAM.



SOURCE: Rydell and Mickelson, 1991.

Fig. 20—Structure of the MTA Model

Rydell and Mickelson (1991) provide detailed specifications for the MTA. DPMDW recently implemented a prototype version of the model.

SCREENING MODELS

The Retirement Policy Analysis Model

The middle-term loss and extension models have simple structures. They view the outcome from an airman's decision to be a linear function of the airman's traits, circumstances, and economic opportunities. These specifications work effectively across a wide variety of changes in economic opportunities. However, for some kinds of compensation changes, such simple models will not forecast well. For example, since the U.S. military retirement policy has changed only recently, and then only for new accessions, it is difficult to estimate the potential effects of changes to the policy.

Arguden (1986) developed a simulation model called the Retirement Policy Analysis Model (RPAM) that is part of the EFMS and can be used to estimate the effect of complex changes in military compensation. It is based on the Dynamic Retention Model (DRM) of Gotz and McCall (1984), which offers a consistent framework for explaining how complicated changes in airman compensation, such as changes in the retirement system, would alter stay/leave decisions throughout an airman's career. Because of difficulties in estimating the parameters of the DRM, Arguden did not formally estimate it. Instead, the DRM was "calibrated" using retention rates of airmen during the period 1971–1981. The parameters obtained from the calibration were used as inputs to the RPAM. The RPAM was shown to track actual retention rates very well. It was therefore taken as an adequate representation of reality for (1) assessing the effects of alternative retirement policies, and (2) evaluating the performance of simpler behavioral models of airman retention.[2]

The RPAM is a large FORTRAN program, which is not intended to be integrated into the system of EFMS models. But it can be accessed and run in a batch mode from a user's microcomputer workstation. It probably will be run fairly rarely because its database is so large and because major changes in compensation structure are considered so seldom. It is a screening model, since it is useful primarily for identifying major effects on large groupings of airmen. (For example, its inventory does not include a YOS dimension. Effects are measured for five YOS groups: first termers, second termers, career termers, retirement-eligible airmen with 20-25 YOS, and retirement-eligible airmen with 26-30 YOS.)

The model was used in 1986 to assess the effect of the new Military Retirement Reform Act on personnel retention (see the appendix).

Aggregate Dynamic Analysis Model

The Aggregate Dynamic Analysis Model (ADAM) was designed, developed, and documented by Mickelson and Rydell (1989a, 1989b). It falls into the middle-term aggregate category of EFMS inventory projection models. ADAM projects the aggregate enlisted inventory (by category of enlistment, grade, and years of service), and the Military Personnel Account (MPA) budget costs for this force, 12 years into the future. The projections depend upon user-specified management actions and forecasts of background economic conditions. It runs in a few seconds on standard Air Force microcomputers, offering enlisted force planners

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[2]See Arguden (1986) for a detailed description of the calibration and testing.

and programmers a rapid method for screening alternative force management programs and policies.

ADAM is similar in many respects to the MTA. In fact, the data for ADAM are taken from the EFMS database for the MTA model. Roughly speaking, the two models are different implementations of the same core specifications. As a screening model, ADAM enables rapid comparison of many alternative plans using summary measures of performance. As an impact assessment model, the MTA is slower but more accurate and comprehensive, making it more appropriate for detailed comparisons of a smaller number of plans. In contrast to the MTA, ADAM (1) has summary outputs, (2) does not model demotions, (3) does not model Officer's Training School or miscellaneous gains and losses, and (4) does not distribute fiscal year inventory flows across months.

ADAM has two operating modes: a "what-if" (descriptive) mode, and a "goal-seeking" (prescriptive) mode. In the descriptive mode, users choose a set of management actions and the model projects the force that would result. In the prescriptive mode, users choose all management actions except accessions and promotions to the top five grades. The model then determines accessions and promotions to achieve user-specified end strengths for the total force and by grade.

The two modes are designed to be used iteratively. For example, if an initial descriptive run shows that end-strength goals would not be achieved, the user can then do a prescriptive run to find accessions that would achieve the goals. However, the required accessions plan may be unacceptable (for example, it may exhibit too much variation from year to year). In that case, the user can return to the descriptive mode and choose a different set of management actions that include smoother required accessions. Finally, a new prescriptive run can be made to fine tune the accessions plan to hit the end-strength targets.

Because ADAM has a very fast runtime (12 seconds for a 12-year projection on an 80286 microcomputer with math coprocessor), such an iterative approach to finding an acceptable overall plan is simple and fast.

ADAM consists of three modules (see Fig. 21):

- *ADAM1 (Annual Inventory Projection):* This module uses the middle-term loss and reenlistment models (see Sec. IV) to project the enlisted force year by year for 12 years into the future. It responds to user-chosen management actions and economic conditions and projects the annual inventories, flows, and retention rates that result from those actions.
- *ADAM2 (Computer-Aided Design of Management Actions):* This module determines accession and promotion actions—conditional on user-specified choices of all other management actions and the given economic conditions—that will result in meeting user-specified end-strength targets for 12 years into the future. The results from running this module can be automatically identified as the set of management actions to be examined by ADAM1.
- *ADAM3 (Comparison of Plans):* After two or more plans have been constructed and their results saved by ADAM1, this module can be run to compare the differences in force structure and costs resulting from the alternatives. Comparisons can be made for the total force and by grade and years of service.

The documentation for ADAM consists of a user's guide (Mickelson and Rydell, 1989a) and technical documentation (Mickelson and Rydell, 1989b). The model is written in the "C" computer language. In addition to diskettes containing the executable ADAM program and its

