THE ACCURACY OF SIMPLE ENLISTED FORCE FORECASTS (U)
D W GRISSNER
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THE ACCURACY OF SIMPLE ENLISTED FORCE FORECASTS

David W. Grissmer

June 1985

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**Abstract:** See reverse side
This Note presents an analysis of the historical accuracy with which enlisted force manpower strengths can be forecast using simple and widely used modeling assumptions. The accuracy of one-, three-, and five-year forecasts is presented for enlisted personnel groups from all four military services for fiscal years 1971 through 1980. Estimating the accuracy of forecasts and analyzing the pattern of errors allow an assessment of the need for more sophisticated techniques, help in developing a strategy for disaggregating enlisted groups when forecasting, and form a basis for the design of an improved enlisted forecasting system. The author finds that the models tested provide reasonably accurate short-term forecasts of the level and structure of enlisted personnel strength. However, long-term forecasts show very large errors for certain enlisted groups. The error pattern, which is stable across the services, shows a distinct structure when estimated by year of service.
This Note presents an analysis of the historical accuracy with which enlisted force manpower strengths can be forecast using simple--and widely used--modeling assumptions. The accuracy of one-, three-, and five-year forecasts is presented for enlisted personnel groups from all four military services for fiscal years 1971 through 1980. This work is a first step in designing and implementing an enlisted forecasting system for the Office of Enlisted Personnel Management. The study was conducted for that office under Task Order 82-11-2 and 83-11-2 in Contract MDA903-80-C-0652. It was sponsored by the Office of the Assistant Secretary of Defense (Manpower, Installations and Logistics) and performed at Rand's Defense Manpower Research Center.

Each year, military pay increases and bonus payments budgets are determined partly on the basis of forecasts of the number of enlisted personnel who will continue serving. Forecasts showing persistent shortfalls from requirements usually result in additional pay—in the form of either bonus payments or pay raises. The accuracy of these forecasts, so critical to sizing large bonus and pay budgets, has not systematically been tracked.

Forecasts, of course, can be made with a variety of models using different assumptions. This Note focuses on the accuracy of a simple, widely used technique to forecast enlisted strengths. Estimating the accuracy of forecasts and analyzing the pattern of errors allow an assessment of the need for more sophisticated techniques, help in developing a strategy for disaggregating enlisted groups when forecasting, and form a basis for the design of an improved enlisted forecasting system.
SUMMARY

Each of the four military services has an interconnected set of enlisted force planning models which are used to estimate critical aggregate manpower parameters such as end strength, accession requirements, first term/career mix, and budget levels for enlisted pay and bonuses. A critical component of each of these models is a forecast of the number and type of enlisted personnel leaving the service. Poor estimates of enlisted force losses can result in higher than necessary enlisted pay and bonus levels or manpower shortages. It can result in policymaking characterized by reaction rather than anticipation, and can have severe long-term opportunity costs in terms of enlisted force structures which deviate substantially from the required structure.

This study documents the historical accuracy of one-, three-, and five-year forecasts for enlisted manpower cohorts for fiscal years 1971 through 1980 for a simple--and widely used--enlisted force forecasting technique. It documents this accuracy for each of the four services for various disaggregated enlisted force groups. As such, it provides managers with realistic estimates of errors for this technique and an improved ability to hedge policies so that enlisted force objectives can be met with a higher degree of confidence. This study also interprets the pattern of errors in forecasting and compares the errors with those of a standard statistical distribution which suggests directions for improving these forecasts. Finally, it describes possible barriers to implementing improved forecasting techniques. This work was undertaken as a first step in the design and implementation of an enlisted forecasting system for the Office of Enlisted Personnel Management.

The simple continuation rate models tested here provide reasonably accurate short-term forecasts of the level and structure of enlisted personnel strength. However, long-term forecasts show very large errors for certain enlisted groups. The error pattern--which is stable across the services--shows a distinct structure when estimated by year of service. For enlisted personnel in the first two years of service, there is a surprisingly small one-year forecast error. For the years
1976-80, the mean absolute percentage error for one-year forecasts has been less than 4 percent for each service. These errors increase to 15-30 percent for three- and five-year forecasts. The largest error rates are for enlisted groups with between three and six years of service and for groups with greater than 20 years of service. For the former group, mean absolute percentage errors for one-year forecasts are less than 10 percent, and increase to the 10-20 percent range for three- and five-year forecasts. For the latter group, one-year forecast errors are less than 10 percent, but can rise to 40 percent for five-year forecasts. Error rates for year of service groups between 7 and 19 are less than 3 percent for one-year forecasts and 9 percent for three- and five-year forecasts. For year of service groups between 12 and 19, the errors are close to random.

One method used to improve simple forecasts is to disaggregate the enlisted force into finely grained groups prior to forecasting. We have found that disaggregation improves forecasting only slightly, and probably most models could be simplified by less disaggregation. We have also found that simple models do extremely well for many groups, and more sophisticated techniques are warranted only for certain groups with high nonrandom error rates.

The pattern of forecast errors is consistent with the hypothesis that nonrandom factors present during years of service 3 through 10 and 20 through 30 are the primary cause of forecast errors. This pattern seems to support the results of econometric models which have shown the importance of factors connected with the economic cycle in retention decisionmaking. Incorporation of these behavioral models into enlisted force planning models may improve forecasting accuracy markedly. This incorporation will allow the services to address an important continuing problem in enlisted personnel management--developing a set of countercyclical policies to mitigate the effects of economic cycles on enlisted force trends. However, this incorporation must take account of barriers which have prevented this incorporation to date, must recognize that ad hoc methods of incorporation might not improve accuracy, and recognize an associated need to develop a process that both develops common economic assumptions across services and tracks the accuracy of service forecasts.
ACKNOWLEDGMENTS

This analysis relied on the construction of an elaborate set of data files at the Defense Manpower Data Center (DMDC). We wish to thank Michael Dove and Monty Kingsley for constructing these files. We also wish to thank Robert Brandewie, Deputy Director, DMDC, for advice in constructing the file. This Note also benefitted from a constructive review by Grace Carter of Rand. We also wish to thank Barbara Eubank for typing the numerous drafts and Jeanne Heller for editing the manuscript.
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ACTIVE DUTY MARINE CORPS ENLISTED FORCE (FY71-80)

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<td>10,923</td>
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<td>1,975</td>
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<td>993</td>
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<td>1,320</td>
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<td>1,096</td>
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<tr>
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<td>1,262</td>
<td>820</td>
<td>459</td>
<td>291</td>
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<td>1,196</td>
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<td></td>
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<td>1848210</td>
<td>1824219</td>
<td>1790554</td>
<td>1784657</td>
<td>1773868</td>
<td>1739402</td>
<td>1758368</td>
</tr>
</tbody>
</table>
Table 2.3 displays the active enlisted force population by years of service (YOS) as of the end of each fiscal year.2 Tables 2.4 through 2.7 provide a similar display for each service. This period was characterized by a declining force size in the aftermath of Vietnam and the transition to an all-volunteer force. The Army experienced the largest drop in enlisted strength during the period—a decline of 31 percent from 972,000 to 674,000. The other services experienced smaller declines.

Tables 2.8 through 2.12 summarize the continuation rates for individuals enlisted at the beginning of each fiscal year. These data provide the percentage of individuals enumerated in Tables 2.3 through 2.7 who are still present one year later. These annual retention rates are one measure of force stability and are key parameters in manpower planning.

Annual continuation rates differ by years of service and over time in easily explainable ways. Overall continuation rates for DoD enlisted personnel (see Table 2.13) rose from 66.1 to 82.3 percent between FY71 and FY80. This dramatic rise in force-wide retention rates is primarily attributable to changes in manpower policy and personnel characteristics triggered by the end of the Vietnam war and the transition to an all-volunteer force. During the Vietnam war, most of the expansion in force size was from draftees who were cycled through the force for short two-year terms, causing low overall retention rates. The post-Vietnam reduction in force size in FY71 and FY72 reduced the number of draftees.

