MEETING OCCUPATIONAL AND TOTAL MANPOWER REQUIREMENTS
AT LEAST COST: A NONLINEAR PROGRAMMING APPROACH

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I. BACKGROUND

The Army trains and utilizes enlisted personnel in a wide variety of military occupational specialties (MOSs), ranging from relatively unskilled to highly skilled, from large specialties to small--almost 60,000 Army enlistees are Infantrymen, for example, while fewer than 150 are Nike Radar Repairers or Terrain Intelligence Analysts. Specialties may have high civilian transferability (Air Traffic Controller) or low (Tank Crewman), and also vary as to the level of such disamenities as family separation, undesirable tours, etc. Managing personnel to such varied occupations can be challenging, especially as managers must consider not only the number of enlistees needed in each specialty but also a desired skill and grade profile.

Besides developing policies to meet specialty-specific requirements, the Army must also develop manpower policies to meet aggregate manpower objectives. These objectives include meeting end strength goals, staying within budget and grade level ceilings, and maintaining promotion flows and objective force experience profiles. Policies directed towards aggregate goals and those directed toward specialty-specific goals are not independent, and ideally need to be included within a common policy modeling framework. A simple example is the interaction between specialty-specific bonus budgets and base pay budgets. Higher bonus budgets increase overall retention rates as well as specialty-specific rates, and will affect the level of base pay required to meet aggregate Manning requirements. In practice, however, the two sets of policies are managed fairly independently.

In this paper we develop a model designed to evaluate alternate approaches to meeting MOS-specific and aggregate manpower requirements. The analytic model allows the manager to discover the least-cost way of providing the desired first term/second term/career quality and quantity profiles of enlisted personnel in the total force and in each MOS, when MOSs vary as to marginal recruiting costs, training costs, retention histories, and requirements for senior personnel.
The model is a cost-minimizing nonlinear programming model. We develop it in detail and explore possible sources of data for it. We do not implement the model, and so do not draw prescriptive conclusions based on it. If implemented, however, the model would provide Army manpower managers with a tool for taking into account trade-offs among cost categories (and budgets) now more often examined in isolation from one another--most importantly, recruiting costs, enlistment bonus and education benefits costs, training costs, the costs of base pay, the costs of Selective Reenlistment Bonuses (SRBs), and retirement costs. The result would be a better understanding of the least-cost way to achieve desired MOS-specific manpower requirements while also meeting aggregate force requirements.

This is not a simple issue to address. Although many strategies for achieving aggregate and specialty-specific objectives are theoretically possible, the current policy is to meet requirements for senior personnel whenever possible by bringing enlistees up through the ranks. Higher grades within an MOS are filled from lower grades in that MOS, from specified "feeder" MOSs, or, less frequently, from retraining personnel in overmanned MOSs. Lateral entry of prior service personnel or experienced people from the civilian labor force generally occurs only if a severe shortage exists within a skill. Thus, to a much greater extent than a private employer, the Army must manage its labor force in such a way as to both meet current needs and provide ongoing training (and retraining) for future requirements.

In such a system each enlistee fulfills two functions simultaneously: the enlistee provides current labor input to the Army while at the same time gaining experience and perhaps additional training in order to be ready to provide labor input of a more skilled kind in the future. Meeting senior requirements then requires influencing occupational and retention decisions of enlistees over the entire military career--up to 30 years. Inaccurate predictions, imperfect management, or changes in requirements can mean shortages or surpluses which may take years to erase without major retraining and rechanneling efforts.
To meet both aggregate and specialty-specific objectives, the Army has developed an extensive set of tools for managing the size and distribution of the enlisted force. Promotion opportunities, enlistment and reenlistment incentives (bonuses and educational programs), rotation policies, retraining policies, etc., vary by specialty in a way designed (among other purposes) to channel an appropriate number of personnel into each MOS at each skill and grade level.

The flexibility to influence the total number and occupational distribution of more senior personnel exists primarily during the initial years of service of the cohort. The total number of individuals within each cohort in any occupation is mainly influenced by occupational choice at enlistment, accession requirement at enlistment, training success rates, and reenlistment bonus payments and retraining policies at end of first term. The ability to adjust the size of the senior enlisted force is largely lost after the third term due both to the overwhelming influence of the current military retirement system,\(^1\) and the narrowing taste distribution of more senior personnel. This means that shortages or surpluses of senior personnel—once they occur—cannot easily be corrected.

Some limited flexibility may nonetheless exist in shaping of the occupational mix of the senior enlisted force. A bonus that will not affect the retention decision in year 10 or 12 may still affect the choice of MOS. By and large, however, the training and experience a senior enlistee has accumulated in a specialty by that time will dictate, both to the enlistee and to personnel managers, that he or she be switched, if at all, only to a closely related MOS.

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\(^1\) The structure of the present system in which total vesting occurs at 20 years means individuals making rational decisions nearly always reenlist once they have reached around 10 years of service. The services then lose the ability to influence this retention behavior in either direction. In the upward direction, bonus payments have limited leverage because of their small magnitude compared to future retirement payments. In the downward direction the services would have to force out individuals, which they are reluctant to do for reasons of equity and loyalty.
In this situation, choosing the target number of enlistees desired at each of the lower grade/skill levels in each MOS becomes quite important, because such choices will have ramifications for many years. To enable manpower planners to systematically consider costs while making such choices, an analysis is needed that embodies specialty-specific costs for manpower procurement, training, and maintenance from enlistment through retirement.

As one possibility for such a tool, we suggest a nonlinear programming model of the type we describe here. Our prototype model has two basic types of specialties and partitions the career of an enlistee into seven segments. A larger number of specialty groups or career segments could be incorporated without difficulty, but would increase the data requirements and computational costs of the model. The model also incorporates two quality groups of enlistees (where accession costs and retention rates vary with quality).

We begin our presentation of the model with a discussion of alternate approaches to achieving any desired experience mix in the Army, and of the conceptual basis of the approach we model. We then describe the general structure of the model, and present a mathematical statement of it. We indicate for the illustrative model necessary assumptions, required behavioral and cost parameters, and the reasonable size and complexity for which solutions might be attainable. We conclude with a discussion of the uses, strengths, and weaknesses of a model such as the one we develop. A discussion of the data that would be needed to actually implement such a model—both ideal data and data currently available—appears in an appendix. We hope that the model will serve as an example of how both overall and specialty-specific manpower costs and constraints can be considered in an integrated fashion.
II. MANNING STRATEGIES AND COST TRADEOFFS

The Army can choose to meet its need for experienced personnel, in the aggregate and in individual MOSs, through one of several manning strategies. One possible strategy would be to have the number of initial accessions determined by the requirements for first-term personnel, and then to use bonus or selection policies to adjust the reenlistment rate until desired second term strength is achieved. Bonus/selection policies would be similarly used again at each subsequent reenlistment point to reach a desired profile over all years of services. To a large extent, this is the current approach to meeting requirements in shortage MOSs, with Selective Reenlistment Bonuses employed at the first, second, and third reenlistment points in order to encourage enlistees already trained in shortage specialties to reenlist in them.

