A Personnel Inventory Projection and Aging Model for Large Organizations Using Nonlinear Programming

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T-4471

A dissertation submitted to the Faculty and Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Mathematical and Computer Sciences.

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ABSTRACT

This dissertation is based on a project done for the U.S. Army Personnel Command (PERSCOM) in Alexandria, Virginia. With the recent downsizing of personnel in industry, human resource considerations have become obscured in the many issues of personnel hiring freezes, furloughs and layoffs. Employees are disenchanted and are taking a much more selfish approach when dealing with the employers, particularly in regard to employer practices.

The problem of attracting, retaining, and training a qualified workforce can be alleviated in the near to long term by addressing accession of new employees and the aging of the personnel inventory in a qualitative and quantitative way. With the model developed for this project, industry can more efficiently develop the employees they have, foster worker loyalty, and save money on personnel investment and training programs.

The model provides a non-linear approach to solving the problem of accessing and projecting the personnel inventory by skill and grade to meet requirements over time. The benefit to personnel managers is that they have an optimized accession plan and projected inventory to meet requirements.

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ACKNOWLEDGMENTS

It is with my sincerest thanks that I wish to acknowledge Dr. Ruth A. Maurer, Dr. Robert E. D. Woolsey, Professor William R. Astle, Dr. Warren A. Spaulding, and Dr. David E. Fletcher as the guiding force in my graduate education at the Colorado School of Mines. Their patience, encouragement, and exacting high standards have allowed me to learn far more than I imagined possible.

A special thanks to LTC Jack A. Jackson (USAF), LTC C. Neil Fulcher (USA), CW5 Julian "Butch" Davis (USA), CW5 William "Curt" Oldroyd (USA), and Mr. Erdem Ince (AGDT). Their friendship, assistance, and professionalism have helped me immeasurably as I negotiated the tangled halls of academia in pursuit of higher education and while I conducted my research at the U.S. Army Personnel Command (PERSCOM) in Alexandria, Virginia.

Most importantly, I wish to thank my wife Lauretta and our two daughters Katie and Julie for their unflappable support. Their love and understanding through the early mornings, late nights, difficult classes at The Colorado School of Mines and The Catholic University of America and life in the U.S. Army shows me again just how special they are.

Chapter 1
Introduction

1.1 Background Information

Attracting and retaining a qualified work force depends on more than salaries. A working environment in which an employee is positively motivated will prove to be industry's greatest asset. Industry, much like the U.S. Government, is attempting to attract and retain a highly qualified work force to meet the demands of an expanding global economy and new world order. Both institutions rely on marketing strategies that put their offerings in a positive light. Working against this initiative, however, is the recent downsizing of the number of personnel within many industries. Human resources have become obscured in the many issues of personnel hiring freezes, furloughs, and layoffs. The challenge lies in finding a way to motivate the employees who remain, while ensuring fairness and sensitivity towards those who are released. This reality becomes a particularly troublesome area when employees are released shortly after being acquired by a company.

The age old adage that said if you are skilled, devoted and loyal you will be rewarded with a good salary, benefits, promotions, and a retirement is rapidly eroding. Recent events in industry, such as layoffs, demotions, and early retirement programs, have produced employees who are disenchanted and who are taking a much more selfish approach when dealing with their employer. More and more often, employees are now looking out for themselves and questioning employer practices. Recognizing this, Citicorp, Apple Computer, the U.S. Government, and other large corporations have instituted programs to foster employee satisfaction[1].

The key to solving the problem of keeping a qualified work force lies in how the work force is accessed and the inventory aged over time. Some of the more critical variables in this process are employee continuation rates, survival rates, and promotion rates. Other key indicators that are closely monitored by employee organizations are increases in opportunity for jobs with greater responsibilities, authority, and educational advancement.

Accepting the fact that industry and the U.S. Government have released many people from their jobs by different means, whether fair or unfair, these same employers still need to hire new employees in order to maintain a credible and viable work force for the future. Their goal is to achieve a steady-state environment with the accessions, losses and the continuing education of employees.

1.2 Research and Literature Search

Until recently, human resource management has been a low priority for industry and government agencies. Workers' loyalty and

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[1] Soloman, Charlene M. 1992. The Loyalty Factor. Personnel Journal (01 September): 51.

commitment to their industry have been taken for granted[2]. Recent downsizing initiatives and forced job reclassifications have been referred to as necessary to remain competitive economically. However, when not managed properly, the results can prove to be a financial and human disaster. Secretary of Labor Robert Reich stated it well when saying, "Over the long term, I believe firmly that when you cut payrolls, you end up reducing long term performance because employees are worried, demoralized and often you get rid of some of the most experienced people"[3].

An additional problem facing some industries is the perception of being reactionary rather than proactive in respect to the company's well being. Immediately after employee layoffs, stock prices may temporarily increase in value[4]. This is a direct result of the company's slimming down. Two problems that the company is left with for the future are new employee retraining due to recent hiring or retraining, new technology upgrades, and the loyalty of the remaining work force due to these changes[5]. An example of this is the defense buildup of the 1980's, followed by a sharp downturn involving layoffs, and then the subsequent re-hiring of the laid off personnel as the companies took on new directions[6].

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[2] Goddard, Robert W. 1989. Workforce 2000. Personnel Journal (01 February): 64.
[3] Reich, Robert. 1994. Interview. The Washington Post (02 January): D-5.
[4] Managing Survivors, Information Week (15 July 1991): 10.
[5] DEC Realigns Sales. Industry Week (03 August 1992): 15.
[6] Reich, Robert. 1994. Interview. The Washington Post (27 December): 3.

During the defense buildup of the 1980's, rapid expansion of the local economy in the Washington D.C. area was described as substantial. However, now that the Soviet Union has collapsed and the cold war is over, the U.S. military is getting smaller. This has had the effect of fewer weapons systems being needed, which translates to a reduced need for defense contractors, subcontractors, and subsequent spin-off work to related industries. The impact in human terms is hard to measure, but can be evaluated in terms of less office space leased and decreased or eliminated research and development projects. Indirectly, the impact is also felt by the local economy's infrastructure and by the decreased values of commercial and residential real estate and service jobs.

Historically, models were developed to age and access the U.S. Army's inventory, but at a great cost. The Officer Projected Aggregate Levels System (OPALS)[7] model was developed in early '84 and the Officer Projection Specialty System (TOPSS)[8] model came out in late '86 at a combined development cost of over 6 million dollars. The early models provided valuable information, but the personnel manager had problems managing the populations in the Primary Military Occupational Specialty (PMOS) level of detail. Assignment officers used tabulation paper and adding machines or calculators to access and project their inventory. Much was left to the assignment manager's intuition.

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[7] Officer Projected Aggregate Levels System. 1984. Developed by: General Research Corporation, Vienna, VA.

[8] The Officer Projection Specialty System. 1986. Developed by: General Research Corporation, Vienna, VA.

1.3 Special Considerations and Approaches

Many industries have tried to have policies that were flexible and guaranteed no layoffs. However, with recent displacements of personnel from many long standing industries, a new breed of worker has evolved. The worker now tends to be skeptical, seeking job security, and looking for training that will make them invaluable. Additionally, past recruiting strategies now are costing companies much money. For example, in 1991 it cost $5,409.00 to hire a new employee. By 1992 the cost had escalated to $6,624.00 per employee, and it is estimated to be $7,350.00 for a new hire in 1993[9]. Costs are for personnel consultants "head-hunters" who search for and locate people with those skills desired by the company. Costs for the years '91 to '93 haven't been adjusted for inflation and do not reflect discounted cash flow rate of return on investment.

There have been some innovative approaches to the problems of downsizing. One example is the Foxboro industrial plant[10]. As industrial and government jobs became technologically oriented, Foxboro employees took steps to improve themselves, their jobs, and their company. They accomplished this through job retraining with a concerted effort to hire qualified minority and female workers and place them in jobs matching their abilities. While similar initiatives have been

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[9] The Washington Post. (02 January 1994): B-2.
[10] Foxboro's World Class Workforce. 1993. Modern Materials Handling (01 January): 50.

taken by other industries, relatively few initiatives have been taken to ensure the success of a person at the time of hiring.

Recently, in 1992, the small legal firm of Winston and Strawn demonstrated that the downsizing coupled with new accessions could work [11]. After laying off 25 partners, ten of whom were in their mid fifties or older, they still demonstrated that the cuts made good business sense and improved the firm's bottom line within several years. This venture was achieved by holding on to the goal of their strategic plan, rather than to the personalities of their employees. For this business, downsizing with new accessions was a success. Conversely, several large industries including General Motors and Caterpillar, have attempted to downsize with major problems resulting[12]. Employees went on strike and malcontents remained within the group of employees who kept their jobs. The survivors have now been placed into an environment of risk aversion and non-tolerance of mistakes. In the U.S. Army this is commonly referred to as "zero defects". The impact on the employees' morale is formidable, especially when human resources are scarce. Reactions to the fairness of the layoffs and changes within the organization affect the employee and their ambitions. Questions surface as to job security, career prospects, and quality and quantity of responsibilities of the survivors.

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[11] Barker, Billy. 1993. The American Lawyer (01 June): 70.
[12] Personnel Journal 100. 1992. Personnel Journal (01 December): 47.

1.4 Research Results and Recommendations

The literature indicates that the problem of attracting and training a qualified work force can be adjusted in the mid to long term by addressing the problem of accession of new employees and the aging of the personnel inventory in a qualitative and quantitative way. This will ensure that management is candid with all employees in regard to hiring practices and addresses expectations as to personal growth and development. The company will then develop the employees they have, foster worker loyalty, and save money on personnel investment and training programs. The model developed here will provide personnel managers with the tools necessary to access the optimal number of employees annually, adjust the size and determine the skills required of the work force in the out years, age employees by skill utilizing statistical and analytical techniques, and, finally, transition the right number of workers for additional training to meet the demands of changing technology. To the employees this will be viewed as a system that will allow them to see their future prospects with the company and to gauge their expectations for advancement.

Robert Reich, Secretary of Labor, made this statement in an interview with the Washington Post: "The better route is to upgrade not only their technology, but also their employees[13]". The goal of this dissertation is to develop a model so that as industry develops its

[13] Reich, Robert. 1994. The Washington Post: (02 January): D-5.

strategic plan to incorporate new technologies, it will also have a usable tool to manage personnel and their training.

Chapter 2

Major Functions and Objectives of the Model

2.1 New Environment

Productivity and morale of employees are keys to any company's success. A motivated work force has helped the railroad industry recover from a bad economic position to one of higher productivity[14]. Employees who survive layoffs will have a greater impact on the future of the company in many different areas. Factors affecting the employees' performance are the handling of the layoff, perceptions of those laid off and retained, and changes within the organization. Difficult to measure, but very important to the company and especially the employee, are job security, career opportunity, new job responsibilities, and employee perceptions of what is fair. Steps taken before, during, and after the layoff have a direct impact on the productivity and morale of those who remain[15]. Steps to improve the circumstances of the layoff are difficult at best to address; however, a work force that is motivated and managed efficiently and fairly will help to improve morale and the perception of fairness.

Downsizing an organization is done to ensure profitability and survival but companies which conduct poorly planned layoffs may be doing irreversible damage by not managing personnel downsizing in a

[14] People Power on Railroads. 1989. Modern Railroads (01 November): 16.
[15] Brockner, Joel. 1992. California Management Review (Winter): 9.

systematic way[16]. Areas of concern are personnel with critical skills, workers who require specific training programs, and a work force that has a constant rate of attrition/hiring. Difficult to measure and sometimes not given sufficient credibility are the attitudes of remaining workers who will be key in making those "important" business decisions and remaining competent in their jobs. The overall risk, and a great concern to personnel managers, is an employee who will not make a decision because of a work atmosphere where there exists a "risk-averse work paralysis"[17]. When fear of doing the wrong thing interferes with normal decision making, the employees' reaction will be to delay a decision or pass it on to management. When this process is done, resources have been wasted and management may look for a scapegoat to place the blame, thus perpetuating the perception of risk-adverse work paralysis within the workforce.

As the American society has evolved, the impact of government regulations, workers' rights, and accountability of employers and employees' actions have done much to improve the work place. Workers today are better educated than at any other time in history. Today greater numbers are seeking a post high school education or are enrolling in trade schools. Though many prospective employees lack a formal education or specific trade skills, there are large number of personnel who have industry-specific skills that are in demand.

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[16] Rightsizing, Not Downsizing. 1992. Industry Week (03 August): 23.
[17] Rightsizing, Not Downsizing. 1992. Industry Week (03 August): 14.

Technology has outpaced human ability in many areas, particularly the computer with its tremendous applications. In some cases the computer has displaced workers. In other cases, it has forced workers to need additional training. This training is an investment in the employee and in the company.

2.2 Shift in Personnel Management Philosophy

As technology improves, companies must meet the challenge of a new environment. There is a decreasing pool of qualified job applicants as jobs get more industry specific and depend to a lesser degree on a pure academic education. The goal for a personnel manager then becomes finding qualified applicants, training new employees for specific jobs within the company, and aging the company's personnel inventory. Accessing and aging the personnel inventory is the personnel manager's most difficult job in these difficult times. Training programs cost money while the company must remain economically competitive. Management is expecting the personnel manager to do all of this at the lowest possible cost while also providing a continuously improving work force. Taking advantage of current operations research tools, the model developed here will assist personnel managers in making better business decisions.

2.3 Impact of the Model

The model is an analytical algorithm that takes advantage of current resources available to the operations research analyst. The Excel

5.0 Spreadsheet package from Microsoft Corporation offers optimization and resource allocation methods. Some of the techniques available in the program are linear and non-linear optimization, sensitivity analysis, and minimization and maximization algorithms. There are other more elaborate and significantly more expensive software programs available, but the intent here is to be realistic and conservative with resources and to exploit readily available tools.

The model developed here helps personnel managers determine the best uses of scarce resources so that goals and objectives can be pursued realistically. In this case, the objective is to minimize the difference between personnel requirements and calculated end strength while aging the work force and ensuring that the proper number of personnel are accessed at the right time, given current constraints and history. Particular jobs and other factors are included for the personnel manager to consider. Examples would be transitioning employees with certain skills to skill-enhancing training required for promotion. Other considerations involved are factoring in different rates of personnel turnover such as personnel continuation rates and losses from retirement or promotion/non-promotion.

2.4 Model Objectives

The purpose of the model is to provide an automated means of accessing and aging a personnel inventory by skill and grade to meet an organizations personnel requirements over time. It can be used by personnel managers to determine personnel development issues for the work force. Generally, the model is run at the end of each fiscal or calendar year, depending on how the company's reports are done. For this dissertation, it will be done by fiscal year (12 month period from 01 October to 30 September). Personnel requirements can then be determined and supported as needed. The model is actually a series of relationships that produces personnel management information for the personnel manager. The model consists of five principal components which can be tailored for specific circumstances within a company. Components used here are

1. Current inventory
2. Personnel requirements by job type in each of the forecasted years
3. Training program transition matrix (donor to receiver skills)
4. Promotion opportunity by job type
5. Rate statistics (continuation, losses, promotions, and training)

The model's output is a series of End of Fiscal Year projection reports that are used by the personnel manager. Reports are projections by job type of end of fiscal year inventory, accessions, and the number of personnel to train for advanced jobs.

Assumptions used in the model are company-specific; however, the model explained here and in the Warrant Officer Corps example given are based on the following assumptions.

1. There will be a need for job-specific technicians/skills in the future
2. Improvements in training and utilization can be achieved
3. Constrained resources are a factor
4. It is desirable to improve the capability of the work force
5. Hiring and training practices follow government guidelines, e.g. gender, minority, or handicap anti-discrimination policies
6. The company has a uniform promotion system

As is usually the case with mathematical modeling, for a specific case, modifications to assumptions may be necessary. Utilizing these assumptions, the model allows the personnel manager to incorporate personnel requirements into the company's strategic plans. In turn, clearly defined goals for facility and personnel improvements can be addressed in a manner that ensures overall fairness to the employee and the company.

2.5 Benefits Derived from the Model

Strength management of personnel is the first application to ensure a stable work force. Optimization of the model allows the personnel manager to have steady state accessions and training programs. Optimization and sensitivity analysis of the model given all constraints allows for detailed analysis and develops analytical values to predict changes and trends during the year. These trends, if unacceptable to management, allow the personnel managers to intercede at the right place and time. An example could be when personnel from a particular job skill are leaving the work force at a rate higher than average.