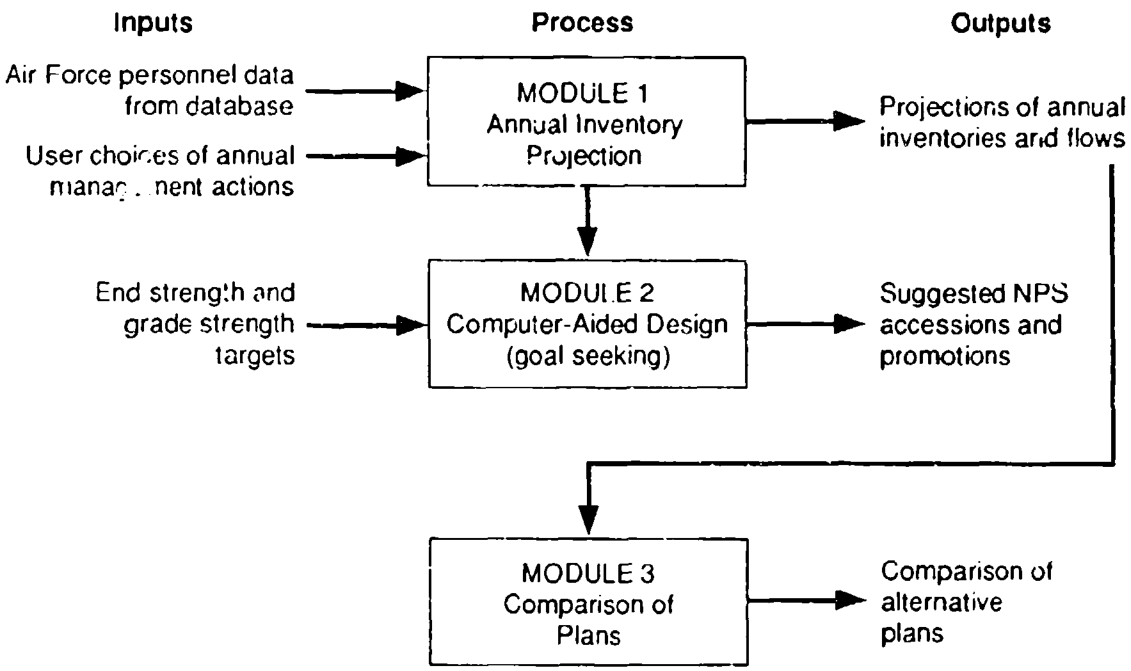

Fig. 21—Modular structure of ADAM

database, the model requires an IBM PC-compatible microcomputer with at least 512K of memory.

SMART-ADAM

The SMART-ADAM model is a microcomputer screening model that can be used to perform aggregate planning and analysis for the enlisted force.

SMART-ADAM is an extension of ADAM that was developed and applied under another Project AIR FORCE project at RAND named "Evaluating the Cost and Effectiveness of Potential Work Force Structures" (WFS). It fills the gap in the EFMS that was created when the Air Force requested a delay in the development of the "Grade Profile Generator" in the conceptual design document (Carter et al., 1983).

Air Force enlisted personnel planners and analysts can use SMART-ADAM to study interactions among personnel management policies and objectives, accession and involuntary separation schedules, and potential outside constraints. Given user-specified limits on annual budgets, accession quantities, and end-strengths, for example, SMART-ADAM identifies four series of management actions for the overall active-duty enlisted force:

- Annual NPS accessions.
- Annual PS accessions.

- Annual involuntary separations of personnel who reach the end of their first TOE.
- Annual involuntary separations of personnel who reach the end of their second TOE.

Users can specify few or many different types and combinations of limits.

When planning management actions, users must answer two fundamental questions: What will they cost in terms of budget dollars? What will they achieve in terms of enlisted force capability?

The budget costs affected by enlisted force management actions and considered in the SMART-ADAM model are basic pay, retirement accrual (calculated as a fraction of basic pay), other pay and allowances (e.g., for housing), costs of recruiting and initial training, reenlistment bonuses, moving costs, and separation pay (if any).

SMART-ADAM uses the same concept of weighted trained-person years (WTPY) that was used in ALEC (Sec. VI) to represent enlisted force capability. Trained-person years are calculated as local enlisted personnel less students, less "training tail" (recruiters, instructors, and training-base operating support). WTPY then, is the sum of the products of (1) the number of people in each year of service within the productive force and (2) weights reflecting the relative productive contributions of people with each length of service.[3]

SMART-ADAM consists of two analytical capabilities that are essentially mirror images of each other:

- Aggregate Dynamic Analysis Model (ADAM).
- Systematic Method of Analyzing Retention Tradeoffs (SMART).

The ADAM component takes management actions as given and predicts the consequences for the force structure and for the achievement of management goals. The SMART component takes the goals as given and applies linear programming to determine the management actions needed to achieve them. The resulting plan is "optimal" within the set of constraints chosen for that analysis.

When applying the SMART-ADAM model, users specify goals and constraints such as annual budgets and limits on NPS accessions. Users also evaluate the results of each model run and then make additional runs. By constructing a sequence of plans, users can explore the tradeoffs among the many criteria for evaluating plans (see Fig. 22). The user's specifications go to ADAM, which first makes a reference-case projection and then systematically varies management actions one at a time from that reference case, to estimate the future consequences of each action. Vectors containing those year-by-year effects (on costs, end-strengths, and capability) go to a programming module, which uses them to choose the actions needed to achieve the user-specified objectives. The optimization program maximizes the enlisted force's capability (WTPY) over a 12-year planning period.

The linear programming results are fed back to ADAM, and the steps are repeated. This iteration refines any approximations introduced in calculating the vectors for the linear programming module. After sufficient convergence is achieved, the results are sent to the "Long-Run ADAM" module, which estimates the consequences of the plan 48 years into the future in order to show the potential long-run effects of near-term management actions.

SMART-ADAM was recently used to examine alternative ways of making major reductions in the size of the enlisted force while mitigating the most serious negative effects (see the appendix). ADAM is written in "C" computer language. SMART-ADAM extends ADAM and

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[3]Unlike ALEC and SMART-ALEC, the SMART-ADAM model does not assume that productive contributions are proportional to average pay rates as airmen gain experience. Users can specify any set of productivity weights.