A second strategy would be to meet first term requirements with new entrants, but to use bonuses in conjunction with retraining at the reenlistment point(s) to help fill shortage specialties. This strategy also is used currently, but retraining options are somewhat restricted.

A third possible strategy would be to begin with the level of accessions needed to meet first term requirements, but instead of using bonuses to increase the flow of personnel to shortage MOSs in later terms (with or without retraining), the Army could use lateral entrants and prior service accessions to meet any shortages of senior personnel. The practicality of this approach has not been well investigated; currently it is not preferred Army policy.¹

A final strategy would involve loosening the link between accessions and the needed number of first term enlistees. First term requirements, instead of targets to be hit precisely, would be minima. Greater numbers of initial accessions would be allowed/encouraged in MOSs where it is less costly to fill downstream requirements through

¹ Prior service accessions are discouraged with the use of loss-of-rank penalties and limited quotas for them. Lateral entrants with no prior military service are not actively pursued as a source of military manpower.
higher accession levels than to fill them through reenlistment bonus payments or other strategies aimed at influencing the retention rate. This approach recognizes that additional enlists at the four year point (for example), can be obtained through (a) an unchanged number of new recruits coupled with an increased retention rate, or (b) an increased number of new accessions with an unchanged reenlistment rate. Whether (a) or (b) is preferable would be determined in part by cost considerations, which vary by specialty. Thus, the experience profile in each specialty would vary both because of varying needs for senior personnel and because of varying emphases on accessions versus retention as means to supply those personnel.

The model we outline here can provide information concerning the tradeoffs inherent in this last strategy. It can reveal the least cost way of meeting both specialty-specific and force-wide requirements, given the behavioral equations and costs governing the flow of personnel into and through the force and its individual occupations. It adjusts pay and incentive levels at various points in a career to meet the requirements at least cost. By adjusting the policy constraints in the model, the model also can be used as a means to evaluate the cost implications of the other strategies discussed above.

In the model presented below recruiting resources, enlistment incentives, and reenlistment bonus payments are assumed to have diminishing marginal returns. The "optimal" (i.e., cost-minimizing) levels of these programs is determined by balancing the costs and returns of additional recruiting and training against those of additional reenlistment incentives.

A better idea of the tradeoff that is the heart of the cost-effectiveness strategy can be obtained with the help of Figure 1. It gives a stylized picture of the training process in a specialty. The width of each bar corresponds to the cost of each step of the pipeline, while the height corresponds to the number of additional enlists needed at each step of the pipeline in order to produce one additional enlistee at the beginning of the second term. The total area enclosed by the bars indicates the cost to get one additional enlistee out of the pipeline—in this case, one additional person at the beginning of the second term.
Figure 1 -- Cumulative Costs to Gain One Person at Fourth Year of Service
If desired, similar figures could be drawn for each year of service (YOS) after the fourth. The figures would differ from Figure 1 in the height of each bar in the training process, because for later YOSs more enlistees are needed at each of the early steps, due to attrition between the fourth year and whatever year is being considered. If one is considering one additional reenlistment at, say, the second reenlistment point, then the appropriate comparison is between (1) the costs of increasing second term reenlistment rates, (2) the costs of increasing first term reenlistment rates and, (3) increasing accessions. It will take more new accessions to get one additional person to the second term (with unchanged reenlistment rates) than it will to get one additional person to some earlier point in the pipeline; the difference will depend on attrition between the earlier point and the second reenlistment point.

More precisely, the relevant comparison for manpower managers to make is between the cost of getting an additional person-month (or person-year) of trained labor from bonuses at reenlistment points versus the cost of expanding the training pipeline. Identifying this as the relevant comparison means cumulating costs along the entire length of the career path, taking account of attrition, and accurately modelling the behavioral sensitivity of flows to manpower and compensation policies.

Using cost-effectiveness as a criterion in bonus and accession decisions is not new, of course. It is a criterion that is frequently misapplied, however, through the use of inappropriately computed costs or the lack of an integrated framework for assessing cost tradeoffs. The nonlinear programming model discussed in detail in the following chapters correctly applies the cost criteria in a way that highlights the tradeoffs while maintaining moderately complex behavioral equations and some aggregate and MOS-specific policy variables.

We should note here that the model does not solve for the "optimal mix" of junior and senior personnel but finds the least-cost way of procuring any desired mix. Thus the model avoids the explicit consideration of productivity trade-offs between first term and career personnel. Implicitly, we are making two assumptions. First, we

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2 For a discussion of such trade-offs, see Mark J. Albrecht, Labor
assume that minimum quality standards at both enlistment and reenlistment decision points are imposed for individuals. Second, we assume that manpower requirements for individuals with different levels of experience and skill by specialty are set to reflect an "optimal experience mix" given the particular set of jobs and tasks within a specialty. Once these standards and required experience mix are set, then it would be desirable to achieve requirements with individuals who meet standards in a way that minimizes the life cycle costs of manpower and manpower programs. The model as presented here is designed to produce that solution. By running the model with different sets of requirements, the costs of different experience mixes could be determined as well.

III. THE STRUCTURE OF THE MODEL

The model proposed here for use by manpower planners is an equilibrium, deterministic, nonlinear, cost-minimization model. As an equilibrium model it will solve for the pay incentives and program levels that would fill MOS-specific and aggregate requirements in a steady state. It does not take account of short term adjustments due to dynamic changes in requirements or short term supply shifts. It is thus best suited to determine and evaluate long-term strategies, and would need to be supplemented by a dynamic short-term adjustment model.¹

The purpose of the model is to determine the enlistment incentives, number of recruiters, enlistment wage level, and reenlistment bonus levels that will in a least-cost fashion fill multiterm manpower requirements.² The model considers both overall manpower requirements--end strengths and experience distributions--and also specialty requirements by term of service. The prototype described here has only two specialties but could be expanded to include more. It concentrates on enlistee choices, and management options at accession, and at the first, second and third reenlistment points.

¹ The model presented here builds on earlier work by Jaquette and Nelson (see David L. Jaquette and Gary 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). Among other differences, our model takes into account occupation-specific requirements and uses logistic equations for attrition and retention, which theirs does not. However, the philosophy of an equilibrium model supplemented by a short-term dynamic response model is outlined in their report. For an example of a short-term adjustment model, see Patricia Munch, A Dynamic Model for Optimum Bonus Management, The Rand Corporation, R-1940-ARPA, January 1977.