These tools, when combined with the company's strategic plan, ensure fairness and understanding. As stated in Chapter One, all personnel are affected by this model. Equity is ensured since marginal performers, who exist in every organization, can be eliminated by non-promotion or left in a lower grade by their non-selection for advanced training or promotion.

These rules are easily modeled and provide the incentive for workers to work harder to achieve promotions and advanced training. The work force will eventually achieve steady state characteristics. For example steady state ensures there are no senior grade level over-strengths in the future. If the senior level population gets too large and voluntarily decides to retire, the larger number of retiring individuals cannot be replaced by the existing pool of mid-career personnel.

The steady state accession and aging model has been developed to meet the total personnel requirements for a company. Given the protective mechanisms and constraints from external and internal sources we have the tools to shape the work force. Shaping is done by grade level and job skill, and is requirements-based in order to build a competitive population and meet future needs. Using this model we can manage the work force quantitatively based on known and projected requirements.

Chapter 3

Fundamental Principles of the Model

In developing an algorithm to solve the problem presented in this dissertation, Banks and Carson's steps of a simulation study[18] and Winston's simulation process[19]. Listed below are the four phases that were followed:

1. Problem formulation and setting of objective and overall design;
2. Model building, data collection, coding, verification, and validation;
3. Experimental design, production runs and analysis, and additional runs; and
4. Documentation of program and implementation.

These phases allowed for a methodical and systematic means to quantify the problem.

3.1 Customer Satisfaction

For any model or application to be successful it must first satisfy the needs of three very different groups of people: top level managers who give guidance and direction, mid-level managers who will implement the model, and operations research analysts who will design and analyze the

[18] Banks, Jerry and Carson, John S. II. 1984. Discrete-Event System Simulation. Englewood Cliffs, New Jersey 07632: Prentice-Hall, Inc.
[19] Winston, Wayne L. 1987. Operation Research: Applications and Algorithms. Boston, Massachusetts 02116: Prindle, Weber & Schmidt Publishers.

specific model. All are concerned with the validity of the concept and application to current projects and practices. Each of the three groups will want something different from the modeling project. Top level management will be interested in the long term planning capability of the model. Mid-level managers are searching for specific information and recommendations that they can implement. Finally, the operations research analyst will need new and improved ways to look at modeling issues to enhance their research efforts.

The three groups differ in their knowledge of the material and in their basis of perception. Top management will be familiar with the concept but will want to know how the concepts are related and if the model will work in practice. Mid-level managers will have to be convinced that the top level managers are supportive while the operations research analysts must be satisfied that the model is valid.

3.2 Systems View of the Model

The operations research analyst, working with the personnel manager, is the key to the successful implementation of the model. Also important are top management's support and the personnel managers' thorough understanding of the concepts behind the model. The personnel managers' needs can be addressed in the model by allowing them the flexibility to adjust the model as the company's situation changes. For example, the personnel manager can adjust the budgeted end strength (maximum number of persons working at the end of a fiscal year) in the out years as the company adjusts to the market demands for products or new equipment. These changes allow the personnel manager to begin adjusting personnel accession plans and training programs. Each year the personnel manager will work with the operations research analyst to develop enhancements to the model based on the previous year's experience. The analyst will also change annual rates and verify the integrity of the model to ensure the model is doing what it is supposed to do. This also allows for software upgrades and product enhancements.

Data inputs to the model can come from many different sources, such as a mainframe, a mini-computer, or paper records. Since any system is made up of inter-related processes; the only difference between companies is in resources available. Computer modernization has allowed users of the personal computer to take advantage of highly complex models and exploit recent technology developments in spreadsheets and relational data bases. Recent improvements in software and computing include optimization, linear and non-linear modeling, advanced mathematical simulation, and probability and statistics.

Optimization of personnel accessions is key to the success of a personnel manager. The analyst, after working closely with the personnel manager, can then start to decide what is essential, what will be done in-house, and what will be done by outside sources. At all times the personnel manager should be involved in the model's development since the personnel manager is the one who will use it and make decisions based on the model's output. This allows top management to integrate outside resources tightly with the rest of the system. The personnel manager's participation in development allows for continuous improvement of the model. Since decisions are being made by the personnel who have knowledge of the overall system, the model has the potential to influence the personnel process at its earliest stages.

By maximizing each person's potential and capabilities, responsibility and accountability have been given to the people whose decisions may be made in a timely and efficient manner.

3.3 Validity and Usefulness of the Model

The validity of the model can be determined by checking whether the current personnel system is accurately represented. This is achieved through comparisons with older models and new insights gained from attempts to improve the older model. The usefulness of the new model is determined by each level of management. Management will want to see if there is anything new to learn and if there is anything that can be applied to their own organization. Some involved will be critical of the new approach taken since they may not realize the capabilities of recent enhancements of software and hardware. Others will be afraid of change, but with top level management's support and a concrete example of a successful application of the models concept, many of these fears will dissipate.

To support the validity of the specific example of the model described in this dissertation, three areas are closely examined.

1. Does the concept meet the common sense test?
2. Can the concept be extended and used in real world applications?
3. Can current software and hardware replace older customized programs[20]?

This dissertation answers all three questions in the affirmative. The general model illustrated in Chapter 4 and the specific example for the U.S. Army Warrant Officer Corps in Chapter 5 are verification and validation of the concept and its architecture.

3.4 Architecture of the Model

The model developed is actually a series of programs that produce personnel management information for top level management and personnel managers. In its current form it consists of six basic components.

1. Inventory
2. Authorizations
3. Budgeted End Strength (BES)
4. Accessions Optimization
5. Aging

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[20] Holtz, Betty. 1980. Interfaces. (December): 37.

6. End of Fiscal Year Outputs

Inventory and personnel loss files are extracted from a database and used to calculate the statistics of continuation rates (CRATE) and training, transient, holding and student rates (TTHS). CRATE and TTHS rates are used later for the aging process. They are calculated as a weighted moving average of historical data determined from the last three years and exponentially smoothed. Trends are relatively short, usually only lasting five to seven years, so this technique has demonstrated to be the best for calculating rates.

Authorizations are determined by top level managers working with the personnel manager and company modernization personnel. Jobs are defined by using the previous year's personnel projections and incorporating known and planned changes to the company's capabilities. The base authorizations used should project out 5 to 8 years and capture any changes planned in the strategic planning document.

Budgeted end strength (BES) is a calculation of the inventory and authorizations components of the model. This number is the total demand by job skill and grade required for each year in the projection model. The total number of authorizations represents the amount of personnel in training and personnel required to operate the company. The BES actually is the ideal distribution of personnel by job skill and grade.

The accession component of the model is the key to development of the ideal state of accessions required to sustain job skills by grade over time. It incorporates all functions of the model and, through the optimization program, develops the steady state optimal number of personnel to access by year over the entire projection period. The term steady state is used loosely but to the personnel education system the intent is to have a uniform number of students for each class. Since the model cannot determine if the accession job skills are over or under represented, the analyst, with the personnel manager, must ensure that the authorization component represents the actual demand for personnel needed. The sensitivity analysis tool of the model allows the analyst to apply different statistical approaches for different scenarios. The aging model does the actual year accession plan and then projects, by default, the steady state accession plan for the out years.

The aging component of the model projects the personnel inventory by job skill and grade over a five year period. The aging procedure incorporates those aspects of the personnel system required for the end of fiscal year projections. The model incorporates CRATE and TTHS rates, promotion rates and opportunities, accessions, job migrations, authorizations, and budgeted end strength against a starting personnel inventory. It produces projected annual losses, operating strength, training strength, migrations, and total inventory by grade and job skill.

The model produces output that captures the information required by the personnel manager. Areas of the forecast projection output by job skill and grade are authorizations, inventory, budgeted end strength, the difference between BES and authorizations, adjusted BES, and calculated BES. Also, in other areas of the model are loss rates, accession plans for the execution year and forecast years. Specific skill categories can be included as in the Warrant Officer case study with the Aircraft Qualification Course (AQC) seats. The model can use either an optimized transition matrix or one that is directed by management. An example of a directed transition matrix would be one limited by aircraft flight time available or by aircraft available. This is specific to the Army model; however, the same principle can be applied to any industry where employees change jobs.

3.5 Personnel Requirements into Personnel Goals

The premise of this model is that each of the components can be captured and statistically evaluated by the Monte Carlo probability technique or some other method. The projections are only as good as the information gathered from available data. Uncertainty in each variable can not be captured if changes occur outside the analyst's area of influence or knowledge. Sensitivity analysis can determine which variables are key and simulations can demonstrate the impact of changes to the inventory over a period of time.

Attrition and accessions are key variables that impact the model greater than any other variables. To compensate for these changes to the projection, the analyst, with top management and the personnel manager, can influence the outcome through several other programs.

Some areas that can be influenced by company policy are promotion rates, job retraining programs, and retirements.

Another area is drawdown goals which target specific job skills for reduction or elimination. To effectively manage and shape the workforce, the entire population is measured by job skill and BES allocation. The projections gained from the model allow personnel managers to quickly identify overages and adjust the optimized accessions component of the model. Unexpected reductions, such as unforecasted elimination of a particular job skill or unexpected closing of a department, can be handled by the model if identified early in the analytical process. Adjustments can be made by transitioning personnel affected into new jobs through retraining or job reclassification. Other options available to personnel managers include mandatory retirements, early retirements, contract buyouts, or as a last resort, layoffs.

3.6 Organizational Operation

Reductions must be handled efficiently and with the knowledge that their mishandling may cause problems as discussed in Chapters 1 and 2. Everyone must be considered in a drawdown to ensure equity and that the shape of the force doesn't deviate from the aging plan. An example of reduction mishandling would be the situation where many senior employees are asked to retire and there are insufficient younger personnel qualified to replace those who leave.

Aging the personnel inventory is difficult to accomplish due to dynamic times and situations. Government regulations and an ever changing marketplace cause problems that are difficult at best to model. Constraints tied with management's strategic plan allow this model to provide a tool that will affect and age the work force. This model projects and promotes personnel to meet future needs, not only by specific job skills but also by grade and years at the company.

Past policies, continuation rates, promotions, and TTHS rates determine the shape of the current inventory. This model works with this inventory both during times of calm and when changes are dynamic. The optimization of accessions and the management of authorizations based on earlier projections give the personnel manager information necessary to develop a valid work force aging model to meet the needs of the organization.

3.7 Non-Linear Optimization

Non-linear optimization is a mathematical technique that selects the best course of action to form a set of feasible solutions. The problem is illustrated in the following way. Optimize the objective function by minimizing or maximizing a non-linear function of the independent variable and decision variable, subject to a series of constraints involving the individual variable. The dependent variable is the objective function and involves the economic concept of the minimum or maximum for a value. See figure 3.1 for the general form of the flowchart. The general equation of this problem is represented below.

Minimize:

$$\left[\sum_{i=1}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{previous inventory})_{j,k}(\text{CRATE})^{i} + (\text{accessions})_{i,j,k}\right]\right]\right]\right] +$$

$$\left[\sum_{i=1}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{promotion eligible})_{j,k}(\text{CRATE})^{i}\right]\right]\right]\right] -$$

$$\left[\sum_{i=1}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{not promotion eligible})_{j,k}(\text{CRATE})^{i}\right]\right]\right]\right] +$$

$$\left[\sum_{i=1}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{transition gains})_{i,j,k}\right]\right]\right]\right] -$$

$$\left[\sum_{i=1}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{transition losses})_{i,j,k}\right]\right]\right]\right].$$

Subject to:

$$\left[\sum_{i=5}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{previous inventory})_{j,k}(\text{CRATE})^{i} + (\text{accessions})_{i,j,k}\right]\right]\right]\right] -$$

$$\left[\sum_{i=5}^{x}\left[\sum_{j=1}^{y}\left[\sum_{k=1}^{z}\left[(\text{Authorizations})_{j,k}(1 + \text{TTHS rate})^{i}\right]\right]\right]\right] \leq 0.$$

all variables are nonnegative

i = years

j = grade

k = job skill

x = maximum number of years

y = maximum number of grades

z = maximum number of job skills

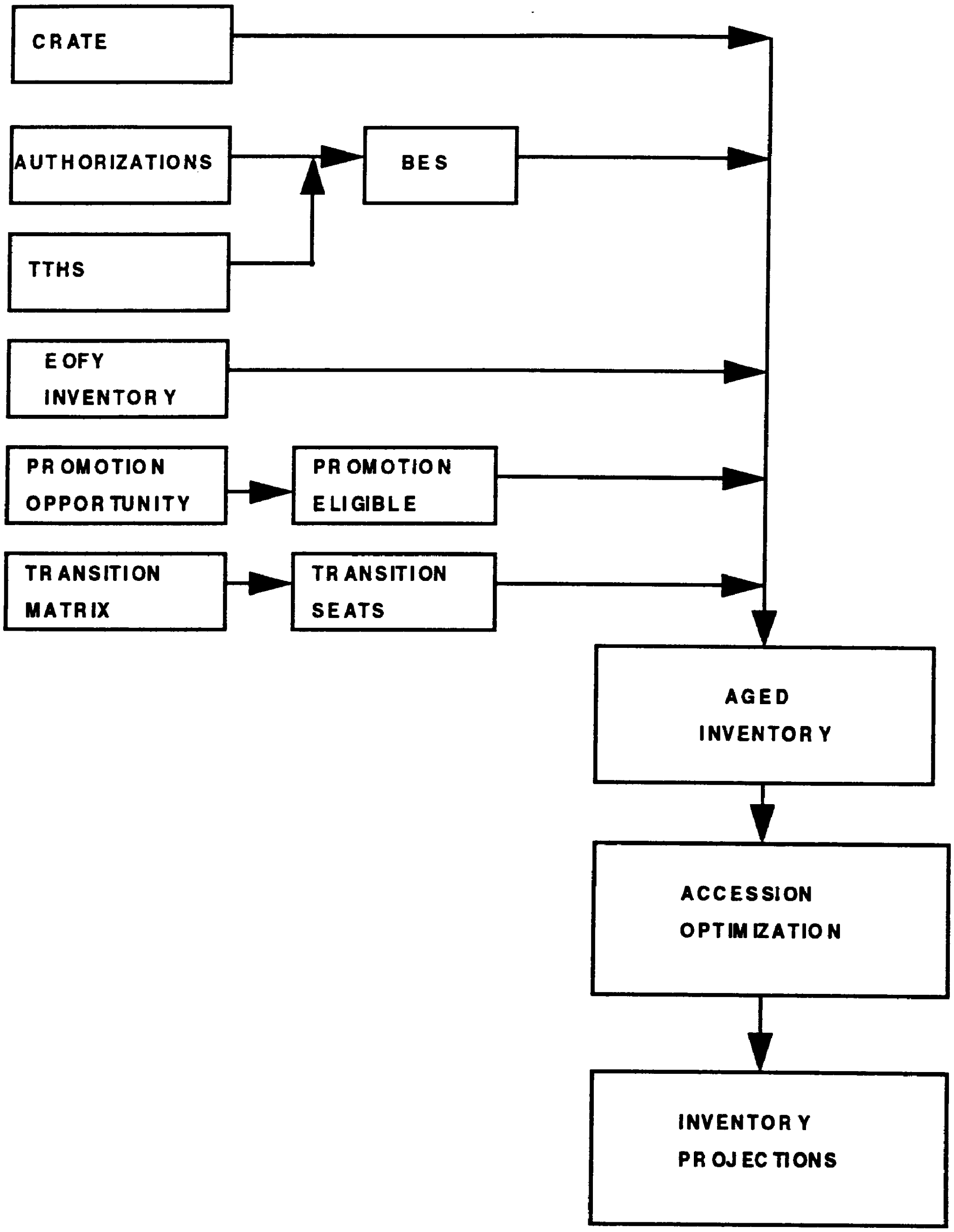
CRATE
AUTHORIZATIONS
BES
TTHS
EOFY INVENTORY
PROMOTION OPPORTUNITY
PROMOTION ELIGIBLE
TRANSITION MATRIX
TRANSITION SEATS
AGED INVENTORY
ACCESSION OPTIMIZATION
INVENTORY PROJECTIONS

Figure 3.1

The best general algorithm for using iterative linearization is the General Reduced Gradient (GRG) method[21]. The GRG algorithm is an extension of the Wolfe algorithm for linear constraints, modified for a non-linear objective function and non-linear constraints. This method uses linear or linearized constraints, defines new variables normal to the constraints and expresses the gradient in terms of the normal basis. In simplified form, general case, the problem solved by the GRG method.