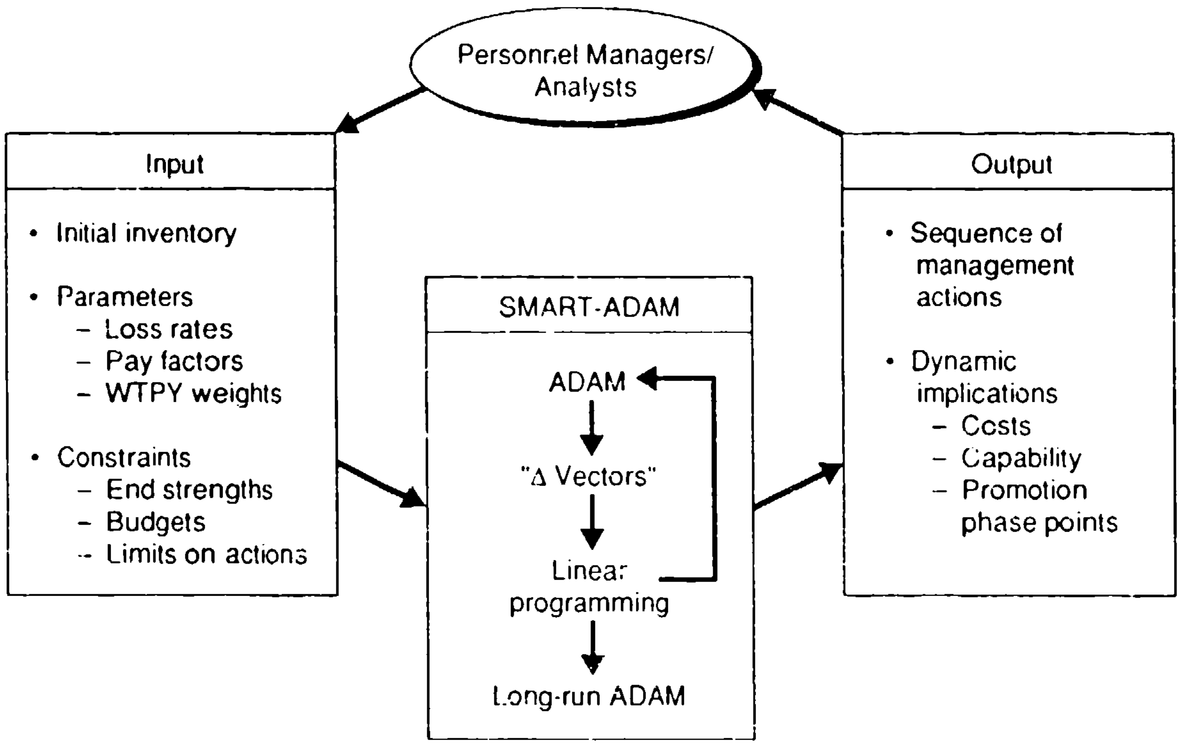


Fig. 22—Structure of SMART-ADAM application

combines it with a spreadsheet program written using LOTUS 1-2-3, from the Lotus Corporation, and an optimization program called Optimal Solutions Plus, from the Enfin Software Corporation. The model requires an IBM PC-compatible microcomputer with expanded RAM memory (to at least 1 megabyte), a hard disk, and a high-density disk drive.

VIII. IMPLEMENTATION

IMPLEMENTATION

One of the first activities carried out on the EFMP, after the conceptual design for the EFMS had been approved, was the determination of the system's software environment and the purchase of the necessary software. This is a reversal of more traditional approaches, in which the hardware is selected first. We believed that tailoring the system to the problem situation and the needs of the user required providing a set of specific capabilities. There were likely to be few software products available off the shelf that would provide all of these capabilities. By adding hardware constraints, the number of possibilities would be reduced even further, leading to the use of a product that might seriously compromise the performance of the system.

Many of the software requirements for the EFMS were generic—not specific to an application (e.g., database management, report generation, menu development). Developing the software to provide such capabilities would take much more time and effort than developing the software for the specific applications (the models). We decided that the only timely and cost-effective method of getting the programs for the system written was to acquire a single, powerful, fourth-generation software package that already had many of the required capabilities pre-programmed. The specific system modules could then be embedded within this general-purpose environment. Sprague and Carlson (1982) refer to packages that provide a set of capabilities to build DSSs quickly and easily as DSS Generators.

Since it is such an important decision, and since there are potentially so many requirements and so many alternative packages to be evaluated, we used a structured approach to choosing the DSS Generator. The process that we used is described in detail by Walker, Barnhardt, and Walker (1986). The basic idea was to carefully match the specific features and capabilities of the generators under consideration with the characteristics and requirements of the applications to be supported. The approach involved six steps:

1. Identify the overall objectives for the generator (what it should accomplish and why).
2. Infer the general capabilities that the generator must have to respond to the objectives (e.g., report generation, graphic displays, database management).
3. Infer a set of specific capabilities that will satisfy the general capabilities (e.g., allow the use of data names that provide consistency with the Air Force's naming conventions).
4. Identify specific software products that appear to have some or all of the specific capabilities.
5. Perform an initial screening of the products to eliminate those products that are obviously unqualified (e.g., by reading product documentation).
6. Perform a detailed analysis of each of the remaining products.

The overall objectives to be achieved with the DSS Generator were spelled out in the conceptual design for the EFMS (see Carter et al., 1983). Most important, it had to permit quick and easy development of the system. It also had to facilitate meshing of the analytic power and technological capabilities of the computer with the judgments, needs, and problem-solving processes of the managers and analysts. And it had to make it easy to modify the system to meet changing needs, knowledge, and situations.

We identified ten general capabilities that the DSS Generator for the EFMS should have:

1. Data management (the ability to build, maintain, and manipulate complex data structures, to provide access to information in a flexible and responsive manner, and to facilitate use and sharing of data).
2. External interfaces (ways to transfer data into and out of the system, and the provision of hooks to other programming languages (e.g., SAS, FORTRAN)).
3. Data analysis (facilities for the statistical analysis of data).
4. Inquiry (an interactive database inquiry facility that would allow users to selectively view the data they need for a given task).
5. Report generation (default formats and customization).
6. Graphics.
7. Command language.
8. Multi-user support.
9. System management facilities.
10. Support for distributed data processing.

Figure 23 shows the relationship envisioned among the users, the command and control features of the DSS Generator, and most of the general capabilities. Note that some of the capabilities would be helpful to end users (e.g., graphics and report generation), some to the systems programmers in the SMO (e.g., system management facilities), and some to both (e.g., data management facilities).

After specifying these general capabilities, we defined specific required capabilities within each category. For example, there were four specific required capabilities within the multi-user support category, including "Provide safeguards for the security and protection of data at the record level or below."

Then we began the search for and selection of a DSS Generator, which involved the following steps:

- Reading technical publications and systems documentation.
- Interviewing system users and talking to vendors.
- Screening (12 of 20 products were screened out).
- Detailed analysis of the remaining eight products:
  - Rating each product (yes/no) on each specific capability (Fig. 24 presents the portion of the scorecard dealing with data management capabilities).
  - Giving a summary rating for each product on each of the ten general capabilities.
  - Comparing the summary ratings of all eight products across all ten categories (Fig. 25 shows this summary).
  - Performing a benchmark test on a sample application.