2From FY71-FY76 the end of the fiscal year was June 30. For FY77-FY80 the end of the fiscal year was September 30.

In this Note, we will use retention or continuation rate to indicate a ratio, where the denominator is given by the number of individuals present at the beginning of a fiscal year and the numerator as the number of those individuals still present as evidenced by social security matches one year later. Reenlistment rate is the ratio of those accepting a new term commitment to those having an ETS decision during a year. Extension rate is the ratio of those staying but not accepting a term commitment to those having an ETS decision. In modeling and characterizing entire manpower systems, retention rates have the advantage that it is unnecessary to distinguish between reenlistment and extension. While most econometric work has focused on a particular reenlistment decision, more recent work has shown that extension behavior is also an important component of retention.
attention because larger deviation from requirements will occur more frequently.

The expected accuracy of prediction also varies with the retention probability. Other things equal, percentage deviation from requirements will be less frequent with retention groups having higher retention probabilities. For instance, at the 95 percent confidence level and \( n = 1000 \), the accuracy falls from 12.3 percent at \( p = .2 \) to 3.1 percent at \( p = .8 \).

Actual retention behavior may not follow the binomial distribution because the decisions are influenced by nonrandom factors such as civilian wage and unemployment, and policy factors such as military pay and reenlistment eligibility criteria. However, the extent to which these nonrandom factors affect retention can be measured by how far the results of year to year variation differ from the binomial distribution.

In our simple model, the binomial distribution gives a minimum possible uncertainty\(^1\) in accuracy of repeated trials. Other nonpolicy influences will always act to increase this deviation over the long run.

THE DATA

At Rand's request, the Defense Manpower Data Center has constructed a file which determines the end of the fiscal year continuation status for each individual in the active force at the beginning of the fiscal year. Starting with the FY71 active force personnel file, a flag has been attached to each individual record indicating whether the individual was present at the end of the fiscal year (June 30, 1972). This file contains records for FY71 through FY80--a total of over 25 million records. (See Appendix A for the data elements on the file.)

This micro-data file basically summarizes the annual retention behavior of each person in the active force over the period FY71-FY80. As such, it can serve as the basis for tracking the accuracy of various methods for forecasting retention.

---

\(^1\)This assumes that the correlation between events is zero. Certain manpower policies directed toward correlating retention decisions can reduce this uncertainty below binomial. An example would be initiating a bonus policy late in a time period in response to low retention rates early in a time period.
### Table 2.2

**EXPECTED YEAR TO YEAR PERCENTAGE ACCURACY IN REENLISTMENT PROBABILITY ASSUMING BINOMIAL DISTRIBUTION**

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>50%</th>
<th>75%</th>
<th>90%</th>
<th>95%</th>
<th>99%</th>
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</thead>
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<tr>
<td><strong>p = .20</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>13.5</td>
<td>23.0</td>
<td>32.9</td>
<td>39.2</td>
<td>51.5</td>
</tr>
<tr>
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<td>4.3</td>
<td>7.3</td>
<td>10.4</td>
<td>12.3</td>
<td>16.2</td>
</tr>
<tr>
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<td>2.3</td>
<td>3.3</td>
<td>3.9</td>
<td>5.2</td>
</tr>
<tr>
<td>N = 100,000</td>
<td>.4</td>
<td>.7</td>
<td>1.0</td>
<td>1.2</td>
<td>1.6</td>
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<tr>
<td><strong>p = .40</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 100</td>
<td>8.3</td>
<td>14.1</td>
<td>20.2</td>
<td>24.0</td>
<td>31.5</td>
</tr>
<tr>
<td>N = 1000</td>
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<td>7.0</td>
<td>10.1</td>
<td>12.0</td>
<td>15.8</td>
</tr>
<tr>
<td>N = 10,000</td>
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<td>1.4</td>
<td>2.0</td>
<td>2.0</td>
<td>3.2</td>
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<tr>
<td>N = 100,000</td>
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<td>.7</td>
<td>1.0</td>
<td>1.2</td>
<td>1.6</td>
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<td>11.5</td>
<td>16.5</td>
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<td>2.58</td>
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<td>8.1</td>
</tr>
<tr>
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<td>.7</td>
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<td>1.7</td>
<td>2.0</td>
<td>2.6</td>
</tr>
<tr>
<td>N = 100,000</td>
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<td>.4</td>
<td>.5</td>
<td>.6</td>
<td>.8</td>
</tr>
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<td>13.4</td>
<td>16.0</td>
<td>21.0</td>
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<td>4.3</td>
<td>5.1</td>
<td>6.7</td>
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<td>.9</td>
<td>1.3</td>
<td>1.6</td>
<td>2.1</td>
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<td>N = 100,000</td>
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<td>.4</td>
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<td>8.2</td>
<td>9.8</td>
<td>12.9</td>
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<td>2.6</td>
<td>3.1</td>
<td>4.1</td>
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<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
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<td>.1</td>
<td>.2</td>
<td>.3</td>
<td>.3</td>
<td>.4</td>
</tr>
</tbody>
</table>

Management techniques for Military Occupational Specialty (MOS) groups of different size. Other things equal, MOS with a small number of people will likely have a larger percentage deviation from requirements than those having more people. In a sense, large MOS groups tend to manage themselves, whereas smaller MOS groups require more management.
Table 2.1
MEAN AND STANDARD DEVIATION OF BINOMIAL DISTRIBUTION

<table>
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<th>Number Reenlisting</th>
<th>Reenlistment Rate</th>
<th>.2</th>
<th>.4</th>
<th>.5</th>
<th>.6</th>
<th>.8</th>
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<td>20 (4)</td>
<td>40 (4.9)</td>
<td>50 (5)</td>
<td>60 (4.9)</td>
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<tr>
<td></td>
<td></td>
<td>1000</td>
<td>200 (12.6)</td>
<td>400 (15.6)</td>
<td>500 (15.8)</td>
<td>600 (15.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10,000</td>
<td>2000 (40)</td>
<td>4000 (49)</td>
<td>5000 (50)</td>
<td>6000 (49)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100,000</td>
<td>20,000 (126)</td>
<td>40,000 (155)</td>
<td>50,000 (158)</td>
<td>60,000 (155)</td>
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</table>

If the binomial distribution accurately describes retention decisions, the confidence levels for predicting next year's retention rate, given this year's rate, can be derived. For instance, if this year's retention rate is \( p \), next year's rate will be between \( p \pm 2 \) PSD in 96 out of 100 years. For \( p = .2 \) and \( n = 1000 \), the limits are \( .20 \pm .063 \). For \( p = .2 \) and \( n = 10,000 \), the limits are \( .20 \pm .02 \). Of course, for a given \( n \) and \( p \), the size of the bands around the mean depends on the confidence level with which the prediction is desired. A band that includes 99 out of 100 predictions will be wider than one that is accurate in only 90 out of 100 predictions. Table 2.2 provides the percentage bands around the mean for different \( n \) and \( p \) combinations and confidence limits. For example, referring to the number in the fourth column (95 percent) and second row (\( p = .2, n = 1000 \)), the interpretation is that in 95 years out of 100, next year's retention rate will differ from this year's by less than 12.3 percent. Thus, in 95 out of 100 years, \( p \) will be between \(.2 \pm (12.3)(.2) = .2 \pm .025 \).