Minimize:	$f(\mathbf{x})$	$\mathbf{x}=(x_1,x_2,\ldots,x_n)^T$
subject to:	$h(\mathbf{x})=0$	$j=1,\ldots,n$
	$L_i \leq x_i \leq U_i$	$i=1,\ldots,m.$

L_i (lower bound) and U_i (upper bound) restrict x_i. The L_i and U_i are treated as inequality constraints because of the technique used to calculate step length and direction of search. Non-linear constraints are taken care of by slack variables, $h_j(x) = g_{jj}(x) - \sigma_j^2 = 0$ and letting the bounds range from $-\infty \leq \sigma_j \leq +\infty$.

Unique to this problem is changing the objective function to zero. The objective function (the dependent variable) is represented in the general formula as (aggregate budgeted end strength)-(aggregate projected strength). Decision variables (independent variables) are represented as (accession by PMOS by year). Finally, the constraints are the (end of fiscal year 1998 projected inventory)-(end of fiscal year

---

[21] Developed by Leon Lasdon, University of Texas at Austin and Alex Warren, Cleveland State University.

budgeted end strength by PMOS by year by grade) ≤ 0, that is the objective function should be less than or equal to zero. The inherent difficulty of this problem lies in the large data sets, number of calculations to perform, and limitations of hardware and software.

Utilizing the Generalized Reduced Gradient[22] method and the Excel 5.0 spreadsheet, the analyst can determine the optimal number of people to access during the execution year (next fiscal year) and each of the projected years. The analyst, when the optimization routine is completed, will have the optimal accession plan and projected inventories to give to the personnel manager.

The gradient algorithm, where the gradient search procedure is modified to keep the search path from penetrating any constraint boundary, is used for this problem. Using the steps of the Generalized Reduced Gradient Algorithm found in Himmelblau's book[23], the optimization process is outlined in its general form. For all iterations it is assumed that $\left[\frac{\partial\ h(x)}{\partial\ x_D}\right]$ is non-singular. For notation purposes, $f(x^k) = f^k$ and $h(x^k) = h^k$, where the superscript k denotes the iteration.

---

[22] Lasdon, L.S. and Warren, A.D., H.G. Greenberg. 1978. Generalized Reduced Gradient Software for Linearly and Nonlinearly Constrained Problems,. Design and Implementation of Optimization Software, Sijthoff an Noordhof, Alphem aan den Rijn, The Netherlands.

[23] Edgar, T.F. and Himmelblau, D.M. 1988. Chemical Engineering Series, Optimization of Chemical Processes; McGraw-Hill Book Company, United States: 327.

Phase I:

Determine the search components for the independent variables. At iteration k linearize the constraint at the feasible point x^k and compute the reduced gradient. The subscripts D and I indicate the dependent and independent variables.

$$(g_R^k)^T = \left[\frac{\partial f^k}{\partial x_I^k}\right]^T - \left[\frac{\partial f^k}{\partial x_D^k}\right]^T \left[\frac{\partial h^k}{\partial x_D^k}\right]^{-1} \left[\frac{\partial h^k}{\partial x_I^k}\right]$$

The search directions of the independent variables are established from the reduced gradient g_{Ri} as follows:

a. If x_i is at one of its bounds, the search direction component is Δ_i^k=0; if the step exceeds its bound, that is

$$\Delta_i^k=0 \qquad \text{if } x_i^k=U_i \quad g_{Ri}<0$$

$$\Delta_i^k=0 \qquad \text{if } x_i^k=L_i \quad g_{Ri}>0$$

b. If $L_i < x_i < U_i$, the search direction is the negative of the corresponding element of the reduced element of the reduced gradient, $\Delta_i^k=-g_{Ri}$.

Phase II:

Determine the search components for the dependent variables to $\tilde{x}_D$maintain feasibility with respect to the linearized constraints.

$$\Delta_D^K = -\left[\frac{\partial \mathrm{h}^k}{\partial \mathrm{x}_D}\right]^{-1} \left[\frac{\partial \mathrm{h}^k}{\partial \mathrm{x}_I}\right] \Delta_I^K$$

Phase III:

Improve the value of the objective function. Minimize $f(x_I^k + \lambda^k \Delta_I^k, x_D^k + \lambda^k \Delta_D^k)$ with respect to $\lambda(\lambda > 0)$ using the quasi-Newton unidirectional search. Lambda (λ) must be carefully chosen so as to limit the magnitude of λ^k since this can lead to an infeasible point.

$$x_I^{k+1} = x_I^k + \lambda^k \Delta_I^k$$
$$\tilde{x}_D^{k+1} = x_D^k + \lambda^k \Delta_D^k$$
where $\tilde{x}_D$ is a tentative point.

Phase IV:

Use the quasi-Newton method to regain feasibility of the dependent variable. If some of the points of the objective function are infeasible, Newton's method will return from the infeasible point to one that will satisfy all of the constraints. Several iterations may be necessary to regain feasibility. Newton's method is

$$x_D^{k+1} = \tilde{x}_D^{k+1} - \left[\frac{\partial\ h(x_I^{k+1}, x_D^{k+1})}{\partial\ x_D^k}\right]^{-1} \partial\ h(x_I^{k+1}, \tilde{x}_D^{k+1})$$

Phase V:

Convergence on Newton's method has four possible outcomes.

1. x^{k+1} is feasible and $f(x_I^{k+1}, x_D^{k+1}) < f(x_I^k, x_D^k)$, adopt x^{k+1} and return to phase I.

2. x^{k+1} is feasible but $f(x_I^{k+1}, x_D^{k+1}) > f(x_I^k, x_D^k)$, reduce λ and return to phase IV. If after twenty iterations Newton's method fails, reduce λ, and start phase IV again.
3. If the three aforementioned strategies fail, change the basis by exchanging
   the dependent variable with a former independent variable.
4. When x_i hits a bound it is removed from the basis, takes the boundary value, and is replaced by a value from the set x_D. A new iteration takes place.

Similar to other commercial codes, stopping criteria fall into one of four categories. They are maximum time, maximum number of iterations, precision, and tolerance. Affecting each of the stopping criteria is the speed of the machine, operation in a multitasking environment, and settings of interim results. To improve speed of solution, the computer should have complete control of the working environment. Turning off screen savers or not printing will improve performance.

Chapter 4
The General Model

4.1 Model Focus

This model has been developed to accurately access and project a company's personnel inventory out to six years. Projections can be made further out, if necessary, but for this example seven years is sufficient. The focus of this model is to ensure a qualified workforce, even when a company's charter involves minimizing the number of personnel needed to do required jobs. For the general model, relationships will be drawn from the specific model illustrated in Chapter 5 to lend clarity.

4.2 Evaluation Criteria

Evaluation criteria used in the example in Chapter 5 must demonstrate that it can correctly access a personnel inventory and provide sufficient information to manage an organizations personnel population.

4.3 Issues Relating to the Model

In developing this model, certain assumptions had to be made. These assumptions were developed through discussions with personnel experts, working as an analyst for the Warrant Officer Corps of the U.S. Army, and by reviewing existing regulations and policies that are discussed in Chapter 2. In developing the model, certain issues were discussed that significantly influence its design. Issues are presented in no specific order.

1. Impact on the organizations personnel system.
2. Accuracy of information.
3. Cost of using this model.
4. Automation of model.
5. Minimize personnel inventory to the organizations desired end strength.

4.4 Steps of the Model

Listed below are the steps used to develop and execute the aging component of the model.

Step 1: Gathering Data and Other Information. The analysts must develop techniques that will allow gaining the information needed to develop and operate their unique models. The recommended technique is to work as an assistant and analyst to the personnel manager. When an analyst has gained sufficient insight to work independently, then the analyst is able to begin gathering information to develop the model. The cost of learning how to do someone else's job is high but the penalty for the mal-utilization of resources is much higher. For the personnel model, in the general and specific case, these variables are important contributors.

<u>Input Variables</u>

1. Continuation Rate. The continuation rate (CRATE) is the percentage of people who stay with an organization from year to year. The technique of a three year moving average is used to calculate the CRATE for each fiscal year. To extract the data from the mainframe computer used at PERSCOM the SAS programming language was used. Below is an example of the code to calculate the CRATE from FY 1992 to FY 1993. The code is left in its raw form to illustrate the technique used.

```
//ALKVXSL3 JOB (ZLP2P413,6N61),'ZLP2P413/BATEMAN' CLASS=X,MSGCLASS=Y
//* THIS IS AN INFORMATION PULLING ROUTINE FOR CONTINUATION RATES
//* OF WARRANT OFFICERS
//*
//  EXEC SAS, OPTIONS='LS=132 NOCENTER NONEWS PS=58'
//WORK   DD SPACE=(CYL,(50,40),,,ROUND)
//*
//START  DD DSN=XXXXXX.XXX.XXXXXXX.ME9209.BACKUP,DISP=SHR
//NEXTY  DD DSN=XXXXXX.XXX.XXXXXXX.ME9309.BACKUP,DISP=SHR
//SYSIN  DD *
//   DATA ONE;
//   INFILE START;

     INPUT RSCD $ 2646        MPC $ 10
           TGRC $ 42          AFS   119-121
            SSN $ 1-9        NAME $ 11-26
           PMOS $ 341-344    EADC $ 96-99
           AFCS $ 122-124;

         IF RSCD = '0' AND MPC = 'W';
         YOS = INT(AFS/12)+1;
         IF YOS >= 30 THEN YOS = 30;
         KEEP SSN;
         DATA TWO;
          INFILE NEXTY;

               RSCD $ 2646           MPC $ 10             AFS 119-121
               PMOS $ 341-344        EADC $ 96-99         AFCS 122-124
               TGRC $ 42             SSN $ 1-9;

         IF RSCD = 'O' AND MPC = 'W';

         YOS = INT(AFS/12) + 1;
         IF YOS >= 30 THEN YOS = 30;
```

```

DATA MERGE;
MERGE ONE(IN=A) TWO(IN=B);
BY SSN;
IF A;
LOST = 0;
SURVIVED = 1;
IF A AND NOT B THEN DO;
        LOST = 1;
        SURVIVED = 0;
END;

PROC TABULATE F=5. MISSING NOSEPS;
        CLASS PMOS TGRC YOS;
        VAR LOST SURVIVED;
        LABEL PMOS ALL= 'AGGREGARE'. YOS = 'YOS' ALL='TOTAL'. TGRC=' '*
        (ALL ='INV'*N=' ' LOST*SUM=' ' SURVIVED*MEAN=' '*F=7.4)
        ALL='TOTAL'*
        (ALL ='INV'*N=' ' LOST*SUM=' ' SURVIVED*MEAN=' '*F=7.4) / RTS=10 PRINTMISS;

TITLE 'CONTINUATION RATES FY 93';
```

To calculate the three year moving average, a SAS run is done for each fiscal year (91-93). Using a SAS program similar to the one above, develop a table of the three year moving average for each grade and primary military occupational specialty (PMOS). Once created the resulting CRATE is used to age the inventory.

2. Transient, Training, Holdee, and Student Rate. The Transient, Training, Holdee, and Student Rate (TTHS) is the percentage of personnel, by grade and job skill (PMOS), who at any time during a year are in a TTHS account. These accounts are PMOS's 001A, 002A, 003A, and 004A. The same technique used in the CRATE calculations are also used to count the TTHS rate. Listed below is the SAS code used to calculate the TTHS rate from FY '92 to FY '93. The code is left in its raw form and shows the technique used.

```
//ALKVXSL7 JOB (ZLP2P413,6N61),'ZLP2P413/BATEMAN' CLASS=X,MSGCLASS=Y
//* THIS IS AN INFORMATION PULLING ROUTINE FOR TTHS RATES
//* OF WARRANT OFFICERS
//*
// EXEC SAS, OPTIONS='LS=132 NOCENTER NONEWS PS=58'
//WORK   DD SPACE=(CYL,(50,40),,,ROUND)
//*
//START  DD DSN=XXXXXX.XXX.XXXXXXX.ME9209.BACKUP,DISP=SHR
//NEXTY  DD DSN=XXXXXX.XXX.XXXXXXX.ME9309.BACKUP,DISP=SHR
//SYSIN  DD *
//    DATA ONE;
//    INFILE START;
      INPUT RSCD $ 2646          MPC $ 10
            TGRC $ 42            AFS     119-121
            SSN $ 1-9            NAME $ 11-26
            PMOS $ 341-344       EADC $ 96-99
            AFCS $ 122-124       CT4CMF $ 3016-3019;
            IF RSCD = '0' AND MPC = 'W';
            KEEP SSN;
            DATA TWO;
                 INFILE NEXTY;
                 RSCD $ 2646          MPC $ 10          AFS 119-121
                 PMOS $ 341-344       EADC $ 96-99      AFCS 122-124
                 TGRC $ 42            SSN $ 1-9;
            IF RSCD = 'O' AND MPC = 'W';
            SCHOOL = 'NOT TTHS';
            IF PMOS IN ('001A' '002A' '003A' '004A') OR
            CT4CMF IN ('001A' '002A' '003A' '004A') THEN SCHOOL = 'TTHS    ';
            DATA MERGE;
            MERGE ONE(IN=A) TWO(IN=B);
            BY SSN;
            IF A;
            LOST = 0;
            SURVIVED = 1;
            IF A AND NOT B THEN DO;
                 LOST = 1;
                 SURVIVED = 0;
            END;
            PROC TABULATE F=5. MISSING NOSEPS;
                 CLASS PMOS TGRC SHCOOL;
                 VAR LAST SURVIVED;
                 LABEL SCHOOL ALL= 'AGGREGARE', YOS = 'YOS' ALL='TOTAL', TGRC=' '*
                 (ALL ='INV'*N=' ' LOST*SUM=' ' SURVIVED*MEAN=' '*F=7.4)
                 ALL='TOTAL'*
                 (ALL ='INV'*N=' ' LOST*SUM=' ' SURVIVED*MEAN=' '*F=7.4) / RTS=10 PRINTMISS;
```

```
TITLE 'TTHS RATES FY 93';
```

To calculate the three year moving average for the TTHS rate, a SAS run is done for each fiscal year (91-93). Using a SAS program similar to the one above, a table of the three year moving average is created for each grade and job skill (PMOS).

Another technique will be used when the drawdown is nearing conclusion, the moving weighted average of the last two observations, with alpha (α) being the weighting factor[24]. The advantage of this technique is that the data will be more descriptive of the time series since the other model is more representative of the past.

New forecast = α(current observation)+(1-α)(last forecast).

3. Authorizations. Authorizations for personnel is done by year and reflect the overall job skill (PMOS) distribution of the inventory. The aggregate accession number is directed by Congress and is fixed, but the Department of the Army has the flexibility to adjust the distribution between Commissioned Officers, Warrant Officers, and Enlisted personnel. Listed is an example from FY '95 showing the distribution of personnel by grade and PMOS.

---

[24] Nahmias, Stephan. 1989. Production and Operations Analysis. Homewood, Ill.: Irwin: 54.

PMOS	W1/C2	CW3	M/C4	CW5	total
000A	0	0	0	0	0
001A	0	0	0	0	0
003A	0	0	0	0	0
004A	0	0	0	0	0
130A	0	0	0	0	0
130B	0	0	0	0	0
131A	65	27	15	4	111
132A	0	0	0	0	0
140A	11	4	2	1	18
140B	33	14	8	2	57
140D	6	3	1	0	11
140E	73	31	17	4	125
151A	116	49	27	7	199
152B/3C	233	99	53	14	399
152C	41	17	9	2	70
152D	176	74	40	10	301

4. Budgeted End Strength. Budgeted End Strength (BES) is the total number of personnel authorized by Congress to be on active duty at the end of each fiscal year. The company would refer to this as the desired end strength determined by management. The BES is represented as the aggregate number that is authorized. Thus 11,410 Warrant Officers are authorized for 1998.

