# An Integrative Modeling Approach for Managing the Total Defense Labor Force

Adele R. Palmer, C. Peter Rydell



RAND | NATIONAL DEFENSE RESEARCH INSTITUTE
PROJECT AIR FORCE

The research described in this report was sponsored jointly by the Office of the Secretary of Defense (OSD), under RAND's National Defense Research Institute, an OSD-supported federally funded research and development center, Contract No. MDA903-85-C-0030 and by the United States Air Force under Contract F49620-86-C-0008.

ISBN: 0-8330-0978-8



Published by The RAND Corporation
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138

R-3756-OSD/AF

# An Integrative Modeling Approach for Managing the Total Defense Labor Force

Adele R. Palmer, C. Peter Rydell

December 1989

Prepared for the
Office of the Secretary of Defense
United States Air Force

RAND

# PREFACE

This report introduces a modeling approach for evaluating the cost-effectiveness of Department of Defense manpower decisions in a "total force" management context—i.e., in a context that simultaneously recognizes the roles of the active, reserve, and civilian work forces in achieving both peacetime and potential wartime operating goals. The report uses simple but plausible numerical illustrations to show that the proposed approach can yield different conclusions from analyses that evaluate choices between active and reserve or active and civilian manning without accounting for the interactions among all goals and all personnel inventories.

The idea for this study grew from two ongoing research projects at RAND: (1) "The Cost-Effectiveness of Active, Civil Service, and Contractor Personnel," sponsored by the Office of the Assistant Secretary of Defense for Force Management and Personnel, and (2) the "Enlisted Force Management Project," sponsored by the Deputy Chief of Staff for Personnel, Headquarters, United States Air Force. The former project deals with the relative costs and productive contributions of the Department of Defense active and civilian work forces, and part of the latter project deals with evaluating the costs of the Air Force active duty enlisted force.

Development of this modeling approach is continuing. Enhanced versions of the model now deal with such personnel management policies as retraining and rotation. However, the current report presents only the initial, simplified model.

The work reported here was supported by equal amounts of research support/concept development funding from the Defense Manpower Research Center, part of RAND's National Defense Research Institute (an OSD-supported Federally Funded Research and Development Center), and the Resource Management Program, part of RAND's Project AIR FORCE.

## SUMMARY

This report documents an exploratory research project that addressed two broad questions:

- What are the salient relationships between wartime and peacetime manpower roles and between military and civilian manpower utilization—and how can these relationships be integrated in a manpower management model? And,
- Would such a model evaluate manning options differently from conventional analysis? That is, could it fundamentally alter DoD labor management?

The report lays out desirable features for a total force management model, builds a rudimentary version of such a model, and exercises it to demonstrate that such a model can, indeed, lead to manning policies different from those favored by existing DoD policy guidance.

The total force modeling approach proposed here has the following major features:

- *The management objective is cost-effectiveness.* Each area of defense endeavor should be prepared to meet its wartime and peacetime performance targets at the lowest possible peacetime cost, and targets for different parts of the force should be set to maximize overall defense capabilities within any given budget. The modeling approach should also help decisionmakers evaluate the cost implications of deviating from these objectives in order to satisfy other social or institutional goals.
- *Peacetime costs are linked to wartime capability goals by the need to establish and maintain peacetime resource inventories for potential wartime use.*
- *Different areas of defense endeavor have different combinations of wartime and peacetime capability goals.* Some parts of the force, such as personnel planning, may have larger roles in peacetime than in wartime, while other parts of the force, such as airborne infantry, have larger wartime roles.
- *Different categories of manpower (active, reserve, and civilian) are linked by their overlapping capacities to contribute to peacetime performance and wartime capability.*
- *A worker's value in defense activities is evaluated in two distinct dimensions.* A worker's contribution to wartime capability is

not necessarily the same as his or her contribution to peacetime performance.

- *The costs and capabilities derived from military manning are heavily influenced by limited lateral entry to the military personnel inventories.*

The rudimentary model that embodies these features is a linear programming model that considers individual areas of defense endeavor. Its equations describe the behavior of personnel inventories (e.g., retention flow rates) and relate both wartime capability and peacetime performance to the size and composition of the inventories. The peacetime and wartime goals appear in the form of constraints that must be satisfied. The objective is to minimize the part-of-force costs subject to the constraints that all goals are met. Although the model is highly simplified in this initial version, it is a working model that could serve as a framework for more advanced formulations.

The model's implications are revealed through realistic numerical illustrations. The cost variables and inventory behavior parameters are averages based on the DoD's published budget data for fiscal year 1987. Parameters describing worker productivity and substitutability are conjectural, but are broadly consistent with values commonly assumed in DoD policy analysis. One use of the model is to evaluate the uncertainty surrounding a manning policy's implications when some parameter values are unknown.

The rudimentary model and numerical illustrations are used here in three applications:

- To evaluate two common types of manning decisions: changes in the active/reserve balance and actions to replace active force manpower with civilian workers;
- To develop basic guidelines for selecting a combination of personnel to man parts of the force having different wartime and peacetime goals; and
- To assess the costs of changing the goals (e.g., increasing wartime capability or peacetime performance targets) in a part of the force.

Based on the values in the numerical illustrations, the analyses show that:

- Manning decisions based on a total force analysis can differ from those recommended by a conventional two-way analysis (i.e., one that compares only active and reserve manning, or only active and civilian manning). This can occur whenever a particular type of personnel contributes jointly to both wartime readiness and peacetime performance.

- A linear total force model supports straightforward general guidelines for choosing combinations of active, reserve, and civilian manning in various parts of the force. With the numerical values used in this study, there are five distinct manning "modes" tailored to the ranking of wartime initial deployment, wartime sustainment, and peacetime workload targets.
- For some parts of the force, the guidelines generated under the plausible numerical values in this study could conflict with existing DoD policy guidance regarding the use of civilians.

Due to the exploratory nature of this study, no conclusions can be drawn about whether particular DoD manning decisions would (or should) be altered if they were evaluated from a total force management perspective. However, the analysis suggests that further development of a total force management approach is feasible, and that it could lead to more cost-effective DoD labor management.

# ACKNOWLEDGMENTS

The authors benefited greatly from discussions with many people both inside and outside the Department of Defense. We owe a special thank you to Deborah Clay-Mendez, Larry Lacy, Lieutenant Colonel Kenneth Williams, Craig Moore, Michael Kennedy, and Joan Buchanan. Each of them offered detailed comments on earlier drafts of the report.

We also thank Glenn Gotz and Charles Kelley at RAND for their encouragement of this line of research. David Osbaldeston, who has participated in our continuing research on this topic, also offered valuable insights that influenced our final revisions of the work.

# CONTENTS

PREFACE . . . . . . . . . . iii

SUMMARY . . . . . . . . . . v

ACKNOWLEDGMENTS . . . . . . . . . . ix

FIGURES AND TABLES . . . . . . . . . . xiii

Section

I. INTRODUCTION . . . . . . . . . . 1
   Background and Motivation . . . . . . . . . . 2
   Outline of This Report . . . . . . . . . . 4

II. BUILDING A TOTAL FORCE MANAGEMENT MODEL . 6
   The Part-of-Force Concept . . . . . . . . . . 7
   Modeling a Single POF: An Overview . . . . . . . . . . 10
   Rudimentary Model Specification . . . . . . . . . . 12
   Setting Illustrative Parameter Values . . . . . . . . . . 17

III. EVALUATING MANNING ALTERNATIVES . . . . . . . . . . 20
   A Two-Way Analysis of the Active/Reserve Balance . . . 20
   A Two-Way Analysis of Civilianization Actions . . . . . . 23
   Findings from the Total Force Model . . . . . . . . . . 25
   General Comments on Methods of Analysis . . . . . . . . . . 27

IV. STRATEGIC DECISIONMAKING IN TOTAL FORCE MANAGEMENT . . . . . . . . . . 30
   Total Force Strategies for Part-of-Force Manning . . . . . 30
   The Marginal Costs of Raising Goals . . . . . . . . . . 34
   Using a TFM Model to Support Other Decisions . . . . . 36

V. PROSPECTS FOR TOTAL FORCE MANAGEMENT . . . . 38
   Consistency with Current Guidance . . . . . . . . . . 38
   Comparison with Alternative Methodological Approaches . . . . . . . . . . 39
   Adaptability to Existing Decision Procedures . . . . . . . . 41
   Feasibility of Building More Realistic TFM Models . . . 42
   Concluding Comments . . . . . . . . . . 43

Appendix

A. RUDIMENTARY MODEL REFERENCE TABLES . . . . . . 45

B. DEVELOPMENT OF THE ILLUSTRATIVE PARAMETERS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 50
C. COMPUTATION OF MARGINAL COSTS . . . . . . . . . . . . . 57

BIBLIOGRAPHY . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 61

## FIGURES

2.1. Overview of a single Part-of-Force model ............. 10
4.1. Categorizing goal structures and manning strategies ...... 32

## TABLES

3.1. Pipeline costs for senior active and reserve members ..... 22
3.2. Pipeline costs for senior active and civilian labor ........ 24
3.3. Costs and labor values for total force analysis .......... 26
4.1. Illustrative marginal costs of peacetime and wartime targets ..................................... 35
A.1. Definitions, labels, and initial values of parameters and variables used in the rudimentary model ........... 46
A.2. Spreadsheet calculations for rudimentary model ......... 48
B.1. Manpower statistics supporting the numerical illustrations ................................ 51
B.2. Cost data supporting the numerical illustrations ........ 53

# I. INTRODUCTION

This report introduces an integrative approach to evaluating the cost-effectiveness of Department of Defense manpower decisions. The approach's objective is to capture cost and effectiveness implications that result from *interactions* among DoD's labor management systems—interactions, for example, among systems that determine:

- Potential wartime operational goals and peacetime operating objectives;
- The mix of active, reserve, and civilian manning;
- The size and structure of peacetime personnel inventories; and
- Coordination between combat-related (or direct) manpower and indirect manpower support activities.

An integrative approach can revise cost-effectiveness findings from those obtained in a narrower context. Indeed, manning decisions that appear cost-effective according to fairly standard evaluation methodologies can be shown to cause higher costs or reduced effectiveness when subjected to a more comprehensive analysis. This report demonstrates that fact using simple numerical illustrations of two prominent types of decisions:

- Decisions about the active/reserve balance, i.e., about whether to shift certain missions from active to reserve components (or vice versa); and
- Decisions about "civilianization," i.e., whether to replace military manning in certain support functions with civilians (or vice versa).

The general observation that a more comprehensive analysis can lead to revised conclusions is not novel. Nonetheless, policy analysts working for and within the Department of Defense (the authors included) continue to rely on models and methodologies that ignore major elements of the DoD labor management environment. The central theme here is that greater emphasis on the development of "cross-cutting" models and methodologies is both warranted and feasible. The report lays a foundation for developing integrative models, and discusses strategies for implementing them.

## BACKGROUND AND MOTIVATION

The U.S. Department of Defense employs over two million active force members and more than one million each of reserve force members and civil servants; in addition, the DoD employs a substantial number of civilians who provide direct labor services under private sector contracts. Personnel pay and support accounts for more than half of the DoD's $274 billion in annual outlays.[1]

This enormous labor force provides the manpower for peacetime operations and represents an inventory of labor resources to support potential wartime operations. Each year, managing this labor force entails numerous decisions about which types of workers to use for various purposes—and hence what form the overall labor force should take.

Many specialized organizational units play a role in DoD manpower management. Some DoD offices specialize in tracking and managing a particular inventory, active or reserve or civilian. Other offices determine the manning necessary to carry out various wartime missions or peacetime functions. And still other offices deal with decisions about the weapons systems, equipment, and logistics support for the missions and functions to be performed. The DoD needs specialization to assure that the many rules and options in each decisionmaking area are fully recognized. But specialization also encourages the development of specialized analytic methods and data resources.

Although we acknowledge the need for specialization, we question whether policy evaluations produced in that environment reliably predict system-wide decision consequences. In particular, we question whether narrow analyses can properly assess the cost-effectiveness of decisions that expand, contract, or shift responsibilities within the total—active, reserve, and civilian—labor force.

The General Accounting Office has raised similar questions. In 1979, the GAO published a report containing the following recommendation:[2]

> The Secretary of Defense should take the lead to develop with the services a *comprehensive* total force policy which includes all manpower resources. The policy should define:

---

[1]Outlays for military and civil service personnel compensation alone were budgeted at $109 billion in FY 1987. See Department of Defense, Office of the Assistant Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 1987*, Washington, D.C., May 1986.

[2]Comptroller General's Report to the Congress, *DoD "Total Force Management"—Fact or Rhetoric?* U.S. General Accounting Office, FPDC-78-82, January 1979, pp. ii–iii [emphasis added].

—The *objectives of total force management in determining* the most cost-effective force consistent with military requirements and resource constraints.

—The manpower elements of the total force—that is, active and reserve military, civilian, and contractor—and their respective peacetime and wartime roles.

—Manpower systems that provide for *integrated management and concurrent consideration of all manpower resources*. . . .

In the years since the GAO report, the armed services have vastly improved the models and data systems they use for manpower and personnel management. Yet many decisions continue to be made based on information systems that do not fully integrate consideration of all manpower resources.

For example, consider the technique known as "billet costing" that is commonly used to assess the cost consequences of filling selected job positions ("billets"). Since there is limited lateral entry into the active personnel inventory (i.e., senior positions are filled almost exclusively by individuals who have been promoted through the ranks), costs for initial recruitment and training and for eventual military separation are usually triggered by filling a mid-level billet with an active military member. Hence, the billet cost measure for an active force member generally includes some allocated share of these other costs as well as pay and benefits for the year the billet is filled. This measure is then used to evaluate the costs of adding a billet, or is compared with costs of reservists or civilians to determine which type of personnel can fill the billet at least cost.

A limitation of this technique is that it stops short of evaluating the implications of using the active member to fill the other billets he or she will occupy over time. The technique clearly acknowledges that an active member's career spans several years, and that, at any given experience level, there may be costs or savings from substitution between active and reserve or civilian labor. Yet the technique does not acknowledge that a decision to use (or not use) active labor at a given career level also has implications for labor substitution costs or savings at all other career levels. In effect, the billet costing technique fails to recognize linkages between decisions about the uses of junior and senior manpower.

Other important linkages among manpower decisions are also omitted from standard policy analysis models. Two of these are:

- Flows of personnel *among* workforce inventories. More than half of the reserve components' current manning consists of individuals with prior active-force training and experience. An undocumented but undoubtedly significant proportion of the civilian workforce also has prior military experience.[3] These inventory "crossflows" are relevant to cost-effectiveness because they determine the long-term benefits of the costly training provided during military service.