² The model assumes wage levels for all career phases are linearly related to the wage level at enlistment. Thus determining an enlistment wage level in effect determines wage levels throughout the life-cycle.
ACCESSIONS GOALS AND OCCUPATIONAL CHOICES AT ENLISTMENT

The accession goals of the Army have at least three dimensions. First, they are designed to meet aggregate manpower goals. Second, they are characterized by a desired overall quality standard. Finally, an attempt is made to channel recruits into MOSs in such a way as to ensure the quantity and quality goals of each specialty are met.

In recent years the Army accession requirement has ranged from 110,000 to 190,000, with the proportion of the total who have high school diplomas varying from 50 to over 80 percent. The major policy tools the Army uses to attract enough enlistees to meet these goals include the wage rate, the number of recruiters, the level of advertising resources, enlistment bonuses, and educational programs. These programs are adjusted annually in reaction to changes in economic conditions, the size of the youth cohort, and other factors. The wage rate is the same for all occupational specialties, while recruiter attention, advertising, bonuses, and educational programs frequently are concentrated on hard-to-fill MOSs. Recruiter attention, bonuses, and education benefits often are targeted as well at high-quality recruits.

Because we are concerned with specialty-specific manpower management, we are particularly interested in a recruit's choice of MOS. This choice will be influenced by individual preferences, the actual specialties available at the time of enlistment (enlistment quotas are enforced for the more popular MOSs), the individual's knowledge and perception of the various specialties, and the differential financial

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3 Throughout this paper "quality" refers to the AFQT scores and educational achievement of enlistees.
4 In the past there has been a tendency to regard low quality recruits as "free goods" that can be obtained in the necessary numbers with little expenditure of recruiter effort or special enlistment incentives. This view may now be changing.
5 Some enlistees will come with strong preferences about desired specialties, perhaps based on later civilian transferability (computer, medical specialties, etc.) or motivated by a need for identity, adventure or risk (paratrooper, special forces, etc.). Those without strong preferences can become highly dependent on the information made available by the recruiter and enlistment counselor at the time of enlistment. Since one objective of the Army is to fill all specialties, information is made available selectively in a way that favors skills in which there are shortages.
incentives available by specialty. The latter currently include enlistment bonus payments, which vary by specialty, and educational benefits, which vary both by specialty and quality class of the enlistee. Enlistment bonus payments currently range from zero to $7500, while educational benefit programs range from base level benefits of about $8000 to over $25,000.

For purposes of our cost minimization life cycle model, it is necessary to develop cost equations, enlistment supply equations and occupational choice equations describing the accession process. Costs include the marginal processing cost per recruit, the marginal costs of fielding additional recruiters, the actual costs of enlistment bonus programs and the "accrual" costs of educational benefit programs. The latter costs would essentially be the amount that would have to be set aside at enlistment to fund the expected stream of education benefits for the average recruit. It would include the expected usage of such benefits as well as proper discounting techniques for the timing of usage.

The accession equations in our model take the form of separate supply equations for each specialty. Exogenous variables in the equations include the level of unemployment and behavioral parameters such as the elasticity of accessions with respect to basic pay, enlistment/educational bonuses, and the number of recruiters. The parameters can either be estimated or taken from previous studies.

The endogenous or policy variables in our model that relate to accessions include the number of recruiters, the enlistment wage level, the level of general enlistment bonus, the level of general educational benefit, and the differential level of bonus and educational benefit for each specialty included in the model. Certain of these variables are constrained in our model—bonuses are constrained by legal restrictions on their maximum amount, while the average wage level at each phase is assumed to be linearly related to the enlistment wage level.

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6 We ignore advertising costs because the relation between their levels and the number and quality of accessions is not known with any accuracy. They could easily be included, however.
THE FIRST TERM OF SERVICE

Once he has been recruited and channeled towards an MOS, the enlistee must be trained before beginning to function in his chosen specialty. Basic combat training (BCT) and advanced individual training (AIT) combined can occupy from four months to over a year depending on specialty. During this period the main behavioral phenomena of interest to the manpower planner is attrition, which varies with the quality of enlistees and with the specialty. In addition, some movement of individuals among different skills occurs during training, typically in response to failing AIT in the first-chosen MOS. Attrition will of course continue after training, so that the number of trained person-months of service actually provided by enlistees will vary with the specialty (and with the quality group of the enlistee).

The costs from this period that are captured by our model are training costs--the marginal costs of instructors, course materials, and overhead--and the enlistee's pay, allowances, and travel costs during training. Attrition rates are taken as exogenous, and vary with quality group and occupation. The model implicitly adjusts for attrition during training (and throughout the first term) by cumulating all costs associated with a group of enlistees (identified by quality group and by specialty) and relating them to the total amount of post-training service provided by the group.

REENLISTMENT AND THE SECOND TERM OF SERVICE

The main policy tool for shaping personnel flows at the first reenlistment point is the Selective Reenlistment Bonus (SRB) program. Each year the Army finds that it faces shortages of trained people in some occupational categories. These shortages may be caused by persistent differentials in civilian and military wages for a particular skill, disamenities connected with particular skills, or other factors. The SRB program aims at alleviating these shortages by means of monetary incentives: Trained personnel reenlisting in designated specialties receive bonuses of varying amounts.\footnote{In recent years 80-90 percent of Army enlistees have been promised a specific MOS at the time the enlistment contract is signed.}\footnote{An enlistee may have trained in the bonus specialty some time before enlistment.}

Funded annually by Congress, the
SRB budget covers numerous specialties short of personnel, and over three separate reenlistment points (although historically most bonuses have been allocated to the first reenlistment point).

The Department of Defense Instruction (DoDI 1304.22, issued in April 1983) which governs the allocation of bonus levels to specialties, lists several criteria to be considered by the services when they recommend bonus levels for different specialties. These criteria include:

- Serious undermanning in three or more year groups
- Chronic and persistent shortages in the specialty
- High replacement costs for personnel in the specialty
- The specialty is arduous or unattractive
- The specialty is essential to the defense mission
- There is a reasonable prospect that the bonus will improve manning enough to justify the cost of the bonus

The DoDI governing SRBs decrees the Services will use a "balanced evaluation" of these criteria to assign bonus levels to specialties. In the absence of more specific guidance, each Service currently interprets the DoDI somewhat differently. Army practice has been to systematically consider only the degree of undermanning in the skill in comparison with improvement expected from an increased bonus. The remaining DoD criteria, in particular replacement cost, are then considered in an ad hoc manner when modifying preferred bonus levels to meet an overall bonus budget constraint.