EOFY	94	95	96	97	98
BES	12,477	12,001	11,524	11,410	11,410

For this model, budgeted end strength is used to calculate the distribution of personnel by grade and PMOS. Authorizations are distributed by PMOS and then multiplied by one plus the TTHS rate to distribute personnel by PMOS and grade. This calculation ensures that there are sufficient total personnel in training and working in their jobs. An example of this is illustrated as the FY '94 Projected End Strength of the grades WO1 and CW2 by PMOS. The "Auth" column is the authorized number of personnel, the "Inventory" column is the projected inventory of officers, "BES" is the authorizations multiplied by 1+TTHS rate (by PMOS and grade), and the "diff" column is the difference of the BES and Inventory columns. This overage of personnel, represented by the parentheses, and shortage of personnel is the PMOS imbalance that the analyst is attempting to minimize.

PROJECTED INVENTORY AS OF EOFY 94				
W O1/CW 2				
PMOS	Auth	Inventory	BES	diff
000A	0	61	0	(61)
001A	0	4	0	(4)
003A	0	6	0	(6)
004A	0	1	0	(1)
130A	0	0	0	0
130B	0	0	0	0
131A	52	68	56	(13)
132A	0	0	0	0
140A	11	9	12	3
140B	37	44	41	(3)
140D	16	6	18	12
140E	73	79	78	(1)
151A	125	131	131	1
152B /153	251	472	302	(170)
152C	39	12	43	31
152D	129	204	149	(55)

5. EOFY Inventory. The end of fiscal year inventory is used as the basis of the aging and accession process of this model. The data are extracted from each of the EOFY tapes. The SAS programming language is used to extract the data from the mainframe database. Those personnel who will continue into the next fiscal year are determined by in the program shown below.

```
//ALKVXSL6 JOB (ZLP2P413,6N61),'ZLP2P413/BATEMAN',CLASS=X,MSGCLASS=Y
//JS010  EXEC SAS,OPTIONS='NOCENTER NONEWS PS=58 LS=132'
//*  THIS PROGRAM IS FOR COUNTING THE WARRANT OFFICER POPULATION
//*  CURRENT PULL: RAWOMF DD DSN=PPAZDP.UMV.ZDP65D7,DISP=SHR
//*  HISTORICAL PULL: RAWOMF  DD DSN=PPAZDP.UMS.ZDP65T7.ME9310,DISP=SHR //*
//*
//WORK    DD SPACE=(CYL,(50,40),,,ROUND)
//RAWOMF  DD DSN=xxxxxx.xxx.xxxxxxx.ME9310,DISP=SHR
//*RAWOMF  DD DSN=xxxxxx.xxx.xxxxxxx,DISP=SHR
//SYSIN   DD *
```

```
DATA VER;
        INFILE RAWOMF;
        INPUT        RSCD $ 2646              MPC $ 10            CT5 $ 3016-3019
                     CT5CMF  $ 3016-3020      TGRC $ 42           AFCS $ 122-124
                     CONGR $ 3576-3577        SSN $ 1-9           TGPGC $ 325
                     TGRSEL  $ 137            SEX $ 501           REDCAT $ 301
                     AFS  119-121             COMPT $ 77          MEL $ 398
                     PMOS  $ 341-344          EADC $ 96-99        OPP $ 318
                     ORCMD  $ 858-859         AREQID $ 2829-2830
                     ORDTGC $ 3119-3124   OCMD $ 871-872      ORIARC $ 860-861;
IF MPC = 'W' AND RSCD = '0';
IF AREQID = 'RR' AND ORDTGC <= 930930 THEN DELETE;
YOS = INT(AFS/12) + 1 ;

IF PMOS < '130 ' OR PMOS > '922A' THEN PMOS = CT5;
IF CT5 < '001A' OR CT5 > '922A' THEN CT5 = '001A';
/*IF CT5CMF < '130  ' OR CT5CMF > '923A ' THEN CT5CMF = 'PMOS';
IF CT5CMF <= '001A' THEN CT5CMF = '001A';
IF SUBSTR(CT5CMF,5,1) = ' ' THEN SUBSTR(CT5CMF,5,1) = ';  */

GRADE = 'XXX
IF TGRC IN ('X' 'W') THEN GRADE = 'CW1/CW2';
IF TGRC = 'V' THEN GRADE = 'CW3    ';
IF TGRC = 'U' THEN GRADE = 'CW4    ';
IF TGRC IN ('S' 'T') THEN GRADE = 'CW5    ';

GRADEP = 'XXX           ';
IF TGPGC IN ('X' 'W') THEN GRADEP = 'CW1/CW2'; IF TGPGC = 'V' THEN GRADEP = 'CW3    ';
IF TGPGC = 'U' THEN GRADEP = 'CW4    ';
IF TGPGC IN ('S' 'T') THEN GRADEP = 'CW5    ';

GRD = 'XXX    ';
IF TGRC IN ('X' 'W') THEN GRD = 'CW1/CW2';

 IF TGRC IN ('U' 'V') THEN GRD = 'CW3/CW4';

IF TGRC IN ('S' 'T') THEN GRD = 'CW5    ';

PROC FREQ;
        TABLE PMOS TGRC TGPGC GRADE GRADEP SEX REDCAT;
PROC TABULATE DATA=VER F=8. NOSEPS;
        CLASS PMOS TGRC;
        TABLE PMOS ALL, TGRC ALL / RTS=12;
        TITLE 'PMOS BY PERMANENT GRADE';

PROC TABULATE DATA=VER F=8. NOSEPS;
CLASS PMOS TGPGC;
TABLE PMOS ALL, TGPGC ALL / RTS=12;

TITLE 'PMOS BY PROMOTABLE GRADE';

PROC TABULATE DATA=VER F=8. NOSEPS;
CLASS PMOS GRADE;
TABLE PMOS ALL, GRADE ALL / RTS=12; TITLE 'PMOS BY PERMANENT GRADE';
PROC TABULATE DATA=VER F=8. NOSEPS;
CLASS PMOS GRADEP;
```

```
TABLE PMOS ALL, GRADEP ALL / RTS=12; TITLE 'PMOS BY PROMOTALBE GRADE';

/* PROC TABULATE DATA=VER F=8. NOSEPS;
CLASS CT5CMF GRD;
TABLE CT5CMF ALL, GRD ALL / RTS=12;
TITLE 'CT5CMF BY PERMANENT GRADE FOR ODP USE';

/*
//
```

6. Promotion Opportunity. Promotion opportunity is a numerical probability that an individual will be selected for advancement to the next grade. The arithmetic mean, of the entire population, is defined by a set of measured responses $y_1, y_2, \ldots, y_n$ and is given by

$$\bar{y} = \frac{1}{n}\sum_{i=1} y_i .$$

Historically, the selection rate has a mean near the directed selection rate, such as promotion to CW3 is 80%, with a very low variance. The variance of the selection rate is calculated by a set of measurements $y_1, y_2, \ldots, y_n$ using the average of the square of the deviations of the measurements about their mean. The variance is represented by

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2 .$$

Statistical values of selection rates at the aggregate level are less important and have been held to within 1% of the promotion board's goal. To analyze the selection rates of subsets of the aggregate population the above statistical technique must be used. An example of this is analysis of selection rates of African American or Female Warrant Officers when compared to other subsets of the personnel population. To measure the difference of each of these subsets, assume that the distributions are normal and the standard deviation is the positive square root of the variance, $\delta' = \sqrt{\delta'^2}$. The analysis of gender or racial distributions are not used in this example but can be included later.

An analysis of variance test can be conducted on randomly selected variables of each of the subsets of the population. The populations are assumed to be normally distributed with equal variances δ^2 and means $\mu_1, \mu_2, \ldots, \mu_k$. Exact parameters can be calculated using the entire population but access to a software program such as SAS/STAT and a mainframe may be necessary.

7. Promotion Eligible. To find the promotion eligible population the analyst must isolate that population that fits certain parameters for promotion. Dates of rank are determined for the zone of consideration. The SAS program below illustrates the technique used to calculate the number of personnel eligible at the EOFY '93.

```
//ALKVXSL8 JOB (ZLP2P413,6N69),'ZLP2P413/BATEMAN',CLASS=O,MSGCLASS=Y
//*  THIS IS AN INFORMATION PULLING ROUTINE FOR WO PROMOTION ELIGIBILITY
//*  BY RANK AND MOS FOR CURRENT AND HISTORICAL TIMEFRAMES.
//*
//*   FOR CURRENT PULL USE  :    xxxxxx.xxx.xxxxxxx,DISP=SHR
//*   OR USE FOR CURRENT PULL:    xxxxxx.xxx.xxxxxxx,DISP=SHR
//* FOR HISTORICAL TAPE RUN USE:   xxxxxx.xxx.xxxxxxx.MEYYMM,DISP=SHR //*
//*
//  EXEC SAS,REGION=5000K,OPTIONS=,SORT=4,WORK='12,2'
//*RAWOMF  DD DSN=xxxxxx.xxx.xxxxxxx,DISP=SHR
//RAWOMF  DD DSN=xxxxxx.xxx.xxxxxxx.ME9309.BACKUP,DISP=SHR
//SYSIN   DD *
 OPTIONS NOCENTER LS=132 PS=58;          /*  SAS: PROMOTE  */
  DATA VER;                              /*  PROMOTIONS    */
  INFILE RAWOMF;
                     INPUT RSCD $ 2646     MPC $ 10              SEX $ 501
                           TGRC $ 42       CT5CMF $ 3016-3019    REDCAT $ 301
                           TDOR $ 43-48    AREQID $ 2829-2830
                           TGRSEL $ 137    PMOS $ 341-344
```

```
                              AFS  119-121     AFCS  122-124;
IF RSCD = '0' AND MPC = 'W';
IF TDOR >= 881001 AND TDOR <= 890930;        /* DATE OF RANK */
IF TGRC = 'V';        /* RANKS ARE: CW1=X CW2=W CW3=V CW4=U  */
IF PMOS > '922A' OR PMOS < '130A' THEN PMOS = CT5CMF;
IF TGRSEL = ' ' OR TGRSEL = '0';
AFS = INT(AFS/12);

PROC FREQ;
TABLE PMOS TGRC AFS SEX REDCAT;

/*PROC TABULATE DATA=VER F=5.;
        CLASS PMOS TGRC;
        TABLE (PMOS ALL),(TGRC ALL) ALL/RTS=8;*/
      TITLE 'PROMOTIONS BY ZONE';
/*
//
```

The numbers generated from this output would then be aged, and the number of personnel eligible by PMOS and Grade for promotion multiplied by the exponent of the difference of the year. An example for EOFY '96 promotions by grade and job skill:

$$\text{Aged Promotion Eligible} = (\text{\# eligible})(\text{CRATE})^{(\text{EOFY '96-EOFY '93})}$$

This forecasting technique allows the projection module to best estimate the number of persons eligible for promotion and calculates the number to eliminate as the difference of those selected for promotion vs. those non-selected for promotion.

8. Transition Matrix and Seat Table. During normal business operations there are going to be personnel who require additional training that upon its conclusion will require a change in the person's job skill (PMOS). Since some of the training programs are expensive or require a lengthy training process, this method has been developed to transition those people. A distribution of positions is done by grade and

is shown below. This illustrates that 85% of the transitions will go to the grade WO1/CW2 and 15% to the grade of CW3.

	Share
WO1/CW	0.85
CW3	0.15

The matrix itself is only a tool that shows the donor job skills (PMOS) along the column and receiver job skill (PMOS) along the rows.

	Receiver A/C								
		152D	152F	152G	153D	154C	155D	155E	156A
Donor	152B/3C	0.80	0.15	0.75	0.20	0.20	0.30	0.00	0.00
A/C	152F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	152G	0.20	0.80	0.00	0.10	0.05	0.20	0.00	0.00
	153B	0.00	0.05	0.25	0.70	0.75	0.50	0.00	0.00
	153D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	154C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	155D	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
	Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Finally, the distribution table shows the transition job skills that are available for each PMOS by fiscal year. A constraint to this table is the "ALL" row. In this case, the ALL row is the total number of aviation job skills available by fiscal year. For the general case the same principle applies for the distribution of personnel.

Aviation Qualification Course (AQC)					
PMOS	'94	'95	'96	'97	'98
152B/3C	0	0	0	0	0
152C	0	0	0	0	0
152D	99	138	170	112	112
152F	72	50	40	40	40
152G	11	16	8	8	8
153A	0	0	0	0	0
153B	0	0	0	0	0
153D	125	144	168	164	164
154C	23	25	50	50	50
155A	0	0	0	0	0
155D	44	45	47	47	47
155E	66	90	52	44	44
156A	6	0	0	0	0
ALL	446	508	535	465	465

The calculation is a straight forward multiplication of (% share by grade)*(donor to receiver ratio)*(seats available for receiver PMOS)*(CRATE)[1] to give the inventory adjustment by year, job skill (PMOS), and grade.

9. Additional Cuts/Gains. The final variable is one not directly related to the accession and projection model. Additional cuts/gains have been added to this model to ensure that mid-year changes to personnel programs can be adjusted and the impact measured during a trial and error analysis. Cuts and gains are directly added to or subtracted from the execution year inventory. The changes can then be measured on the entire model. If the changes come early enough the model can be re-run to again optimize the accession plan. In this example all values are zero since there haven't been any changes to the plan.

TO:		CW3	CW4	CW5
000A		0	0	0
001A		0	0	0
003A		0	0	0
004A		0	0	0
130A		0	0	0
130B		0	0	0
131A		0	0	0
132A		0	0	0
140A		0	0	0
140B		0	0	0
140D		0	0	0
140E		0	0	0
151A		0	0	0
152B/3C		0	0	0
152C		0	0	0
152D		0	0	0

Step 2: Input Variables into Spreadsheet Model.

The user inputs the variables, as listed in step one, into the spreadsheet model. Variables can be placed manually by filling in the outline or can be updated by utilizing the import features of the Excel 5.0 Spreadsheet or mainframe used for this example.

Step 3: Extract the Projected Inventory from the Spreadsheet.

The analyst takes the aged inventory for each of the projected years and uses them as a basis for a starting point for the optimal accession table. In this example the starting point is the previous year's accession plan. This gives the algorithm a feasible solution to start with and minimizes computing time.

Step 4: Optimize the Accession Plan.

This problem has evolved into a non-linear model for several reasons. During the iterative process changing cells are divided and multiplied by each other and exponentiation is used with non-linear derivatives. By adjusting the decision variables (accessions) as the constraints (difference of BES and projected inventory) are driven to values of ≤ 0, the previously selected objective function is then driven to zero. The model could have been written as a minimization to the budgeted end strength but given current constraints and the intent of Congress the model has been forced to optimize the difference of inventory and end strength. If the model had remained a trial and error problem with no optimization required, then the base spreadsheet would have been sufficient for trial and error calculations. Guesswork by its nature is feasible, if done "a priori", but may not give the best solution. This model, using the GRG2 optimization technique, provides a sophisticated numerical analysis which allows the computer to arrive at an optimal solution quickly. There is no guarantee of convergence for this method since this non-linear programming problem is using repeated linearization of the objective function and constraints to estimate the solution. To help ensure optimality the accession plan should start with a feasible solution. By changing any suspect values and re-running the program the optimal solution can be found along a hyper-plane.

4.5 Sensitivity Analysis of the Model

Sensitivity analysis is used to study the uncertainty of variables of this analysis and the associated risks. This technique allows the identification of those variables that, if changed, could significantly affect the company's bottom line. The variables within the accession plan are the ones whose values are changed to study the uncertainty.

In most cases, the single most expensive resource that a company has is personnel. The unnecessary hiring and firing of personnel causes problems well beyond employee resentment. For this analysis, personnel accessions proved to be the critical variable in the aging process. The related costs of salary, training, and benefits are resources a company can't afford to waste.

4.6 Optimized Accessions

Utilizing the GRG optimization program within the spreadsheet the accessions plan is optimized. As conditions change, the plan can be modified to generate subsequent solutions resulting from financial or political problems. This aged inventory will also show overages and shortages by specific job skills included in each of the projection years. Personnel can be moved to new job skills and retrained or an elimination program can be developed for specific grades and job skills.

4.7 Utility of the General Model

Historically, models were written in programming languages that few understood and had to run on mainframe computers. Nonlinear optimization is a sufficiently robust code that is efficient and is able to work with very complicated non-linear models. Cost to develop the older models such as TOPSS and OPALS have been expensive and only the government or large corporations could afford to undertake these projects[25]. Recently, modern desktop computers have allowed analysts to execute and run complicated programs much more conveniently and with less expense. With the development of the Generalized Reduced Gradient non-linear code[26], complicated optimization can be done on a desktop computer. The technique developed here allows a company to have optimization of their resources and still have the flexibility to develop the algorithm on a desktop computer using professional office software.