- Differential contributions to peacetime and wartime operations. While active force members can supply essentially full-time labor services in both peacetime and wartime, most reservists supply only part-time services during peacetime and most civilians are barred from wartime deployment. Consequently, shifting job responsibilities from one workforce to another can critically affect the combination of peacetime and wartime operations the overall labor force can support.

Although these relationships are widely observed and clearly relevant to decisionmaking, they do not appear explicitly in the models and methodologies commonly used to evaluate labor force decisions.

This report argues that modeling to integrate various aspects of manpower management is feasible and desirable. Such models may not simulate manpower and personnel management systems in as much detail as existing, administrative models. Yet, by virtue of recognizing important relationships that are otherwise ignored, integrative models may discern a broader range of cost and effectiveness implications—and do so earlier in the decisionmaking process. And, as we shall illustrate, research concerning the properties of integrative models can support the development of general guidelines for policy evaluation and implementation.

## OUTLINE OF THIS REPORT

Section II presents our approach to building a total force management model. The basic building block in this approach is what we call a "Part of the Force." The section explains what it is and how it can be used. The section also postulates a simple version of a total force management model, and constructs (in conjunction with App. A) a data set based on reported costs for fiscal year 1987 and hypothetical labor effectiveness parameters.

[3]Data are available on the proportion of the DoD's civil service workforce consisting of "technicians" for whom concurrent membership in a reserve component is a job requirement. The statement in the text refers, however, to civilians whose current DoD responsibilities make use of skills or expertise developed during previous military experience. Although a career path from military to civilian DoD employment is widely recognized to exist, we could identify no data source or report documenting its prevalence.

We designed this rudimentary model to show how two familiar types of analyses—concerning the active/reserve balance and civilianization actions—are affected by accounting for two widely known but rarely modeled aspects of the labor management environment:

(1) Active force personnel as a prominent source of reserve accessions, and
(2) The active force's simultaneous roles as sources of peacetime labor and as an inventory of labor capacity for wartime contingencies.

Section III compares the results from the rudimentary total force model with findings that use the same data set but nonintegrative methods. The illustration shows that a decision that appears cost-effective using conventional methods (and our illustrative data) may not appear so when viewed in an integrative framework.

Section IV discusses the use of integrative modeling to (a) develop guidelines for cost-effective manning for different types of missions and functions and (b) evaluate the costs of expanding certain missions or functions. The illustrations continue to rely on our highly simplified model and illustrative data, and are not intended to generate actual recommendations or findings. Rather, the goal is to suggest by example how an integrative assessment methodology can be used for those purposes.

Having shown that integrative assessment modeling could improve the way decisions are evaluated—and hence could alter those decisions—we turn in Sec. V to the broader issues of feasibility and desirability. We discuss variations in integrative modeling—such as dynamic modeling and modeling under end-strength constraints—designed to address different types of decisionmaking issues. And we also comment on some of the institutional, analytic, and technical issues involved in developing and using an integrative approach to total labor force management.

# II. BUILDING A TOTAL FORCE MANAGEMENT MODEL

A Total Force Management (TFM) model is a quantitative analysis tool for evaluating decisions that affect the amounts and usage of labor resources in the Department of Defense. The central criterion for evaluating such decisions is cost-effectiveness. Consequently, a TFM model must address not only the costs of labor resources but also their contribution to meeting defense goals.

Any such model must abstract from the complex reality of the DoD environment. In our view, however, the model should embody at least the following features:

- The primary goal of peacetime defense management is to prepare for future military contingencies.[1] An important part of such preparation is the development of appropriate resource inventories, including skilled manpower as well as weapons systems, facilities and equipment, and materiel.
- Developing, managing, and supporting resource inventories creates a demand for labor services during peacetime. The same personnel inventories that support wartime capabilities may supply labor services in support of peacetime operations.
- There is limited lateral entry to the active and reserve personnel inventories; labor skills and abilities are generally supplied by prior military experience. In at least some occupational areas, civilian personnel also acquire defense job skills through prior DoD experience.
- Personnel with differing characteristics can be substituted for one another in (a) meeting wartime capability goals and (b) satisfying peacetime demand for labor services. However, personnel are not necessarily perfect substitutes (i.e., some contribute more to a goal than others), and an individual's contributions to wartime and peacetime goals are not necessarily equal.
- Many defense activities have both wartime and peacetime operating goals, but the combination varies considerably from one type of activity to another. For example, fighter pilot workloads are likely to be much higher in wartime than in

[1]The *ultimate* purpose of defense is to prevent war by deterring foreign military aggression. The statement in the text assumes that preparation for military contingencies is the primary means of serving the deterrence goal.

peacetime, while the workloads for long-range personnel planners are probably higher in peacetime than wartime.

In short, a TFM model should integrate information about wartime and peacetime operating goals, features of labor demand and labor supply, and opportunities for using alternative combinations of personnel.

This section proposes a technique for developing TFM models that could address a wide array of total force policy issues. The basic building block of the technique is a Part of Force (POF). This section explains what it is and how it can be used.

This section also builds a rudimentary TFM model that can be used to analyze manning decisions for a single Part of Force. The model will be used in Sec. III to illustrate fundamental differences between integrative TFM modeling and conventional methods of analysis.

## THE PART-OF-FORCE CONCEPT

Our total force modeling approach is based on the premise that defense activities are essentially like other productive activities: they use inputs to produce outputs. In the case of defense, the inputs are labor (manpower), capital (equipment, weapons systems, and facilities), and supplies (e.g., fuel and utilities). The output might be combat missions such as bombing sorties, a combat support workload such as aircraft repair, or the workload in an indirect support activity such as accounting or procurement contracting.

The Department of Defense commonly distinguishes between deployable and nondeployable (or, almost equivalently, "wartime" and "peacetime") activities. In general, deployable activities involve combat or combat support, would be relocated in the event of war, and depend heavily on military (active or reserve) personnel during wartime. Nondeployable activities typically have substantial peacetime responsibilities, would not be relocated in wartime, and depend heavily on full-time (active or civilian) personnel during peacetime. Because of differences in output goals and manning needs, deployable and nondeployable activities are often treated as though they can be managed separately according to distinct principles.

In contrast, we apply a single management modeling approach to all types of activities. The unit of analysis is always a production process; it may be one that would be fully utilized only in combat, or it may be one with a substantial peacetime workload. We call this unit of analysis a Part of Force,[2] and we model it by specifying:

- A set of output goals for both wartime and peacetime environments, and a corresponding set of production parameters describing the amounts of resource inputs required to meet those output goals; and
- A set of supply parameters determining the POF's access to resource inputs and their costs.

This approach emphasizes the need for coordinated management of peacetime and potential wartime operations. In practice, most activities have both wartime and peacetime operating responsibilities. (For example, combat units conduct training exercises during peacetime—and thereby generate repair and maintenance workloads—whereas so-called peacetime functions, such as payroll, would continue operations in wartime.) And, in practice, activities may depend on manpower inventories established during peacetime—inventories of skilled active, reserve, and civilian personnel—to carry out both peacetime and wartime missions. To be cost-effective, each POF should use the least costly manpower inventories sufficient to support its combination of peacetime and wartime output goals.

Within a single modeling framework, differences among POFs can be captured in three ways:

- By specifying a different combination of wartime and peacetime output goals. If a combat-related POF had no peacetime operating responsibilities, its peacetime output goal would be zero, but it could still have a high wartime output goal. In contrast, another POF could have a zero (or small) wartime goal and a large peacetime goal.
- By specifying different production parameters describing the amounts of resources needed to produce various levels of output. For example, the model could specify that civilians cannot contribute to wartime output in a deployable POF, even though civilians might be used during wartime in a nondeployable POF.
- By specifying different supplies of resources. In particular, the model can use different rates of personnel retention and different personnel costs for alternative POFs.

---

[2]The Department of Defense uses various terminology to describe its productive activities. Deployable activities are often described in terms of organizational structure—a squadron, battalion, command, etc.—whereas nondeployable activities are often described as "functions." Because we use a common modeling approach for all types of productive activities, we use the general term Part of Force to describe them.

The representation of a particular Part of Force may be a submodel within a larger Total Force Management model that analyzes several interrelated POFs. A multi-POF model can be designed to capture the following types of POF interactions:

- Interdependent goals. When several POFs must coordinate their activities, the output goals for all of them might derive from a "higher" statement of goals. For example, the wartime goal of delivering materiel to Europe could be the basis for determining both airlift flight hour and sealift steaming hour goals; if airlift and sealift are at least partially substitutable means of achieving a given deployment target, a multi-POF model can be used to identify the airlift-sealift combination with the least costly resource requirements.
- Supporting or subsidiary goals. Many defense activities, such as equipment maintenance and repair, provide support to other activities. A multi-POF model can be used to analyze decisions about a supported activity, taking into account the collateral effects of those decisions on the level (and cost) of operations in a supporting POF.
- Interdependent supplies of personnel. Different POFs might draw from the same "pool" of personnel, so that any one of the POFs has access to that labor only part of the time. Examples include rotation programs (personnel rotating between CONUS and overseas assignments), mobilization programs (personnel assigned to an activity during peacetime would mobilize with a different activity for wartime), and retraining and reassignment actions (personnel are moved from one occupational area to another during their careers). In these situations, a multi-POF model can show how decisions about manning a given POF could affect costs and output capacities in other POFs.

In current research, we have devised prototype models with up to five POFs linked in several of the foregoing ways.

For the illustrative purposes of this report, however, we use a relatively simple model of a single Part of Force. The model examines cost-effective manning for a particular type of job in a particular POF, assuming that output goals and resource usage in all other defense activities are held constant (and in the POF under analysis, holding nonlabor resources and manning for other types of jobs constant). This assumption is not uncommon in conventional methods of analysis for total force management, and will be maintained throughout Sec. III when we compare our rudimentary model with those conventional methods.

## MODELING A SINGLE POF: AN OVERVIEW

Figure 2.1 illustrates our rudimentary model of a single POF that uses labor from a single occupational category. For example, the model might represent a particular type of flight-line repairs to support C-141 airlift operations. The POF might represent a single repair work center or the aggregate of all work centers that face common labor demand and supply conditions.

At the top of the figure, the model specifies output goals and translates them into labor requirements. The output goals may be measured in terms of some established workload indicator variable, such as the number of flight hours to be supported. Labor requirements are measured in standardized units: the amount of work a full-time, fully qualified worker could perform in a year. This portion of the model can be specified by reference to the Service's management engineering studies for the POF in question.

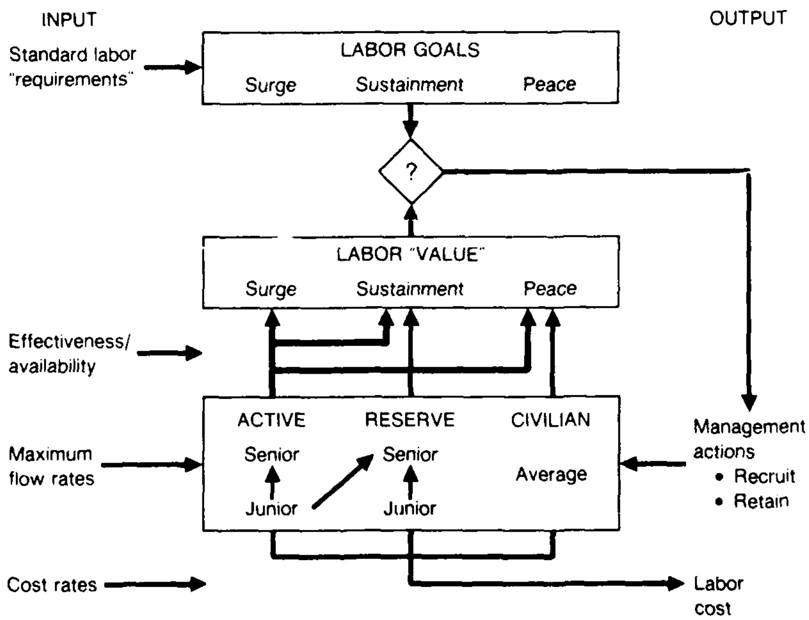


Fig. 2.1—Overview of a single Part-of-Force model

Figure 2.1 indicates that this POF has output goals in not just two but three defense environments:[3]

- The "surge" environment of initial hostilities or immediate response to a military contingency. In C-141 repair, for example, the surge goal might reflect flight hours desired for rapid-deployment missions.
- The "sustainment" environment in which defense resources become fully mobilized—in particular, reservists are deployed for full-time duty—to counter a continuing threat. In C-141 repair, the sustainment goal might reflect heavy responsibilities for transporting materiel to distant theaters.
- The "peacetime" environment during which the Department of Defense carries out activities under benign conditions. In C-141 repair, the peacetime goal would depend on the intended level of peacetime transport operations, possibly including crew training operations.

Existing criteria for total force management typically distinguish among these three environments because (a) civilians have limited availability for deployment in wartime (surge and sustainment) and (b) part-time ("drill") reservists, although deployable for sustainment, have limited availability *for surge*. Our model distinguishes among the three environments for the same reason.

At the bottom of the figure, the model specifies inventories of active, reserve, and civilian personnel. Accessions and retention rates determine inventory size and structure, much as they do in conventional personnel management models. The figure also shows that inventory costs can be assessed by associating pay, benefits, and other costs with the numbers of workers in various inventory categories.

In its center, the figure shows that the model evaluates the labor that the inventories can supply. The "value" of personnel in a given category depends on the extent to which those personnel are available to perform work in the POF and on their effectiveness while working there. Both availability and effectiveness can differ from one environment to another; hence a given inventory structure has a separate labor value for each operating environment.

[3]In principle, a POF might be expected to operate in any number of distinct wartime or peacetime environments. However, if several environments entail the same production and labor supply parameters, they can be summarized in the model by a single environment for which the goals are the highest among those of the subsumed situations. In continuing research, we have also developed techniques for translating some complex dynamic scenarios (e.g., those involving wartime personnel losses) into a single, summary goal for a generalized environment.

Finally, to the right of center, the figure lists the management actions the model is designed to evaluate: the number of accessions of active, reserve, and civilian personnel, and the extent to which personnel willing to remain in defense employment will be retained. For the inventory structure determined by these actions, the model answers two questions: How much output would be achievable in each wartime and peacetime environment? How much would the inventory cost in peacetime?

The model in this report is designed to compare alternative steady-state outcomes: output goals, accessions, retention, and hence overall inventory structure are held constant over time. Although it is possible to model transitions from one inventory structure to another, such a "dynamic" model would be far too complex for the illustrative purposes here. Moreover, steady-state outcomes are currently the primary basis for evaluating total force mix decisions in the Department of Defense.

The model also approximates production and supply relationships by linear equations. Linearity is commonly assumed in defense management studies, and is generally deemed a good approximation for purposes of making decisions "at the margin" (e.g., for adding a squadron or maintenance unit to an existing defense program).