In this process Army bonus managers attempt to meet both short-run and long-run goals. Sometimes the major consideration is an "immediate" shortage in a specialty--i.e., a shortage that will appear before new personnel could be recruited and trained. In decisions about bonus levels designed for this purpose, replacement costs are irrelevant (and largely ignored by SRB managers).  

prior to his original end-of-first-term date, or he may be allowed to extend his first term in order to retrain into a bonus specialty.

Money expended in the past on training enlistees in the specialty should have no bearing on the current decision, because current decisions cannot change past expenditures. The cost of training future
When recommending bonus levels, however, SRB managers also consider potential shortages 18 months or more in the future, and in addition recognize that "immediate" shortages may be chronic in some specialties. For these decisions, training costs are relevant because in the medium and long run there is a trade-off between accession-plus-training expenditures and bonus expenditures. It is this longer-run use of SRBs that we incorporate in our model.

In the model bonuses that vary by specialty are included as a policy variable, and therefore are endogenous. Specifically, the model has specialty- and quality-specific retention equations which depend on the civilian/military pay ratio, level of SRB, and unemployment rate. The retention equations are logistic, and hence nonlinear. The costs included for this stage are ordinary pay and allowances plus the actual costs incurred from paying SRBs.

THE THIRD TERM AND THEREAFTER

The considerations in the model at second term reenlistment and beyond are similar to those at first term. The equations used to describe reenlistment behavior at each term have similar form (SRBs are also paid at the second and third reenlistment points), but may have different behavioral parameters. For instance, pay elasticities will decline with increasing years of service. The costs included in the model will include pay, allowances and bonuses.

recruits is equally irrelevant, because they cannot be trained in time to solve the current problem. The costs of retraining a current enlistee into the shortage specialty may be relevant, but not properly considered part of replacement costs.
IV. MATHEMATICAL STATEMENT OF THE MODEL

In this section the conceptual approach and structure described above are given mathematical form. As stated earlier, the model is a nonlinear programming model which minimizes cost subject to a series of constraints. It has been developed here using two specialties, two quality types, and seven "career phases" from enlistment to more than 20 years of service. The data requirements for the model are considered in detail in the appendix.

We begin by establishing the following notation:

Subscripts--Quality Group
i = 1 High quality
i = 2 Low quality

Subscripts--Occupational Specialty
j = 1 Occupation one
j = 2 Occupation two

Superscripts--Career Phase
k = 0 Enlistment
k = 1 Training (basic combat training + advanced individual training)
k = 2 End of training to end of first term
k = 3 Second term
k = 4 Third term
k = 5 Fourth term
k = 6 Fifth term and beyond, to 20 years of service
k = 7 Greater than 20 years of service

Policy Variables (Endogenous)

The policy variables in the model that adjust so as to minimize life-cycle costs are:
N = Number of recruiters

\[ Y_{i} = \text{Level of general education benefit for quality group } i \]
\[ Y_{ij} = \text{Level of occupation-specific educational benefit for quality group } i \text{ in occupation } j \]

\[ Z_i = \text{Level of general lump sum enlistment bonus for quality group } i \]

\[ Z_{ij} = \text{Level of occupation-specific lump sum bonus for quality group } i \text{ in occupation } j \]

\[ E_{jk} = \text{Level of lump sum reenlistment bonus for occupation } j \text{ at the beginning of career phase } k \ (k = 2, 4, 5) \]

\[ P^0 = \text{Total monthly pay and benefits at enlistment} \]

**Exogenous Variables:**

In the model, the following variables describe the manpower system:

\[ C_E = \text{Marginal costs of enlistment processing per enlistee} \]

\[ C_N = \text{Annual marginal recruiting cost per recruiter} \]

\[ C_{ij} = \text{Marginal cost of training per enlistee (exclusive of enlistee pay and allowances) for quality group } i \text{ in occupation } j \]

\[ C(Y_i) = \text{Accrual amount needed per enlistee to fund general educational benefits of quality group } i \]

\[ C(Y_{ij}) = \text{Accrual amount needed per enlistee to fund educational benefits in occupational group } j \text{ for enlistees of quality } i \]

\[ M_j = \text{Length of training in months for occupation } j \]

\[ R_{ij} = \text{Requirement for enlistees of quality group } i \text{ in occupation } j \text{ in} \]

\[ \]

\[ \]

\[ ^1 \text{We have assumed lump sum bonus payments to simplify presentation. Installment payments properly discounted could be included.} \]
career phase $k$

$T_k = \text{Length of } k^{th} \text{ term in months}$

$U = \text{General level of unemployment}$

$f = \text{Overall requirement for first term personnel as a fraction of all enlisted personnel}$

$g_j = \text{Requirement for high quality accessions as a fraction of total accessions in occupation } j$

$n_i = \text{Elasticity of accessions of quality group } i \text{ with respect to the number of recruiters}$

$p_i = \text{Elasticity of accessions of quality group } i \text{ with respect to initial pay}$

$u_{ij} = \text{Elasticity of accessions of quality } i \text{ in specialty } j \text{ with respect to the general level of unemployment}$

$v_k = \text{Elasticity of retention in career phase } k \text{ with respect to the general level of unemployment}$

$y_i = \text{Elasticity of accessions of quality group } i \text{ with respect to the level of the education benefits}$

$y_{ij} = \text{Channeling elasticity for quality group } i \text{ toward occupational category } j \text{ at accession}$

$z_i = \text{Elasticity of accessions of quality group } i \text{ with respect to enlistment bonuses}$

$z_{ij} = \text{Channeling elasticity for quality group } i \text{ toward occupation category } j \text{ at accession}$
\[ \alpha_i = \text{An estimated constant characterizing the enlistment behavior of quality group } i \]

\[ \beta_{ij} \text{ and } \gamma_{ij} = \text{Estimated constants characterizing the reenlistment behavior of personnel of quality type } i \text{ in occupation } j \text{ at the beginning of career phase } k \ (k = 3, \ldots, 7) \]

**Definitions**

Finally, we define the following terms:

\[ x_{ij}^k = \text{Number of personnel of quality group } i \text{ in occupation } j \text{ in career phase } k \]

\[ S_{ij}^{k+1} = \text{Survival probability between career phase } k \text{ and } k+1 \text{ for quality group } i \text{ in occupation } j \]

\[ C^k = \text{Costs during career phase } k \]

\[ p^k = \text{Average monthly pay (including retirement accrual amount) for phase } k \ (k = 1, \ldots, 7) \]