Only one product met all of the requirements that had been established—EXPRESS, a product of Information Resources, Inc. (IRI). In September 1983, the Air Force submitted a request for sole source procurement of EXPRESS to the General Services Administration (GSA). (This meant the Air Force had to demonstrate that the product selected was the only one that had all of the features and capabilities necessary to meet the requirements.) GSA approved the acquisition in February 1984. EXPRESS was initially used on a time-sharing

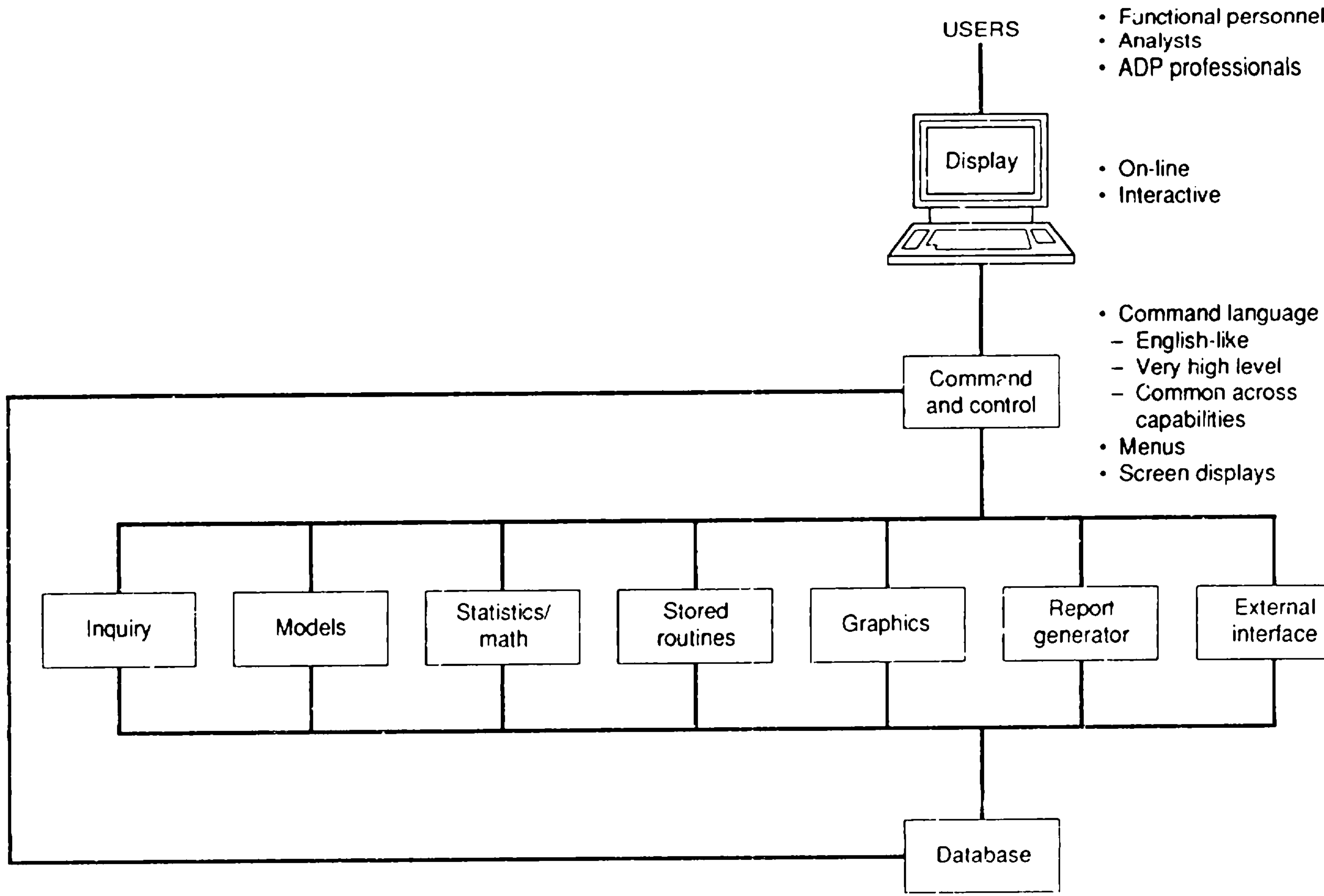


Fig. 23—EFMS decision support system architecture

Capability	EXPRESS	DSS A	DSS B
Build and maintain data in structures that allow the data to be managed so as to reflect the natural relationships among data elements—e.g., AFSC, grade, years of service, and time. This includes capabilities to delete, add, and rearrange fields and records.	Yes	No	Yes
Give system managers the capability to control and manage data and data structures as part of an integrated database.	Yes	No	No
Permit the user to operate on multiple structures, and perform transformations—i.e., combine, compare, consolidate, extract, and copy.	Yes	No	Yes
Allow the user to determine the organization and content of the data.	Yes	Yes	Yes
Permit the storage of other than numeric information in structures.	Yes	Yes	Yes
Allow the use of data names that provide consistency with Air Force naming conventions and are descriptive of the data.	Yes	No	No

Fig. 24—Analysis of data management capabilities

basis. It was purchased and installed on an Air Force computer in August 1985. The Air Force also purchased SAS and FORTRAN for use on the system. A new DSS Generator, MDB, was released by IRI in 1987 and the Air Force purchased it and pcEXPRESS (the same language as MDB, but implemented on a PC). It is using pcExpress for aggregate model development.

HARDWARE

Once the software was selected, the system's hardware configuration could be specified in detail. EXPRESS was available only for IBM and Prime mainframe computers. The Air Force set to work designing a general physical configuration that would implement the concepts contained in the conceptual design (see, for example, Fig. 7).