Using linear equations, the model can be operated in two modes: In the *what-if?* mode, the user specifies particular inventory management actions and uses the model to determine what the output and cost implications would be. In the optimization mode, the model uses conventional linear programming methods to identify the set of inventory management actions that can support all output goals at least cost.[4]

The following discussion elaborates on the model's mathematical specification and the assumptions reflected therein.

## RUDIMENTARY MODEL SPECIFICATION

Appendix A contains tables summarizing the rudimentary model's parameters and equations. This section uses the same notation, which follows these conventions:

---

[4]In principle, the model could operate in an "output maximizing" (rather than cost minimizing) mode: the user would introduce a budget or inventory (e.g., end-strength) constraint and a set of parameters describing the relative importance of output in the alternative environments; the model could then select the highest valued combination of output levels achievable within the specified constraints. However, DoD analysts frequently lack guidance on the relative desirability of output increments in alternative environments, and budget or end-strength constraints apply to entire inventories rather than to individual POFs. For these reasons, prospective TFM model users would be more likely to use the *what-if?* mode in analyzing a single POF when budgets or end-strengths are constrained.

- The subscripts d, m, and p indicate the values of a variable in the surge (initial deployment), sustainment (full mobilization), and peacetime environments, respectively.
- The subscripts a, r, and c indicate the values of a variable with respect to active, reserve, or civilian personnel, respectively.
- Numeric subscripts refer to more detailed personnel inventory categories (such as junior reservists). In addition, the subscript x refers specifically to personnel who complete a term of active military service and subsequently enter the reserves; these are also described as "crossflow" or "prior service" reservists.

### Output Goals and Labor Requirements

Translating output goals into specific resource goals is analogous to translating operating objectives into resource "requirements" in conventional DoD requirements analyses. For example, a management engineering analysis might indicate that 20 fully qualified, full-time mechanics are needed to perform the C-141 repair workload generated by a planned number of peacetime sorties.

Equations showing the relationship between outputs and labor requirements would be useful in a more complex model dealing with a wider range of resources. For example, we have devised a model of combat units that holds crew size per weapon constant, so that decisions about numbers of personnel and numbers of weapons are not separable. However, our rudimentary model does not explicitly translate output goals into standard labor requirements. Instead, we simply measure surge, sustainment, and peacetime goals directly in terms of standard manyears, as indicated by the variables $G_d$, $G_m$, and $G_p$, respectively.

### Inventory Specification and Management

The rudimentary model deals with three major personnel classifications: active duty military, reserve military, and civilian. A larger model could distinguish between active personnel in the regular and reserve components, between regular civil servants and contractor employees, and between officers and enlisted personnel—but the rudimentary model does not. Similarly, a larger model could identify several pay grades or lengths of service in each personnel classification. However, the rudimentary model distinguishes only between "junior" and "senior" personnel.[5]

[5]Appendix B shows that we computed plausible values for average lengths of stay in the junior and senior categories by defining juniors as personnel with less than four years of defense experience. However, other definitions could be used, and can vary from one personnel classification to another.

The model assumes all personnel remain in the same POF throughout their careers, in both wartime and peacetime. As we noted earlier, a model containing more than one POF can evaluate situations where personnel are retrained from one POF to another, are rotated between POFs, or do peacetime work in one POF but are mobilized with a different POF. However, our rudimentary model examines a single POF in which all personnel inflows are from the civilian sector.

Senior active and civilian personnel are obtained by retaining juniors in the same classification—but senior reserves can be obtained from junior reservists or prior service accessions (crossflows). Again, a more complex model could allow for other inventory flow patterns, including the option of receiving some senior workers directly from the civilian sector.[6]

The size and configuration of the personnel inventories depend on:

- The numbers of junior accessions, as indicated by management variables $M_1$, $M_2$, and $M_3$ for active, reserve, and civilian personnel, respectively.
- The numbers of personnel retained to become senior workers. Management variables $M_4$, $M_5$, $M_6$ indicate the numbers of workers retained in the same classification to become senior active, reserve, and civilian personnel. In addition, $M_x$ indicates the number of crossflows to the senior reserves.
- The average number of years a worker spends within a personnel category, where $Y_1$, $Y_2$, and $Y_3$ are average stays in the junior active, reserve, and civilian categories, and $Y_4$, $Y_5$, and $Y_6$ are average stays in the corresponding senior categories.[7]

Constraints in the model prevent the numbers of workers retained after the junior term from exceeding the number willing to remain in defense work. For example, the constraint on active retention is:

$$M_4 - (M_1)(B_a) \leq 0, \tag{2.1}$$

where $M_1$ is the number of junior accessions, $M_4$ is the number of

---

[6]An initial version of the rudimentary model assumed that civilians could be hired directly into the senior experience group, but knowledgeable DoD staff noted that retaining civilians to take advantage of their special defense experience is an important management issue. Therefore, the current version of the model assumes that experienced civilians can be obtained only by retaining junior civilians.

[7]Note that the average stays for senior personnel exclude the junior length of stay. For example, if active personnel become seniors after four years of military service, the overall average length of stay for a senior active would be $Y_4 + 4$. This definition of average stays is unconventional, but well suited to the model's mathematical specification.

entrants to the senior active category, and $B_a$ is the maximum fraction of junior active accessions willing to enter the senior active force. Equations (A.4) through (A.7) in App. A list the full set of retention constraints.

In this steady-state model, the size of the inventory in a particular category is the product of the number of entrants to the category and the average length of stay in the category. For example, the number of people on the senior active roster in any year is given by:

$$I_4 = (M_4)(Y_4) \quad . \tag{2.2}$$

Note that, following the defense convention, the model measures inventory sizes by the numbers of individuals who would be listed as defense workers, even though they might not be on duty throughout the year; for example, reservists are considered to be in the inventory throughout a year even though they are on military duty only part-time. Duty time is taken into account in computing labor valuation (see below), not in computing inventory size. Equations (A.8) through (A.13) in App. A compute the inventory sizes for all personnel categories.

### Labor Valuation and Cost

The model evaluates the combined personnel inventories in two ways. One is cost, which depends on pay rates, the costs of training and other personnel support, and accession and retirement costs. Because the model explicitly analyzes personnel flows through the inventory, costs associated with particular events (such as basic training) are captured when those events occur; there is no need to allocate such costs among man-years. For example, the total personnel cost associated with the junior active inventory is:

$$C_1 = M_1[J_a + (Y_1)(J_1)], \tag{2.3}$$

where each of the $M_1$ junior active accessions incurs the cost $J_a$ for recruitment and training, and each year of junior service incurs the cost $J_1$ for annual pay and benefits. The full set of personnel cost equations appears in App. A, Eqs. (A.43) through (A.52).

The other evaluation computes the amount of labor supplied by the combined inventories for comparison with the standardized labor requirements. This "value" of the inventory depends on two basic types of parameters:

- Availability parameters (denoted by subscripted values of A) indicate the fraction of personnel in each inventory that would be on duty in the POF in each environment. For example, drill reservists are on duty for only part of each year during peacetime, and hence have very limited availability for peacetime work or immediate deployment (surge).
- Effectiveness parameters (denoted by subscripted values of E) compare the amount of work personnel can accomplish *while on duty in the POF* with the standard used to define requirements. If a typical senior active member's productivity is the standard, then the senior active would have an effectiveness rating of 1.0; by comparison, a junior active might have a rating of (hypothetically) 0.5, indicating that he (or she) would typically take twice as long or make twice as many attempts before completing a POF task successfully.

The labor valuation (Q) for each inventory category is the product of the size of the inventory (I), its availability in an environment (A), and its effectiveness in that environment (E). For example, the labor equivalent of the junior active inventory in peacetime is:

$$Q_{p1} = (I_1)(A_{p1})(E_{p1}) \quad . \tag{2.4}$$

If, for example, a junior active is typically on duty in a POF about 60 percent of the time and has an effectiveness rating of 0.625, one junior active man-year would provide just 37.5 percent as much labor as a fully qualified, fully available worker. The full set of labor valuation equations appears in (A.14) through (A.42) in App. A.

The model allows personnel with relatively low availability and/or effectiveness to meet a goal if those personnel are supplied in sufficient numbers. In the rudimentary model, the implied rates of substitution among personnel are constant, but the model could be expanded to apply a different substitution rate when the number of better qualified personnel crosses some specified threshold. Alternatively, constraints can be added to the model, for example, to prevent the ratio of senior to junior personnel from falling below a level needed to assure adequate supervision.

### Optimization Equations

When used in optimization mode, the model selects management variables $M_1$ through $M_6$ and $M_x$ in order to minimize total personnel costs (C in App. Eq. (A.52)) subject to the following constraints:

$$G_d - Q_d \le 0, \qquad (2.5)$$

$$G_m - Q_m \le 0, \qquad (2.6)$$

$$G_p - Q_p \le 0. \qquad (2.7)$$

Equation (2.5) requires the total surge labor valuation of the inventory ($Q_d$) to at least meet the surge labor goal ($G_d$); Eqs. (2.6) and (2.7) apply the corresponding constraints to the sustainment and peacetime environments, respectively.

## SETTING ILLUSTRATIVE PARAMETER VALUES

For military personnel, the service length, retention, and overall average cost data used in our illustrations are all based on actual data for fiscal year 1987. For civilians, service length and retention data were not readily available, and we simply assumed plausible values. However, the overall average civilian cost is an actual value for fiscal year 1987. The data sources and the methods we used to compute values of the foregoing variables are described in detail in App. B.

Separate values for average junior and senior pay in each personnel classification were not readily available. We calculated values based on the assumption that senior pay averages about 1.5 times junior pay. This is approximately the ratio of enlisted E-9 to E-4 pay in fiscal year 1987.

Our illustrations include cost values for recruitment and initial (basic and skill) training for military personnel. (As in most defense studies, the illustration assumes there are no recruitment or initial training costs for civilians.) These indirect cost values are for nonlabor costs only. We account for labor costs by recognizing that for every junior military accession, some portion of senior military personnel time is needed to provide recruitment and instructional services. In other TFM models under current development, these uses of senior personnel time are modeled explicitly. However, the rudimentary model in this report simply accounts for such time usage by reducing senior active personnel availability to the POF under analysis, as described below.

Since we measure the POF's labor goals in terms of the amount of work a fully available (and fully qualified) worker could do, a worker who is on full-time duty in a POF has, by definition, an availability rating of 1.0. (Note that we assume the goal is measured in a way that allows for the fact that even a "fully available" worker may be sick or otherwise unable to perform POF duties for some portion of each year.)

We assume that the surge goals are measured so that personnel in the active-duty inventory all have surge availability rates of 1.0, and that sustainment goals are measured so that both active and reserve personnel have sustainment availability rates of 1.0. Although it is reasonable to suppose that some fraction of reservists are on duty at a given time and hence could have some surge value, we have simplified the calculations in this report by assuming reserve personnel have zero availability for surge. We also assume civilians have zero availability for wartime (both surge and sustainment), which is an approximation particularly appropriate to a deployable POF.

Under the benign conditions of peacetime, there are a number of reasons why even full-time workers would not be fully available to a POF. Examples include vacation leave, time spent in training, and duties that temporarily call an individual away from his or her work center. Commonly cited estimates of defense worker "nonavailable" time, which are based on varying definitions of nonavailability, range from 10 to 20 percent of a full man-year. We use 0.85 as the peacetime availability parameter for civilians.

For active duty personnel, we begin with that same 0.85 factor, but then adjust it downward to account for labor time consumed in training and other indirect support, based on estimates contained in Palmer and Osbaldeston (1988).[8] For all active personnel, we reduce annual availability by 0.144 man-years to account for indirect labor in such supporting activities as base operating support, medical care in military treatment facilities, and morale, recreation, and welfare services. We also reduce active duty availability to account for 0.4 man-years of junior active trainee time and 0.23 senior active instructional man-years per accession. On average, therefore, the peacetime availability rate for junior actives is about 60 percent, and the rate for senior actives is about 65 percent.[9]

Just as we simplify by assuming zero availability of civilians for wartime, we assume zero availability of reserves during peacetime. This is

---

[8]Note that we are not necessarily assuming that indirect support labor is provided by the same individuals who provide labor in the POF under analysis. Rather, we are assuming that obtaining one full-time man-year of labor in the POF under analysis requires more than one full-time man-year of labor to be added to the defense workforce as a whole. This means of accounting for indirect labor is an approximation to a more complete and explicit multi-POF model.

[9]Based on an average stay in the junior active category of 2.85 years, total junior active availability is 85 percent of 2.9 − 0.4 − (0.144)2.9, or 61 percent of the 2.9 man-years. For seniors, our illustrative data indicate that there are 1/0.58 = 1.72 accessions required to obtain one entrant to the senior active category—so instructional time amounts to 1.72(0.23) = 0.4 man-years per senior entrant. Based on an average stay in the senior category of 6.0 years, total senior active availability is 85 percent of 6.0 − 0.4 − (0.144)6.0, or 67 percent of the 6.0 man-years. We actually use 60 and 65 percent as convenient approximations in our calculations.

a reasonable approximation if the indirect support required by reservists offsets any labor contribution they make during their part-time duty.

Although the Department of Defense is increasingly devoting attention to the measurement and evaluation of personnel performance and productivity, estimates of labor effectiveness remain sparse and case-specific. Until data on this important aspect of defense management become more readily available, decisionmakers must continue to rely on informed judgment. A TFM model does not avoid the need for some kind of expert judgment on how well different kinds of personnel perform, but it provides a tool for exploring the sensitivity of manning decisions to different judgments. Section III will illustrate how changing an estimate of relative labor productivity could affect cost-effective manning strategies.

The assumed effectiveness values for the Sec. III illustrations are listed in App. A. They omit values for environments in which workers are not available: civilians in wartime and reservists in peacetime. Senior actives are assumed to set the standard for measuring labor productivity, and hence are given effectiveness values of 1.0 in both wartime and peacetime. Senior civilians are assumed to be as effective as actives in peacetime, but (because of their more limited work experience) senior reserves are assumed to be 80 percent as effective as senior actives in sustainment. (This means that it would take 1.25 senior reserve man-years to perform the same sustainment work as one senior active man-year.) Junior personnel are initially assumed to be ineffective in wartime, and to be 62.5 percent as effective as senior actives during peacetime.

In Sec. III, we compare our TFM model results with those of more conventional methods of analysis *when the same parameter values are used.* We will show that, for some combinations of POF wartime and peacetime goals, the different methods of analysis lead to the same cost-effectiveness conclusions. But for other goal combinations—combinations that may be relevant in actual defense activities—the TFM modeling approach provides new insights into cost-effective management.

# III. EVALUATING MANNING ALTERNATIVES

This section applies the rudimentary Total Force Management model to two recurring decisions in DoD manpower management:

- Changes in the active/reserve balance: for example, determining whether certain military POFs should be converted from active to reserve manning.
- Civilianization actions: for example, determining whether certain peacetime labor positions should be converted from active to civilian manning.