**The Objective Function:**

The model can then be described as follows: The model minimizes costs subject to a number of constraints. In so doing it solves for the optimal (cost-minimizing) values of the policy variables. The objective function is:

\[ C = \sum_k C^k \quad \text{Life cycle costs} \]

The \( C^k \) can be described as follows:

Costs during enlistment phase:

\[ C^0 = C_{NN}^0 + \sum_{i,j} x_{ij}^0 [C(Y_i) + C(Y_{ij}) + Z_i + Z_{ij} + C_e] \]
Costs during training phase:
\[ C^1 = \sum_{i,j} \left( C_{ij} + M_j P^1 \right) \left( x_{ij}^0 + x_{ij}^1 \right) / 2 \]

Costs from the end of training to end of first term:
\[ C^2 = \sum_{i,j} T^2 P^2 \left( x_{ij}^1 + x_{ij}^2 \right) / 2 \]

Costs from end of first term to end of second term:
\[ C^3 = \sum_{i,j} \left[ T^3 P^3 \left( x_{ij}^2 + x_{ij}^3 \right) / 2 + B_{ij}^3 x_{ij}^3 \right] \]

Costs from end of second term to end of third term:
\[ C^4 = \sum_{i,j} \left[ T^4 P^4 \left( x_{ij}^3 + x_{ij}^4 \right) / 2 + B_{ij}^4 x_{ij}^4 \right] \]

Costs from end of third term to end of fourth term:
\[ C^5 = \sum_{i,j} \left[ T^5 P^5 \left( x_{ij}^4 + x_{ij}^5 \right) / 2 + B_{ij}^5 x_{ij}^5 \right] \]

Costs from end of fourth term to 20 years of service:
\[ C^6 = \sum_{i,j} T^6 P^6 \left( x_{ij}^5 + x_{ij}^6 \right) / 2 \]

Costs after 20 years of service:
\[ C^7 = \sum_{i,j} T^7 P^7 x_{ij}^7 \]
We also introduce the following constraints to capture current military compensation policy and enlistment and retention supply equations.

**Exogenous Pay Constraints:**

\[ p^k = a^k p^{k-1} \quad \text{Pay growth assumption} \]

\[ 0 \leq B_{ij} \leq b_{ij} \quad \text{Assumption of upper and lower limits on reenlistment bonus levels} \]

\[ 0 \leq Z_{ij} \leq e_{ij} \quad \text{Assumption of upper and lower limits on occupation-specific education benefits} \]

\[ 0 \leq Z_i \leq e_i \quad \text{Assumption of upper and lower limits on quality-specific education benefits} \]

\[ 0 \leq Y_{ij} \leq d_{ij} \quad \text{Assumption of upper and lower limits on occupation-specific enlistment bonuses} \]

\[ 0 \leq Y_i \leq d_i \quad \text{Assumption of upper and lower limits on quality-specific enlistment bonuses} \]

**Enlistment Constraint Equations:**

Cobb-Douglas enlistment supply functions:

\[ x_{1j}^0 \leq a_1 R_{1j} p^{\gamma_{11}} Z_1^{\gamma_{1j}} Y_{1j}^{\gamma_{1j}} Y_{1j}^{\gamma_{1j}} Z_1^{\gamma_{1j}} U_{1j}^{\gamma_{1j}} \quad \text{for } j = 1, 2 \]

\[ x_{2j}^0 \leq a_2 R_{2j} p^{\gamma_{22}} Z_2^{\gamma_{2j}} Y_{2j}^{\gamma_{2j}} Y_{2j}^{\gamma_{2j}} Z_2^{\gamma_{2j}} U_{2j}^{\gamma_{2j}} \quad \text{for } j = 1, 2 \]
Flow Constraint Equations:

\[ x_{ij}^{k+1} = x_{ij}^k + k_{ij}^{k+1} \quad \text{for } k = 0, \ldots, 7 \]
\[ i = 1, 2 \]
\[ j = 1, 2 \]

Where

\[
S_{ij}^{k,k+1} = \frac{1}{1 + \exp \left( \sum_{k=0}^{K} \beta_{ij}^k + \gamma_{ij}^k \left( P + B_i \right) + v U \right)}
\]

Manpower Requirement Constraint Equations:

Requirements constraint:

\[ x_{ij}^k \geq R_{ij}^k \quad \text{for } k = 0, \ldots, 7 \]
\[ i = 1, 2 \]
\[ j = 1, 2 \]

First-term quality constraint:

\[
\sum_{k=0}^{2} x_{ij}^k = f \sum_{k=0}^{7} x_{ij}^k \quad i = 1, 2 \]
\[ j = 1, 2 \]

Enlistment quality constraint:

\[ 0 \leq g_j x_{2j} \quad j = 1, 2 \]

As is evident from the above, the model contains several equality and inequality constraints that control the flow of personnel through the enlisted force. The inequality constraints include requirements (by
term and specialty, and overall end strength), upper and lower levels for enlistment incentives and reenlistment bonuses, and experience mix constraints. The equality constraints include enlistment supply equations, Markov transition equations describing attrition and retention, and equations linking the two specialties to overall manning. Of course, not all constraints need be binding, and some of the interesting applications of the model involve estimating the cost differentials as constraints are imposed or loosened.

The model contains nonlinearities in both the objective function and the constraints. Retention and attrition equations are logistic in form. Enlistment equations in contrast have a Cobb-Douglas functional form.

From the standpoint of developing solution procedures, the problem belongs in the nonconvex classification and therefore global optimality cannot be guaranteed. However, problems of a not too dissimilar nature have yielded sensible, stable local optima under a variety of initial conditions using nonlinear programming techniques.²

As formulated here, the model is designed to take as given (i.e., as exogenous) the maximum permissible levels of enlistment and reenlistment bonuses. This feature allows current legal and policy limits on these incentive payments to be incorporated. The model may also be expressed without these limits; a comparison of the results with and without these restrictions will indicate the amount by which lifecycle costs increase due to the restrictions—which is one measure of their economic cost.³

² Although the model described here has not been exercised to any significant extent, a predecessor nonlinear programming model has been. That version of the model converges and yields sensible results. It did not, however, include occupation subdivisions (nor occupation-specific bonuses and educational benefits), being designed instead as a total-force model with quality subgroups. We anticipate that a model of the type described here, with occupational detail, also would converge.

³ Of course, if the restrictions are non-binding, the results of the model will be the same whether they are included or not, and the cost of the restrictions will be zero.
V. USES AND EXTENSIONS

EXTENSIONS OF THE MODEL

Several extensions to the current model are relatively easy; these include incorporating prior service accessions and occupational retraining. More difficult directions for extension would be (1) the inclusion of more quality groups and occupations, and (2) better treatment of skill- and grade-specific requirements.