Figure 26 provides an overview of the current hardware configuration for the EFMS. The primary computers are an IBM 4381 mainframe computer located at the Air Force Military Personnel Center (AFMPC) at Randolph Air Force Base, Texas, and an IBM 3090 mainframe computer located in the Pentagon. The IBM 4381 is also directly linked to MPC's transaction-based personnel data system, which runs on a Honeywell DPS 8 mainframe. The

Capability	EXPRESS	DSS A	DSS B	DSS C	DSS E	DSS F	DSS G	DSS H
Data Management	Yes	No	No	No	No	No	No	No
External Interfaces	Yes	Yes	Yes	No	No	No	No	Yes
Data Analysis	Yes	Yes	Yes	No	Yes	No	No	No
Inquiry	Yes	No	Yes	No	No	No	No	No
Report Generation	Yes	No	No	No	No	No	No	No
Graphics	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Command Language	Yes	No	No	No	No	No	No	No
Multi-User Support	Yes	No	No	No	No	No	No	No
System Management	Yes	No	No	No	No	No	No	No
Distributed Data Processing	Yes	No	No	No	No	No	No	No
Meets All Criteria	Yes	No	No	No	No	No	No	No

Fig. 25—Summary evaluation for DSS Generators

two IBM mainframes are integrated into a distributed data processing network using NCR COMTEN network processors linked by the Defense Data Network.

The user workstations are IBM-compatible microcomputers with color graphics. The primary standard microcomputer is the DoD standard Zenith Z248, enabling integrated micro and mainframe information processing. The main model development microcomputers are 386-based machines. The workstations are linked with the IBM 3090 through the Air Force's local area network in the Pentagon.

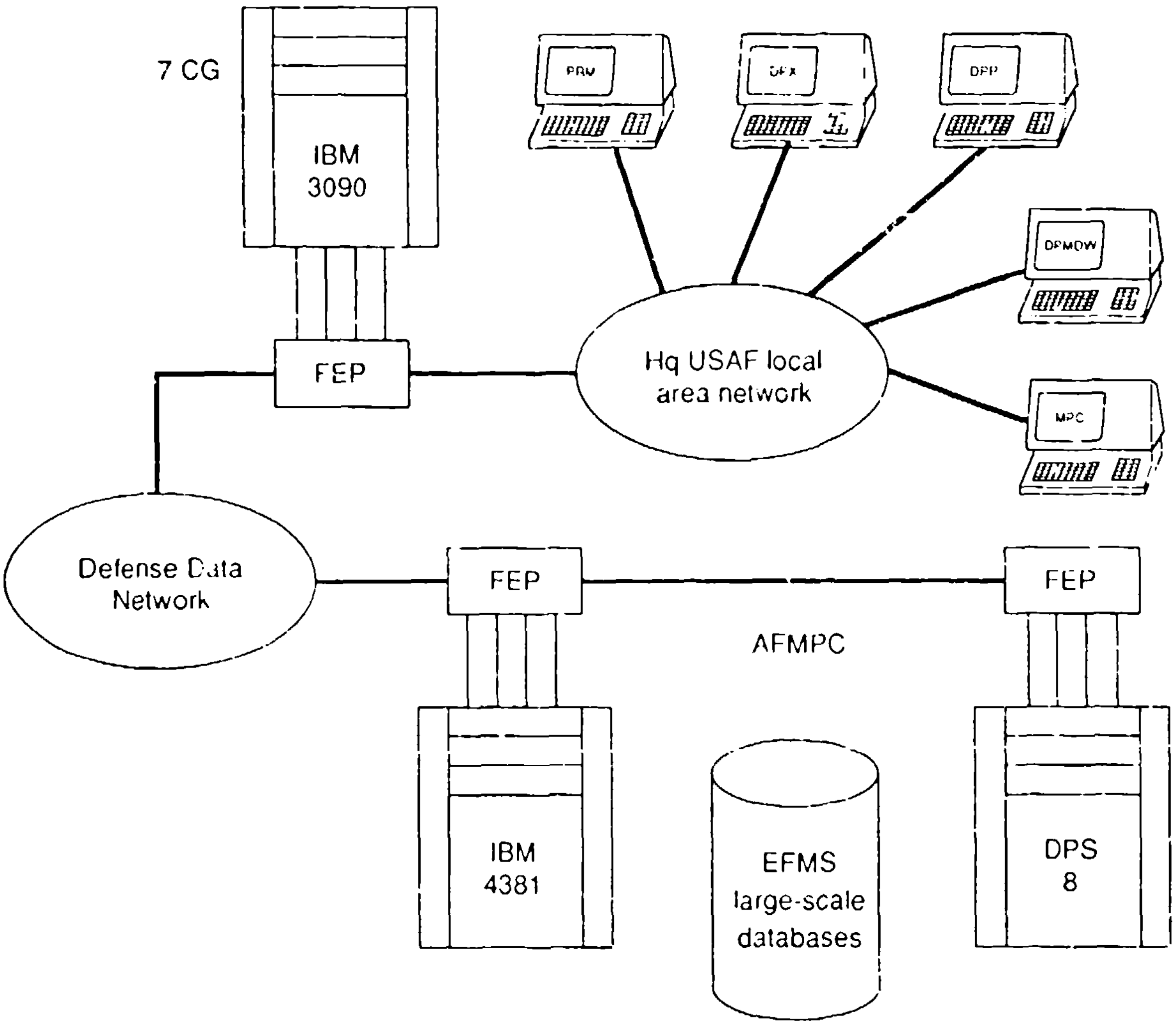


Fig. 26—Enlisted Force Management System architecture

Appendix

POLICY ANALYSES USING EFMS MODELS

The ultimate purpose of the EFMS is to help manpower and personnel managers determine what policies can be used for enlisted force management, to predict how those policies will affect airman behavior and other performance measures, and to evaluate the alternatives. RAND and Air Force analysts have already begun to use the models (both prototype and operational versions) to perform policy analyses. This appendix includes some examples.