The expected accuracy of prediction varies strongly with the number of personnel making decisions. At the 95 percent confidence limit, our accuracy of 12.3 percent is expected with 1000 people, while 3.9 percent is expected with 10,000 people. This fact has implications for...
In the binomial model, the magnitude of year to year variation in retention rates will depend on the number of people making decisions each year and the average probability of a retention decision. Taking the standard deviation as a measure of the expected year to year variation, Table 2.1 presents the expected number of individuals retained and the year to year variation for different group sizes and average reenlistment probabilities. For instance, if we take \( p = 0.20 \) for an individual first-term retention decision and 100 individuals are making retention decisions, then

\[
M = 0.2(100) = 20
\]

\[
S = \sqrt{100}(0.2)(0.8) = 4
\]

The mean number of personnel retained is 20 and in a sequence of 25 years where exactly 100 individuals make retention decisions each year, we would expect that \( M \) would fall between \( M + \sigma = 24 \) and \( M - \sigma = 16 \) for 17 out of the 25 years, or \( M \) would fall between \( M + 2\sigma \) and \( M - 2\sigma \) in 24 out of the 25 years. If actual retention rates in a series of years show greater variation than predicted from this model, it is likely that nonrandom factors are present that change the average reenlistment probability from year to year.

Another measure of variation is the percentage standard deviation (PSD) given by

\[
d = \frac{S}{M} = \frac{q}{np}
\]

For 100 people making retention decisions where \( p = 0.2 \), the annual PSD is 20 percent. The PSD declines as the number of individuals making decisions increases. For \( p = 0.2 \), a group of 1000 people has a PSD of 6.3 percent, while a group of 10,000 has a PSD of 2.0 percent.
II. TESTING FOR THE INFLUENCE OF NONRANDOM VARIABLES ON RETENTION DECISIONS

Each individual retention decision can be modeled as an event with two possible outcomes—either stay or leave the service. If we assume that each decision is made randomly, the binomial model can provide the expected number of individuals retained and the level of year-to-year variation expected in retention rates. This variation represents the minimum year-to-year variation achievable when nonrandom factors are absent. In this section, we will compare the historical accuracy of year-to-year continuation rates with those generated by the binomial model to determine the extent of influence of nonrandom factors. The pattern of error can also help determine the factors causing the nonrandom errors.

A SIMPLE BINOMIAL MODEL OF RETENTION DECISIONS

If we assume each reenlistment decision to be a binomial event, then \( p \) can be taken as the annual probability of retention for an individual in a given military service:

\[
M = np
\]

\[
\sigma = \sqrt{npq}
\]

where

\( M \) = the mean of the binomial distribution
\( \sigma \) = the standard deviation
\( n \) = the number of individuals making retention decisions
\( p \) = the probability of retention for a single individual
\( q = (1 - p) \) = the probability of retention not occurring in a single trial
techniques, but on the ability to produce timely and accurate forecasts. Without systematic analysis of the forecasting records of models, no basis exists to choose between alternative models or to provide a coherent rationale for policy choices.

The results indicate that error rates vary widely according to enlisted group. Certain nonrandom factors contribute heavily to forecast errors for enlisted groups with 3 to 10 years of service making reenlistment decisions. The pattern of these errors points to factors associated with the economic cycle. These factors have been incorporated through behavioral models into enlisted force planning systems since the early 1980s, which should markedly improve enlisted force forecasting. Forecasting records for other enlisted groups show fewer errors. For enlisted personnel with 11 to 20 years of service, errors were close to random. Enlisted groups with more than 20 years of service showed moderate nonrandom components. Forecasts for attrition in the early years of service showed nonrandom factors; however, actual percentage deviations were fairly small—usually less than 3 percent.

With the simple continuation models tested here, the expected accuracy of one-year forecasts is extremely good. Maximum error rates occur for groups with 2 to 4 and 20 to 30 years of service, where the average forecast error is less than 10 percent. For other groups, error rates are generally less than 3 percent. However, this accuracy is somewhat misleading, since only about 20 to 25 percent of the force makes an ETS (end of term of service) decision each year. Error rates for three- and five-year forecasts are much worse and tend to show the cumulative effects of poor forecasting at the ETS point. Error rates for five-year forecasts for the hardest to predict groups in the early years of service range between 15 and 30 percent. Patterns in error rates among the services are remarkably similar.

Section II compares errors from a simple forecasting technique used in the FY71-80 time period to those predicted by the binomial model to determine the presence of nonrandom factors. Section III documents the accuracy of the simple technique in predicting the size of various enlisted force groups. Section IV describes ways of improving enlisted force forecasting and the implications of the results for design of an OSD enlisted force planning system. Section V summarizes results of this analysis.
In developing strategies for improving manpower forecasts, the errors can provide a guide to which groups have the largest systematic errors, and therefore have the highest potential for improvements through development of more sophisticated behavioral models. The error estimates also indicate how much improvement might be expected from more sophisticated models. The simple nonbehavioral estimates tested here were the primary technique used in large planning models during the FY71-80 period. Since that time, the services have begun to incorporate some behaviorally based forecasting techniques for certain enlisted groups in their planning models, which should improve their forecasting ability. However, many enlisted groups are still forecast using the simpler models. The analysis in this Note can help in deciding if appropriate choices are being made for using the more sophisticated models.

Knowing the level of random and systematic error can also improve policymaking by allowing uncertainty to be taken more explicitly into account. Knowing the level of uncertainty allows managers to hedge in order to meet manpower requirements with a given degree of confidence. For instance, for certain critical skill requirements where shortages have high costs, planners can efficiently meet requirements with given confidence levels if the likely errors are known.

Beyond the specific uses of error analysis mentioned above, this Note seeks to encourage the analysis of errors as a central part of the enlisted planning system at the OSD level. Duplication of the large models used by each service in their planning process is not warranted; however, careful and systematic monitoring of the manpower forecasts for each service and analysis of errors can provide the proper incentives for the services to improve their models and to identify unexpected and perhaps harmful long-term impacts of service policies. In the long run, it will also identify successful modeling techniques in each service which might be transferred to other services, and help develop an improved base of common forecasting assumptions across the services. An example of the latter would be common macroeconomic assumptions in forecasts. Ultimately, the value of any model that forecasts manpower depends not on the sophistication of the statistical or economic
statistical fluctuation. Systematic errors in manpower forecasts that change these average year to year forecasts can arise from multiple sources, but one common source is behavioral responses of enlisted personnel to changing policies or civilian economic opportunities or changes in the organizational environment. Estimates of the level of systematic errors can be obtained empirically from historical forecasts if comparisons are made between simple estimated random error levels and actual changes in year to year manpower levels.

This Note develops estimates of the errors in manpower forecasts using enlisted force data from fiscal years 1971 through 1980. Statistical assumptions are first used to estimate the magnitude of random errors in various kinds of forecasts. These forecasts include projections of the enlisted inventory for each service by years of service and for various demographic groupings. Next, the empirical accuracy of a simple--and widely used--nonbehavioral forecasting technique which assumes stable year to year retention is calculated for one-, three-, and five-year forecasts for the same enlisted force groups. Comparisons between the level of random errors and actual errors using the nonbehavioral forecasts allow inferences about the level of systematic errors in manpower forecasts.

Knowing the level of random and systematic errors in various kinds of manpower forecasts can aid the design of improved enlisted force manpower models. This study addresses a series of preliminary questions that need to be addressed prior to the design of an enlisted manpower forecasting system for OSD. These questions are:

1. Does the historical accuracy of simple projection methods indicate the need for more sophisticated techniques?
2. Does the pattern of forecast deviations indicate the need to incorporate variables tracking economic cycles?
3. Does the pattern of forecast errors indicate which manpower groups need more sophisticated models?
4. Does the pattern of forecast errors determine an appropriate disaggregation scheme when forecasting for enlisted personnel?
1. INTRODUCTION

Manpower forecasts of the number and quality of enlisted personnel who will remain in the service are critical components in setting and changing enlisted manpower policies. Forecasts that show persistent shortfalls in occupational areas result in increased bonus payments or special pays. Forecasts of aggregate manning levels are used to help determine the annual adjustments to the basic pay tables and figure prominently in suggested changes to the military retirement system.