Quality and Occupational Group Disaggregation

More extensive disaggregation by quality group and occupation is necessary to creditably track the major resource and manpower flows within occupational groupings and at the aggregate level. It would be a major task to develop intermediate levels of disaggregation that balance descriptive power of the model, computational feasibility and policy utility.

Several methods of grouping occupations currently exist. Examples include the Army method of grouping by career management field (CMF), or the Department of Defense classification by broad function such as combat, support, electronics.\(^1\) Classification methods may also include considerations of skill level, training time, and civilian transferability. For purposes of the model the clustering should group skills with similar behavioral and cost parameters. Unfortunately, groupings which make sense for enlistment behavior and costs may not be appropriate for attrition or reenlistment behavior. As one attempts to develop homogeneous groups that cluster across enlistment, occupation attrition, and several retention decisions, extensive disaggregation may be required.

Increasing the number of skills and quality classes is limited by two factors: data requirements and computational feasibility. From a computational point of view, the number of variables for which solutions can be efficiently found cannot be defined precisely without more computational experience with this specific problem, but is probably limited to the low hundreds.

\(^1\) One-digit DoD occupation codes.
As the number of skills and quality classes increase, new data and measurement requirements emerge. Occupation- and quality-specific costs and behavioral parameters become necessary to take advantage of the increased disaggregation. For instance, differential effects of enlistment and reenlistment bonus payments by skill and quality groups would be needed. These kind of data and estimation requirements probably put more limits on the feasible level of disaggregation than does the requirement that the model be computationally tractable.

Requirements/Authorizations

The Army currently maintains requirements data by pay grade (E1-E9) for three-digit Military Occupational Specialties. These requirements are generated through Tables of Organization and Equipment (TOE), Tables of Distribution and Allowances (TDA), and other processes. For model input structure, these requirements must be translated into requirements by term of service. This can be done using expected promotion patterns or current distributions of pay grades by YOS.

This simple method of generating requirements ignores two critical aspects of occupational planning. The first is substitution between pay grade and YOS groups within an occupation. The second is the criticality of shortages. Both processes could be handled in the model provided some additional data were available.

In the case of year-group or pay-grade substitution, data providing productivity relationships between different groups would be necessary. The model could then incorporate overall productivity constraints and upper and lower level manning constraints for each term group, thus allowing some tradeoffs between groups for meeting the overall productivity constraint.

In addition, simple requirements data do not indicate the criticality of meeting the requirements. This criticality may vary by occupation and YOS group. One method of incorporating criticality would be to specify a "stockout cost" which, if accurately estimated, could be incorporated into the cost optimization framework. The model would then balance the cost of surpluses against possible shortages to determine the "optimal requirements." A simpler method would be to include an
"allowable shortage" for each specialty which reflected a degree of
criticality; those skills which are critical would receive lower (or
zero) increments.

Unfortunately, the information necessary to include in the model
either substitution possibilities or varying levels of skill criticality
is not now available, nor likely to be in the near future.

USES AND MISUSES OF OPTIMIZATION MODELS

Optimization models of the type presented here are often used to
provide detailed prescriptive results applicable to the real world
policy problems they attempt to capture. Such prescriptions should be
taken with care. Mathematical models that can be solved often lose the
descriptive power necessary to accurately capture the full policy and
behavioral system. They therefore should be treated with healthy
skepticism and should undergo extensive "calibration" tests to determine
their applicability. Nonetheless, optimization models, when they
capture the important objectives, constraints and behavior, can often
yield insights unseen by analyses that focus on less global systemic
factors.

The initial purpose of our model is descriptive and exploratory--
deepening our understanding of the ways occupational and total
requirements are met--rather than prescriptive. The Army has evolved a
set of enlistment and reenlistment incentives by occupation which have
been determined by experience, program and budget constraints, and
allocation policies. Comparing the "optimal" set of incentives from a
model such as ours with the actual allocations across several different
types of skills can provide a basis for asking better questions
concerning differential bonuses by specialty and other issues concerning
occupational management. The interpretation of any variance between
actual practice and the model results, however, requires careful
examination of the model's assumptions and the policymaking system.

Variance between actual allocations and model prescriptions can
indicate 1) limitations in the descriptive power of the model, 2) flaws
in the policy allocation process, or 3) short term disequilibrium
conditions within the occupation. The descriptive power of the model
can be limited by the various simplifying assumptions made in
constructing the model and errors arising from the processes used for various behavioral estimations. Prescriptions that differ from current practice may also result from a situation where the allocation of incentive payments is dominated more by short term disequilibrium conditions than by long term, fundamental factors. However, the results could also be different because the current allocation process does not search for least-cost solutions jointly considering enlistment and reenlistment incentives. This would not be surprising since different offices deal with enlistment and reenlistment incentives, and budgets are determined separately.

Model testing can lead to the identification of further factors for inclusion in the model. It can lead to identification of behavioral and cost parameters that are particularly sensitive in determining model output, and perhaps need improved measurement. Conversely it can identify parameters that only weakly affect model results and for which improved measurement would have little payoff. It can lead to requirements for further data collection and the need for improved modeling of particular phenomena—for instance occupational choice at enlistment. Since data collection and measurement efforts can be costly, identification of which parameters are important can be useful.

If sufficient confidence can be developed in the model and convergence procedures, then it can address—with various degrees of strengths and limitations—several important policy issues.

First, it can be used to evaluate broad budgetary allocations among base pay, enlistment and reenlistment incentives, retirement pay, and recruiting and training resources. It could be helpful in determining budgetary responses to changing external factors like declining unemployment rates. It could provide estimates of long term savings achieved from new approaches to reducing first term attrition. It could also be used to evaluate compensation policy responses to changing objective force structure and skill requirements.

The model may be used to investigate the balance between accession and retention incentives. Each occupation will have a unique balance of enlistment and retention incentives based on its peculiar recruiting and training costs, attrition levels, retention behavior, requirements structure and other substitution possibilities included in the model.
One aspect of this analysis would be to examine the various manning strategies mentioned earlier. For instance, for which skills would increasing reenlistment bonus payments and decreasing accession requirements and incentives result in lower overall costs? How much could be saved by finding ways of reducing first term attrition?

When costs are included in an analytic framework that incorporates all career phases of the enlistee, questions such as these begin to be addressed. Current models used in manpower planning have such a framework only at the aggregate level, if indeed they include a systematic consideration of life-cycle costs at all. It is our hope that the model presented here will provide a beginning for the process of applying such analysis to the combined problem of aggregate and occupation-specific manpower planning.
APPENDIX: DATA - FACT AND FANCY

Most--but by no means all--of the data required to implement a nonlinear programming model of the type described above are available now. In this section we briefly review existing data sources, and indicate likely substitute data where the preferred data are unavailable or inordinately costly to obtain. There will remain a few areas where no acceptable figures exist; in these cases, the model should be used to explore the impact of alternate plausible values of the unknown parameters.