We begin by describing how the two conversion decisions might be judged if subjected to conventional analysis. We then compare those results with analysis based on the rudimentary TFM model from Sec. II. We show that even when the alternative methods make the same assumptions about inventory changes and use the same parameter values, they can yield different conclusions. The reason is that conventional analysis does not fully recognize the implications of coordinating wartime and peacetime output goals.

## A TWO-WAY ANALYSIS OF THE ACTIVE/RESERVE BALANCE

Suppose that a Service is considering whether to convert a part of the force, such as a combat support activity, from active to reserve manning. A basic question about this decision is whether reducing the active inventory and increasing the reserve inventory would, on balance, raise or lower costs for this part of the force.

In practice, this question would be analyzed in several steps. Aside from addressing case-specific issues, the general analytic procedure would follow this outline:

1. Specify the wartime resource requirements associated with the alternative active or reserve POFs. For defense programming, requirements would be specified over the several years of the Service's fiscal plan, during which the unit's capability goals might vary. The requirements to be specified would include nonlabor as well as manpower resources. Manpower requirements would identify a number of job positions (billets) to be filled.

2. Allocate required billets to classes of personnel. Billets required for rapid deployment would normally be allocated to active duty personnel. By policy, nondeployable billets would be allocated to civilians unless military manning is needed for training or other military manpower management purposes. The remaining billets are the ones considered for allocation to active or reserve personnel.
3. Compute and compare the costs of meeting the requirements for the alternative active or reserve allocation. The comparison would consider the time profile of annual costs, the "typical" annual costs in steady state at full manning, and perhaps the present value of the time profile of costs.

There are several features of this analytic strategy that we will set aside in order to focus attention on the central cost-effectiveness issue. First, an actual conversion decision may include not only the reallocation of missions (output goals) from active to reserve units but also output changes that could affect costs even if the conversion did not occur; our illustration will hold all output goals constant before and after the conversion. Second, an actual conversion decision would address the transition from active to reserve manning, whereas our illustration compares only the steady-state outcomes. Third, an actual conversion might involve materiel, equipment and/or facilities cost changes; our illustration assumes there are none.

Furthermore, a conventional analysis typically estimates manpower costs by assuming that personnel changes will occur only in the billets in question, without regard to whether filling just those billets is consistent with personnel career management. In contrast, one of the motivations for developing a TFM model is to account explicitly for the relationship between managing "faces" and managing "spaces." This difference alone could cause a contrast between the conventional assessment of a decision's cost-effectiveness and the results from TFM modeling. However, we will abstract from that difference in our illustrations by showing how the conventional analytic approach would compute costs if it examined the full inventory management implications of filling selected billets. That is, we will suppose that both the conventional approach and the TFM model would estimate the costs of filling a senior job position in the same way.

Table 3.1 shows how manpower costs per senior military man-year would be calculated from the illustrative parameter values listed in App. A. We call these "pipeline" costs because they assume all active seniors come (eventually) from junior active accessions and all reserve seniors come from junior reserve accessions; crossflow reserves (i.e., senior reserves obtained from junior actives) are ignored in this table, just as they would be in a conventional cost assessment.

Because the conventional analysis begins by allocating certain positions to active duty personnel and civilians, the cost assessment would concentrate on those remaining positions that could be filled by either active or reserve personnel—wartime sustainment positions. If the same number of senior positions would be filled by either active and reserve personnel, the pipeline costs from Table 3.1 clearly imply that reserves should be used because they are much less costly. In fact, since the pipeline cost for actives is over three times as high as for reserves, converting the activity to reserve manning would be advisable unless meeting the wartime mission would require more than three times as many reservists as actives. Based on the sustainment

Table 3.1

PIPELINE COSTS FOR SENIOR ACTIVE AND RESERVE MEMBERS

| Item | Count per Senior Man-Year | Cost per Count | Cost per Senior Man-Year |
|---|---|---|---|
| | Active Personnel | | |
| Accessions | 0.28 | $4,400 | $1,232 |
| Junior man-years | 0.83 | 25,100 | 20,917 |
| Senior man-years | 1.00 | 37,700 | 37,700 |
| Pipeline cost per man-year | | | $59,849 |
| | Reserve Personnel | | |
| Accessions | 0.358 | $4,400 | $1,577 |
| Junior man-years | 1.075 | 7,000 | 7,527 |
| Senior man-years | 1.000 | 10,500 | 10,500 |
| Pipeline cost per man-year | | | $19,604 |

SOURCE: Computed from parameter values in App. A as follows: Since an active accession is expected to yield 0.58 retainees who will serve an average of 6.0 years in the senior force, the number of senior active man-years per accession is 3.48. Dividing the accession, the number of junior active man-years (2.9), and the number of senior active man-years by 3.48 yields a "count" of each of these items per senior active man-year. The same procedure also yields reserve item counts per senior reserve man-year. Pipeline costs are the sums of the products of the item counts and their costs.

availability and effectiveness parameters in App. A, a reserve senior has 80 percent as much sustainment value as an active senior; hence, for example, 125 senior reserves could replace 100 senior actives to meet a wartime sustainment goal at an annual saving of $3,534,400.

The foregoing comparison would encourage decisionmakers to reduce active force strength to the minimum needed to satisfy surge requirements and to use reserves to satisfy the remaining sustainment need. Thus, our numerical illustration is consistent with the common perception that it should be much cheaper to support wartime capabilities by relying on reserves rather than additional actives to supplement a basic core of active force strength.

As we shall see, this conclusion is based on the premise that peacetime output goals would be met under either active or reserve manning. If, however, peacetime output goals are not met by the combination of a minimum active force and civilians in nondeployable positions, reserve manning would leave a shortfall in peacetime performance. In practice, the Service's iterative decisionmaking processes would probably recognize the potential shortfall and make adjustments in the planned peacetime manning for the activity. However, those adjustments would not necessarily be anticipated in the cost analyses conducted to assess the basic active/reserve choice. A TFM model, in contrast, is designed specifically to anticipate this outcome and reveal its cost implications.

## A TWO-WAY ANALYSIS OF CIVILIANIZATION ACTIONS

Suppose a Service is considering whether to convert positions in a part of force from active to civilian manning. This question is most likely to be asked about an indirect support function that has a significant peacetime workload. Under existing DoD policy guidelines, such functions are normally manned by civilians. However, active personnel would be used if they are needed for such reasons as training, rotation, or security. Consequently, a basic issue raised in the civilianization context is whether the rationale for using active personnel to man the function remains valid. The cost implications of civilianization are analyzed primarily to estimate how civilianization would affect costs or to judge which of several candidate functions might offer the greatest savings from civilianization.

As in the case of decisions about the active/reserve balance, certain billets would be set aside at the outset: deployable billets (if any) and billets needed for military training would be set aside for military manning. Only the remaining billets would be considered suitable for civilianization. And, as in the case of active/reserve decisions, costs for the billets in question would normally be estimated without regard to personnel inventory management.

However, we shall again ask how conventional analysis would compare costs if it took full account of personnel inventory management. Table 3.2 repeats the pipeline costs per senior active man-year from Table 3.1, and shows the pipeline costs per senior civilian man-year. Since we simplified the numerical illustration by supposing there are no recruitment or training costs for civilians, the expenditure rate per senior civilian simply reflects pay over the civilian career.

The table suggests that there would be small savings from civilianization if replacement occurred on a job-for-job basis. According to the peacetime availability and effectiveness parameters in App. A, however, an active member supplies 3.3495 standard units of labor over his or her career—or 0.9625 per senior man-year—whereas a civilian career provides 5.525 labor units—or 1.3812 per senior man-year.[1] This

Table 3.2

PIPELINE COSTS FOR SENIOR ACTIVE AND CIVILIAN LABOR

| Item | Count per Senior Man-Year | Cost per Count | Cost per Senior Man-Year |
|---|---|---|---|
| | Active Personnel | | |
| Pipeline cost per man-year | | | $59,849 |
| | Civilian Personnel | | |
| Junior man-years | 1.00 | $23,700 | $23,700 |
| Senior man-years | 1.00 | 35,600 | 35,600 |
| Pipeline cost per man-year | | | $59,300 |

SOURCE: The estimate for active personnel is taken from Table 3.1. The civilian personnel values are computed from parameters in App. A, as follows: Since a civilian accession is expected to yield 0.5 retainees who will serve an average of 8.0 years as seniors, the number of senior man-years per accession is 4.0. Dividing the accession, the number of junior man-years (4.0), and the number of senior man-years by 4.0 yields a "count" of each of these items per senior man-year. Pipeline costs are the products of the item counts and their costs.

[1]An active accession supplies 2.9 junior man-years having a peacetime labor value of (0.625)(0.6) = 0.375 units per year, and an expected 3.48 senior man-years having a peacetime labor value of (0.65)(1.00) = 0.65 units per year. The total for the active career is 3.3495, or 0.9625 per senior man-year. Corresponding calculations for civilians

implies that meeting the (peacetime) labor goal would require filling 70 rather than 100 senior billets if civilians are used instead of active military personnel, yielding an annual saving of over $18,000 per converted billet.

Our illustrative cost and labor value parameters are consistent with the common view that it should be cheaper to use civilians than active military personnel to meet peacetime labor goals. Nonetheless, these illustrative values do not necessarily imply that it is cheaper to use civilians when both wartime and peacetime labor goals are considered jointly—as our rudimentary TFM model will show.

## FINDINGS FROM THE TOTAL FORCE MODEL

The total force evaluation perspective differs fundamentally from the perspective illustrated above. Rather than focus on the cost of a resource, *the total force management model focuses on the costs of simultaneously meeting all goals.* Consequently, the total force approach can yield different conclusions whenever there is joint production—i.e., when a particular resource contributes to more than one goal.

Like conventional analyses, our TFM model assumes only active military personnel can meet surge requirements for deployable labor. (Using our illustrative parameter values, one senior active man-year is needed for each unit of the surge goal.) The model determines how much additional sustainment and peacetime labor are needed beyond what is supplied by this "minimal" active force. The model selects the least costly mix of (additional) active, reserve, and civilian personnel to fulfill the residual sustainment and peacetime goals.

Table 3.3 provides the basic calculations for evaluating alternative force mixes. The table's first three columns reiterate our illustrative cost and labor values measured on a per-accession or per-man-year basis. (Only the sustainment and peacetime labor value rates are needed to choose the best way to supplement the minimal active force.) The middle column shows accession and man-year item counts, and the final three columns show the costs and labor values associated with each item count. Like Table 3.1, this table measures the active force inventory in terms of the number of active accessions (0.28) that yields one senior active man-year. However, the current table also shows

show that a career provides four expected senior man-years and a total career labor value of 5.525 units.

that 0.28 active accessions can yield up to 0.35 crossflow reservist man-years.[2]

The values in Table 3.3 support the same conclusions as the preceding two-way analyses to this extent:

- Replacing just the sustainment labor value provided by a senior active would require 1.25 senior reservists, and would save $35,344 annually.
- Replacing just the peacetime labor value provided by a senior active during his or her career would require the career labor of 0.697 senior civilians, and would save $18,525 annually.

Table 3.3

COSTS AND LABOR VALUES FOR TOTAL FORCE ANALYSIS

| | Values per Item | | | | Values per Count | | |
|---|---|---|---|---|---|---|---|
| Item | Cost | Sustainment | Peacetime | Item Count | Cost | Sustainment | Peacetime |
| | | | Active Inventory | | | | |
| Accession | $4,400 | — | — | 0.280 | $1,232 | — | — |
| Junior | 25,100 | — | 0.375 | 0.833 | 20,917 | — | 0.3125 |
| Senior | 37,700 | 1.0 | 0.650 | 1.000 | 37,700 | 1.00 | 0.6500 |
| Total before crossflows | | | | | $59,849 | 1.00 | 0.9625 |
| Reserve | 10,500 | 0.80 | — | 0.350 | 3,675 | 0.28 | — |
| Total after crossflows | | | | | $63,524 | 1.28 | 0.9625 |
| | | | Reserve Inventory | | | | |
| Accession | $4,400 | — | — | 0.358 | $1,577 | — | — |
| Junior | 7,000 | — | — | 1.075 | 7,527 | — | — |
| Senior | 10,500 | 0.8 | — | 1.000 | 10,500 | 0.80 | — |
| Total | | | | | $19,604 | 0.80 | — |
| | | | Civilian Inventory | | | | |
| Junior | $23,700 | — | 0.531 | 1.000 | $23,700 | — | 0.5312 |
| Senior | 35,600 | — | 0.850 | 1.000 | 35,600 | — | 0.8500 |
| Total | | | | | $59,300 | — | 1.3812 |

SOURCE: Calculations based on data in App. A.

[2]The maximum number of crossflows to the senior reserves is 0.131 per active accession, and each crossflow yields 9.3 senior reserve man-years. Hence, an active accession can yield 1.2183 expected senior reserve man-years as well as 3.48 senior active man-years—or 0.35 senior reserves per senior active. (Due to rounding, multiplying the number of crossflow reserve man-years by 0.28 active accessions would yield a value of 0.34 crossflows per senior active.)

In addition, however, Table 3.3 accounts for the crossflow reservists made available by active accessions. If these crossflows are cost-effective, either in the POF in question or elsewhere in the force, then replacing active personnel would also mean replacing the crossflow reservists that derive from active accessions. In that case, replacing just the sustainment labor value provided by a senior active and associated crossflow reserves would require 1.6 senior reserves obtained from nonprior service accessions, and would save $32,158.[3]

But what if replacing active members requires replacing *both* sustainment and peacetime labor value? If there are no crossflows, replacing a senior active billet would require 1.25 senior reserve billets *and* 0.697 senior civilian billets. Rather than falling, personnel costs would rise—by over $2,000 per senior active billet. And if crossflows are cost-effective, replacing the combination of sustainment and peacetime labor provided by a senior active would raise costs even more (by over $9,000). In our illustration, active personnel cost less to provide a combination of sustainment and peacetime labor than an equally effective combination of reserve and civilian personnel. The implication is that, for the parameter values used in our illustrations, parts of force that have both sustainment and peacetime operating goals that exceed their surge goals should use more active members than are needed strictly for surge.

Of course, defense managers readily acknowledge that the active force should be larger than the size needed for immediate deployment. However, that conclusion is based on the fact that any given active inventory necessarily includes some personnel who are not ready and able to deploy—such as personnel in training, on leave, in the hospital, or temporarily assigned to duties away from their combat unit. In contrast, the total force modeling analysis indicates that *even after nonavailability is taken into account* it may be cost-effective to have an active force larger than needed to provide qualified surge labor. This is the case if meeting both wartime and peacetime labor goals would require replacing active members with a more costly combination of reserves and civilians.