Besides these obvious direct effects on compensation policy, forecasts also play a prominent role in estimating and allocating annual budgets for compensation, training, and recruiting resources. Each year the services must forecast manpower losses and establish accession requirements sufficient to meet Congressionally imposed fiscal year end strengths. These accession requirements—which depend on forecasts of losses—are used to establish annual resources for training and recruiting. The annual compensation budget is then based on the grade and experience distribution of those remaining as well as the number and timing of new accessions.

The efficiency of the various policies established on the basis of manpower forecasts depends critically on the accuracy of those forecasts. Inaccurate forecasts can result in base pay, benefit, and bonus levels higher or lower than necessary, leading to either a surplus or shortage of personnel. They can further result in inefficient allocations of resources between compensation, training, and recruiting budgets. For instance, predicting a higher level of accession requirements than necessary would mean unnecessarily high training and recruiting budgets.

Errors in forecasts are usually classified as either random or systematic. The level of random errors presumably provides a lower limit to the ultimate accuracy of forecasts, and this level of random errors can be estimated if certain statistical assumptions are made concerning manpower decisions. This simple statistical model would predict stable average forecasts from year to year with random
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Table 2.13
OVERALL CONTINUATION RATES FOR
DOD ENLISTED PERSONNEL

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required, and increased the proportion of the force with longer commitments. In addition, the average length of the first term of service was further increased by the volunteer force policy, which completely eliminated two-year draftees and offered more attractive pay and training opportunities for longer commitments.

First-term retention rates have also increased dramatically since FY75 because volunteers enter with more taste for service life. These factors led to higher overall force-wide continuation rates. The higher continuation rates are dramatically illustrated by tracking individuals who entered in FY71-72. During this period, enlistments could be classified as draft-motivated or nondraft-motivated depending on an individual's lottery number. Table 2.14 shows the percentage of individuals left in service from those FY71-72 cohorts. As the data
Table 2.14
PERCENTAGE OF FY71-72 ENLISTED ACCESSION COHORTS REMAINING

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indicate, volunteers (high lottery numbers) have significantly higher long-term retention rates than do draft-motivated personnel. These higher retention rates have in turn contributed to lowered accession requirements (see Table 2.15). The lower accession requirements for a given force size enable the services to raise enlistment quality standards, and will be particularly important to maintain during the coming decline in the 17-21 year old population pool and improving economy.

Overall continuation rates for the four services generally follow an upward trend, with the most pronounced trend being for the Army and Marine Corps. These services were most affected by the Vietnam buildup and the influence of the draft. However, even the Navy and Air Force show a higher overall continuation rate after 1976—mainly due to the higher reenlistment rates of volunteers.
Table 2.15
NONPRIOR SERVICE ENLISTED ACCESSION LEVELS
(Thousands of personnel)

<table>
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<tr>
<th>Fiscal Year</th>
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<th>Navy</th>
<th>Marine Corps</th>
<th>Army</th>
<th>DoD</th>
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<td>41</td>
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<td>80</td>
<td>38</td>
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*a* Includes 2,064 inductions.
*b* Includes 156,075 inductions.
*c* Includes 35,678 inductions.

One effect of the end of the draft and the higher volunteer era reenlistment rates has been a structural change in the distribution of service personnel by years of service experience (see Table 2.1b). For total active enlisted personnel, the mix of junior* to career personnel has shifted from a 61/39 mix to a 58/42 mix. Perhaps more important is

*We have defined junior level personnel to be those in the first three years of service.*
Table 2.16

PERCENTAGE OF ENLISTED PERSONNEL IN YEAR OF SERVICE GROUPS

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</tr>
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the dramatic change in the structure of the career force. Younger career personnel with 5 to 10 YOS have increased from 14.8 to 23.1 percent of the force, while the percentage of older career personnel has declined from 24.0 to 19.3 percent of the force. Each of the services shows similar trends in both first-term career mix as well as the mix of junior to senior level careerists. In the absence of policy intervention, the higher reenlistment rates of an all-volunteer force essentially provide a larger career force than does a draft. Two advantages of this mid-career bulge is the greater selectivity available for NCOs or the potential to use this bulge as the base to build a larger force size. It also raises an important policy issue of how many individuals should be continued to retirement.

Retention rate differences by YOS (Tables 2.3-2.7) show fairly well-known patterns. In the first two years of service, retention rates are determined by attrition prior to end of term of service (ETS). This attrition is primarily determined by the quality of the enlistment cohort. Attrition tends to be higher in the Army, where quality is lowest. For DoD enlisted personnel since 1977, first-year attrition has been between 13-14 percent, while second-year attrition has been between 10-12 percent.

Continuation rates between 3 and 12 years of service are dominated by first-, second-, and third-term reenlistment decisions. The lowest continuation rates are experienced at the first-term decision, which can occur as early as the end of the second year and as late as the sixth year. This reenlistment behavior is more clearly shown if continuation rates are calculated only for those individuals having an ETS during the year (see Table 2.17). For DoD enlisted personnel, these continuation rates generally rise between 3 and 20 years of service, illustrating both the effects of self-selection and the pull of the military retirement system.

*First-year attrition is somewhat underestimated here for the first year only because some individuals enlist and leave during the fiscal year. These individuals do not appear on our file.
### Table 2.17  
CONTINUATION RATES FOR ETS DOD ENLISTED PERSONNEL

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The continuation behavior of groups with 3 to 19 YOS not having an ETS (see Table 2.18) shows stable and high continuation rates. Once past the first term, non-ETS separations can occur by death, disability, hardship, AWOL, or nonsatisfactory service. Attrition of this type is a small proportion of overall losses, and probably has only small non-random components. Continuation rates fall at 20 YOS with retirement eligibility and are fairly uniform across services.

STATISTICAL TESTS FOR THE PRESENCE OF NONRANDOM FACTORS

A common method used by manpower analysts to forecast the population of a manpower group is to disaggregate the group into "homogeneous" subgroups and assume a future retention or continuation rate equal to the rate for the previous time period.

\[ p_{t+1} = \sum_i p_i r_{i, t-1} \]

where \( p_{t+1} \) = population of group in time period \( t + 1 \)

\( p_i \) = population of homogeneous subgroup \( i \) in time period \( t \)

\( r_{i, t-1} \) = retention rate of subgroup \( i \) between time period \( t \) and \( t - 1 \).

The underlying assumption of this technique is that homogeneous groups can be found for which retention rates are stable over time and are described by a distribution like the binomial distribution. Differences in retention rates between subgroups are recognized, but retention rates are assumed stable over time.

Probably the sole advantage of this type of model is its simplicity. Forecasting from this model requires only personnel records from two previous years to calculate \( r \) and a current population profile. In military manpower applications, the force is typically disaggregated by demographic characteristics, educational and mental category, and MOS. Retention rates similar to those displayed earlier are then
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FORECASTING ACCURACY FOR NAVY ENLISTED PERSONNEL WITH
SIMPLE CONTINUATION RATE ASSUMPTION

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<tr>
<td>23</td>
<td>0.024</td>
<td>0.031</td>
<td>0.096</td>
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<tr>
<td>24</td>
<td>0.035</td>
<td>0.035</td>
<td>0.084</td>
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<tr>
<td>25</td>
<td>0.026</td>
<td>0.028</td>
<td>0.051</td>
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<tr>
<td>26</td>
<td>0.047</td>
<td>0.037</td>
<td>0.101</td>
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<tr>
<td>27</td>
<td>0.044</td>
<td>0.048</td>
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<td>28</td>
<td>0.059</td>
<td>0.065</td>
<td>0.750</td>
</tr>
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<td>29</td>
<td>0.074</td>
<td>0.055</td>
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</tr>
<tr>
<td>30</td>
<td>0.235</td>
<td>0.173</td>
<td></td>
</tr>
</tbody>
</table>
For a one-year forecast, two time periods have been summarized--FY71-79 and FY76-79. The latter time period removes the effect of draft-motivated personnel on first-term retention decision, and thus may be more indicative of accuracy in an all-volunteer environment. For three- and five-year forecasts, the summary statistics are given by

\[
A_{71,79} = \frac{1}{9} \sum_{j=1}^{9} |E_{1,j}| \\
A_{76,79} = \frac{1}{4} \sum_{j=6}^{9} |E_{1,j}|
\]

\[
T_{72,77} = \frac{1}{6} \sum_{j=1}^{6} |E_{1,j}| \\
T_{72,75} = \frac{1}{4} \sum_{j=1}^{4} |E_{1,j}|
\]