UNINTENDED EFFECTS OF THE NEW MILITARY RETIREMENT SYSTEM

In June 1986, the Military Retirement Reform Act was signed into law with the intention of saving $2.9 billion in the 1986 accrual funding of the military retirement budget. The EFMS's Retirement Policy Analysis Model (Sec. VII) was used to examine the retention implications of the act. The analysis (Arguden, 1987) showed that the new system might have several negative side effects:

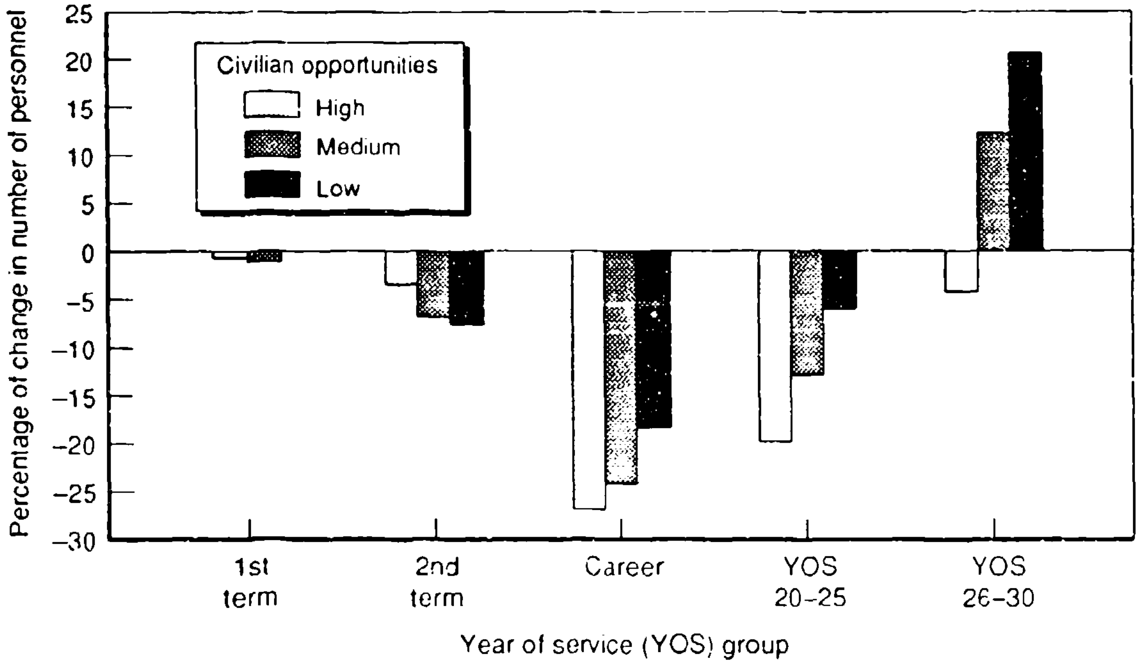
- Losses of personnel are likely to be much larger than expected.
- The average length of service per recruit is likely to decrease more than 10 percent.
- Retention of higher-quality personnel is likely to suffer more than retention of other personnel. For example, Fig. A.1 shows that there are likely to be fewer airmen serving in the YOS 8 to YOS 20 group (second-term and career airmen) and that those who leave are likely to be those with high civilian opportunities.

It was also shown that the timing of the intended cost savings and the unintended side effects would be different. The negative retention effects of the new retirement system are likely to be observed sooner than the intended reduction in outlays.

HOW BONUSES AFFECT THE FUTURE INVENTORY

An important policy analysis that was performed in the process of building the EFMS models was an empirical investigation of how a bonus offer to a specialty affects the future inventory. The analysis was conducted while we were building the middle-term loss models and resulted in an estimate of the extent to which adding or increasing a bonus to a specialty lowered the fraction of airmen who left at their ETS. We also found that bonuses increase the fraction of persons who reenlist for another full term rather than extending for a shorter period.

More important, the analysis showed the effects of bonuses are not limited to changes in loss and reenlistment rates. (These were the traditional measures of the performance of bonuses.) Bonuses have substantial effects on the length chosen for the reenlistment contract and on the choice of occupational specialty at the end of the first term. Table A.1 shows the effect of a bonus offer on contract length. In the early 1980s the Air Force greatly increased



SOURCE: Arguden (1987).

Fig. A.1—Predicted effect of Military Retirement Reform Act of 1986 on inventory of enlisted personnel

the number of specialties in which it offered a zone A bonus. The first two columns of this table show that as the number of reenlistees receiving a bonus increased, so did the number who chose long (usually six-year) contracts. The last two columns of the table strongly suggest that the bonus caused this increase. There was no change in the contract length of those in specialties that were never offered a bonus. In specialties that switched from no bonus to some bonus, the percent choosing a long contract typically switched from about 7 percent to 70 percent. Thus, we showed that a better measure of bonus performance is the additional man-years of service it produces.

These findings showed not only that bonus effects can be large, but that their effects persist for many years. In fact, as shown in Fig. A.2, the maximum effect on a cohort of airmen offered a bonus in a specialty occurs (in terms of the number of airmen retained who would otherwise have left) six years after the bonus is offered.[1]

We also found that a zone A bonus offer to a specialty greatly decreased the proportion of airmen who chose to retrain out of the specialty when they entered the career force, and increased the proportion of retrainees who chose to enter the specialty. We developed regression models to predict the effect of the bonus on the length of enlistment contract and on spe-

[1]The gradual rise in the first years of the graph reflect persons who are not offered a bonus leaving the service from extension status. It is likely that with current policy, which strongly discourages extensions, the rise in the first two years would be more abrupt.

Table A.1

EFFECT OF BONUS ON CHOICE OF LENGTH OF REENLISTMENT CONTRACT

Time Period	Percent Receiving a Bonus	Percent of Airmen Who Reenlist for More Than Four Years: All Airmen	Bonus Specialties	No-Bonus Specialties
7/79-6/80	23	22.0	70.9	7.4
7/80-6/81	51	40.3	71.3	7.7
7/81-6/82	61	44.8	69.0	7.0