## GENERAL COMMENTS ON METHODS OF ANALYSIS

Two-way and total force analyses are equally dependent on having good data on pay, indirect costs, and inventory flow rates, and both

[3]The combination of a senior active man-year and its associated crossflow reservists costs $63,524, whereas 1.6 senior reservists obtained from nonprior service accessions cost $31,664.

types of analysis must ultimately incorporate some judgments about worker performance in order to reach specific conclusions about a manning option's cost-effectiveness.

Good evidence on labor performance has proven difficult to obtain. It is possible to document worker substitutions that have occurred, but effects on output—especially combat capability—are notoriously difficult to assess. In practice, studies to assess defense labor substitution decisions generally assume that actives, reserves, and civilians are equally effective in performing the jobs for which they are available and qualified.

Our illustrative parameter values also assume that active and civilian personnel are equally effective at peacetime duties, but we suppose that reserves are somewhat less effective than actives for sustainment. However, other assumptions can easily be explored. For example, if we assumed that the senior reserves and senior actives were equally effective in sustainment, we would find that replacing a senior active billet with a comparable combination of reserve sustainment and civilian peacetime labor would increase costs by a little over $1,000 rather than by $2,000. One of the advantages of using an explicit total force model is that it can be automated, allowing a user to test a variety of effectiveness assumptions.

More generally, an explicit total force model permits analysts to examine the sensitivity of costs to a wide range of alternative conditions. In the model, the cost-effectiveness of using more than the minimal active force depends on three factors:

- The combination of goals in a part of force. If the minimal active force supplies sufficient peacetime labor, then only reserves would be needed to meet any additional sustainment goal, or if the minimal active force supplies sufficient sustainment labor, then only civilians would be needed to meet any additional peacetime goal. In both those cases, the two-way analytic approach would yield the same conclusions as the total force model.
- Labor valuation parameters. For example, active personnel become less cost-effective for peacetime labor if their availability falls (due to either shorter work hours or increased amounts of manpower required for training and other indirect support) or if they are less productive than comparably experienced civilians. Active personnel become less cost-effective at providing sustainment if junior personnel have some wartime labor value, because there are fewer junior man-years per active senior than there are in a reserve career. In any particular part of force,

the cost and labor valuation parameters may be such that it would be cost-effective to replace active members even if a combination of reserve and civilian replacements were needed.

- Personnel inventory costs. The total force model accounts for the full cost of maintaining an inventory structure adequate to fill required billets. Therefore, the cost of filling a billet depends not only on the pay and benefit rates for qualified personnel, but also on the extent to which it is feasible to obtain a personnel seniority profile suited to the desired billet structure. For example, if the billet structure calls for a higher ratio of seniors to juniors than normal retention permits, the total force model recognizes that filling the desired senior billets will require adding a number of underemployed juniors to the force.

By comparison, more conventional methods of analysis usually reflect inflexible simplifying assumptions about output goals, labor valuation, and inventory costs.

In Sec. IV, we will continue to use the illustrative parameters from App. A, but will look more closely at how cost-effective manning patterns vary with the combinations of wartime and peacetime output goals in various defense activities—and what that implies for the costs of meeting the goals.

# IV. STRATEGIC DECISIONMAKING IN TOTAL FORCE MANAGEMENT

This section will show how a total force model can be used (a) to develop general guidelines for cost-effective manning to meet peacetime and wartime output goals and (b) to assess the cost implications of changing a goal in a part of the force.

Since our rudimentary total force model is linear, it generates straightforward guidelines for selecting a combination of active, reserve, and civilian labor. Based on the initial numerical values set in App. A, the model recommends a manning strategy that contains five distinct manning "modes" described in this section.

Once the manning guidelines are established, the model can be used to determine the cost of changing an output goal. The cost depends on how manning would be altered to satisfy the new combination goals, and hence differs from one manning mode to another. This section computes each goal's marginal costs based on our numerical illustration. The results demonstrate that these costs are often quite different from the expenditures for the manpower added to satisfy the increased goal.

Another property of the model is that it can be used to generate "shadow prices"—estimates of the savings that could be achieved by relaxing the model's constraints. The marginal costs of goals are shadow prices on the constraints that all goals must be met. In addition, the model yields shadow prices for personnel retention constraints and can thus be used to assess what a part of force could save if it could increase retention. This section notes how such information could benefit personnel management decisionmaking.

## TOTAL FORCE STRATEGIES FOR PART-OF-FORCE MANNING

Our total force modeling approach uses a linear programming specification that can be solved for the cost-minimizing personnel mix for any given set of goals (and other constraints) using conventional techniques. By optimizing repeatedly for different combinations of output goals, it is possible to trace how the optimal personnel mix changes. A listing of different classes of goal combinations and their optimal manning patterns constitutes a manning "strategy"—a statement of guidelines for manning a part of force depending on its goal structure.

A manning strategy depends on the pay and other costs, inventory flow rates, and comparative availability and effectiveness of different categories of personnel. For example, if filling a senior active billet were more costly than filling an equally productive combination of civilian and reserve billets, then the manning strategy would not use more senior active personnel than necessary to meet the surge labor goal. Since cost, retention, and performance parameters can differ from one part of force to another, manning strategies can differ as well.

However, for a hypothetical POF that has the illustrative parameter values given in App. A, Sec. III showed that:

- It is less costly to meet sustainment labor requirements with reserves than with active personnel;
- It is less costly to meet peacetime labor requirements with civilians than with actives;
- It is less costly to meet a combination of sustainment and peacetime labor requirements with actives than with an equally effective combination of reserves and civilians.

In addition, crossflow reservists (reservists with prior active service) are more cost-effective than nonprior service reservists, since the latter incur costs but (we assume) provide no labor services during their junior terms of service.

Given a POF that operates under the foregoing conditions, the manning strategy contains five distinct options that will be cost-effective under alternative goal structures. Figure 4.1 illustrates the five goal structures and identifies their corresponding options.

The axes in the figure measure the sustainment goal ($G_m$) and the peacetime goal ($G_p$) relative to the surge goal ($G_d$, which always exceeds zero in the figure). Active personnel always provide any required surge labor because neither reserves nor civilians are considered available for surge in our illustrative POF; we refer to the smallest active inventory sufficient to meet the surge goal as the "minimal" active force. Each of the shaded regions in the figure indicates a different way in which sustainment or peacetime goals might compare with the surge goal, and hence a different way in which the minimal active force should be supplemented to meet all goals.

Consider, for example, the region labeled "1." It lies to the left of the dotted line that indicates $G_m/G_d = 1.28$. In Sec. III, Table 3.3 showed that active accessions sufficient to fill one senior active billet provide a surge labor value of 1.0 and, when the maximum number of crossflow reservists are retained, also provide sustainment labor value

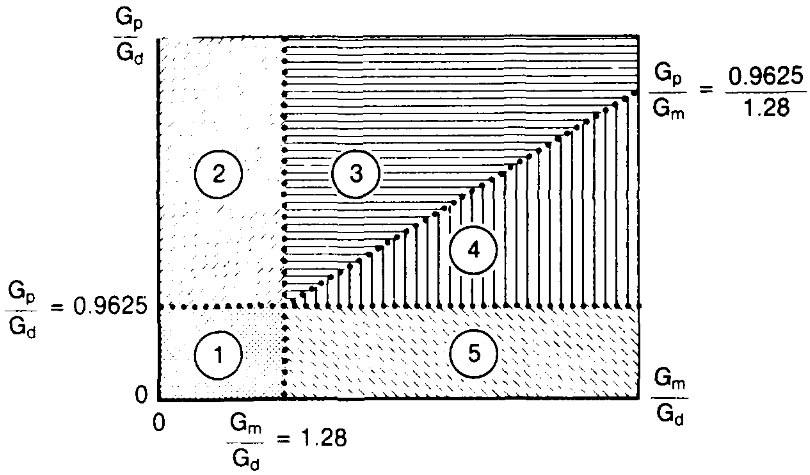


Fig. 4.1—Categorizing goal structures and manning strategies

of 1.28. Consequently, if $G_m/G_d$ is less than 1.28, all wartime labor needs can be met by using the minimal active force and retaining some portion of the junior actives who are willing to remain in the force as senior reserves. Similarly, region 1 lies below the dotted line that indicates $G_p/G_d = 0.9625$, which is the value of peacetime labor provided by the number of active accessions that supplies a surge value 1.0; since region 1 lies below that line, the minimal active force is sufficient to satisfy the entire peacetime labor goal. Hence, in region 1, where both sustainment and peacetime labor goals are small relative to the surge goal, all three goals can be met by using the minimal active force and accepting enough crossflow reservists (who are less costly than nonprior service reservists) to meet any remaining sustainment requirement. That is the least costly way to meet the region 1 goals.

The region labeled "2" differs from region 1 only in that there are peacetime labor requirements that are not met by the minimal active force. (That is true because $G_p/G_m > 0.9625$ in region 2.) Since both the wartime goals are met by using the minimal active force and perhaps some crossflow reservists, it is not cost-effective to add more actives to the force. The least costly way to meet the remaining peacetime goal is to add civilians.

In contrast, the region labeled "5" differs from region 1 only in that there are sustainment labor requirements that are not met by the minimal active force, even when all available crossflows are accepted. It is also not cost-effective to add more actives to the force in this case. Instead, the minimal active force and its associated crossflows should be supplemented by adding nonprior service reservists.

Perhaps the most interesting regions are the ones labeled "3" and "4." The minimal active force (including all its crossflows) leaves a shortfall in both peacetime and sustainment labor. So long as that is true, adding active accessions is more cost-effective than adding a combination of civilian and reservist accessions. In region 3, where $G_p/G_m > 0.9625/1.28$, adding active accessions will eventually eliminate the shortfall in sustainment labor before the peacetime labor need is fulfilled; at that point, civilians should be added. In region 4, on the other hand, adding active members will eliminate the peacetime labor shortfall before the sustainment need is satisfied; then reserve accessions should be added.

According to Fig. 4.1, our hypothetical POF should use either a combination of active and reserve accessions (with all crossflows accepted) or a combination of active and civilian accessions (perhaps with some crossflow reserves), depending on how its peacetime and sustainment goals compare with its surge goal. This particular POF would never find it cost-effective to access juniors in all three personnel classifications—although a POF with different parameter values might.[1]

How, then, does this manning strategy differ from what would be recommended by two-way analysis methods? The two-way approach to evaluating the active-reserve balance ignores peacetime labor requirements, which is appropriate in regions 1 and 5; the two-way approach to civilianization decisions ignores the sustainment goal, which is appropriate in region 2. With those three goal structures, a two-way analysis that recognizes inventory flows (and crossflows) and uses the same cost and parameter values as the total force model will yield exactly the same conclusions about the most cost-effective manning and the savings it offers over any alternative manning. What makes the TFM model different is its treatment of the goal structures in regions 3 and 4. In those areas, the model recommends using more

[1]It is established policy in the reserve components to limit the number of prior service accessions in order to maintain a flow of personnel from junior to senior ranks. This policy is predicated on a number of factors, such as morale, that are not recognized by the total force model. The purpose of the model is not to supplant decisionmaking based on a wider array of concerns, but to assist such decisionmaking by providing insight into its potential cost and effectiveness implications.

than the minimal active force—a recommendation not supported by the two-way findings.

The manning guidelines generated by the rudimentary model are straightforward. Once the various manpower substitution opportunities have been assessed, the choice of a cost-effective manning option follows logically from judgments about the relative magnitudes of a POF's surge, sustainment, and peacetime goals.

Of course, the simplicity of the guidelines depends in part on the simplicity of our rudimentary model. In current research, we are developing more complex guidelines based on more complex models that acknowledge, for example, that reserves might have some surge availability. And the guidelines would become even more complex to derive and explain if we considered nonlinear models to accommodate, for example, variable rates of labor substitution over different output ranges.

The sensitivity of guidelines to the complexity of the model raises the general issue of the validity of decisionmaking guidelines. By their nature, guidelines can only recommend broadly applicable courses of action that more detailed and specific investigation might call into question. Compared with two-way analysis, a linear total force model tailors guidelines more closely to variations in manpower management objectives. And if a more sophisticated total force model led to more complicated guidelines, that would simply corroborate the obvious fact that managing the total force cost-effectively is a complex task.

## THE MARGINAL COSTS OF RAISING GOALS

A TFM model can also be used to determine how a POF's total cost would change if wartime or peacetime goals were raised (or lowered). Decisionmakers can use that information to judge whether, on balance, reallocating a given total defense budget among parts of the force could improve overall defense.

Based on our illustrative data, Table 4.1 shows the marginal cost implications of adding one "unit" (i.e., the amount of output produced annually by one fully available, fully qualified worker) to each goal, holding the other two goals constant. These estimates are generated automatically as shadow prices on the three goal constraints when the TFM model is operated as an automated linear optimization model. As the table indicates, the estimates differ depending on the POF's goal structure; a different set of estimates pertains to each of the goal regions in Fig. 4.1.

Table 4.1

ILLUSTRATIVE MARGINAL COSTS OF PEACETIME AND WARTIME TARGETS

| Region/Manning | Costs of Adding One Unit to: Surge Goal | Sustainment Goal | Peacetime Goal |
|---|---|---|---|
| 1. Minimal active force. Add crossflows to attain sustainment goal. | $46,724 | $13,125 | $0 |
| 2. Minimal active force. Use crossflows to attain sustainment goal. Add civilians to meet peacetime goal. | $5,400 | $13,125 | $42,934 |
| 3. Use actives with crossflows to meet sustainment goal. Add civilians to meet peacetime goal. | $0 | $17,338 | $42,934 |
| 4. Use actives with crossflows to meet peacetime goal. Add reserves to attain sustainment goal. | $0 | $24,505 | $33,412 |
| 5. Minimal active force. Use all crossflows. Add reserves to meet sustainment goal. | $32,158 | $25,404 | $0 |

Given the simplicity of our rudimentary model, it is also possible to compute the marginal cost estimates manually using the technique shown in App. C. The cost of raising a particular goal depends on how the goal increment would be achieved. For example, in goal region 4, the manning guideline is: Use active personnel (and allow all crossflows) until the peacetime goal is satisfied, then add reserve accessions to satisfy the sustainment goal. Since this means using more than enough active force personnel to satisfy the surge requirement, adding one to that target imposes *no* additional costs. However, increasing the sustainment goal by one unit would raise costs by $24,505 to support 1.25 additional senior reserve billets. Finally, if the peacetime goal were raised by one unit, the additional labor requirements would be met by adding 1.039 senior active billets (along with the junior actives and crossflow reserves that come with them). Although this would add $66,001 in expenditures for active and crossflow personnel, it would also replace 1.66 senior reserve billets (saving almost $32,590) in meeting the sustainment goal—so the net marginal cost per unit of the peacetime goal is just $33,412.