Tables 3.1 through 3.5 provide the forecasting errors by service and for DoD personnel.
FORECAST ERROR FORMULAS

Forecast errors for one-, three-, and five-year forecasts for the simple models can easily be derived and are given as follows:

\[ E^1_{i,j} = \frac{C_{i,j} - C_{i,j+1}}{C_{i,j+1}} \]

\[ E^3_{i,j} = \frac{\sum_{k=0}^{2} C_{i+k,j} - \sum_{k=0}^{2} C_{i+k,j+k+1}}{\sum_{k=0}^{2} C_{i+k,j+k+1}} \]

\[ E^5_{i,j} = \frac{\sum_{k=0}^{4} C_{i+k,j} - \sum_{k=0}^{4} C_{i+k,j+k+1}}{\sum_{k=0}^{4} C_{i+k,j+k+1}} \]

where \( E^n_{i,j} = \text{error for the } n \text{ year forecast of service cohort } i \text{ in year } j \)

\( C_{i,j} = \text{continuation rate for service cohort } i \text{ in year } j \)

Essentially, the above equations forecast for 1, 3, or 5 years using continuation rates from a given year, and then compare the forecast to the actual number of personnel present in the forecast year.

Estimates of forecasting accuracy can be made with the FY71-80 data. For a one-year forecast, estimates of accuracy can be made for FY71-79. For a three-year forecast, estimates can be made for FY71-77, and for a 5-year forecast, estimates can be made for FY71-75. Rather than provide forecasts for each YOS group for each service, summary statistics have been compiled. The mean absolute percentage error has been used to summarize the data.
III. HISTORICAL FORECASTING ACCURACY UNDER SIMPLE CONTINUATION ASSUMPTIONS

The results of the previous section imply that the presence of nonrandom factors is the dominant component of forecast errors, but the amount of influence of nonrandom factors varied considerably depending on YOS group and degree of disaggregation. Only for highly disaggregated groups with between 12 and 19 YOS did the random component seem to dominate. In the latter case, the accuracy of forecasts can be predicted by simple continuation models. In the case where nonrandom factors dominate, models which incorporate the nonrandom factors can probably be used to improve accuracy.

From a policy perspective, a better measure of predictive accuracy than deviation from binomial statistics is the percentage error in forecasts. The binomial theory imposes stringent standards of accuracy—especially for large groups—and nonadherence to binomial standards may still lead to acceptable forecasting errors from a policy perspective. In this section, the percentage errors in forecasts are calculated for simple continuation rate models.

The simplest model of retention decisions is to simply assume the retention rate will be equal in the future to the most recently measured rate. While these types of models have the virtue of being relatively simple, require minimum data, and guarantee continuity with past history—they are unlikely to predict well if nonrandom, noncyclic factors are present. Here we have calculated the historical accuracy of this forecasting technique, widely used in the 1971-1980 period. Small percentage errors would provide little motivation to incorporate more complex techniques into large-scale models. If large percentage errors emerge, their pattern will be important in determining the source of error as well as some idea of the expected improvement should behavioral models be incorporated.
Table 2.23
NUMBER OF DEVIATIONS (10% SIGNIFICANCE) FROM BINOMIAL DISTRIBUTION IN NINE YEAR TO YEAR ARMY RETENTION COMPARISONS

<table>
<thead>
<tr>
<th>YOS</th>
<th>Actual Number of Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White Male, Cat I&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
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<tr>
<td>2</td>
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</tr>
<tr>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
</tr>
</tbody>
</table>

<sup>a</sup>Recruits are classified into Category I, Category II, Category III, and Category IV mental groups, based on scores received on the entrance examination (Armed Forces Qualifying Test, or AFQT). Category I receive scores of 80 and above; Category IV receive scores of 30 and below.
the same summary statistics for ETS groups, and Table 2.23 provides the statistics for more highly disaggregated groups in the Army. (Appendix B contains the full Z statistics for these tables.)

Disaggregation by service and ETS group improves the correspondence with binomial statistics. Groups having an ETS during the year generally show more deviation during YOS 4 through 19 than non-ETS groups. However even non-ETS groups in the years of service 12 through 19 do not correspond to predictions from binomial statistics.

The data show that further disaggregation by demographic, education, and mental category reduces the number of deviations somewhat, but there remain substantial differences from the expected number of deviations predicted by the binomial distribution. These differences are highest for the early years of service and gradually decrease until—for the most disaggregated groups—the binomial distribution seems to hold only for years of service 12 through 19. Other groups are clearly dominated by nonrandom factors.
Table 2.22

NUMBER OF DEVIATIONS (10% CONFIDENCE LEVEL) FROM BINOMIAL DISTRIBUTION IN NINE (FY71-80) YEAR TO YEAR RETENTION COMPARISON

<table>
<thead>
<tr>
<th>YOS</th>
<th>Expected Number of Deviations from Binomial Distribution</th>
<th>Actual Number of Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Army</td>
<td>Navy</td>
</tr>
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<td>30</td>
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- 34 -
Table 2.21
NUMBER OF DEVIATIONS (10% CONFIDENCE LEVEL) FROM BINOMIAL DISTRIBUTION IN NINE (FY71-80) YEAR TO YEAR RETENTION COMPARISONS

<table>
<thead>
<tr>
<th>YOS</th>
<th>Army</th>
<th>Navy</th>
<th>Marine Corps</th>
<th>Air Force</th>
<th>DoD</th>
</tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</table>

Expected Number of Deviations from Binomial Distribution

<table>
<thead>
<tr>
<th>YOS</th>
<th>Actual Number of Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>8 9 8 7 9 9 8 9 8</td>
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<tr>
<td>30</td>
<td>4 3 1 7 6 6 6 6 6</td>
</tr>
</tbody>
</table>
would expect only one in ten (1 in 20, 1 in 100) comparisons to be rejected at the 10 (5, 1) percent confidence level if the means were all chosen from the same binomial distribution. The results for this row clearly indicate variations from nonrandom sources.

The summary statistics indicate strongly that large variations from binomial errors occur between 1 and 10 YOS. In the region 11 to 19 YOS, much less frequent deviations from binomial errors occur. However, even for 11 to 19 YOS, the frequency of deviation is larger than expected on a purely statistical basis. For 20 to 30 YOS, the frequency of deviation from binomial errors again increases.

This pattern is the expected pattern given the vesting structure and level of benefits in the military retirement system and the presence of economic factors in nonrandom sources of variation. The current vesting of military retirement at 20 YOS forces military personnel to make career decisions between the 4th and 12th year of service. Effective military pay which includes the present value of retirement benefits is large enough after a certain point to make it extremely unlikely that civilian pay could provide higher long-term compensation. Thus, personnel decisions are increasingly insulated (but never completely) from the cyclical variations in the civilian labor market, and between 12 and 19 YOS essentially random factors such as death and disability dominate the retention statistics.

Retention for groups not as strongly affected by the structure of military retirement will depend on the availability and wage level of civilian jobs that varied cyclically over the period 1971-1980. Thus, groups from 3 to 10 and 20 to 30 YOS will have military compensation whose level is much closer to civilian opportunities, and will thus show cyclical behavior as civilian opportunities change. Retention rates for personnel with 1 to 2 YOS probably deviate from random variation not because of economic factors, but simply because of differing cohort quality compositions.