[25] As of January 1994 the U.S. Army has invested $ 6,052,000 on development of these models. Additional money has been spent on hardware and CPU time.
[26] Developed by Leon Lasdon, University of Texas at Austin and Alex Warren, Cleveland State University.

Chapter 5

U.S. Army Warrant Officer Corps Example

The Warrant Officer Management Act (WOMA) became law on 01 February 1992 when an amendment to the Defense Authorizations Act for fiscal years 1992-1993 was signed into law[27]. The law provided a uniform and comprehensive system for appointment, promotion, separation, and retirement of Warrant Officers. The gain for the personnel manager is that WOMA provides a life cycle management system. This ensures that all warrant officers are afforded the opportunity for an Army career while providing the Army a fully qualified Warrant Officer Force.

The example shown here gives the Warrant Officer Division at U. S. Personnel Command (PERSCOM) and the Warrant Officer personnel managers at the Office of the Deputy Chief of Staff for Personnel (ODCSPER) a steady state accession model that provides information by which to manage the warrant officer population. From the information developed, decisions are made by the Commands for promotions, accession plans, voluntary and involuntary separations, and shaping of the warrant officer inventory to meet future requirements.

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[27] Perspective. January-February 1992: 5.

5.1 Model Architecture

While developing the algorithm, I had the option of writing a unique code utilizing a programming language that might be difficult for the Warrant Officer personnel managers or my replacement as an analyst to update. Instead, for reasons of utility, I wrote an algorithm using the Excel spreadsheet[28], a Solver[29] utility program, and a GRG2[30] optimization code. This model can thus be updated, as circumstances change, by a non-programmer with a strong mathematical or statistical analysis background. Since the U.S. Army at PERSCOM and ODCSPER are licensed users of the Excel 5.0 spreadsheets and other add on utility programs, I chose Excel 5.0 for this model. Additionally, I used an IBM 3090 and IBM 3070 mainframe computer to store and manipulate information. The means to extract and manipulate data was the SAS[31] language with the models of SAS Operations Research (SAS OR) and SAS Statistics (SAS STAT).

Probability Analysis is calculated using the Monte Carlo simulation technique. *Probability Theory* allows us to measure the uncertainty of the occurrence of events that we are considering. Statistics is the mathematics' of the collection, organization, and interpretation of numerical data. These tools, when used with the model, impact the

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[28] Microsoft Excel, version 5.0, Microsoft Corporation.
[29] Frontline Systems, Inc., Incline Village, Nevada.
[30] GRG2 Optimization Code, Leon Lasdon, University of Texas at Austin.
[31] SAS Institute, v. 6.08, Cary, North Carolina.

models' events and their calculations involve the probability that the personnel forecasts will meet the projections of the model.

5.2 Model Variables

To run the model, some variables and tables are used to generate calculations needed to determine the personnel inventory projections and accession plans. The variables and tables are explained below to illustrate interactions within the model.

<u>Budgeted End Strength:</u> Budgeted End Strength (BES) is the total number of personnel that Congress has authorized to be on active duty at the end of each fiscal year listed. These end of year values will be used to determine the maximum number of personnel on active duty at the end of fiscal year (EOFY).

EOFY	94	95	96	97	98
BES	12,477	12,001	11,524	11,410	11,410

<u>EOFY 1993 Inventory:</u> The end of fiscal year 1993 inventory is used as the basis of the aging and accession process of this model. The inventory is displayed as a table where the primary military occupational specialties (PMOS) are displayed as rows and the grades are displayed as columns as shown in the example below. The junior grade is Warrant Officer One (WO1 and W1 for this example) and the most senior of grades is Chief Warrant Officer Five (CW5). The table displays the actual

number of CWOs on active duty on the last day of the fiscal year by PMOS and grade.

CURRENT INVENTORY AS OF EOFY '93					
Updated 15 February 1994					
PMOS	W1/C2	CW3	M/C4	CW5	Total
000A	61	0	0	0	61
001A	4	0	1	0	5
003A	6	0	0	0	6
004A	1	0	0	0	1
130A	0	1	0	0	1
130B	0	0	0	0	0
131A	66	29	10	2	107
132A	0	0	0	0	0
140A	9	2	1	0	12
140B	43	23	8	0	74
140D	7	4	6	2	19
140E	79	17	8	0	104
151A	136	58	31	6	231
152B/153	450	105	66	6	627
152C	13	23	15	2	53
152D	131	97	42	7	277

<u>Continuation Rate:</u> The continuation rate (CRATE) is the percentage of warrant officers who stay in the army from year to year. A three year moving-average is the technique used to calculate the CRATE for each projection fiscal year. Since all data points are available by PMOS and grade, the moving-average forecast is merely a weighted moving-average of the last three years. For this example the end of fiscal year populations are measured from FY '91 to FY '93. The table displays the actual percentages of CWOs that stay on active duty by job skill.

PMOS	WO1/CW	CW3	CW4	CW5
000A	1.000	1.000	1.000	1.000
001A	1.000	1.000	1.000	1.000
003A	1.000	1.000	1.000	1.000
004A	1.000	1.000	1.000	1.000
130A	1.000	1.000	1.000	1.000
130B	0.941	0.714	0.600	0.600
131A	0.899	0.800	0.886	0.886
132A	1.000	1.000	1.000	1.000
140A	0.918	0.722	0.714	0.714
140B	0.877	0.825	0.867	0.867
140D	0.829	0.742	0.862	0.862
140E	0.901	0.808	0.733	0.733
151A	0.886	0.770	0.903	0.903
152B/153	0.925	0.914	0.824	0.824
152C	0.926	0.911	0.881	0.881
152D	0.915	0.959	0.895	0.895

Training, Transient Holdees, and Student Rate: The training, transient[32], holdees[33], and student rates are the percentage of warrant officers by grade and PMOS in each of these four accounts. Like the continuation rate, these percentages are calculated as three year moving-averages by job skill and grade. The table displays the actual percentages of CWOs that are in the training, transient, holdees, or student accounts by grade and job skill

[32] Transient Officers are those who are moving from one location to another. An example would be an officer moving from Ft. Bragg, NC to Golden, CO for attendance at the Colorado School of Mines.
[33] Holdee Officers are those who are in a hospital or under confinement for a long duration, normally more than three months.

PMOS	W 1/C 2	CW 3	M/W 4	AVG.
000A	0.000	0.000	0.000	0.000
001A	0.000	0.000	0.000	0.000
003A	0.000	0.000	0.000	0.000
004A	0.000	0.000	0.000	0.000
130A	0.000	0.000	0.000	0.000
130B	0.000	0.333	0.000	0.200
131A	0.067	0.083	0.100	0.077
132A	0.000	0.000	0.000	0.000
140A	0.143	0.500	0.000	0.191
140B	0.118	0.097	0.143	0.112
140D	0.113	0.044	0.125	0.095
140E	0.075	0.111	0.167	0.087
151A	0.055	0.123	0.073	0.076
152B/3C	0.204	0.103	0.078	0.175
152C	0.111	0.103	0.214	0.131
152D	0.156	0.073	0.059	0.113

<u>Authorizations:</u> Authorizations for Warrant Officers are by rank and PMOS and go six years into the future. Currently the Army has a technique to develop the workforce of the future. They utilize a notional force structure, in this case NOF-32[34], which provides the annual force structure to EOFY 1999 by PMOS and grade. This structure, when multiplied with the training, transient, holdees, and student rates (TTHS), will give the total budgeted end strength. The table displays the actual number of CWOs by PMOS and grade for EOFY 1994

PMOS	W 1/C 2	CW 3	M/C 4	CW 5	total
000A	0	0	0	0	0
001A	0	0	0	0	0
003A	0	0	0	0	0
004A	0	0	0	0	0
130A	0	0	0	0	0
130B	0	0	0	0	0
131A	52	22	12	3	89
132A	0	0	0	0	0
140A	11	4	2	1	18
140B	37	16	8	2	63
140D	16	7	4	1	2[illegible]
140E	73	31	17	4	124
151A	125	53	29	7	[illegible]
152B/3C	251	106	57	15	429
152C	39	16	9	2	66
152D	129	54	29	7	[illegible]

[34] Notional Force number thirty-two.

To read this table, take PMOS 152B/3C and grade CW3. The value 106 of that cell is the total number of authorizations for that grade and PMOS for EOFY '94.

<u>Accessions:</u> The accessions table is a method to dictate the number of officers by job skill to satisfy the projected budgeted end strength. The minimum number of Warrant Officers are accessed to meet this demand. The optimization procedure used to access the current force is described later in this chapter.

PMOS	'94	'95	'96	'97	'98
000A	0	(0)	(0)	(0)	(0)
001A	0	(0)	(0)	(0)	(0)
003A	0	(0)	(0)	(0)	(0)
004A	0	(0)	(0)	(0)	(0)
130A	0	(0)	(0)	(0)	(0)
130B	0	(0)	(0)	(0)	(0)
131A	9	36	36	36	36
132A	0	(0)	(0)	(0)	(0)
140A	1	4	4	4	4
140B	6	7	7	7	7
140D	0	1	1	1	1
140E	8	23	23	23	23
151A	10	25	25	25	25
152B/3C	176	111	111	111	111
152C	0	13	13	13	13
152D	0	(20)	(20)	(20)	(20)

To read this table take PMOS 152B/3C and year '95. The value 111 of that cell is the total number of accessions for that PMOS for EOFY '95.

<u>Promotions:</u> With the establishment of WOMA, a single promotion system was created that gave the warrant officers standardized procedures for promotions. Officers selected for promotion continue to serve in their grade until promotion without having to be considered for

the same grade again. Warrant Officers who are twice non-select[35] for the next grade are retired or separated from active duty. Warrant officers will be considered for promotion to CW2 at 2 years of warrant service, promotion to CW3 at 8 years of warrant service, CW4 at 14 years of warrant service, and to CW5 at 20 years of warrant officer service. The table displays the number of CWOs by PMOS and grade eligible for promotion during FY '95.

TO:	CW 3	CW 4	CW 5
000A	0	0	0
001A	0	0	0
003A	0	0	0
004A	0	0	0
130A	0	0	0
130B	0	1	0
131A	5	2	1
132A	0	0	0
140A	5	1	0
140B	5	6	0
140D	1	1	2
140E	16	1	0
151A	22	8	2
152B/3C	9	14	4
152C	1	3	0
152D	9	21	5

Promotion Opportunity: The WOMA allows for a standardized promotion system and hence the law sets forth certain guidelines for advancement to the next grade. Promotion opportunity refers to the statistical probability of one being selected for advancement to the next grade. Those who are non-select twice for a grade may retire, if they have achieved twenty years of active federal service, or will be separated seven

[35] Officers who are twice non-select for promotion have been looked at by a promotion board two separate times and rejected both times.

months after the Secretary of the Army signs the promotion list. The table displays the promotion opportunity for the warrant officer by grade.

Promotion Opportunity			
rank:	CW3	CW4	CW5
Rate	0.800	0.760	0.440

<u>Transition Seats and Matrices:</u> Within any organization there are those people who have critical skills that require additional training. The technique used here is to develop a matrix showing transition from one job skill to another and a distribution by grade. This ensures that the right number of personnel are available to work in specific job skills. Aviation assets are the most expensive to train and therefore are managed very carefully within the Warrant Officer Corps. For example, the cost to train a pilot in an advanced aircraft, such as the AH-64 Apache, can cost upward of $1,000,000. The table below displays the distribution by grade followed by the transition matrix with donor job skills on the rows and receiver job skills on the columns. The Aviation Qualification Course matrix represents the total available seats for each fiscal year. Finally, the working matrix is a check to ensure that the distribution by job skill is a zero sum game with the ALL row having zero values for each fiscal year.

Distribution of grades:

WO1/CW2	0.85
CW3	0.15

Donor and Receiver Matrix:

	152D	152F	152G	153D	154C	155D	155E	156A
152B/3C	0.80	0.15	0.75	0.20	0.20	0.30	0.00	0.00
152F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
152G	0.20	0.80	0.00	0.10	0.05	0.20	0.00	0.00
153B	0.00	0.05	0.25	0.70	0.75	0.50	0.00	0.00
153D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
154C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
155D	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Aviation Qualification Course (AQC)					
PMOS	'94	'95	'96	'97	'98
152B/3C	0	0	0	0	0
152C	0	0	0	0	0
152D	99	138	170	112	112
152F	72	50	40	40	40
152G	11	16	8	8	8
153A	0	0	0	0	0
153B	0	0	0	0	0
153D	125	144	168	164	164
154C	23	25	50	50	50
155A	0	0	0	0	0
155D	44	45	47	47	47
155E	66	90	52	44	44
156A	6	0	0	0	0
ALL	446	508	535	465	465

Working Matrix					
PMOS	'94	'95	'96	'97	'98
52B/3C	(141)	(177)	(206)	(259)	(259)
152C	0	0	0	0	0
152D	99	138	170	112	112
152F	72	50	40	40	40
152G	(99)	(76)	(87)	(75)	(75)
153A	0	0	0	0	0
153B	[illegible]	(149)	[illegible]	[illegible]	[illegible]
153D	125	144	168	164	164
154C	23	25	50	50	50
155A	0	0	0	0	0
155D	(28)	(45)	(5)	3	3
155E	66	90	52	44	44
156A	6	0	0	0	0
ALL	0	(0)	0	0	0

Unprojected Losses or Gains: During the course of the execution year it may become necessary to adjust projections due to unexpected losses or cancellation of voluntary or involuntary elimination programs.

The capability to adjust the forecast allows the personnel manager alternatives to programs that may be used. The table displays the job skill by grade. In this case the values are all zero, which reflects no unexpected losses in FY '94.

TO:	CW 3	CW 4	CW 5
000A	0	0	0
001A	0	0	0
003A	0	0	0
004A	0	0	0
130A	0	0	0
130B	0	0	0
131A	0	0	0
132A	0	0	0
140A	0	0	0
140B	0	0	0
140D	0	0	0
140E	0	0	0
151A	0	0	0
152B/3C	0	0	0
152C	0	0	0
152D	0	0	0

5.3 Optimizing the Accession Plan

The goal of this model is to develop a five year accession and inventory projection plan for the Warrant Officer Corps. This objective is to ensure that sufficient Warrant Officers are accessed to meet the demand of authorizations and budgeted end strength. The model described in this dissertation is significantly cheaper, in relative terms, and achieves the same result as the larger model. The benefits come from improved hardware, new software, and the model's responsiveness to "what if" questions. To an assignment manager or division chief, this translates into the ability to find an optimal solution and conduct their own sensitivity analysis. If their accession plan is changed, the analyst can re-run the non-linear optimizer and create a new optimal solution for the personnel managers.

The Personnel Accession and Inventory Projection Model for the Warrant Officer Corps of the U.S. Army is an optimization and resource allocation program. Using techniques of non-linear and linear programming, the personnel accessions are optimized to minimize total personnel based on requirements and constraints set by the Army or Congress. These combined techniques constitute a powerful optimization and resource allocation tool. They allow the analyst to determine the optimal accession plan for the personnel manager using the algorithm entitled "Generalized Reduced Gradient Two", a non-linear code developed by Leon Lasdon, University of Texas at Austin and Alex Warren, Cleveland State University. The Generalized Reduced Gradient Two (GRG2) method allows the analyst to find the optimal value for the BES by adjusting the values of the accessions plan as the difference in the authorizations and projected inventory that is forced to zero. The model consists of three main components, which are familiar in linear and non-linear optimization.

1. The objective function, in this example, is the difference of the EOFY '98 BES and the EOFY '98 projected inventory. The goal is to get a zero difference which would mean that the inventory meets requirements. A negative value would be the shortage of inventory compared to the budgeted end strength.

2. Decision variables are used to achieve steady state accessions[36]. Accessions are held constant for the years '95-'98 to achieve this goal. The principal reason for this is to ensure that resources (school seats, training dollars, and educators) are available on a uniform basis. It also ensures that there won't be a surge of officers by PMOS in any one year. This allows the Army to be proactive in planning and distributing resources.
3. Constraints are determined by limiting the difference of the overage and shortage of officers in EOFY '98 to be less than or equal to zero. During the optimization process the less than or equal to constraints allow the computer to run much faster and still allow the algorithm to get an optimal solution. This will ensure that the personnel managers have the right number of officers available at the right time.