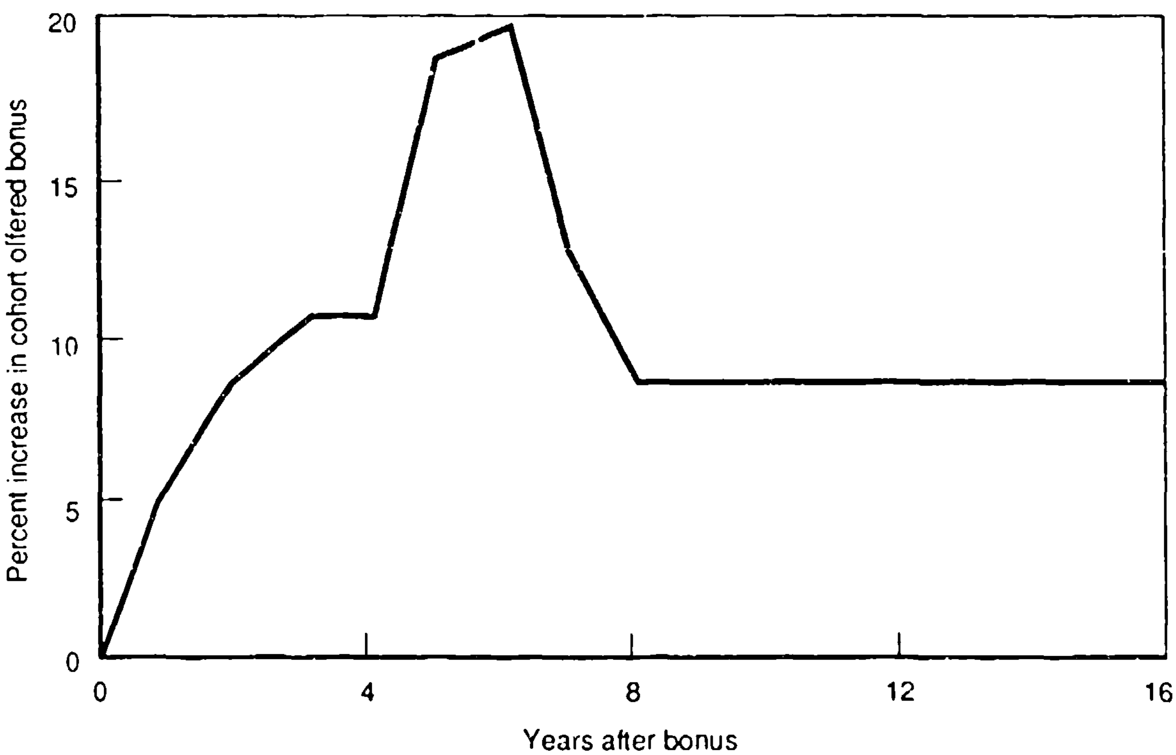


Fig. A.2—Effect of Zone A reenlistment bonus on cohort size

cialty choice. These models are used within the DMI, the BEM, and the YOSTG to estimate how the inventory would change in response to a change in the bonus offer.

Although the analysis was aimed at model development for the EFMS, it has substantial implications for Air Force policy. Combining the effects of bonuses on reenlistments, term of enlistment, and career choice in an IPM demonstrated the extent to which bonuses have long-term effects on the occupational distribution of the career enlisted force. Official DoD policy at the time said that bonuses were to be used only to deal with temporary, short-term shortages. However, the most cost-effective use of bonuses is to continually offer them to specialties with high training costs and a reenlistment rate that is too low to meet the long-term need for skilled personnel. Using bonuses for short-term shortages in low training cost skills is never cost-effective and can introduce manning problems in subsequent years.

Furthermore, we found that first-term (zone A) bonuses appeared to have a substantially greater numerical effect than bonuses offered to more senior personnel. Also, since those who have completed two or more terms in the Air Force are very likely to reenlist, almost all of the bonuses offered to zone C airmen are received by persons who would reenlist anyway. Thus, zone B bonuses are rarely a cost-effective long-term management tool and zone C bonuses are almost never cost-effective.[2] These insights combined with specific information from the BEM led to dramatic changes in the Air Force's Selective Reenlistment Bonus program for FY 1987. The number of enlisted skills receiving zone C bonuses was reduced from 40 to 21, which resulted in savings of $1.9 million per year.

MANAGING ENLISTED FORCE REDUCTIONS

A budget squeeze and an easing of Cold War tensions in Europe have led to pressures for reductions in the size of the enlisted force. In unpublished RAND research, Rydell and Mickelson used SMART-ADAM to explore force management alternatives for handling a major force drawdown given a set of competing objectives:[3]

- Reduce costs.
- Promote on time.
- Stabilize experience mix (ratio of senior force to junior force).
- Maintain opportunity to serve (minimize involuntary separations).
- Maximize personnel capability (weighted trained-person years).

There are very many ways to shrink the enlisted force and its associated costs—e.g., by further reducing the number of new entrants, delaying promotions, reducing pay raises, releasing people early, and forcing members out. Rydell and Mickelson used SMART-ADAM to construct and compare several plans for drawing down the force by one-third over a five-year period. They showed that it would be impossible to achieve all five objectives simultaneously during a force drawdown this large. They also showed how SMART-ADAM can be used to develop policies that mitigate the worst effects and produce reasonable compromises among the objectives.

Figures A.3–A.6 depict some of the SMART-ADAM results for this analysis. Figure A.3 shows one result of allowing accessions to fall very low: temporary but very severe delays in promotion opportunity. This problem could be mitigated by allowing a greater proportion of the force in higher pay grades—e.g., by leaving the high-grade strengths at their 1990 levels until 1998. Naturally, this would raise the average cost of senior personnel in the force, necessitating even fewer initial enlistments to stay within the budget drawdown constraint.

Figure A.4 shows that recruiting and training would virtually disappear under this scenario, setting up a comparative shortage of junior personnel (represented here by those with

[2]See Rydell (1987a).

[3]SMART-ADAM's development and application were part of a project entitled "Evaluating the Cost and Effectiveness of Potential Work Force Structures," which is being performed in the Resource Management and Systems Acquisition Program of Project AIR FORCE.