The Z statistics for aggregate DoD personnel across services would be expected to show the largest deviation from binomial distributions. One question is the extent to which disaggregation of military personnel into more "homogeneous" groups will reduce these deviations. Table 2.21 shows the summary statistics for the four services, Table 2.22 provides
The hypotheses that \( C_t \) and \( C_{t-1} \) are from the same underlying distribution can then be tested at a given confidence level. Table 2.19 gives the relationship between \( Z \) and the confidence level. Larger \( Z \) values basically indicate a higher probability that the mean difference was not drawn from the same binomial distribution.

Table 2.20 displays \( Z \) values for active force enlisted personnel obtained from using consecutive year continuation rates. For instance, the entry in the row (YOS = 1) and column (1975) indicates that the difference in continuation rates between 1975 and 1976 was 11.72 times the binomial standard error, a highly unlikely result if both means were drawn from the same binomial distribution.

A summary of the \( Z \) statistics for DoD for each YOS is given at the right side of Table 2.20. Of the nine comparisons made in each row, the summary provides the number of comparisons which are rejected at confidence levels of 10, 5, and 1 percent. For the first row, eight of nine comparisons would be rejected at the 10 percent level. Since we

\[
Z = \frac{C_t - C_{t-1}}{SD/\sqrt{n}} = \frac{C_t - C_{t-1}}{\sqrt{pq/n}}
\]

Table 2.19

<table>
<thead>
<tr>
<th>( Z )</th>
<th>Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>.675</td>
<td>Larger mean difference will occur 50 percent of the time</td>
</tr>
<tr>
<td>1.15</td>
<td>Larger mean difference will occur 25 percent of the time</td>
</tr>
<tr>
<td>1.645</td>
<td>Larger mean difference will occur 10 percent of the time</td>
</tr>
<tr>
<td>1.96</td>
<td>Larger mean difference will occur 5 percent of the time</td>
</tr>
<tr>
<td>2.575</td>
<td>Larger mean difference will occur 1 percent of the time</td>
</tr>
</tbody>
</table>
applied repeatedly to obtain 1, 3, or 5 year forecasts for a given YOS group.

\[ P_{YOS}^{t+5} = \prod_{i} P_{i, YOS-5}^{t} \prod_{j=1}^{5} r_{i, YOS-j}^{t-1} \]

where

- \( P_{YOS}^{t+5} \) = population of enlisted personnel with given YOS in time period \( t + 5 \).
- \( P_{i, YOS-5}^{t} \) = population of enlisted personnel in homogeneous group \( i \) with year of service equal to \( YOS - 5 \) at time period \( t \).
- \( r_{i, YOS-j}^{t-1} \) = retention rate between time period \( t \) and \( t - 1 \) for homogenous group \( i \) with year of service equal to \( YOS - j \).

The historical consistency of these data with binomial statistics can be estimated using the data described earlier. We will determine the extent to which the variation in retention rates by YOS between 1971-1980 is consistent with a binomial distribution. If consistent, then year to year accuracy can be predicted with the simple binomial model. If not consistent, the variation could be either larger or smaller than binomial. Smaller variation could indicate that retention decisions are intercorrelated—perhaps through manpower policy instruments. A simple example would be to offer higher bonus amounts later in the year to compensate for lower retention generated randomly earlier in the year. Larger variation may indicate the existence and extent of nonrandom factors influencing retention decisions.

A test commonly used to measure variation from a statistical distribution is to compare the ratio of the actual year to year variation with that predicted from the assumed statistical distribution.
Table 3.4
FORECASTING ACCURACY FOR MARINE CORPS ENLISTED PERSONNEL
UNDER SIMPLE CONTINUATION RATE ASSUMPTION

<table>
<thead>
<tr>
<th>Years of Service</th>
<th>One Year</th>
<th>Three Years</th>
<th>Five Years</th>
</tr>
</thead>
<tbody>
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<td>71-80</td>
<td>76-80</td>
<td>72-77</td>
</tr>
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<td>0.010</td>
<td>0.190</td>
</tr>
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<td>0.132</td>
</tr>
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<td>3</td>
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<td>0.057</td>
<td>0.145</td>
</tr>
<tr>
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<td>0.078</td>
<td>0.097</td>
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<tr>
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<td>0.034</td>
<td>0.012</td>
<td>0.089</td>
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<td>0.030</td>
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Table 3.5
FORECASTING ACCURACY FOR AIR FORCE ENLISTED PERSONNEL UNDER SIMPLE CONTINUATION RATE ASSUMPTION

<table>
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<td>0.036</td>
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<td>0.059</td>
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<td>0.109</td>
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<tr>
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<tr>
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ONE-YEAR FORECASTS

In the 1971-79 period, the greatest percentage errors in forecasting in each service occurred in the years of service 2 through 4 and 20 through 30, where average percentage errors are almost always less than 10 percent. For between 5 and 10 years of service, average percentage errors are usually less than 3 percent. In the YOS range 11 to 19, average percentage errors are less than 1 percent. For the first year of service, average percentage error does not exceed 4 percent for any service.

Forecasting accuracy should improve for the 1976-79 period around first-term retention because of the absence of draft-motivated personnel. The data generally show reduced average error rates for this period when compared to the 1971-79 period.

The somewhat surprising accuracy of one-year forecasts during a period marked by a rapidly changing economic environment and a policy environment marked by transition to an all-volunteer force can be attributed partly to a key structural parameter of the military manpower system—the term of service. Most military personnel have at least 3-year terms of service and some have up to 6-year terms. The result is that only about 20 to 25 percent of military personnel make an ETS decision annually (see Table 3.6). Thus, 75 percent of personnel are in a highly stable and fairly predictable non-ETS status. This is illustrated when accuracy is calculated for both ETS and non-ETS groups (see Tables 3.7 through 3.11). This accurate forecasting in the short term does not require highly accurate forecasting of ETS decisions. The remarkable accuracy of one-year forecasts hides a somewhat inaccurate forecast for ETS groups. One-year errors for ETS groups range from 10 to 30 percent for groups with 2 to 4 YOS.
Table 3.6
PERCENTAGE OF ENLISTED MILITARY PERSONNEL HAVING AN ETS DECISION EACH YEAR

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<th>1971</th>
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<th>Navy</th>
<th>Marine Corps</th>
<th>Air Force</th>
<th>DoD</th>
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<td>20.7</td>
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<tr>
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<td>26.0</td>
<td>27.4</td>
<td>21.8</td>
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<td>22.2</td>
<td>24.1</td>
<td>18.5</td>
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<tr>
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<td>21.4</td>
<td>19.7</td>
<td>22.5</td>
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<td>22.1</td>
<td>16.5</td>
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<tr>
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<tr>
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<td>79</td>
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<td>20.6</td>
<td>25.3</td>
<td>18.7</td>
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<tr>
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<td>22.5</td>
<td>24.3</td>
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Table 3.7
A MEASURE OF FORECASTING ACCURACY UNDER A SIMPLE CONTINUATION ASSUMPTION FOR DOD ENLISTED PERSONNEL

Mean Absolute Percentage Error/100

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<td>0.027</td>
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A MEASURE OF FORECASTING ACCURACY UNDER A SIMPLE CONTINUATION ASSUMPTION FOR NAVY ENLISTED PERSONNEL

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A MEASURE OF FORECASTING ACCURACY UNDER A SIMPLE CONTINUATION ASSUMPTION FOR MARINE CORPS ENLISTED PERSONNEL

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Table 3.11
A MEASURE OF FORECASTING ACCURACY UNDER A SIMPLE CONTINUATION ASSUMPTION FOR AIR FORCE ENLISTED PERSONNEL

Mean Absolute Percentage Error/100

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THREE- AND FIVE-YEAR FORECASTS