The total force analysis can provide insights not found in two-way analyses, even when they correctly identify a cost-effective manning strategy. In region 2, for example, a two-way analysis would correctly recommend using civilians to meet residual peacetime labor demand. But the two-way analysis would reach this conclusion by ignoring any active personnel positions set aside to meet the surge goal, and therefore could not address questions about the costs of changing that goal. In contrast, Table 4.1 not only evaluates the cost of raising the surge goal, but shows it is quite different from the pipeline cost ($59,849) of adding a senior active billet to the force.

At a still higher level of decisionmaking, information about marginal costs in various parts of the force can aid decisions about allocating the overall budget among them. Suppose, for example, that a Service wishes to expand some surge response capability that could reasonably be performed by more than one existing POF. (Perhaps the proposal is to expand some air support units' sea rescue duties.) If the military POFs differ in their output goal structures, they might have different marginal costs. The marginal cost analysis could suggest which units could support the added surge requirement at least cost. Or the analysis might suggest that certain units could add a higher level of surge than others at any given additional expenditure. In this context, the TFM model does not dictate the best course of action, but it can provide vital cost information to support manpower utilization decisions.

## USING A TFM MODEL TO SUPPORT OTHER DECISIONS

Just as the goal constraints generate shadow prices that indicate the marginal costs of raising the goals, other constraints in a TFM model generate other shadow prices indicating how defense costs would be affected by relaxing the constraint. This means the model can be used to evaluate the implications of any type of defense policy or situation that can be expressed as a linear constraint on the TFM solution.

The rudimentary TFM model in this report, for example, includes four retention constraints (Eqs. (A.4) through (A.7) in App. A). Each of these constraints dictates that the number of entrants to a senior personnel category cannot exceed a maximum fraction of accessions. The shadow prices on the constraints estimate the amount of savings the POF would incur if it could obtain one additional retainee (i.e., if one more entrant beyond the maximum could enter the senior category). This savings estimate (which would be zero if retaining additional personnel is not cost-effective) may be interpreted as the maximum amount the Department of Defense should be willing to spend to raise retention. For example, in goal region 4, the shadow price on the active retention limit is $26,656; it would not be cost-effective to pay more than this amount to obtain one additional senior active retainee.

# V. PROSPECTS FOR TOTAL FORCE MANAGEMENT

Our total force management model addresses itself to the objectives stated in the GAO report cited at the outset of this analysis. That report took as given that the Department of Defense should implement a management system that uses both military and civilian personnel in the most cost-effective manner. But legitimate questions might be raised about the desirability and feasibility of applying our TFM modeling approach in the context of existing defense policies and procedures. This section discusses the following aspects of desirability and feasibility:

- Consistency with existing defense policy guidance;
- Comparison with alternative methodological approaches;
- Adaptability to existing decision procedures; and
- Feasibility of building more realistic TFM models.

## CONSISTENCY WITH CURRENT GUIDANCE

Existing DoD policy guidance may be inconsistent with using cost-effectiveness as the standard for selecting between military and civilian manning. According to DoD Directive 1100.4:

> Civilian personnel will be used in positions which do not require military incumbents for reasons of law, training, security, discipline, rotation, or combat readiness, which do not require military background for successful performance of the duties involved, and which do not entail unusual hours not normally associated or compatible with civilian employment.

This instruction could be interpreted as opposing the use of a larger than minimal active force to meet peacetime operating goals, even though our rudimentary model suggests that such manning can sometimes be cost-effective.

At present, it is not certain whether the Department of Defense would be amenable to altering this guidance to make cost-effectiveness a central manning criterion. As we have illustrated, a standard two-way analysis suggests that civilians are more cost-effective than military personnel at providing peacetime labor. Since the standard analysis does not reveal a potential conflict between following

Instruction 1100.4 and using cost-effective manning, there has been little reason to question whether the instruction should be changed.

But suppose that a conflict between 1100.4 (or other management guidelines) and cost-effective manning were proven and the Department of Defense nevertheless favored retaining current policy. (For example, Instruction 1100.4 might be considered justified on the grounds that it is socially undesirable to maintain a standing force larger than absolutely necessary for defense readiness.)[1] Would that mean the kind of total force management evaluation envisioned in this report is irrelevant?

We think not. Just as a total force model can be used to identify cost-effective manning strategies, it can also be used to determine how much more it costs to use a strategy that is not strictly cost-effective. For example, the model can reveal whether it costs more (and by how much) to maintain given levels of wartime and peacetime capability while minimizing the standing military force—and thus can attach a price tag to that social objective. And, from a practical standpoint, the model can suggest where and how the minimal standing force should be used during peacetime to keep that price tag as low as possible.

## COMPARISON WITH ALTERNATIVE METHODOLOGICAL APPROACHES

The POF modeling technique described in Sec. II embodies three features that distinguish it from some other manpower management evaluation methods:

1. The POF technique explicitly coordinates manning to meet both wartime and peacetime operating goals, and hence explicitly accounts for the value of personnel who can jointly support goals in multiple environments. In contrast, some analysis methods begin by sorting jobs into wartime and peacetime categories before evaluating cost-effectiveness.
2. The POF technique explicitly models the personnel inventory flows that fill defense billets, and hence accounts for the cost of personnel who may be underutilized in some environments but are needed to maintain desired manpower supplies. In contrast, the Department of Defense usually prices out only the billets to be filled (perhaps with some allocated share of

---

[1] This motivation was suggested in an unpublished report by Dr. Deborah Clay-Mendez, a Pentagon analyst. Her paper also suggested that there might be a conflict between 1100.4 and cost-effective total force management, and recommended further investigation along the lines of our study.

training and other acquisition costs) when evaluating manning decisions.

3. In a multi-POF framework, the technique permits a TFM model to capture not only interactions in which various defense activities support one another (e.g., when a repair activity maintains equipment for use in a combat activity), but also interactions involving flows of personnel among activities (e.g., for rotation).

In this report, we used a simple, single-POF model to demonstrate the implications of the first feature listed above. However, research to be documented in future reports show that features 2 and 3 can also produce conclusions different from more conventional methods.

Feature 1—recognition of both wartime and peacetime goals—can be (and sometimes is) incorporated in analyses that compare fully specified manning alternatives. In cases where a mission might be assigned to either an active or reserve component, for example, analysts in each component might develop a fully specified "proposal" for manning and supporting the mission, taking into account both wartime and peacetime operational needs. A comparison of the alternative proposals would then implicitly account for joint production. However, features 2 and 3 of our TFM modeling approach are not reflected in *active/reserve analyses*, so a fully specified TFM model can still yield conclusions different from more conventional methods.

Feature 2—recognition of inventory flow requirements—is a matter that has often been considered by model builders but not explicitly incorporated in model designs. A common argument is that the costs for personnel needed to maintain inventory flows into a required billet need not be considered because such personnel would not be left idle; instead, according to this argument, such personnel would be fully utilized in some other, unspecified activity where their value in production would offset their costs. This argument would be valid if there were mechanisms to assure that personnel were always assigned to tasks in a way that equates their marginal replacement cost with their current pay and benefits. However, it is precisely the difficulty of achieving such a result in the defense context that warrants the development of TFM models to support manning decisions.

Feature 3—the ability to assess the implications of flows of personnel among POFs—represents perhaps the most promising and significant opportunity to gain new insights into manpower management via a TFM model. Given limited lateral entry to personnel inventories, policies that rotate personnel through various billets or assign them differing wartime and peacetime jobs become critical to achieving the least costly personnel inventory structure consistent with meeting wartime and peacetime goals. Yet methodological tools for addressing rotation and mobilization assignment policies in the context of making manning decisions are virtually nonexistent. This is a particularly disturbing shortfall in analyses of civilianization actions, where the cost-effectiveness of replacing military personnel depends critically on the roles they would play in other activities during an overseas tour or if mobilized elsewhere in event of war.

In short, extensions to the rudimentary, single-POF model presented in this report hold considerable promise for improving upon existing capabilities for manpower and personnel policy evaluation.

## ADAPTABILITY TO EXISTING DECISION PROCEDURES

Under the Planning, Programming, and Budgeting System (PPBS) and the associated acquisition decision process, the Department of Defense has established a complex system of analytical procedures. Methods of analysis differ somewhat from one level and phase of decisionmaking to another. Accordingly, some aspects of a TFM model design would vary depending on where and how the model would be applied.

The rudimentary model developed here examines manning decisions in a long-run, steady-state context, where the objective is to select the least costly personnel structure consistent with output goals. Such a model would be best suited to studies in support of weapons system cost analysis (in the acquisition decision process) or in the planning phase of PPBS. In addition, such a model is especially appropriate for evaluating and developing general manning guidelines, as Sec. IV illustrated.

During programming and budgeting efforts, however, compliance with cost or end-strength constraints and year-to-year changes in costs and effectiveness are central concerns. The rudimentary model is not well suited to those needs.

In principle, a TFM model might be developed to assess time-phased manning policies, taking account of inventory dynamics. As described below, existing dynamic inventory projection models might be adapted for this purpose.

However, attempting to optimize in programming and budgeting exercises poses a far more difficult challenge: Since budgets or end-strength limits impose annualized, aggregative constraints, optimization appears to hinge on modeling the full range of defense activities and attaching comparative values to achieving all goals at all points in time. In current research, we are investigating alternatives to building such a comprehensive model. In the interim, it appears that TFM modeling is better suited to planning applications and guidelines development.

## FEASIBILITY OF BUILDING MORE REALISTIC TFM MODELS

Our rudimentary TFM model oversimplifies in two ways. One is that it uses simplified equations to describe the operation of a part of force. The other is that it contains only one POF and does not deal with interactions among POFs.

The most complex component of a POF model is its inventory management module. Our rudimentary model characterizes inventory management in terms of a steady-state module containing only a few personnel categories. However, each of the services has fairly sophisticated inventory management models that are able to predict, in considerable detail, dynamic adjustments in military personnel inventories for many years into the future. These models allow personnel planners to assess how military personnel inventories would change if retention, accession, and promotion policies change.

Tailoring the existing inventory projection models for use in manning policy evaluation would take some development. In some cases, the models do not associate costs with the inventories, although this should be a relatively easy extension. The larger challenge lies in developing inventory models that can identify the personnel policies needed to meet a particular inventory outcome, rather than simply predict future outcomes of specified personnel management policies. However, this extension is essential only if a TFM model is to be operated in an optimization mode; relatively little adaptation would be required to apply existing inventory projection models for use in TFM models applied solely in a *what-if?* mode.

Additional development would be needed to create inventory management modules for civilian manpower and to characterize crossflow patterns among the active, reserve, and civilian inventories. These are all areas in which improvements in DoD personnel models would be desirable for various management purposes quite apart from their use in TFM modeling. Similarly, a TFM model is not the only potential application warranting the development of modeling techniques to address the cost and effectiveness implications of civilian contracting and the role of noninventoried personnel in wartime production.[2]

The other major components of a POF model are the relationships the model specifies between manning and the satisfaction of peacetime and wartime labor goals. As Sec. II noted, the Services already have developed data sources and methods for computing standardized labor requirements to achieve various operating and capability levels; a POF model is amenable to using such requirements data to set labor goals, or to incorporating entire production models and deriving requirements internally. Existing manpower planning procedures also use data on personnel availability that would be useful in a POF model. The principal area in which existing data bases provide inadequate information to support POF modeling is the shortage of data on the comparative performance of different types of personnel—the need for data for general management purposes is widely acknowledged within the Department of Defense.

Dealing with interactions among POFs entails characterizing the ways POFs can interact and capturing the relationships in a multi-POF model. In continuing research, we have devised models containing up to five POFs that interact by drawing on the same personnel pools (through rotation and mobilization patterns) or by setting mutually consistent goals. Much larger models are clearly feasible, although our research to date suggests that many TFM issues can be addressed adequately by modeling selected portions of the overall defense system; further research along these lines is warranted to find suitable ways to keep TFM models sufficiently small and swift to retain their value as exploratory analytic devices.

## CONCLUDING COMMENTS

This report has explored the nature of a total force approach to DoD labor management. The aim was not to judge existing management, but to test whether explicit recognition of joint production in meeting peacetime and wartime goals could lead to conclusions different from the familiar analytic approaches. For that purpose, we set illustrative numerical values that had some basis in fact and seemed plausible based on our previous research experience. As it turned out, those values produced results consistent with familiar analyses, yet could

---

[2]By our definition, noninventoried personnel are individuals who can be called upon to supply defense labor in wartime but are not on the defense payroll during peacetime. Prominent examples are recallable retired military personnel and the Individual Ready Reserve.

yield very different conclusions when used in a simple total force management model. And we found that the total force analytic approach could offer additional insights into various aspects of personnel management, such as in evaluating retention bonus levels.

The suggested approach to total force management modeling shows promise as a basis for developing applied models. However, the aims of the study will be met if it simply encourages other analysts to consider the broader wartime capability and peacetime performance implications of the policy options they evaluate and the manpower management systems they design.

## Appendix A

# RUDIMENTARY MODEL REFERENCE TABLES

This appendix contains a full listing of the parameters, variables, and equations for the rudimentary model described in Sec. II. Table A.1 lists the variables and parameters for the complete model; the table also shows initial values for the input parameters, as derived in App. B. Table A.2 lists "spreadsheet" equations that compute various summary values used in the linear programming solution.