Lasdon's and Warren's GRG2 non-linear code has been incorporated into the model using the Excel 5.0 spreadsheet. The code is sufficiently robust to allow this large non-linear model, a result of huge, disproportional relationships within accessions and projections, to be solved on an advanced spreadsheet. In this spreadsheet the model became non-linear for these main reasons: decision variables are multiplied and divided by each other, exponentiation during the projection calculations, and logarithmic functions[37] in the spreadsheet.

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[36] A stable accession plan (condition) that does not change over time.
[37] Savage, Sam L. 1993. <u>Fundamental Alternative Spreadsheet Tools for Quantitative Management</u>. New York: McGraw-Hill, Inc.: 157.

5.4 Using the Generalized Reduced Gradient Method

The GRG2 method for non-linear programming has been demonstrated to be a robust code that can handle large problems quickly on a personal computer[38]. What once took a specialized code on a mainframe computer is now solved on a personal computer. Essentially, the GRG2 code solves a general non-linear problem by linearizing the model and applying linear programming techniques to solve it.

Formulation of the general method is done by linearizing all constraints and objective function. The constraints are successively linearized and improved. At each feasible solution, the program improves the preceding solution until the solution becomes non-feasible. Using the previous solution, the problem is reformulated and the program starts again. The functions are linearized in piecemeal fashion so that the successive set of straight line segments are used to approximate the objective function and constraints. Within the GRG2 program, the solution process is controlled by setting certain specifications within the model and code. Options available to the analyst are:

1. Search techniques. Those included are the quasi -Newton and the conjugate gradient search methods[39]. Each has its own

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[38] Edgar, T.F. and Himmelblau, D.M. 1988. Chemical Engineering Series, Optimization of Chemical Processes: McGraw-Hill Book Company, United States: 322.
[39] Edgar, T.F. and Himmelblau, D.M. 1988. Chemical Engineering Series, Optimization of Chemical Processes: McGraw-Hill Book Company, United States.

advantages and disadvantages. The quasi-Newton requires more memory with less iterations while the conjugate gradient search method requires less memory with more iterations to reach a particular point of accuracy. However, the conjugate gradient search method is preferred with larger problems.

2. Derivatives. The analyst can use one of two similar methods for approximating partial derivatives of the objective function and constraints. The forward differencing method has a fixed step size and requires less calculations without a loss in accuracy. The central differencing method for partial derivatives requires more calculations but achieves great accuracy. Central differencing is preferred because it is better for improving solutions.
3. Estimates. Initial estimates of the basic variables are needed for each of the single dimensional searches. This can be achieved through tangent estimates which use linear extrapolation from a tangent vector or through quadratic extrapolation estimates. The quadratic extrapolation estimates work better than the tangent estimates for highly non-linear problems, such as in this example.

Inherent to any optimization problem is the solution time. This depends on many variables. Complexity and size of the model contribute to the overall difficulty of the problem. Having defined how to solve the problem, a method must be determined how to stop the model. Similar to other commercial codes, stopping criteria fall into one of four categories. They are maximum time, maximum number of iterations, precision, and tolerance.

1. Maximum time is the time limit for solution process and is measured in real time.
2. Maximum iterations is the limit of the number of iterations calculated; it is measured by a complete processing cycle.
3. Precision determines when a constraint meets a value of upper or lower bound specified and is measured as a function of the difference of values.
4. Tolerance is the percent error allowed in the optimal solution where integer constraints are used on any element in the problem. A higher tolerance 5% vs. 1% for example, would speed up the solution process. Tolerance is measured as a function of the percent difference of the constraint equations and the decision variables.

Affecting each of the stopping criteria is the speed of the machine, operation in a multitasking environment, and settings of interim results. To improve speed of solution, the computer should have complete control of the working environment. Turning off screen savers or not printing will improve performance.

5.5 Building and Running the Model

To run the model, the analyst creates the worksheet model within Microsoft Excel 5.0. Next the objective function, decision variables, and constraints to be optimized must be determined. In this example, the objective function is the BES for EOFY '98, decision variables are the accession plans, and the constraint is the difference of the projected inventory and the authorization. The analyst would now call up the add-in program for non-linear optimization and select the appropriate settings. Settings used here are stopping criteria, type estimate, derivative differencing method, and search technique. Finally, after the problem is defined, the model will find a solution.

The GRG2 code runs in six phases. It is assumed all prior conditions are met, such as the requirement that the Hessian matrix being non-singular. The six phases are.

1. Determine the search components for the independent variables.
2. Determine the search components for the dependent variables.
3. Improve value of the objective function.
4. Use quasi-Newton's method to regain feasibility of the dependent variable.
5. Check convergence to precision criteria.
6. If the model is set up correctly, the optimal solution will be obtained, and three reports will be generated.

In many of the reports, it will be observed that there are values of "#NA". This is only because the objective function was set to a value less than or equal to zero. If this model had been run as a maximization or minimization problem then values would have appeared. Additionally, there are values of "##" in several of the reports. This is an early warning to the analyst and is a reflection of an underlying problem in the distribution of additional training seats, such as having too many people in the additional training matrix. Listed below are the reports that summarize the results of the first attempt at the model.

The sensitivity report contains two tables of information demonstrating how sensitive a solution is to changes in the calculated model.

Microsoft Excel 5.0 Sensitivity Report
Worksheet: (AGENOF32.XLS)AGETWOS
Report Created: 15/2/94 12:02

Changing Cells

Cell	Name	Final Value	Reduced Gradient
BD188	000A '98	(16)	0
BD189	001A '98	(2)	0
BD190	003A '98	(2)	0
BD191	004A '98	(1)	0
BD192	130A '98	(1)	0
BD193	130B '98	(0)	0
BD194	131A '98	36	0
BD195	132A '98	(0)	0
BD196	140A '98	4	0
BD197	140B '98	7	0
BD198	140D '98	1	0
BD199	140E '98	23	0
BD200	151A '98	25	0
BD201	152B/3C '98	111	0
BD202	152C '98	13	0
BD203	152D '98	(18)	0

The reduced gradient measures the increase in the objective function per unit increase in the decision variable. "Changing Cells" refers to the decision variables. For PMOS 000A with an excess to requirements of 16 officers per year would mean that these people with PMOS 001A must be moved to another PMOS. For this model PMOSs 001A to 004A are those officers in initial Warrant Officer training who haven't been awarded a PMOS. PMOS 140E has a demand of 23 officers per year to maintain sufficient number of officers in that job skill (PMOS).

Constraints

Cell	Name	Final Value	Lagrange Multiplier
DM10	000A diff	1	0
DM11	001A diff	1	0
DM12	003A diff	1	0
DM13	004A diff	1	0
DM14	130A diff	1	0
DM15	130B diff	1	0
DM16	131A diff	1	0
DM17	132A diff	1	0
DM18	140A diff	1	0
DM19	140B diff	1	0
DM20	140D diff	1	0
DM21	140E diff	1	0
DM22	151A diff	1	0
DM23	152B/153C diff	1	0
DM24	152C diff	1	0
DM25	152D diff	(23)	0

The Lagrange multiplier measures the increase in the objective function of the corresponding constraint. The final value for PMOS 000A is one, this means that it is exactly at the constraint, where PMOS 152D is 23 officers over the constraint but within the 1% tolerance set.

The answer report shows the relationship of the objective function, decision variables, and constraints.

Microsoft Excel 5.0 Answer Report
Worksheet: (AGENOF32.XLS)AGETWOS
Report Created: 15/2/94 12:01

Target Cell (Value Of)

Cell	Name	Original Value	Final Value
CT90	EOFY FY '98	561	0

Adjustable Cells

Cell	Name	Original Value	Final Value
BD188	000A '98	0	(16)
BD189	001A '98	0	(2)
BD190	003A '98	0	(2)
BD191	004A '98	0	(1)
BD192	130A '98	0	(1)
BD193	130B '98	0	(0)
BD194	131A '98	9	36
BD195	132A '98	0	(0)
BD196	140A '98	1	4
BD197	140B '98	6	7
BD198	140D '98	0	1
BD199	140E '98	8	23
BD200	151A '98	14	25
BD201	152B/3C '98	176	111
BD202	152C '98	0	13
BD203	152D '98	0	(18)

The final value in the answer report is the actual accession plan needed for each EOFY '95 to EOFY '98. The Target Cell refers to the objective function starting with 561 officers under the BES and achieving the final value of 0, or the BES directed by Congress. Adjustable cells refer to the decision variables and the change from the FY '93 accession plan. The optimized accession plan changed from 877 personnel to 1,063 people for the accession years of FY '94 to FY '98. In some cases the changes are minor but in others it is dramatic. PMOS 152B/3C is an aviation skill with a FY '93 accession plan of 176 and an optimized plan for accessions, based on requirements, of 111. To train the additional 65 officers would have meant an additional cost of approximately 15 million dollars.

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
DM10	000A diff	1	DM10<=1	Binding	0
DM11	001A diff	1	DM11<=1	Binding	0
DM12	003A diff	1	DM12<=1	Binding	0
DM13	004A diff	1	DM13<=1	Binding	0
DM14	130A diff	1	DM14<=1	Binding	0
DM15	130B diff	1	DM15<=1	Binding	0
DM16	131A diff	1	DM16<=1	Binding	0
DM17	132A diff	1	DM17<=1	Binding	0
DM18	140A diff	1	DM18<=1	Binding	0
DM19	140B diff	1	DM19<=1	Binding	0
DM20	140D diff	1	DM20<=1	Binding	0
DM21	140E diff	1	DM21<=1	Binding	0
DM22	151A diff	1	DM22<=1	Binding	0
DM23	152B/153C diff	1	DM23<=1	Binding	0
DM24	152C diff	1	DM24<=1	Binding	0
DM25	152D diff	(23)	DM25<=1	Not Binding	24

The second part of the status report gives information as to whether a variable is binding or not-binding. Binding means that the final constraint value equals the constraint value and has a slack value equal to zero. A not-binding constraint is met but does not equal the constraint value and has a non-zero slack value.

The limits report lists the objective function, decision variables with their values, lower and upper limits, and the objective function values.

Microsoft Excel 5.0 Limits Report
Worksheet: (AGENOF32.XLS)AGETWOS
Report Created: 15/2/94 12:02

Cell	Target Name	Value
CT90	EOFY FY '98	0

Cell	Adjustable Name	Value	Lower Limit	Target Result	Upper Limit	Target Result
BD188	000A '98	(16)	(16)	0	#N/A	#N/A
BD189	001A '98	(2)	(2)	0	#N/A	#N/A
BD190	003A '98	(2)	(2)	0	#N/A	#N/A
BD191	004A '98	(1)	(1)	0	#N/A	#N/A
BD192	130A '98	(1)	(1)	0	#N/A	#N/A
BD193	130B '98	(0)	(0)	0	#N/A	#N/A
BD194	131A '98	36	36	0	#N/A	#N/A
BD195	132A '98	(0)	(0)	0	#N/A	#N/A
BD196	140A '98	4	4	0	#N/A	#N/A
BD197	140B '98	7	7	0	#N/A	#N/A
BD198	140D '98	1	1	0	#N/A	#N/A
BD199	140E '98	23	23	0	#N/A	#N/A
BD200	151A '98	25	25	0	#N/A	#N/A
BD201	152B/3C '98	111	111	0	#N/A	#N/A
BD202	152C '98	13	13	0	#N/A	#N/A
BD203	152D '98	(18)	(25)	24	#N/A	#N/A

The lower limit of this report is the smallest value that a decision variable can take while holding all other decision variables fixed and satisfying all constraints. Upper limits are the same as lower limits except they refer to the largest value that a decision variable can take while holding all other decision variables fixed and satisfying all constraints. Target result is the value of the objective function when the decision variable is at its upper or lower limit.

5.6 Finding the Solution

In any search program there are only three possible outcomes to the routine. They are:

1. A solution is found;
2. or, a current solution is found but stopping criteria set in the program causes it to stop (maximum time or iterations criteria is met);
3. or, the program fails.

Some reasons for a program failing are the objective function is increasing or decreasing without limit, integer constraints were used and the tolerance is too tight, or input values are several orders of magnitude apart.

Chapter 6
Conclusion and Recommendations

This model has significantly enhanced the Warrant Officer Corps ability in determining an optimal accessions program and inventory projections. For the first time, personnel and assignment managers have an optimal solution to their accession plan and an accurate projection of the personnel inventory. Flexibility of the model allows them to conduct their own sensitivity analysis and lets them answer questions from the field in a quantifiable manner.

6.1 Impact and Implementation of the Model

In 1993, the accession plan called for the accession of 977 Warrant Officers. The impact was an uneven distribution of personnel resources across the Army. The same methodology was used in earlier years and caused certain skills to be over represented while others were under represented. The optimal accession plan for FY '95 is 1,063 personnel identified by PMOS.

When the drawdown of FY '91 started, it was realized that certain PMOSs would take the brunt of the reductions while others would not be reduced. This situation was uncomfortable and caused resentment among some of the Warrant Officers. This model begins the process of fixing earlier problems and works towards ensuring an equal distribution of personnel by PMOS in the future. What is important to note is the fundamental change in philosophy from having more resources than necessary to one of ensuring that the Army has exactly what it needs. This places the personnel managers in a position to address questions related to other areas.

A common complaint of Warrant Officer Assignment Officers is that they have no way to answer questions from the field in a quantifiable manner. Questions could range from what is the projected inventory by PMOS in FY '97 to how many people can we send to advanced aircraft training in FY '96?

At the Officer Personnel Management Directorate (OPMD) and Deputy Chief of Staff, Plans (DCSPLANS) at the U.S. Army Personnel Command (PERSCOM), and the Office of the Deputy Chief of Staff of Personnel (ODCSPER) at the Pentagon, personnel managers have begun the learning process of how to use the model.

6.2 Implications for the U.S. Army Warrant Officer Corps

With the introduction of this model, the methodology of conducting Warrant Officer business has changed. The accession plan has been optimized and the force will begin to shape itself to fit the BES directed by Congress. The older methods had inventory imbalances of over 25% of authorizations by grade in PMOS. This model by EOFY 1998 is projected to have the imbalances reduced to less than 10% by PMOS and grade. As the world situation changes and requirements for the Warrant Officer Corps change, so will the accession plan and projected inventories. Having the additional flexibility of this model over the older mainframe models allow policy makers to weigh the effects of a rapidly changing policy. Policy changes could include promotion opportunity or how and when personnel are accessed.

Personnel Managers and Assignment Officers now have the additional tool of this model to assist them. Currently the model is being used by the Warrant Officer personnel managers and passes the most important test of all, that of customer satisfaction.

6.3 Conclusion

This dissertation addresses three types of audiences. Top level management, personnel managers, and assignment officers. These people have been critical of the theoretical approach and have examined the model from their perspective. Most people don't care about theory and the analytical approach but more about the function and capability of the model. This model passed the evaluations of all three levels of management. This isn't a guarantee of success but is a start to ensure the model is used. The U.S. Army has incorporated the Warrant Officer model into current personnel actions and processes. Concrete benefits have been demonstrated by the use of this model. The reduction in force and selective early retirement boards were canceled because of the models ability to correctly project the force size. Programs that were used to shape the Warrant Officer force due to imbalances were voluntary separation incentive programs. Immediate cost savings are estimated to be around 12 million dollars for FY '95 due to the accuracy of the model.

6.4 Recommendations for Improvement

As the model evolves and experience is gained with its use, enhancements will be made to ensure the model meets expectations of the Personnel Managers. Changes would be the updates to rates and inclusion of specific sub-programs such as gender and racial ethnic provisions. Applying updated tools and techniques will ensure that the model doesn't become outdated quickly.

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Appendix A

Fiscal year '93 inventory used as the basis for the personnel inventory projections.