Forecasting errors for three and five years are larger than those for one-year forecasts. If random events were the determining factor, these errors should be approximately the same magnitude. The increases are probably due to the fact that by five years practically all individuals will have had an ETS decision, and nonrandom factors operating at that point in each year cause a widening cumulative error. Average errors for cohorts moving from year of service 1 and 2 generally fall between 12 and 20 percent for 3-year forecasts and between 20 and 30 percent for 5-year forecasts. This means that the size of a cohort moving from year 1 or 2 to year 4 to 5 cannot be estimated—using the simple models—to accuracy greater than 12 to 20 percent or 20 to 30 percent for movement from year 1 or 2 to year 6 or 7. Accuracy improves for later cohorts. For cohorts beginning at YOS 3 or 4, 3-year errors tend to be between 10 and 15 percent, whereas 5-year errors are between 12 and 20 percent. The magnitude of errors decreases until for cohorts starting between years of service 12-14, 3-year errors are usually less than 2 percent, whereas 5-year errors are less than 5 percent. Errors dramatically increase for personnel moving through the reenlistment point of 20 years. Three-year forecast errors are generally less than 15 percent, whereas 5-year errors are usually less than 20 percent. The four services show remarkably similar patterns, with the Marine Corps showing a slightly higher error rate than the other services.
IV. INTEGRATING BEHAVIORAL ESTIMATES INTO LARGE, OPERATIONAL ENLISTED FORCE MODELS

Understanding the accuracy with which projections of enlisted force strength and structure can be made is essential to the design of models that have as their purpose the control of key aggregate manpower parameters such as end strength, accession requirements, first term/career mix, and pay and bonus budgets. A knowledge of this accuracy allows more cost effective hedging of personnel policies and suggests where controls need to be implemented to better manage the enlisted force. More importantly, it can provide directions for improving enlisted force modeling in a way that leads to greater accuracy and more parsimonious models. The latter criterion is an important consideration in model design--especially at the OSD level--where staff size can limit the scope of modeling activities and staff turnover can quickly make complex models extinct.

Manpower models designed for setting enlisted force policy have been of two types. The first type has as their primary purpose the control of aggregate manpower parameters such as end strength, trained strength, accession requirements, direct manpower compensation costs, and enlisted force profiles. These models basically project manpower losses at different experience levels, generate the level and type of manpower gains needed to meet end strengths, and then produce future enlisted force profiles and budgetary costs. The format, approach, and sophistication of these models differ markedly by service.

The second type of modeling has been directed at deriving equations that describe retention or continuation behavior. These models provide measurements of the effect of a variety of variables on enlisted force retention. Variables typically included in such models include military and civilian pay levels, policy variables, unemployment, and demographic characteristics. The models are usually directed at modeling a particular enlistment or reenlistment decision (first term or second term), but models also have been developed which attempt to explain
sequences of retention decisions. These types of models serve two purposes. The first is to define certain key parameters which are used in the policy adjustments of retention rates. These parameters essentially specify how changes in pay and unemployment will affect retention rates. The second purpose is to make forecasts. Forecasts can be made provided the future values of independent variables are known.

The results of these enlistment and retention models as well as results from earlier sections have shown the importance of economic variables in enlistment and retention decisions. Enlistment and retention decisions have been shown to be sensitive to unemployment rates and civilian and military pay levels. It would seem a natural step to incorporate these models into the framework of the larger operating models which need estimates of retention and continuation rates as critical components. This integration would allow simulation of the effects of changes of policy and economic cycles on aggregate manpower trends and development of countercyclical policies to smooth cyclical effects. It should also, in principle, allow more accurate forecasting of retention rates—although this point has not been subject to well documented empirical validation.

Realizing the potential for increased accuracy by integrating behavioral models into manpower systems models means overcoming several

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2 Other nonbehavioral techniques for projecting losses have been used or suggested. One technique involves maintaining the basic disaggregation strategy but estimating future continuation rates from a series of past continuation rates. Techniques can include simple averages of past rates, time trends, exponential smoothing, or spectral analysis. Exponential smoothing is a flexible curve-fitting technique where user intervention can set certain constants. Setting these constants can reflect either assessments of the relative weight given to historical data or possible future economic conditions. This subjective intervention makes evaluation of these models difficult, and leaves them highly dependent on the quality of "experts." Spectral analysis techniques are also flexible and are especially suited to fitting cyclical or periodic data which require no user intervention. However, this technique works best when a long series of historical data is available so that cyclical and periodic patterns can be detected. Since current enlisted force data bases contain only 10 years of data, these techniques do not seem currently useful.
barriers which can prevent successful integration and avoiding some pitfalls which could actually decrease accuracy.

One critical problem is that econometric equations are rarely developed for the ideal time periods or precise manpower groups needed by manpower systems models. This mismatch is due fundamentally to differing primary objectives of the two activities. Econometric estimates usually have as their main purpose the measurement of a policy parameter like pay elasticity rather than a time-sensitive forecast. The choice of a data series to make an estimation is often based on some measurement advantage or simple data availability. In the former case, the measurement advantage might include experimental conditions or a large time series or cross-sectional variation in certain variables. Estimation can be a lengthy process, so that available equations cover time periods which lag by a year or two the starting point for needed manpower forecasts.

On the other hand, manpower systems models need econometric equations estimated for specific longitudinal data series specified by the disaggregation scheme of the model. These data series should include the most recent time periods prior to the forecasting periods. Continuously providing these kinds of estimates would considerably expand the scope of present manpower systems models. These models would need an extensive decision support system devoted to storage of longitudinal data. This data base would need to contain not only longitudinal data at the individual level for specific manpower cells, but also extended data series of independent variables. These would include civilian and military pay series, bonus payments, unemployment indicators, and policies affecting retention such as changing benefits. These series could differ between manpower groups so the number of series would proliferate with the number of disaggregated groups. For instance, civilian pay series would differ for males and females, and for different races and education groups.

Since present manpower systems are usually highly disaggregated—often containing thousands of cells—integration of behavioral equations and the associated data support could be a significant investment. This integration also makes the models more complex and somewhat less
responsive, and raises the "price" of disaggregation. For such integrated models parsimony and concern for accuracy should dictate where econometric estimates are used and the basic disaggregation structure of the model. Part of the large-scale disaggregation in present models may be an attempt to compensate for the lack of accuracy inherent when economic parameters are not taken into account. Less disaggregated models incorporating economic variables may be more accurate than highly disaggregate models without them.

Using more sophisticated econometric models and further disaggregation is warranted only where significant gain in accuracy is achievable. Our results in this Note fortunately indicate that high levels of disaggregation may not improve accuracy much, and econometric models may be warranted only for longer term forecasts for ETS groups with between 3 and 10 years of service. Although error rates are high for groups with greater than 20 years of service, the small size of these groups make improved models unnecessary for most policy applications. A more problematical group is the 1-3 YOS group. It is important to predict these groups accurately since they are the largest in the enlisted force. Non-ETS attrition in these groups appears to be more stable than present attrition models based on personnel characteristics would predict. This may indicate that service attrition policies are directed toward creaming any incoming cohort regardless of composition. Thus, traditional methods of disaggregation of these groups by qualitative characteristics may not produce accurate estimates. Instead, qualitative criteria supplemented by upper level bounds on overall attrition levels may produce more accurate estimates.

A second major problem with integrating behavioral models into manpower systems models is the instability of estimations from econometric models. This instability can be caused by dynamic instability in the behavioral phenomena being measured—but is probably more often caused by other factors. These factors include the lack of a unique theoretically determined model, different measures of variables, different estimation techniques, and use of different time periods in the estimations. Estimation is still somewhat of an art loosely constrained by theory. Thus, it is important to have a uniform, well-regulated process for comparing forecasts and for documenting
assumptions, model specifications, and estimation procedures. It is important to distinguish between differences in models and differences in forecasts. Differences in models or estimations might frequently produce little differences in forecasts.