In linear optimization, the objective is to select the personnel management variables, $M_1$ through $M_x$, so as to minimize total costs (C in Eq. (A.52)), subject to the following constraints:

- Labor valuation in each environment must meet or exceed the corresponding labor goal:

$$\text{Surge requirement: } G_d - Q_d \leq 0 \ , \tag{A.1}$$

$$\text{Sustainment requirement: } G_m - Q_m \leq 0 \ , \tag{A.2}$$

$$\text{Peacetime requirement: } G_p - Q_p \leq 0 \ . \tag{A.3}$$

- The number of retainees accepted in the senior forces cannot exceed the numbers of volunteers:

$$\text{Active retention limit: } M_4 - (M_1)(B_a) \leq 0 \ , \tag{A.4}$$

$$\text{Reserve retention limit: } M_5 - (M_2)(B_r) \leq 0 \ , \tag{A.5}$$

$$\text{Civilian retention limit: } M_6 - (M_3)(B_c) \leq 0 \ , \tag{A.6}$$

$$\text{Crossflow retention limit: } M_x - (M_1)(B_x) \leq 0 \ . \tag{A.7}$$

Table A.1

DEFINITIONS, LABELS, AND INITIAL VALUES[a] OF PARAMETERS AND VARIABLES USED IN THE RUDIMENTARY MODEL

| Input Variables | Label | Value |
|---|---|---|
| LABOR GOALS (in standard units) | | |
| Surge labor | $G_d$ | (b) |
| Sustainment labor | $G_m$ | (b) |
| Peacetime labor | $G_p$ | (b) |
| INVENTORY PARAMETERS | | |
| Junior active EYOS[c] | $Y_1$ | 2.9 |
| Junior reserve EYOS[c] | $Y_2$ | 3.3 |
| Junior civilian EYOS[c] | $Y_3$ | 4.0 |
| Senior active EYOS[c] | $Y_4$ | 6.0 |
| Senior reserve EYOS[c] | $Y_5$ | 9.3 |
| Senior civilian EYOS[c] | $Y_6$ | 8.0 |
| Active maximum retention[d] | $B_a$ | 0.58 |
| Reserve maximum retention[d] | $B_r$ | 0.30 |
| Civilian maximum retention[d] | $B_c$ | 0.50 |
| Crossflow maximum retention[d] | $B_x$ | 0.131 |
| AVAILABILITY PARAMETERS | | |
| *Surge availability:* | | |
| Junior active | $A_{d1}$ | 1.00 |
| Junior reserve | $A_{d2}$ | 0.00 |
| Junior civilian | $A_{d3}$ | 0.00 |
| Senior active | $A_{d4}$ | 1.00 |
| Senior reserve | $A_{d5}$ | 0.00 |
| Senior civilian | $A_{d6}$ | 0.00 |
| *Sustainment availability:* | | |
| Junior active | $A_{m1}$ | 1.00 |
| Junior reserve | $A_{m2}$ | 1.00 |
| Junior civilian | $A_{m3}$ | 0.00 |
| Senior active | $A_{m4}$ | 1.00 |
| Senior reserve | $A_{m5}$ | 1.00 |
| Senior civilian | $A_{m6}$ | 0.00 |
| *Peacetime availability:* | | |
| Junior active | $A_{p1}$ | 0.60 |
| Junior reserve | $A_{p2}$ | 0.00 |
| Junior civilian | $A_{p3}$ | 0.85 |
| Senior active | $A_{p4}$ | 0.65 |
| Senior reserve | $A_{p5}$ | 0.00 |
| Senior civilian | $A_{p6}$ | 0.85 |
| EFFECTIVENESS PARAMETERS | | |
| *Surge effectiveness:* | | |
| Junior active | $E_{d1}$ | 0.00 |
| Junior reserve | $E_{d2}$ | N/A |
| Junior civilian | $E_{d3}$ | N/A |
| Senior active | $E_{d4}$ | 1.00 |
| Senior reserve | $E_{d5}$ | N/A |
| Senior civilian | $E_{d6}$ | N/A |

Table A.1—continued

| Input Variables | Label | Value |
| --- | --- | --- |
| *Sustainment effectiveness:* | | |
| Junior active | $E_{m1}$ | 0.00 |
| Junior reserve | $E_{m2}$ | 0.00 |
| Junior civilian | $E_{m3}$ | N/A |
| Senior active | $E_{m4}$ | 1.00 |
| Senior reserve | $E_{m5}$ | 0.80 |
| Senior civilian | $E_{m6}$ | N/A |
| *Peacetime effectiveness:* | | |
| Junior active | $E_{p1}$ | 0.625 |
| Junior reserve | $E_{p2}$ | N/A |
| Junior civilian | $E_{p3}$ | 0.625 |
| Senior active | $E_{p4}$ | 1.00 |
| Senior reserve | $E_{p5}$ | N/A |
| Senior civilian | $E_{p6}$ | 1.00 |
| COST PARAMETERS | | |
| Active entry (nonlabor) | $J_a$ | $4,400 |
| Reserve entry (nonlabor) | $J_r$ | $4,400 |
| Civilian entry (nonlabor) | $J_c$ | $0 |
| Junior active annual pay | $J_1$ | $25,100 |
| Junior reserve annual pay | $J_2$ | $7,000 |
| Junior civilian annual pay | $J_3$ | $23,700 |
| Senior active annual pay | $J_4$ | $37,700 |
| Senior reserve annual pay | $J_5$ | $10,500 |
| Senior civilian annual pay | $J_6$ | $35,600 |

| Management Variables | Label | Value |
| --- | --- | --- |
| Active accessions | $M_1$ | NA |
| Reserve accessions | $M_2$ | NA |
| Civilian accessions | $M_3$ | NA |
| Active retainees | $M_4$ | NA |
| Reserve retainees | $M_5$ | NA |
| Civilian retainees | $M_6$ | NA |
| Crossflows | $M_x$ | NA |

[a]See App. B for information on how initial values were estimated.

[b]Alternative values for labor goals reflect hypothetical parts of force with varying combinations of wartime and peacetime operating responsibilities.

[c]EYOS = expected length of service, in years, *within* a personnel category. See Sec. II for further discussion.

[d]Throughout the model, retention rates are stated as a fraction of accessions into a junior personnel category. Maximum rates indicate the fraction volunteering to remain in DoD service beyond four years and hence to enter the corresponding senior personnel category. The maximum "crossflow" retention rate is the fraction of junior active accessions volunteering to enter the senior reserves. The model permits the DoD to accept fewer retainees than the maximum rate indicates.

Table A.2

SPREADSHEET CALCULATIONS FOR RUDIMENTARY MODEL

| Category | Equation | Equation Number |
|---|---|---|
| | Steady-State Peacetime Inventories | |
| Junior active | $I_1 = (M_1)(Y_1)$ | (A.8) |
| Junior reserve | $I_2 = (M_2)(Y_2)$ | (A.9) |
| Junior civilian | $I_3 = (M_3)(Y_3)$ | (A.10) |
| Senior active | $I_4 = (M_4)(Y_4)$ | (A.11) |
| Senior reserve | $I_5 = (M_5 + M_x)(Y_5)$ | (A.12) |
| Senior civilian | $I_6 = (M_6)(Y_6)$ | (A.13) |
| | Labor Valuation (standard labor unit equivalents) | |
| *Values in surge environment:* | | |
| Junior active | $Q_{d1} = (I_1)(A_{d1})(E_{d1})$ | (A.14) |
| Junior reserve | $Q_{d2} = (I_2)(A_{d2})(E_{d2})$ | (A.15) |
| Junior civilian | $Q_{d3} = (I_3)(A_{d3})(E_{d3})$ | (A.16) |
| Senior active | $Q_{d4} = (I_4)(A_{d4})(E_{d4})$ | (A.17) |
| Senior reserve | $Q_{d5} = (I_5)(A_{d5})(E_{d5})$ | (A.18) |
| Senior civilian | $Q_{d6} = (I_6)(A_{d6})(E_{d6})$ | (A.19) |
| Total active | $Q_{da} = Q_{d1} + Q_{d4}$ | (A.20) |
| Total reserve | $Q_{dr} = Q_{d2} + Q_{d5}$ | (A.21) |
| Total civilian | $Q_{dc} = Q_{d3} + Q_{d6}$ | (A.22) |
| Total force | $Q_d = Q_{da} + Q_{dr} + Q_{dc}$ | (A.23) |
| *Values in sustainment environment:* | | |
| Junior active | $Q_{m1} = (I_1)(A_{m1})(E_{m1})$ | (A.24) |
| Junior reserve | $Q_{m2} = (I_2)(A_{m2})(E_{m2})$ | (A.25) |
| Junior civilian | $Q_{m3} = (I_3)(A_{m3})(E_{m3})$ | (A.26) |
| Senior active | $Q_{m4} = (I_4)(A_{m4})(E_{m4})$ | (A.27) |
| Senior reserve | $Q_{m5} = (I_5)(A_{m5})(E_{m5})$ | (A.28) |
| Total active | $Q_{ma} = Q_{m1} + Q_{m4}$ | (A.29) |
| Total reserve | $Q_{mr} = Q_{m2} + Q_{m5}$ | (A.30) |
| Total civilian | $Q_{mc} = Q_{m3} + Q_{m6}$ | (A.31) |
| Total force | $Q_m = Q_{ma} + Q_{mr} + Q_{mc}$ | (A.32) |
| *Values in peacetime environment:* | | |
| Junior active | $Q_{p1} = (I_1)(A_{p1})(E_{p1})$ | (A.33) |
| Junior reserve | $Q_{p2} = (I_2)(A_{p2})(E_{p2})$ | (A.34) |
| Junior civilian | $Q_{p3} = (I_3)(A_{p3})(E_{p3})$ | (A.35) |
| Senior active | $Q_{p4} = (I_4)(A_{p4})(E_{p4})$ | (A.36) |
| Senior reserve | $Q_{p5} = (I_5)(A_{p5})(E_{p5})$ | (A.37) |
| Senior civilian | $Q_{p6} = (I_6)(A_{p6})(E_{p6})$ | (A.38) |
| Total active | $Q_{pa} = Q_{p1} + Q_{p4}$ | (A.39) |
| Total reserve | $Q_{pr} = Q_{p2} + Q_{p5}$ | (A.40) |
| Total civilian | $Q_{pc} = Q_{p3} + Q_{p6}$ | (A.41) |
| Total force | $Q_p = Q_{pa} + Q_{pr} + Q_{pc}$ | (A.42) |

Table A.2—continued

| Personnel Costs ($) | | |
|---|---|---|
| Junior active | $C_1 = M_1[J_a + (Y_1)(J_1)]$ | (A.43) |
| Junior reserve | $C_2 = M_2[J_r + (Y_2)(J_2)]$ | (A.44) |
| Junior civilian | $C_3 = (M_3)(Y_3)(J_3)$ | (A.45) |
| Senior active | $C_4 = (M_4)(Y_4)(J_4)$ | (A.46) |
| Senior reserve | $C_5 = [M_5 + M_x](Y_5)(J_5)$ | (A.47) |
| Senior civilian | $C_6 = (M_6)(Y_6)(J_6)$ | (A.48) |
| Total active | $C_a = C_1 + C_4$ | (A.49) |
| Total reserve | $C_r = C_2 + C_5$ | (A.50) |
| Total civilian | $C_c = C_3 + C_6$ | (A.51) |
| Total force | $C = C_a + C_r + C_c$ | (A.52) |

# Appendix B

# DEVELOPMENT OF THE ILLUSTRATIVE PARAMETERS

The DoD *Manpower Requirements Report for FY 87*[1] provided the basic data to estimate the inventory flow rates and personnel pay and expenditure rates used in this study's numerical illustrations. Table B.1 lists the military manpower data we obtained from that report, whereas Table B.2 shows the aggregate costs and the average cost factors we computed from them. The remainder of this appendix explains how we translated those data into:

- Average lengths of stay in the junior and senior categories for active and reserve personnel;
- Flow rates from the junior to senior military categories (including crossflows); and
- Average pay and indirect costs per person in the junior and senior categories, active, reserve, and civilian.

Although this appendix computes detailed values, App. A shows that we rounded all costs to the nearest $100.

## AVERAGE LENGTHS OF SERVICE

As Sec. II noted, we defined the junior category as consisting of military personnel with less than four years of military service. According to Table B.1, the Department of Defense expected to have 968,400 junior active members and 381,900 junior reserves in ending inventories.

For the junior military categories, the average length of service was estimated by dividing total junior man-years by junior (i.e., nonprior service (NPS)) accessions; this assumes that the NPS accessions for FY 87 are the number that would be necessary annually to maintain the FY 87 junior inventory. Since accessions data for officers were not complete, we developed a rough approximation. If the ratio of officer NPS accessions to officers in the junior category matched the ratio for

[1]Department of Defense, Office of the Assistant Secretary of Defense (Force Management and Personnel), *Manpower Requirements Report for FY87*, Vol. III, *Force Readiness Report*, selected tables and computations from tabular data, Washington, D.C., 1987.

## Table B.1

MANPOWER STATISTICS SUPPORTING THE NUMERICAL ILLUSTRATIONS

| | Active Forces | | | | | National Guard | | Other Selected Reserve | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Army | Navy | Air Force | Marines | Total Active | Army | Air Force[a] | Army | Navy[b] | Air Force[a] | Marines | Total Reserves |
| Manpower (000) | | | | | | | | | | | | |
| Enlisted | 666.4 | 513.5 | 493.3 | 180.0 | 1,853.2 | 417.1 | 96.3 | 262.2 | 92.2 | 54.8 | 46.1 | 968.7 |
| (with 4 YOS) | (292.4) | (258.5) | (340.6) | (75.3) | (966.8) | (273.6) | (73.3) | (133.8) | (63.0) | (43.7) | (13.2) | (600.6) |
| Warrant officers | 15.3 | 3.4 | N/A | 1.4 | 20.6 | 10.3 | 8.0 | 4.8 | 0.0 | na | 0.6 | 23.7 |
| (with 4 YOS) | (14.6) | (3.4) | N/A | ( 1.4) | (19.5) | (10.2) | (8.0) | (4.8) | (0.0) | na | (0.6) | (23.6) |
| Commissioned officers | 9[illegible].4 | 70.0 | 109.1 | 13.4 | 286.9 | 35.1 | 12.9 | 45.7 | 21.5 | 8.1 | 2.9 | 126.2 |
| (with 4 YOS) | (64.4) | (50.6) | (77.7) | (13.4) | (203.9) | (30.1) | (11.8) | (40.7) | (20.4) | (7.1) | (2.4) | (112.5) |
| All grades[c] | 776.6 | 586.9 | 602.4 | 194.8 | 2,160.7 | 462.5 | 117.2 | 312.7 | 113.7 | 62.9 | 49.6 | 1,118.6 |
| (with 4 YOS) | (371.4) | (312.5) | (418.3) | (90.1) | (1,192.3) | (313.9) | (93.1) | (179.3) | (83.4) | (50.8) | (16.2) | (736.7) |
| Average YOS | | | | | | | | | | | | |
| Enlisted | 5.5 | 6.2 | 8.0 | 5.8 | 6.4[d] | 7.9 | 11.2 | 6.8 | 14.8 | 10.4 | 13.1 | 9.0 |
| Warrant officer | 12.8 | 21.5 | na | 13.0 | 14.2[d] | 20.4 | 36.5 | 19.9 | 24.8 | N/A | 13.0 | 25.5 |
| Commissioned officers | 10.0 | 10.4 | 9.1 | 13.0 | 9.0[d] | 14.3 | 12.4 | 14.3 | 14.8 | 13.6 | 12.0 | 14.4 |
| All grades[e] | 6.2 | 6.8 | 8.2 | 6.3 | 6.8[d] | 8.7 | 13.4 | 8.1 | 14.8 | 10.8 | 13.3 | 9.9 |

Table B.1— continued

| | Active Forces | | | | | National Guard | | Other Selected Reserve | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Army | Navy | Air Force | Marines | Total Active | Army | Air Force[a] | Army | Navy[b] | Air Force[a] | Marines | Total Reserves |
| Accessions (000)[g] | | | | | | | | | | | | |
| Enlisted: | | | | | | | | | | | | |
| NPS | 126.6 | 91.7 | 62.8 | 31.7 | 312.8 | 55.0 | 5.1 | 30.0 | 10.0[g] | 3.7 | 8.4 | 112.2 |
| Prior service | 11.0 | 6.4 | 3.1 | 1.9 | 22.4 | 44.0 | 8.8 | 48.3 | 29.4 | 10.4 | 5.9 | 146.8 |
| Officer | 9.3 | 7.6 | N/A | 1.6 | N/A | 6.4 | 1.8 | 7.2 | 8.3 | 2.0 | N/A | N/A |
| Reenlistments (000)[g] | 75.1 | N/A | 66.4 | 19.1 | N/A | 61.9 | N/A | 37.1 | N/A | N/A | N/A | N/A |
| Career | 22.2 | N/A | 44.7 | 11.0 | N/A | 47.5 | N/A | 27.8 | N/A | N/A | N/A | N/A |

SOURCE: Department of Defense, Office of the Assistant Secretary of Defense (Force Management and Personnel), "Manpower Requirements Report for FY87," Vol. III, *Force Readiness Report*, Washington, D.C., 1987, unless otherwise noted.