CURRENT INVENTORY AS OF EOFY '93					
Updated 26 Oct. '93					
PMOS	W1/C2	CW3	M/C4	CW5	Total
000A	61	0	0	0	61
001A	4	0	1	0	5
003A	6	0	0	0	6
004A	1	0	0	0	1
130A	0	1	0	0	1
130B	0	0	0	0	0
131A	66	29	10	2	107
132A	0	0	0	0	0
140A	9	2	1	0	12
140B	43	23	8	0	74
140D	7	4	6	2	19
140E	79	17	8	0	104
151A	136	58	31	6	231
152B/153	450	105	66	6	627
152C	13	23	15	2	53
152D	131	97	42	7	277
152F	613	273	132	30	1,048
152G	341	127	83	27	578
153A	190	0	0	9	199
153B	631	209	161	33	1.034
153D	1.018	399	235	35	1,687
154C	285	144	130	38	597
155A	1	2	1	2	6
155D	6	32	31	1	70
155E	18	132	147	39	336
156A	7	39	30	6	82
180A	214	104	2	0	320
210A	20	12	5	2	39
213A	0	0	0	0	0
215D	20	15	3	0	38
250A	102	91	37	3	233
250B	37	18	1	0	56
251A	40	47	13	0	100
256A	181	96	41	1	319
311A	206	123	59	8	396
350B	49	39	15	1	104
350D	45	31	9	0	85
350L	18	21	7	0	46
351B#	265	67	39	3	374
351C#	45	20	10	3	78
351E#	67	32	8	2	109
352C	89	43	8	0	140
352D	10	3	1	0	14
352G	49	12	8	0	69
352H	12	8	1	0	21
352J	28	19	5	0	52
352K	10	4	0	0	14
353A	36	18	2	1	57
420A	66	75	78	5	224
420C	21	16	10	1	48
550A	30	21	9	0	60
600A	33	25	12	0	70
640A	30	22	0	0	52
670A	45	20	8	0	73
880A	43	17	11	4	75
881A	60	21	10	1	92
910A	53	36	16	0	105
911A	1	12	8	3	24
912A	56	25	12	1	94
913A	24	32	19	0	75
914A	32	18	11	0	61
915A	543	353	96	9	1,001
916A	11	11	4	0	26
917A	44	17	12	0	73
918A	22	9	4	0	35
919A	61	58	22	4	145
920A	198	157	66	4	425
920B	129	95	41	4	269
921A	20	15	7	0	42
922A	20	33	26	2	81
ALL	7,201	3,627	1.894	307	13.029

Appendix B

Inventory projections for years 1994 to 1998.

PROJECTED INVENTORY AS OF EOFY '94																				
WO1/CW2					CW3				CW4				CW5					Total		
PMOS	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Tot. Auth	Inventory	C-BES	A-BES	delta
000A	0	61	0	(61)	0	0	0	0	0	0	0	0	0	0	0	0	0	61	0	0	(61)
001A	0	4	0	(4)	0	0	0	0	0	1	0	(1)	0	0	0	0	0	5	0	0	(5)
003A	0	6	0	(6)	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	(6)
004A	0	1	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130A	0	0	0	0	0	1	0	(1)	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131A	52	68	56	(13)	22	23	24	1	12	9	13	4	3	2	3	2	89	102	96	97	(5)
132A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140A	11	9	12	3	4	1	7	5	2	1	2	2	1	0	1	1	18	11	22	22	11
140B	37	44	41	(3)	16	19	17	(2)	8	7	10	3	2	0	2	2	63	70	70	72	2
140D	16	6	18	12	7	3	7	4	4	5	4	(1)	1	2	1	(1)	27	16	30	30	15
140E	73	79	78	(1)	31	14	34	20	17	6	19	14	4	0	5	5	124	99	136	139	40
151A	125	131	131	1	53	45	59	14	29	28	31	3	7	5	8	2	213	209	229	233	24
152B/153	251	472	302	(170)	106	75	117	42	57	54	62	8	15	5	16	11	429	606	497	506	(101)
152C	39	12	43	31	16	21	18	(3)	9	13	11	(2)	2	2	3	1	66	48	74	76	28
152D	129	204	149	(55)	54	108	58	(50)	29	38	31	(6)	7	6	8	2	220	356	246	251	(105)
152F	580	632	633	1	245	269	257	(12)	133	116	137	21	34	26	35	8	991	1,043	1,062	1,080	38
152G	222	223	247	24	94	101	102	1	51	67	54	(13)	13	22	14	(8)	379	413	417	424	11
153A	57	152	69	(83)	24	0	24	24	13	0	15	15	3	7	4	(3)	98	159	111	113	(46)
153B	451	640	514	(126)	190	161	203	42	103	132	109	(23)	26	27	28	1	771	960	854	869	(91)
153D	893	1,047	965	(82)	377	384	416	31	205	208	217	9	52	31	55	24	1,527	1,670	1,653	1,683	13
154C	283	286	297	11	119	141	130	(12)	65	124	67	(58)	16	36	17	(19)	483	588	511	520	(68)
155A	14	1	14	13	6	2	6	4	3	1	4	3	1	2	1	(1)	24	6	25	25	19
155D	46	(18)	50	68	19	25	21	(4)	10	23	12	(11)	3	1	3	2	78	31	87	88	57
155E	137	73	156	83	58	133	69	(64)	31	124	34	(89)	8	33	9	(24)	235	363	268	273	(90)
156A	18	12	23	11	8	36	9	(27)	4	25	5	(21)	1	5	1	(4)	31	78	38	38	(40)
180A	214	254	231	(22)	90	95	97	2	49	2	49	47	12	0	12	12	365	351	390	397	46
210A	23	21	26	5	10	9	11	2	5	4	5	1	1	2	1	(0)	40	36	44	45	8
213A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215D	18	19	18	(1)	7	12	8	(4)	4	3	4	1	1	0	1	1	30	35	31	32	(3)
250A	111	105	118	13	47	74	50	(24)	25	31	28	(3)	6	3	7	4	189	212	203	206	(6)
250B	47	42	49	7	20	16	22	5	11	1	11	10	3	0	3	3	81	59	84	85	26
251A	60	42	63	21	25	38	26	(12)	14	11	14	3	3	0	3	3	102	92	107	109	17
256A	147	185	157	(28)	62	78	67	(11)	34	32	35	3	9	1	9	8	251	296	268	273	(23)
311A	235	214	250	36	99	101	107	6	54	43	56	14	14	6	14	9	401	363	428	435	72
350B	71	54	75	21	30	36	32	(4)	16	13	16	3	4	1	4	3	122	104	127	130	26
350D	46	49	47	(2)	20	28	23	(5)	11	7	11	3	3	0	3	3	79	84	83	85	1
350L	29	22	33	11	12	19	13	(6)	7	6	7	1	2	0	2	2	49	47	55	56	8
351B #	198	276	212	(63)	84	49	89	40	45	29	51	22	12	2	13	11	339	356	365	372	15
351C #	46	43	48	6	19	20	21	1	10	9	11	2	3	3	3	0	78	74	83	85	11
351E #	85	69	90	22	36	27	40	13	20	6	21	15	5	2	5	4	146	104	157	160	56
352C	97	95	104	9	41	35	42	8	22	7	28	21	6	0	7	7	165	136	181	185	48
352D	4	10	4	(6)	1	2	1	(1)	1	1	1	0	0	0	0	0	6	13	6	6	(7)
352G	32	48	36	(13)	13	10	14	4	7	7	9	2	2	0	2	2	54	65	61	62	(3)
352H	12	12	13	2	5	6	6	0	3	1	3	2	1	0	1	1	21	18	23	23	5
352J	27	30	30	1	11	16	12	(4)	6	5	6	1	2	0	2	2	46	51	50	51	(0)
352K	9	10	10	0	4	3	4	1	2	0	2	2	1	0	1	1	16	13	17	17	4
353A	26	37	28	(10)	11	14	13	(1)	6	1	6	5	2	1	2	1	45	54	49	49	(4)
420A	120	72	126	53	51	57	55	(2)	27	66	28	(38)	7	4	7	3	205	200	216	220	20
420C	25	23	26	3	10	14	12	(2)	6	8	6	(2)	1	1	2	1	42	47	45	46	(1)
550A	35	32	36	4	15	18	15	(3)	8	8	8	0	2	0	2	2	59	57	61	62	4
600A	2	14	2	(13)	1	9	1	(9)	0	8	0	(8)	0	0	0	0	3	32	3	3	(29)
640A	31	32	34	2	13	18	14	(4)	7	0	7	7	2	0	2	2	53	50	56	57	8
670A	44	47	47	(0)	19	16	20	4	10	7	10	4	3	0	3	3	75	69	80	81	12
880A	49	49	50	1	21	15	23	8	11	10	12	2	3	3	3	(0)	83	77	88	89	12
881A	53	67	57	(10)	22	17	25	8	12	8	13	5	3	1	3	3	91	93	98	100	7
910A	46	49	49	0	20	27	21	(7)	11	13	12	(2)	3	0	3	3	79	89	84	86	(4)
911A	0	1	0	(1)	0	9	0	(9)	0	6	0	(6)	0	2	0	(2)	0	18	0	0	(18)
912A	42	59	44	(14)	18	21	19	(2)	10	11	10	(1)	2	1	2	1	71	92	76	77	(15)
913A	40	25	43	18	17	26	18	(8)	9	17	10	(7)	2	0	2	2	68	68	73	74	7
914A	31	33	32	(0)	13	12	15	3	7	10	7	(3)	2	0	2	2	53	55	56	57	3
915A	525	563	555	(8)	222	289	235	(53)	120	70	125	55	31	7	32	25	898	927	947	964	36
916A	18	13	19	6	8	10	8	(1)	4	3	4	1	1	0	1	1	31	25	33	33	8
917A	36	56	42	(14)	15	15	17	2	8	10	8	(2)	2	0	2	2	61	81	68	70	(11)
918A	22	24	23	(1)	9	8	10	2	5	3	5	2	1	0	1	1	37	34	39	40	5
919A	76	62	84	23	32	49	36	(13)	17	19	19	1	4	3	5	2	130	133	144	147	14
920A	228	207	244	37	96	127	105	(22)	52	51	57	6	13	3	14	11	390	388	420	428	39
920B	154	117	173	55	65	77	71	(5)	35	33	39	6	9	3	10	7	263	230	292	297	67
921A	30	21	31	10	13	12	13	1	7	6	8	2	2	0	2	2	51	40	55	56	16
922A	47	28	52	24	20	27	21	(6)	11	20	11	(8)	3	2	3	1	81	76	87	89	12
ALL	6,619	7,374	7,209	(164)	2,795	3,125	3,032	(93)	1,516	1,586	1,609	23	385	261	408	147	11,315	12,346	12,258	12,477	131

	FY '94	BES '94
C BES	12,258	12,477
Auth:	11,315	
Avn	6,358	6,032
Tech	5,988	6,445
sum	12,346	12,477
2xNS	0	
BES '94	12,477	12,477
EOFY	131	0

PROJECTED INVENTORY AS OF EOFY '95																					
WO1/CW2					CW3				CW4				CW5					Total			
PMOS	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Tot Auth	Inventory	C-BES	A-BES	diff
000A	0	46	0	(46)	0	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	(46)
001A	0	3	0	(3)	0	0	0	0	0	1	0	(1)	0	0	0	0	0	4	0	0	(4)
003A	0	5	0	(5)	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	(5)
004A	0	1	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130A	0	(0)	0	0	0	1	0	(1)	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130B	0	0	0	(0)	0	(0)	0	0	0	0	0	(0)	0	0	0	0	0	0	0	0	(0)
131A	65	96	69	(26)	27	21	30	9	15	8	16	8	4	2	4	2	111	127	119	121	(6)
132A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140A	11	10	12	2	4	4	7	3	2	1	2	2	1	0	1	1	16	15	22	22	7
140B	33	43	37	(6)	14	16	15	(0)	8	9	9	(0)	2	0	2	2	57	68	64	64	(4)
140D	6	6	7	1	3	2	3	1	1	4	2	(3)	0	2	0	(2)	11	15	12	12	(2)
140E	73	85	79	(6)	31	21	34	13	17	5	20	15	4	0	5	5	125	111	137	139	28
151A	116	128	123	(5)	49	45	55	11	27	28	29	0	7	6	7	2	199	206	214	216	10
152B/153	233	392	281	(111)	99	39	109	70	53	52	58	5	14	5	15	9	399	489	462	466	(22)
152C	41	25	45	21	17	18	19	1	9	14	11	(2)	2	2	3	1	70	58	79	80	22
152D	176	276	203	(73)	74	115	80	(36)	40	47	43	(4)	10	7	11	3	301	446	337	340	(106)
152F	512	598	559	(39)	216	267	227	(40)	117	119	121	2	30	32	31	(1)	875	1,016	937	946	(70)
152G	209	175	233	58	88	83	96	13	48	58	51	(7)	12	24	13	(11)	357	340	393	396	56
153A	57	153	68	(85)	24	0	24	24	13	0	14	14	3	6	4	(2)	97	158	110	111	(47)
153B	398	587	454	(133)	168	109	179	71	91	119	96	(22)	23	30	24	(5)	681	844	754	761	(83)
153D	923	1,016	997	(20)	390	387	429	42	211	209	224	15	54	36	57	21	1,577	1,649	1,707	1,723	74
154C	282	239	297	58	119	128	129	1	65	128	67	(61)	16	44	17	(27)	482	539	510	514	(24)
155A	11	4	11	6	4	1	4	3	2	2	3	1	1	2	1	(1)	18	9	19	19	10
155D	47	(29)	52	81	20	16	22	6	11	18	13	(5)	3	2	3	1	81	8	90	91	83
155E	126	80	143	64	53	127	64	(63)	29	109	31	(77)	7	38	8	(30)	216	353	246	249	(104)
156A	9	4	12	8	4	27	5	(22)	2	26	2	(24)	1	5	1	(5)	16	62	19	20	(43)
180A	214	267	231	(35)	90	80	97	17	49	13	49	35	12	0	12	12	365	360	390	393	33
210A	21	25	23	(2)	9	7	10	3	5	3	5	2	1	2	1	(1)	36	37	40	40	3
213A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215D	15	17	15	(2)	6	10	7	(4)	3	4	3	(1)	1	0	1	1	25	32	26	26	(5)
250A	99	106	105	(0)	42	60	45	(16)	23	29	25	(5)	6	4	6	3	169	199	181	183	(16)
250B	47	47	48	2	20	15	21	6	11	2	11	9	3	0	3	3	80	64	83	84	20
251A	54	49	57	8	23	29	24	(5)	12	13	12	(1)	3	0	3	3	92	92	96	97	5
256A	136	179	146	(33)	58	64	62	(2)	31	31	32	1	8	2	8	7	233	276	249	251	(25)
311A	232	229	247	18	98	108	106	(3)	53	38	56	18	13	6	14	8	396	381	422	426	45
350B	78	65	81	17	33	33	35	2	18	14	18	4	5	2	5	3	133	114	139	140	27
350D	51	51	53	1	22	27	25	(2)	12	7	12	5	3	0	3	3	88	86	93	94	8
350L	29	27	33	6	12	15	13	(2)	7	7	7	(0)	2	0	2	1	49	49	55	55	6
351B #	198	275	212	(63)	84	48	89	41	45	23	51	28	12	3	13	9	339	349	365	369	19
351C #	45	43	48	5	19	19	20	1	10	8	11	3	3	2	3	0	77	72	82	83	10
351E #	88	83	93	10	37	22	41	19	20	9	22	13	5	2	6	4	150	115	162	163	48
352C	100	109	108	(1)	42	31	44	13	23	7	29	22	6	1	7	7	171	148	188	190	42
352D	4	8	4	(4)	2	2	2	(0)	1	1	1	0	0	0	0	0	7	11	7	7	(4)
352G	32	49	36	(13)	13	7	14	7	7	8	9	1	2	1	2	2	54	64	61	61	(3)
352H	12	13	13	(0)	5	5	6	1	3	1	3	1	1	0	1	1	20	19	22	22	3
352J	27	30	30	(0)	11	13	12	(1)	6	5	6	1	2	1	2	1	46	49	50	50	1
352K	9	11	10	(1)	4	3	4	0	2	0	2	2	1	0	1	1	15	14	16	16	2
353A	26	38	27	(10)	11	11	13	1	6	2	6	4	1	1	1	1	44	51	47	48	(4)
420A	114	91	119	29	48	47	52	5	26	56	27	(29)	7	8	7	(1)	195	202	205	207	6
420C	23	20	24	4	10	17	11	(6)	5	7	6	(1)	1	1	1	0	39	45	42	42	(3)
550A	35	33	36	3	15	17	15	(2)	8	6	8	1	2	0	2	2	59	57	61	61	5
600A	1	5	1	(3)	0	4	1	(3)	0	6	0	(5)	0	1	0	(1)	2	15	2	2	(12)
640A	31	35	34	(1)	13	14	14	(0)	7	3	7	5	2	0	2	2	53	51	56	57	6
670A	43	49	46	(3)	18	13	19	6	10	9	10	1	2	0	2	2	73	71	78	78	8
880A	41	52	42	(10)	17	13	19	6	9	7	10	3	2	4	3	(1)	70	76	74	75	(2)
881A	50	67	53	(14)	21	18	23	5	11	7	12	5	3	1	3	2	85	93	92	93	(1)
910A	50	52	54	2	21	23	22	(0)	12	12	13	0	3	1	3	3	86	88	92	93	5
911A	0	(2)	0	2	0	6	0	(6)	0	5	0	(5)	0	3	0	(3)	0	12	0	0	(12)
912A	36	49	39	(10)	15	22	17	(5)	8	11	8	(2)	2	2	2	(0)	62	84	66	67	(17)
913A	36	27	38	11	15	23	16	(7)	8	14	9	(5)	2	2	2	0	61	66	65	66	0
914A	28	32	29	(3)	12	11	14	2	6	8	6	(1)	2	1	2	0	48	53	51	51	(2)
915A	504	546	532	(13)	213	307	226	(81)	116	57	120	63	29	9	30	22	862	919	909	917	(1)
916A	13	15	14	(1)	5	10	6	(4)	3	2	3	1	1	0	1	1	22	27	23	23	(3)
917A	30	52	35	(16)	13	11	14	3	7	11	7	(4)	2	0	2	1	52	74	58	59	(15)
918A	18	22	18	(4)	7	8	8	0	4	2	4	2	1	0	1	1	30	32	32	32	(0)
919A	67	60	75	15	28	48	32	(17)	15	15	17	2	4	5	4	(1)	115	129	128	129	(0)
920A	218	217	234	16	92	117	100	(16)	50	47	54	8	13	5	14	9	373	385	402	406	21
920B	154	150	173	22	65	63	71	8	35	30	39	8	9	5	10	4	263	249	292	295	46
921A	30	26	31	5	13	11	13	2	7	4	8	4	2	1	2	1	51	42	55	55	13
922A	56	59	62	3	24	20	25	5	13	16	13	(3)	3	2	3	1	96	98	103	104	7
ALL	6,422	7,315	6,992	(323)	2,711	2,864	2,941	78	1,471	1,518	1,561	43	373	321	396	75	10,977	12,017	11,890	12,001	(16)