A third problem with incorporation is the need to predict future values of independent variables in the econometric models. The models contain variables that are outside DoD policy control and for which future values may be highly uncertain. The accuracy of forecasts is thereby dependent not only on the "quality" of model specifications and the statistical characteristics of the model estimations, but also on uncertainty in assigning values to future parameters.

Another complication is that the functional forms used to fit econometric equations may not be compatible with those needed in manpower systems models. Nonlinear logit functions are often used to fit the dichotomous retention or attrition behavior. The logit estimates give the probability of attrition or retention for individuals with differing characteristics under different choices of policy parameters (military pay) and other factors (unemployment). This functional form is chosen primarily because of its asymptotic behavior which limits the probability value to between zero and one. The problem arises when these individual level estimates are used to predict the retention or attrition behavior of a heterogeneous group of enlisted personnel. The accepted method for deriving the retention rate of a group is to calculate the logit probability for each individual and sum these probabilities over the group. In manpower systems models this procedure requires an unmanageably large individual level data base and redesign of the models using microsimulation. Instead, simple linear fits using estimates from the logit fits are usually developed that can be varied continuously within certain limits of the independent variables.

A second reason is that nonlinear functions can complicate these larger optimization models which attempt to choose values or policy variables contained in the continuation rate. Large-scale linear optimization models can easily adapt to linear functions. However, retention rates cannot be estimated with linear functions since values of the dependent variable must be kept between zero and one.
Incorporating nonlinear function means additional computational work to develop piecewise linear functions or change to a nonlinear programming environment. In the latter case, the "size" of the problem is much more restrictive than with linear programming.

A final reason for lack of integration is that the magnitude of differences in forecasting accuracy between the simple continuation models and more sophisticated models has not been estimated. The difference between the two types of models may not be sufficient to justify the resources necessary for incorporating the more complex models. Unfortunately, forecasts are not routinely made by those building econometric retention models. Given that forecasts occur, a tracking system to measure the historical accuracy of various models is critical to the process of model validation and improvement. This process is perhaps the key missing ingredient in improving enlisted force forecasting.

Tracking the accuracy with which enlisted manpower levels can be forecast is useful not only in designing improved forecasting levels, but the expected uncertainty in forecasts is itself a key policy planning parameter. Determining the likely accuracy of forecasts allows managers to properly hedge their actions to meet requirements with prescribed levels of confidence. It is often more important to assume with a high degree of confidence that manpower of certain types will exceed a certain level than to simply be able to predict the expected value of a level. The amount of hedging required will depend partly on the level of uncertainty—more uncertainty means more hedging. Hedging is accomplished through planning for a level of manpower above requirements. Several other parameters determine the increment over requirements necessary for hedging—the level of confidence, the perceived cost of shortages, the cost of the additional manpower, and the number of personnel in the inventory.

Taking account of uncertainty in planning the levels of enlisted manpower inventories of various types is essential to effective management of the enlisted force. These factors make enlisted force planning not a simple quantitative exercise in forecasting from existing historical data, but a coordinated organizational effort to make explicit and estimate (sometimes subjectively) the uncertainty in forecasts, costs of shortages, and required levels of confidence.
V. CONCLUSIONS

This study of the accuracy of enlisted strength forecasting in the four services for fiscal years 1971 through 1980 shows that simple continuation rate models have severe limitations when projecting over three or five years. Forecasting errors arise because of large errors encountered in forecasting for ETS groups that tend to be cumulative. These ETS errors are largest for personnel at first and second term and between 20 and 30 YOS. Breaking enlisted groups into finely disaggregated subgroups improves forecasting only a little. The major component contributing to error appears to be a nonrandom component occurring at the point of ETS that is correlated across enlisted groups by YOS. Failure to incorporate these nonrandom components severely limits the accuracy of enlisted force forecasting. These nonrandom components are being systematically incorporated into the enlisted force models of the four services. Many analytical and practical problems remain to valid integration. Thus, forecasting accuracy of these models may be limited and need systematic tracking.

These nonrandom components are attributable to variations associated with the economic cycle. Econometric estimates made over a number of years have shown the sensitivity of ETS decisions to economic variables. Moreover, the pattern of errors found in this study is consistent with the hypothesis that missing economic variables are the main contributors to the error rates for three- and five-year forecasts. Making enlisted forecasting more accurate means finding ways of incorporating these variables into the enlisted models of the services.

This incorporation of economic variables into the large-scale enlisted force models of the services should be one goal of enlisted force management. Perhaps the major problem in enlisted force management in the next five years will be developing countercyclical policies during a period of improving economy. This kind of planning will be impossible unless the services themselves can generate these estimates. Moreover, OSD should not duplicate the capability that exists within the services for enlisted force modeling.
should be in a position to exert influence on the direction of modeling activities within the services through its review and understanding of model assumptions, and to coordinate, where appropriate, modeling assumptions across services. Three critical components in performing these functions are the ability to test and track the accuracy of enlisted manpower projections, a process for coordinating and establishing common assumptions across services, and revised Department of Defense Instructions that emphasize model assumptions in addition to model outputs.

Testing the accuracy of enlisted models requires developing a certain type of enlisted force model at the OSD level that can be used to check the output of service models against some standard model assumptions. Such models should emphasize flexibility and decision support capability rather than comprehensiveness or even technical sophistication or complexity.

There are several barriers to incorporating behavioral estimates into the large-scale models. The high degree of disaggregation used in most models means making a large number of behavioral estimates. This study, however, indicates that a high degree of disaggregation may not contribute greatly to improving accuracy. In fact, less disaggregated models incorporating economic variables may provide far greater accuracy than highly disaggregated models without economic variables.

This study has also shown that behavioral estimates may only be needed for certain key groups. Simple continuation models often provide surprisingly good estimates. Another barrier is development of estimates that are based on the behavioral history of the group being forecast. Although several econometric estimates have been made on differing groups at different times, ad hoc extractions of parameters from these models and incorporation into other models are dangerous. Rather, resources need to be devoted to maintaining a fairly large support system of longitudinal data so that estimates can be generated for key groups rather easily. The problem will still remain that econometric estimates are not highly reliable or repeatable across similar groups at different times. So part of the estimation capability must be ways of statistically testing the effect of different parameters on the overall quality of fit.
Yet another barrier is that behavioral models themselves need estimates of future economic parameters. These estimates have not been highly reliable in the past. Thus, it is important to have a mechanism for establishing consistent estimates of these parameters across services and a means to test sensitivities to variations from forecasts. Another barrier concerns the specification and linking of functional forms for the behavioral models. Current logit functional forms—often used in behavioral estimates of discrete choice—may provide poor quality of fits over certain portions of the curve. These poor fits could interfere with the goal of providing overall improved accuracy. More research is needed to develop better fitting forms. Finally, incorporating these more complex functional forms into enlisted force models may be simple in certain types of models, but more complex in optimization models which have traditionally relied on linear estimates. However, none of these barriers is of sufficient complexity to deter movement forward. Indeed, the results of this study seem to indicate a marked improvement in enlisted forecasting accuracy may be possible with models that are estimated from continuous longitudinal data for the group in question—but that incorporate fairly simple economic variables.
Appendix A
THE DATA BASE

The data base was constructed by matching (by Social Security number) beginning fiscal year master file records for each service with ending fiscal year records. Flags were then attached to the data records to indicate either a match or a nonmatch. Master file records were next extracted and saved for each beginning year record—where a match existed—for an end year record. An extract of this tape with the data elements of Table A.1 was then made.
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Appendix B

COMPARISON OF ERRORS WITH BINOMIAL ERRORS FOR FOUR SERVICES
## Table B.1

### Z STATISTICS FOR ARMY ENLISTED PERSONNEL

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