COST DATA

Basic to the model is the need for appropriate data on the costs of all steps involved in recruiting, training, and retaining enlisted personnel. The Army has historically collected and published information identifying the cost elements involved, and total and average costs at each step. Unfortunately, the costs so reported are frequently inappropriate for purposes of analyzing the kinds of choices that concern us here, usually for one of three reasons: (1) the costs reported are budgeted amounts rather than true costs; (2) marginal costs are not reported;\(^1\) or (3) the costs are not specialty-specific. Thus for use in our model we need to look carefully for cost figures that avoid these pitfalls. Sources for the cost numbers of the more important elements are discussed in turn below.

Recruiting Costs

The costs of recruiting additional personnel for active military service has been a topic of intense interest, both to DoD's own analysts and to outside researchers, since the advent of the All Volunteer Force in 1973. Numerous estimates have been made of the marginal cost of recruits in general, and of "high quality" recruits in particular.

\(^1\) We assume changes in the training throughput needed to adjust the supply of trained personnel in a specialty will be small relative to the total number of trainees. In this situation, the fixed costs of training will not change with decisions on the mix of new recruits versus reenlistees.
Deriving analytically sound costs is more difficult for recruiting than for training. In formal school courses it is possible to guess with some accuracy the quantity and price of additional physical inputs (e.g., instructors, course materials) needed for adding a trainee to an existing course. Course-specific marginal costs can be constructed accordingly. In contrast, with recruiting the way in which inputs (recruiters, advertising budgets, etc.) are related to output (new accessions) is much less well understood. Current cost estimates for recruiting are based primarily on econometric estimation of the relation between inputs and output in the recruiting process, and on the per unit prices of the inputs. Unfortunately, past estimation techniques have taken little account of the role of recruiter management practices (incentives, quotas, DEP length, etc.) and as a result may have overestimated the additional inputs needed to recruit an additional enlistee.²

In addition, for our model we need marginal recruiting costs by subgroup based on future MOS. This leads to two difficulties, a lesser one of how to identify the future specialty of new recruits, and a greater one of how to estimate the costs of any subgroup of recruits, be they distinguished by future specialty or by other attributes.

Identification of a group of recruits who are to become, say, future machinists, is possible for most recruits based on the training agreed to at the time of enlistment. However, cost estimation to date has concentrated on "quality" subgroups, not occupational ones. Thus it will be more practical to identify subgroups not by promised specialty but by the "quality" attributes associated with entry to a specialty. If the characteristics are chosen to be ones of general interest, cost estimates for subgroups identified by those characteristics are likely to be more readily available.

² Simply put, cost overestimation may occur when additional inputs are observed to have only a small effect on accessions. The lack of impact may be due to a quota system for recruiters that does not always provide an incentive to use additional resources to increase accessions. If additional resources provided are not directed at increasing the number of recruits, then an inflated idea of the level of resources necessary for an additional recruit may result. This source of bias was first considered in detail by James N. Dertouzos, and is discussed in
Currently, however, even cost estimates by quality subgroup may be unreliable. One difficulty is the choice of an underlying implicit or explicit model used to allocate recruiting costs to subgroups. At one extreme is the approach that assigns zero marginal cost to recruiting nonhigh school graduates or low AFQT score entrants, on the reasoning that these enlistees are virtually "free goods" that come easily as a side-product of activities primarily aimed at the harder-to-recruit high AFQT high school graduates. At the other extreme, prorating recruiting costs on the basis of the observed proportions of each type of recruits in the total will probably yield an overestimate of the marginal costs of recruiting "low quality" recruits.

The true cost allocation among quality types is a matter not yet resolved among analysts. The use of currently available cost estimates may well mismeasure the relative costs of recruiting for different specialties. In this circumstance, this initial step in the training pipeline should be costed at the same figure for all specialties. Marginal recruiting costs, even if misestimated, then will at least not systematically bias decisions regarding the allocation of bonuses across specialties, because the ranking of specialties by costs will not be affected.

Training Costs

After enlistment comes training. Specialty-specific training costs of various kinds are published regularly by the U.S. Army Cost and Economic Analysis Unit,\(^1\) and disseminated in the form of the Military Occupational Specialty Training Cost Handbook, (MOSB), most recently published in October 1983. Among other figures, the MOSB gives average variable costs by MOS for every step from basic combat training through the most advanced training.

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\(^1\) This Unit is the successor to the Cost Analysis Division of the U.S. Army Finance and Accounting Center (USRFAC), which formerly had MOS costing responsibility.
For our purposes, the MOSB numbers have two drawbacks. First, marginal costs are not reported. Average variable costs, however, are a reasonable substitute as long as there are no large economies (or diseconomies) of scale in the training process. More seriously, MOSB cost figures are only incompletely adjusted for attrition during the training sequence, and the cumulative costs reported there are not accurate as measures of the cost to get one student out of the training pipeline. In any event, the training costs needed for the model presented in this paper are costs unadjusted for attrition, because the model internally adjusts for enlistees leaving the Army at any time—either during or after training. Indeed one of the strengths of the model is the calculation of cost per additional year of service provided, rather than the (less correct) use of cost per additional enlistee. Fortunately, the unadjusted variable cost of training an enlistee (which the model then combines with the years of service provided by an enlistee) in each specialty is inherent from the raw numbers underlying the MOSB calculations, and so are obtainable.  

4 Briefly, MOSB calculates costs for each formal course, adjusted for attrition that occurs within the course, to yield a cost per graduate. It then sums across all courses needed to qualify for the specialty in question. But adding together the cost per graduate of each step in a multi-step process does not capture all the costs of producing one graduate of the entire process. It may take three graduates of basic training as input into electronics training in order to ensure one person will survive the full training experience; obviously adding the cost of just one basic-training graduate to the cost of one electronics-school graduate will not represent the actual system cost of obtaining an additional electronic technician. This issue is discussed in detail in Chapter III of Selective Reenlistment Bonuses and the Cost of Training by Military Specialty, by Judith C. Fernandez, The Rand Corporation, N-2321-MIL, forthcoming.

5 At least, the data can be obtained if the Cost and Economic Analysis Unit retains the original information on which they base their calculations. This data may be lost or discarded, however (as apparently happened with the data underlying the 1983 MOSB). In this case, the published MOSB numbers for successive training steps could be differenced to estimate cost per course, then "unadjusted" for attrition using independent attrition estimates. The resultant cost figures, though not strictly accurate, would be fairly close to the true numbers.
Currently neither MOSB nor other Army sources provide cost data on training provided outside of formal courses. Computing marginal costs for such on-the-job training (OJT) will rank with estimating marginal costs of recruiting as one of the more difficult data elements to obtain.