NOTE: YOS - years of service; NPS - nonprior service; na - not applicable; N/A - not available.

[a]Air Force reserve manpower statistics pertain to FY 85.

[b]Average YOS and commissioned officers with four YOS apply to FY 84 and are from the FY 86 *Manpower Requirements Report*. More recent data on naval reserve experience were not reported.

[c]Computed as the sum of programmed enlisted, warrant officer, and commissioned officer inventories.

[d]Computed as a weighted average for the four Services.

[e]Computed as a weighted average over all grades.

[f]Data for officer accessions and reenlistments indicated programmed goals rather than actual results.

[g]SAM and OSAM program accessions are treated as NPS.

Table B.2

COST DATA SUPPORTING THE NUMERICAL ILLUSTRATIONS

| Cost Element | Aggregate Cost ($000,000) | Number of Recipients (000) | Average Cost[a] |
|---|---|---|---|
| Military personnel appropriations[b] | $67,058 | 2,181 | $30,746 |
| Reserve and Guard personnel appropriations[b] | 9,756 | 1,186 | 8,226 |
| Civilian costs | 33,032 | 1,114 | 29,652 |
| Personnel support: | | | |
| Recruiting | 595 | 456[c] | 1,305 |
| Training | 3,233 | 456[c] | 7,090 |
| Other[d] | 12,347 | 2,300[e] | 5,368 |

SOURCE: Department of Defense, Office of the Assistant Secretary of Defense (FM&P), *Manpower Requirements Report for FY 87, Force Readiness Report*, Vol. III, Table VIII-3, page VIII-6, unless otherwise noted.

[a]Computed as the ratio of aggregate cost to number of recipients.

[b]Includes retirement pay accrual.

[c]Estimated total nonprior service accessions, active and reserve.

[d]Includes medical support, overseas dependent education, half of base operating support, and other personnel support. Excludes labor costs and housing construction.

[e]Active strength plus 10 percent of reserve strength.

enlisted personnel, there would be over 29,000 active officer and over 4200 reserve officer NPS accessions. Since officers have higher continuation rates than enlisted personnel, we arbitrarily reduced the values of NPS officer accessions to 25,000 for actives, and to 4000 for reserves. This implies that there would be 337,800 NPS active accessions and 116,200 NPS reserve accessions. The implied average years of service in the junior categories are:

$$Y_1 = 968.4/337.8 = 2.9 \text{ years} \; ; \qquad \text{(B.1)}$$

and

$$Y_2 = 381.9/116.2 = 3.3 \text{ years} \; . \qquad \text{(B.2)}$$

In principle, two methods could be used to compute senior lengths of stay: taking the ratio of senior manpower to first (and interim) term retention or using data on the current overall average lengths of service. The two methods will yield similar results when an inventory is in steady state or growing only slowly, as is the case for the active inventory. However, when an inventory is growing rapidly—as is true for the selected reserves—the ratio method will tend to understate current senior stays. For that reason (and because the retention data are far from complete), we used the overall average stay data to compute senior man-years per retainee.

The overall average length of service is a weighted average of the junior and senior averages, where the weights are the shares of personnel in the junior and senior categories.[2] Letting x represent the total length of stay for seniors, the formula for the active force is:

$$(6.8)(2{,}160.7) = 1{,}192.3\,x + (968.4)(2.9) \ , \qquad \text{(B.3)}$$

and the formula for the reserve force is:

$$(9.9)(1{,}118.6) = 736.7\,x + (381.9)(3.3) \ . \qquad \text{(B.4)}$$

In each case, the resulting value for x includes four years of junior service which were subtracted to obtain the average number of years in the senior category. The results are:

$$Y_4 = 6.0 \text{ and } Y_5 = 9.3 \ . \qquad \text{(B.5)}$$

## INVENTORY FLOW VALUATION

The number of entrants to a senior category necessary to sustain its size is the ratio of the category size to the average years of service in the category. For the active force, the requirement is (1,192,300/6 =) 198,700 flows into the senior category. This represents 58 percent of the active junior accessions, so $B_a = 0.58$. This rate tends to be a bit higher than actually observed retention rates because it ignores the fact that some senior actives come from junior reserves.[3]

For the reserve force, the required number of steady-state entrants to the senior category is (736,700/9.3 =) 79,215, including both retention flows from the junior reserves and prior service accessions. Because the reserve force is in a growth phase, current accessions are

[2]This assumes that the reported averages were computed by totaling the years of experience in the force and dividing by total inventory. Note that this is only an approximation to the career average length of stay since it is based on a "snapshot" of average stays at a particular point in time.

[3]The value of $B_a$ also appears higher than published first-term retention rates because the value is based on retention at the fourth year. For example, unpublished data from the Enlisted Force Management System RAND is developing jointly with the Air Force indicate that the average enlisted first-term retention rate is 0.31, but that the rate for attaining four years of service is 0.46.

much larger than necessary to sustain the current senior reserve force size. Therefore, we computed the hypothetical number of prior service accessions necessary to achieve the steady-state inflow, given currently observed reserve retention rates.

According to Table B.1, the ratio of career reenlistments for the Army Guard and Army Reserve to the size of those junior forces is 0.3, and we set $B_r$ to this value. If this applied to all reserve forces, the number of senior reserve inflows from retention would be (0.3 times 116.2 =) 34,860—and the prior service accessions needed to achieve 79,215 senior inflows would be 44,355. Assuming that all of the prior service accessions represent crossflows from the junior active to senior reserve force, the steady-state number of crossflows would represent 13.1 percent of junior active accessions, so $B_x = 0.131$. This crossflow rate is quite consistent with statistics from a current RAND study on reserve enlistment following active service.

## AVERAGE COST VALUES

As Sec. II noted, we assume that the average pay for a senior active member is 1.5 times the average for a junior active member. This assumption was based on observing estimated average pay by grade for FY 86 from Palmer and Osbaldeston (1988). (In the Army, for example, the ratio of E-5 to E-2 pay is 1.4, whereas the ratio of O-5 to O-1 pay is 2.5.) We solved for the pay rates by noting that the overall average active pay ($30,746) is the weighted average of the junior and senior rates, where the weights are the shares of the force in each category. Lacking evidence to the contrary, we made the same assumption about relative junior and senior pay to compute the reserve pay rates.

Data on civilians with different lengths of defense employment are not readily available. Arbitrarily, we specified that the average length of junior service is four years, the average length of senior service is eight years, and half of all civilian hires continue into the senior category. This implies that the civilian workforce would be half juniors and half seniors. Applying 1.5 as the ratio of senior to junior pay results in the junior and senior pay rates shown in App. A. Notably, since we assume senior civilians are 1.6 times as effective as junior civilians, the assumed civilian pay rates make senior civilians somewhat more cost-effective than juniors.

The only indirect costs included in our illustrations are for recruiting and entry-level basic and skill training. Although the manpower report for FY 87 included values for these costs, we used estimates from Palmer and Osbaldeston (1988), which were $430 for recruiting and about $400 for initial training. These estimates are for nonlabor costs only; see Sec. II for an explanation of how indirect labor costs are recognized in the model. We also assumed (as civilian cost studies often do) that there are no recruitment, basic, or entry skill training costs for civilians.

# Appendix C

## COMPUTATION OF MARGINAL COSTS

This appendix shows how the marginal costs in Sec. IV were derived.

### NOTATION

Equations are easier to read if we use a slightly modified version of the model notation. The notation used below is:

D = Surge goal
M = Sustainment goal
P = Peacetime goal
A = Number of senior active man-years obtained under a manning option
X = Senior reserve man-years obtained from crossflows
R = Senior reserve man-years obtained from junior reserve accessions
N = Senior civilian man-years
C = Total expenditures under a manning option

### NUMERICAL VALUES

For easy reference, the following summarizes the numerical values used in these calculations:

- Pipeline expenditure per unit A (excluding crossflows): $59,849.
- Expenditure per unit A, including crossflows: $63,524.
- Pipeline expenditure per unit R: $19,604.
- Expenditure per unit X (excluding cost of junior active man-years): $10,500.
- Expenditure per unit N: $59,300.
- Crossflow man-years available per unit A: 0.350.
- Units of sustainment labor provided:
  Per unit A, excluding crossflows: 1.000
  Per unit A, including crossflows: 1.28
  Per unit X: 0.80

Per unit R: 0.80
Per unit N: 0

- Units of peacetime labor provided:
  Per unit A, excluding crossflows: 0.9625
  Per unit A, including crossflows: 0.9625
  Per unit X: 0
  Per unit R: 0
  Per unit N: 1.3812

## COMPUTATIONS

The general cost equation for any manning option is:

$$C = \$59{,}849A + \$10{,}500X + \$19{,}604R + \$59{,}300N \ . \qquad (C.1)$$

When all crossflows from active juniors are accepted into the senior reserves, the cost equation can also be written:

$$C = \$63{,}524A + \$19{,}604R + \$59{,}300N \ , \qquad (C.2)$$

where \$63,524A includes the costs for $X = 0.350$.

The marginal costs are found by:

1. Specifying the cost-effective manning option by relating manning levels (A, X, R, N) to the targets (D, M, P); and
2. Substituting the manning-level conditions in the cost equation, (A.1) or (A.2), and solving for total cost as a function of D, M, and P.

The coefficients in the resulting cost function are the marginal costs per unit of D, M, and P, holding the other two targets constant.

### Region 1

Cost-effective manning is to use the minimum acceptable active force, and accept just enough crossflows to satisfy the sustainment goal. The conditions are

$$A = D;\ 0.80X = M - D \ (\text{or } X = 1.25(M - D));$$
$$R = 0;\ N = 0 \ . \qquad (C.3)$$

The cost function is

$$C = 59{,}849A + 10{,}500X$$
$$= 59{,}849D + 10{,}500(M - D)(1.25)$$
$$= \$46{,}724D + \$13{,}125M\ . \quad (C.4)$$

The marginal cost of P is zero.

**Region 2**

Cost-effective manning is to use the minimum acceptable active force, accept just enough crossflows to satisfy the sustainment goal; then add civilians to satisfy the peacetime goal. The conditions are

$$A = D;\ X = 1.25(M - D);\ R = 0;\ N = (P - 0.9625D)/1.3812\ . \quad (C.5)$$

The cost function is

$$C = 59{,}849A + 10{,}500X + 59{,}300N$$
$$= 59{,}849A + 10{,}500(1.25)(M - D) + 59{,}300(P - 0.9625D)/1.3812$$
$$= \$5{,}400D + 13{,}125M + \$42{,}934P\ . \quad (C.6)$$

**Region 3**

Cost-effective manning is to use active personnel (with all crossflows) to meet the sustainment goal, then add civilians to satisfy peacetime demand. The conditions are

$$1.28A = M\ (\text{or } A = 0.781M);\ N = (P - 0.9625A)/1.3812;\ R = 0 \quad (C.7)$$

The cost function is

$$C = 63{,}524A + 59{,}300N$$
$$= 63{,}524(0.781M) + 59{,}300[P - 0.9625(0.781S)]/1.3812$$
$$= \$17{,}338M + \$42{,}934P\ . \quad (C.8)$$

The marginal cost of D is zero.

**Region 4**

Cost-effective manning is to use active forces (with all crossflows) to meet the peacetime labor goal, and then use reserve accessions to meet the sustainment goal. The conditions are

$$0.9625A = P \text{ (or } A = 1.039P); 0.80R = M - 1.28A$$
$$\text{(or } R = 1.25(M - 1.28A)); N = 0 \quad . \qquad \text{(C.9)}$$

The cost function is

$$C = 63{,}524A + 19{,}604R$$
$$= 63{,}524(1.039P) + 19{,}604(1.25[M - 1.28(1.039P)]$$
$$= \$24{,}505M + \$33{,}412P \quad . \qquad \text{(C.10)}$$

The marginal cost of D is zero.

## Region 5

Cost-effective manning is to use the minimum acceptable active force, accept all crossflows, and then add reserves to satisfy the sustainment goal. The conditions are

$$A = D; R = 1.25(M - 1.28D); N = 0 \quad . \qquad \text{(C.11)}$$

The cost function is:

$$C = 63{,}524A + 19{,}604R$$
$$= 63{,}524D + 19{,}604(1.25)(M - 1.28D)$$
$$= \$32{,}158D + \$25{,}404M \quad . \qquad \text{(C.12)}$$

The marginal cost of P is zero.

# BIBLIOGRAPHY


Binkin, M., *Military Technology and Defense Manpower*, Chap. 4, "Implications for Manpower Requirements," The Brookings Institution, Washington, D.C., 1986.

Comptroller General's Report to the Congress, *DoD "Total Force Management"—Fact or Rhetoric*? U.S. General Accounting Office, FPDC-78-82, January 1979.

Department of Defense, Office of the Assistant Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 1987*, Washington, D.C., May 1986.

Department of Defense, Office of the Assistant Secretary of Defense (Force Management and Personnel), *Manpower Requirements Report for FY87*, Vol. III, *Force Readiness Report*, Washington, D.C., 1987.

Hosek, S. D., J. L. Buchanan, and G. A. Goldberg, *Reconciling Air Force Physicians' Peacetime and Wartime Capabilities: Demonstration of a Workforce Design Methodology*, The RAND Corporation, R-3202-AF, August 1985.

Jaquette, D. L., and G. R. Nelson, *The Implications of Manpower Supply and Productivity for the Pay and Composition of the Military Force: An Optimization Model*, The RAND Corporation, R-1451-ARPA, July 1974.

Jaquette, D. L., G. R. Nelson, and R. J. Smith, *An Analytic Review of Personnel Models in the Department of Defense*, The RAND Corporation, R-1920-ARPA, September 1977.

Palmer, A. R., and D. J. Osbaldeston, *Incremental Costs of Military and Civilian Manpower in the Military Services*, The RAND Corporation, N-2677-FMP, July 1988.