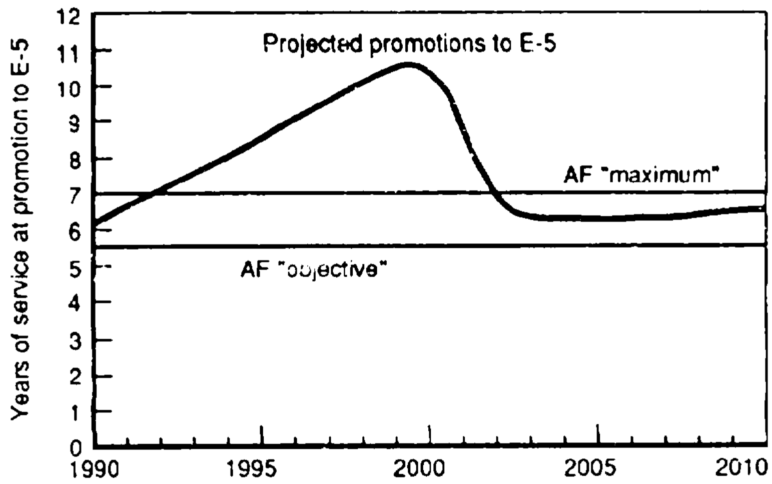


Fig. A.3—Delayed promotions

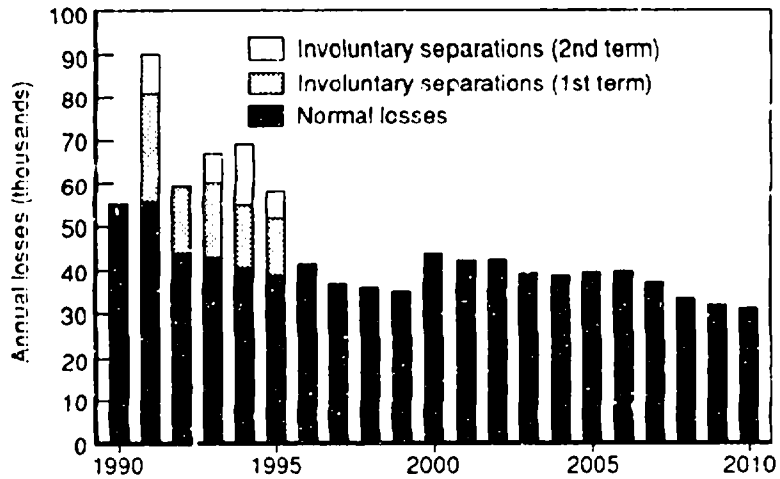


Fig. A.5—Reduced opportunity to serve

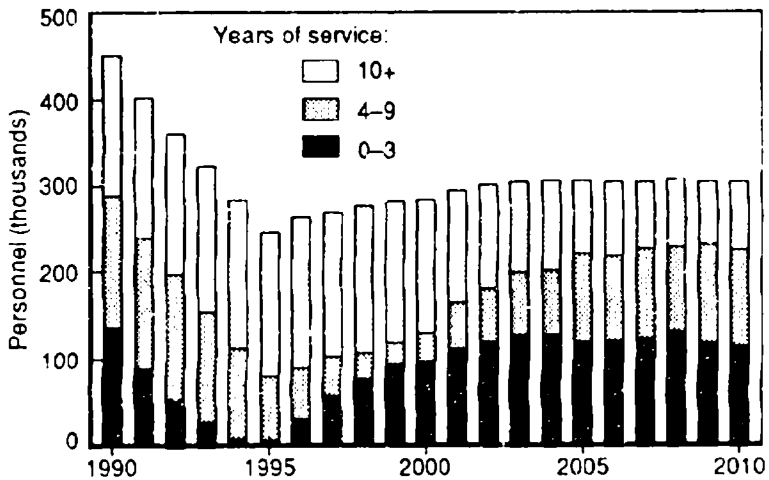


Fig. A.4—Unstable experience mix

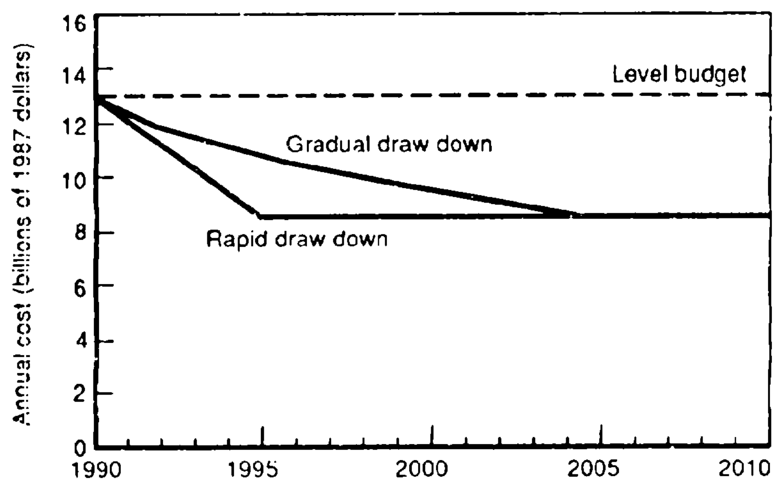


Fig. A.6—Alternative draw-down plans

less than four years of experience) in the near term. This shortage would shift into the middle and senior experience levels as the "empty cohorts" moved through the force. In turn, this problem could be eliminated by placing a floor under recruiting and training levels; but again, the budgetary limit would necessitate saving money elsewhere.

Figure A.5 shows what would happen if accessions were kept at 33,400 per year or higher, the level needed to sustain the less costly force in equilibrium over the long run: nearly 120,000 involuntary separations would be required during the five-year drawdown, almost a third of them involving members who had served two terms of enlistment.

Finally, Fig. A.6 shows what would happen if the budget could be drawn down slower. In this example, accessions would stay at 33,400 and 13,000 first-termers would be allowed to reenlist each year, the number that would sustain the less costly force in equilibrium. It would take 14 years to achieve the one-third cost reduction this way, and the total costs over the next 20 years would total about $13.4 billion (about 7.3 percent more than if the drawdown were achieved in only five years).

MANAGING ENLISTED FORCE REDUCTIONS BY AFSC

The Air Force uses quotas (called Career Job Reservations or CJRs) for first termers who wish to reenlist in a given AFSC. This program has been in place for several years, but has been used only sparingly, with the great majority of AFSCs being unconstrained (any individual who asked for a CJR received one). The program may be used to achieve a variety of goals: (1) to restrict first-term reenlistments by AFSC to produce a desired steady state or sustaining force structure, (2) to encourage AFSC changes to structure career fields, and (3) to force additional losses to meet budget or end-strength goals.

The EFMS has been used to support recent policy changes in the CJR program that have been designed to reduce the budget while maintaining productive and sustainable force structure. First, the APM was used to provide the target authorizations for each AFSC. Then the YOSTG was used to develop the sustaining year group profiles and associated desired number of first-term reenlistments. Finally, projected reenlistments and inventories in each AFSC from the DMI were used to formulate different CJR plans. These tools enabled the CJR program manager and personnel policymakers to assess the authorization targets, the sustaining needs under a variety of policies, and the dynamic effects of various CJR quotas in the aggregate and by AFSC in terms of overall manning, grade manning, experience levels, and the reenlistment opportunity being offered.

Although the models had not been designed for this purpose, they were able to be adapted to the new and unexpected situation. They performed well given only a few days' notice. With some reprogramming, they will be made more efficient and responsive and will be integrated into the body of forecasts that support the rest of the enlisted force programming decisions.

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