Surveys and studies have been done concerning the amount of supervisor time required for enlistees just out of formal training versus that required for more experienced specialists, and about productivity differences between the two.\(^6\) OJT costs properly calculated would include the costs of supervisor's time, and of that fraction of the enlistees' time spent learning. Systematic information of this kind by occupational specialty is not now available, however, and will not be in the foreseeable future.

As an immediately implementable alternative, the following should be considered: Both Defense Manpower Data Center (DMDC) and service records identify the specialty of an Army enlistee by a combination of specialty code and skill level. Skill level 1 represents basic qualification in the occupation and is generally assigned at the completion of the initial formal training for the specialty. Personnel at skill level 2 are generally considered "fully" trained in the sense that the enlistee has not only completed formal coursework, but also the necessary OJT to become fully familiar with the necessary occupational skills.\(^7\) Thus an estimate is readily available from personnel records, indicating the length of time between the end of formal coursework and full facility in a specialty. Personnel experts can estimate the fraction of time spent on OJT in each segment of this period. A share of the enlistees' pay and allowances during this period, based on this fraction, is properly considered OJT costs.

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\(^7\) Eighteen months or more may elapse between the achievement of the first skill level and the second. The intensity of OJT will vary over that period.
OJT costs calculated this way will be incomplete. They incorporate no costs for supervisory personnel during OJT, and assume no OJT occurs after the second level of skill is achieved. If data on either topic are available for all specialties, this information should be incorporated into the estimate of OJT costs. Absent information for all occupations, however, the best approach is the consistent use of time between skill levels and a judgment of the intensiveness of OJT for all specialties. The variation in OJT costs so estimated should provide roughly accurate relative costs, even if OJT costs are underestimated for all occupations.

For lack of better information, we assume for purposes of our model that actual training, and therefore training costs, cease when the enlistee reaches the second skill level in his occupation.

Other Personnel Costs

The pay and allowances of enlistees after the completion of formal course work can be obtained from current tables, and used directly in the model. Ideally, the model also should take account of the costs of benefit levels such as health, family services, housing, and Permanent Change of Station (PCS) allowances. These benefits generally increase in costs with years of service due to the increase in the number of servicemen who are married and have families. Our model does not include these costs; if data on them were to become available, they could be incorporated readily into cost equations for all year groups.

Recent Congressional action has mandated accrual accounting for retirement costs. These accrual amounts can be included in the model as additions to pay costs if they can be assigned to career phases. There is, however, no single way to assign accrual costs to career-phase groups. An accounting convention such as "age-entry normal" and several other critical assumptions (regarding discount rates, future continuation rates, etc.) also need to be made to arrive at retirement costs specific to each career phase. Sensitivity analysis using alternate plausible values may be the most appropriate treatment here.
ATTRITION AND REENLISTMENT RATES

First term attrition rates and first and second term reenlistment rates will be key components in determining the cost effectiveness of different subgroups of individuals as well as the choices between enlistment and reenlistment incentives. In the first term the model must balance the higher costs of recruiting higher quality enlistees against the lower costs associated with lower first term attrition rates. However, for multiterm optimization it must simultaneously balance the possible lower reenlistment rates of higher quality enlistees with these first term recruiting and attrition costs.

First term attrition has been studied extensively and attrition rates for several different demographic groups are readily available. These studies show that first term attrition rates depend mainly on enlistee educational attainment and AFQT, but also depend on other demographic characteristics. In the prototype model, the two quality groups might be split into either high school and nonhigh school graduates or Cat I-IIIA high school graduates and the remaining group. In the longer term it will be important to include more disaggregation since recruiting costs, attrition rates, reenlistment rates and productivity can vary widely among different groups.

Several models of first and second term reenlistment decisions also exist. These models show strong retention effects for military and

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9 See W. K. Chow, and J. M. Polich, Models of the First-Term
civilian pay levels, unemployment, bonus payments and certain
demographic variables. The behavioral parameters used in the model (pay
elasticity, retention elasticity with respect to unemployment, etc.) may
be taken from the published results of these models, or may be estimated
independently. Either way, some sensitivity analysis would be
indicated—using alternate plausible values of the parameters and
observing the resultant changes in cost-minimizing values of the policy
variables. The magnitude of the effects of pay and unemployment
diminish as enlistses approach retirement vesting at 20 years of
service. Thus for reenlistment decisions beyond 10 years of service,
simple average continuation rates may suffice.

THE EFFECT OF SRBs

Bonuses paid at reenlistment to those eligible in designated
specialties are an important element in the cost of alternate ways of
obtaining trained personnel. Much previous research concerning this
issue has revolved around estimating the number of additional
reenlistments attracted by varying bonus levels. Analogous with the
case of training costs, however, the relevant consideration is not how
much it costs to gain an additional reenlistment, but rather how much it
costs (via reenlistment bonuses) to gain an additional year of trained
service. Recent research has indicated that SRBs influence attrition
before the end of the first term, and the length of the second term
chosen,\textsuperscript{10} as well as the reenlistment rate itself. Unfortunately,

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Reenlistment Decision, The Rand Corporation, R-2468-MRAL, September
1980; J. H. Enns, Reenlistment Bonuses and First Term Retention, The
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Behavior in the NAVF Era, Clemson, SC: Clemson University, December
1982; and J. T. Warner, Alternative Military Retirement Systems: Their
Effect on Enlisted Retention, Report No. RC 376, The Center for Naval
Analysis, Alexandria, Virginia, September 1979; J. Hosek and C.
Peterson, Reenlistment Bonuses and Retention Behavior, The Rand
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\textsuperscript{10} See Daniel Kohler, Occupation-Specific Effects of Selective
Reenlistment Bonuses, The Rand Corporation, forthcoming, and Grace
Carter, Effect of Selective Reenlistment Bonuses on Terms of Enlistment
although the existence of a positive relation between additional years of service and the size of the SRB is known,\textsuperscript{11} quantitatively effects are not currently well-estimated. Pending further advances in estimation techniques, estimates of the impact on reenlistment rates must suffice. They are incorporated into the model we suggest through the impact of bonuses on survival rates.

\textit{in the Air Force}, The Rand Corporation, unpublished draft, February 1985.\textsuperscript{11} The dollar amount of Selective Reenlistment Bonus granted a reenlistee depends not only on the specialty but also on the term of reenlistment--more years of obligated service mean a larger bonus, up to a maximum set by Congress.