	FY '95	BES '95
C BES	11,890	12,001
Auth	10,977	
Avn	5,999	5,802
Tech	6,019	6,199
sum	12,017	12,001
2xNS		
BES '95	12,001	12,001
EOFY	(16)	0

PROJECTED INVENTORY AS OF EOFY '96																				
WO1/CW2					CW3				CW4				CW5					Total		
PMOS	Autr	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Tot Auth	Inventory	C-BES	A-BES	diff
000A	0	30	0	(30)	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	(30)
001A	0	2	0	(2)	0	0	0	0	0	1	0	(1)	0	0	0	0	0	3	0	0	(3)
003A	0	3	0	(3)	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	(3)
004A	0	1	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130A	0	(0)	0	0	0	1	0	(1)	0	0	0	0	0	0	0	0	0	1	0	0	(1)
130B	0	0	0	(0)	0	(0)	0	0	0	0	0	(0)	0	0	0	0	0	(0)	0	0	0
131A	75	120	80	(41)	32	19	34	15	17	8	19	11	4	2	5	2	128	149	138	140	(9)
132A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140A	11	13	12	(1)	4	4	7	3	2	1	2	2	1	0	1	0	18	17	22	22	5
140B	33	42	37	(4)	14	17	15	(2)	8	8	9	1	2	0	2	2	57	67	64	65	(2)
140D	6	5	7	2	3	2	3	0	1	4	2	(2)	0	2	0	(2)	11	14	12	12	(1)
140E	73	91	79	(12)	31	26	34	8	17	4	20	16	4	0	5	5	125	121	137	140	19
151A	109	116	115	(0)	46	55	52	(3)	25	26	27	1	6	8	7	(1)	187	204	201	204	0
152B/153	160	285	193	(92)	68	10	75	65	37	51	40	(12)	9	6	10	4	274	352	317	323	(29)
152C	42	33	46	13	18	18	19	1	10	13	12	(1)	2	2	3	1	71	66	80	81	15
152D	257	365	297	(68)	108	135	116	(19)	59	53	62	9	15	7	16	9	439	560	491	499	(61)
152F	470	531	514	(17)	199	288	208	(80)	108	133	111	(22)	27	29	28	(1)	804	981	861	875	(106)
152G	167	120	186	66	71	72	77	5	38	53	41	(12)	10	21	10	(11)	286	266	315	320	54
153A	66	153	79	(75)	28	0	28	28	15	0	17	17	4	5	4	(0)	112	158	127	129	(29)
153B	271	490	309	(181)	115	78	122	44	62	113	66	(47)	16	29	17	(13)	464	710	514	522	(188)
153D	945	967	1,021	54	399	434	440	6	217	214	230	16	55	38	58	21	1,616	1,653	1,750	1,778	125
154C	273	199	287	88	115	137	125	(12)	62	136	64	(72)	16	45	16	(29)	466	518	493	501	(17)
155A	11	8	11	3	4	1	4	3	2	2	3	1	1	2	1	(1)	18	13	19	19	7
155D	41	(4)	45	49	17	13	19	6	9	15	11	(5)	2	2	3	1	70	27	78	79	52
155E	106	54	120	66	45	112	53	(58)	24	107	26	(80)	6	35	7	(28)	181	307	207	210	(97)
156A	9	(4)	12	16	4	20	5	(15)	2	27	2	(24)	1	5	1	(4)	16	47	19	20	(28)
180A	214	273	231	(42)	90	70	97	27	49	26	49	23	12	0	12	12	365	370	390	396	26
210A	21	24	23	(1)	9	9	10	1	5	3	5	2	1	2	1	(0)	36	38	40	40	3
213A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215D	15	16	15	(0)	6	9	7	(2)	3	4	3	(1)	1	0	1	0	25	29	26	27	(3)
250A	94	103	100	(3)	40	51	42	(9)	21	30	23	(7)	5	4	6	2	160	188	172	174	(14)
250B	42	49	43	(5)	18	17	19	2	10	3	10	7	2	0	2	2	72	68	75	76	7
251A	53	57	56	(1)	22	22	23	1	12	13	12	(1)	3	1	3	3	90	93	94	96	3
256A	129	176	138	(38)	54	51	59	8	29	30	31	0	7	2	8	5	220	259	235	239	(20)
311A	232	259	247	(12)	98	99	106	7	53	33	56	22	13	5	14	9	396	397	422	429	33
350B	76	72	80	8	32	31	34	3	17	18	17	(0)	4	2	4	2	130	123	136	138	15
350D	51	56	52	(4)	21	22	25	3	12	9	12	3	3	1	3	2	87	88	92	93	5
350L	29	32	33	2	12	12	13	2	7	7	7	(1)	2	0	2	1	49	51	55	55	4
351B#	182	269	195	(75)	77	52	82	30	42	20	47	27	11	3	12	9	311	344	335	341	(3)
351C#	37	42	39	(3)	16	19	17	(2)	8	7	9	2	2	2	2	0	63	71	67	68	(3)
351E#	77	95	82	(13)	33	19	36	18	18	9	19	10	4	1	5	3	132	124	142	144	20
352C	95	117	102	(14)	40	30	42	12	22	11	27	16	6	1	7	6	162	159	178	181	22
352D	4	6	4	(2)	2	2	2	(1)	1	1	1	0	0	0	0	0	7	10	7	7	(2)
352G	32	46	36	(10)	13	8	14	6	7	8	9	1	2	1	2	1	54	63	61	62	(2)
352H	12	14	13	(2)	5	4	6	2	3	2	3	1	1	0	1	1	20	20	22	22	2
352J	26	31	29	(1)	11	10	12	2	6	6	6	(0)	2	1	2	0	45	48	49	50	1
352K	9	11	10	(2)	4	3	4	1	2	0	2	2	1	0	1	1	15	14	16	16	2
353A	25	35	27	(8)	11	13	12	(1)	6	2	6	4	1	0	1	1	43	50	46	47	(3)
420A	112	111	117	6	47	33	51	18	26	52	26	(25)	6	8	7	(1)	191	204	201	204	1
420C	22	19	23	4	9	16	11	(5)	5	8	6	(3)	1	1	1	0	38	44	41	42	(2)
550A	32	34	33	(1)	14	13	14	1	7	9	7	(1)	2	0	2	2	55	56	57	58	1
600A	1	1	1	(0)	0	1	0	(1)	0	4	0	(4)	0	0	0	(0)	1	7	1	1	(6)
640A	30	31	33	2	13	17	13	(4)	7	5	7	2	2	0	2	2	52	53	55	56	3
670A	42	53	45	(8)	18	10	19	9	10	8	10	1	2	0	2	2	71	72	76	77	5
880A	41	52	42	(10)	17	13	19	6	9	7	10	3	2	4	3	(2)	70	76	74	75	(1)
881A	50	65	53	(12)	21	20	23	3	11	7	12	5	3	1	3	2	85	94	92	94	(0)
910A	47	55	50	(5)	20	20	21	1	11	11	12	1	3	1	3	2	80	86	85	87	0
911A	0	(3)	0	3	0	3	0	(3)	0	5	0	(5)	0	2	0	(2)	0	7	0	0	(7)
912A	35	33	37	4	15	28	16	(11)	8	13	8	(5)	2	2	2	(0)	59	76	63	64	(12)
913A	35	28	37	9	15	20	16	(5)	8	13	8	(5)	2	3	2	(0)	59	64	63	64	(0)
914A	27	31	28	(3)	11	13	13	0	6	7	6	(1)	2	2	2	(0)	46	52	49	50	(2)
915A	497	531	525	(6)	210	315	223	(92)	114	56	118	63	29	8	30	22	850	911	896	911	0
916A	17	17	18	1	7	9	8	(1)	4	2	4	2	1	0	1	1	29	28	31	31	3
917A	29	43	34	(8)	12	14	14	(0)	7	11	7	(4)	2	0	2	1	50	67	56	57	(10)
918A	15	21	16	(5)	6	8	7	(1)	3	2	3	1	1	0	1	1	26	31	27	28	(3)
919A	64	63	71	8	27	41	30	(11)	15	18	16	(2)	4	5	4	(1)	109	126	121	123	(3)
920A	208	225	223	(3)	88	106	96	(10)	48	47	52	5	12	5	13	8	356	383	384	390	7
920B	149	172	167	(5)	63	56	69	13	34	29	37	9	9	5	10	4	255	262	283	288	26
921A	27	30	28	(1)	11	11	12	1	6	4	7	3	2	1	2	1	46	45	49	50	5
922A	72	80	79	(1)	30	17	32	14	16	13	17	4	4	2	4	2	123	113	132	135	22
ALL	6,128	7,092	6,664	(428)	2,588	2,779	2,806	28	1,404	1,542	1,489	(52)	356	318	378	60	10,476	11,731	11,338	11,524	(207)

	FY '96	BES '96
C BES	11,338	11,524
Auth	10,476	
Avn	5,676	5,572
Tech	6,054	5,952
sum	11,731	11,524
2xNS	0	
BES '96	11,524	11,524
EOFY	(207)	0

PROJECTED INVENTORY AS OF EOFY '97																				
W O1/CW2					CW3				CW4				CW5					Total		
PMOS	Auth	inventory	BES	diff	Auth	inventory	BES	diff	Auth	inventory	BES	diff	Auth	inventory	BES	diff	Tot Auth	inventory	C-BES	A-BES	diff
000A	0	15	0	(15)	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	(15)
001A	0	0	0	(0)	0	0	0	0	0	1	0	(1)	0	0	0	0	0	1	0	0	(1)
003A	0	2	0	(2)	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	(2)
004A	0	0	0	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)
130A	0	(1)	0	1	0	1	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	(0)
130B	0	0	0	(0)	0	(0)	0	0	0	0	0	(0)	0	0	0	0	0	(0)	0	0	0
131A	86	138	92	(47)	36	20	39	20	20	9	22	13	5	3	5	2	147	170	158	161	(9)
132A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140A	11	15	12	(3)	4	4	7	2	2	1	2	2	1	0	1	0	18	20	22	22	2
140B	33	42	37	(6)	14	13	15	2	8	10	9	(1)	2	1	2	1	56	66	62	64	(2)
140D	6	4	7	3	3	3	3	(1)	1	3	2	(2)	0	2	0	(2)	11	13	12	12	(1)
140E	73	103	79	(24)	31	22	34	12	17	4	20	15	4	0	4	4	125	130	137	139	10
151A	106	106	112	5	45	62	50	(12)	24	24	26	2	6	9	6	(3)	181	201	194	198	(3)
152B/153	122	208	147	(62)	51	7	57	50	28	52	30	(22)	7	6	7	1	208	273	240	245	(28)
152C	42	42	47	5	18	17	20	3	10	14	12	(2)	2	3	2	(0)	72	75	81	82	7
152D	314	393	362	(31)	132	149	142	(7)	72	57	76	19	18	8	18	11	536	607	599	611	3
152F	498	421	544	123	210	357	221	(136)	114	141	118	(24)	29	29	29	0	851	948	911	929	(19)
152G	111	70	123	54	47	76	51	(25)	25	49	27	(22)	6	18	6	(12)	189	213	207	212	(1)
153A	79	154	95	(59)	33	0	33	33	18	0	20	20	5	4	5	1	135	157	153	156	(2)
153B	271	399	309	(90)	115	70	122	52	62	99	66	(33)	16	28	16	(12)	464	597	513	523	(74)
153C	903	926	976	50	381	470	420	(49)	207	214	220	5	52	42	52	10	1,544	1,653	1,668	1 702	49
154C	269	152	283	131	114	161	123	(38)	62	138	64	(74)	16	48	16	(32)	460	499	486	496	(3)
155A	11	11	11	(0)	4	1	4	3	2	2	3	1	1	2	1	(1)	18	16	19	19	3
155D	41	28	45	17	17	9	19	10	9	14	11	(3)	2	2	2	(0)	70	54	77	79	25
155E	106	26	120	94	45	98	53	(44)	24	100	26	(74)	6	32	6	(26)	181	256	206	210	(46)
156A	9	(13)	12	25	4	14	5	(10)	2	27	2	(24)	1	5	1	(4)	16	33	19	20	(13)
180A	214	279	231	(48)	90	56	97	41	49	44	49	5	12	0	12	12	365	379	390	397	18
210A	20	25	23	(3)	9	8	10	2	5	4	5	1	1	2	1	(0)	35	38	38	39	1
213A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215D	15	15	15	0	6	6	7	0	3	5	3	(2)	1	0	1	0	25	27	26	27	(1)
250A	93	102	99	(3)	39	43	42	(1)	21	31	23	(7)	5	3	5	2	159	179	170	173	(6)
250B	43	48	45	(4)	18	18	20	1	10	6	10	4	3	0	3	3	74	73	77	78	5
251A	52	57	55	(2)	22	22	23	1	12	13	12	(1)	3	2	3	1	89	94	93	95	1
256A	127	161	136	(25)	54	55	58	3	29	27	30	3	7	2	7	5	217	245	232	236	(9)
311A	232	284	247	(37)	98	92	106	14	53	32	56	24	13	5	13	9	396	412	422	430	18
350B	76	76	80	3	32	33	34	2	17	19	17	(2)	4	2	4	2	130	131	136	139	8
350D	51	58	52	(6)	21	21	25	4	12	10	12	1	3	1	3	2	87	90	92	94	4
350L	29	35	33	(2)	12	10	13	4	7	8	7	(2)	2	0	2	1	49	53	55	56	3
351B #	179	249	192	(58)	76	69	81	11	41	18	46	28	10	2	10	8	306	339	328	335	(4)
351C #	37	42	39	(3)	16	18	17	(2)	8	7	9	2	2	2	2	0	63	70	67	68	(1)
351E #	76	104	80	(23)	32	18	36	18	17	11	19	8	4	1	4	3	130	133	140	142	9
352C	92	121	100	(22)	39	34	41	7	21	12	26	14	5	1	5	5	158	168	172	176	8
352D	4	5	4	(1)	2	2	2	(1)	1	1	1	0	0	0	0	0	7	8	7	7	(1)
352G	31	33	35	3	13	22	14	(8)	7	7	9	1	2	1	2	1	53	62	59	60	(2)
352H	12	15	13	(2)	5	4	6	2	3	2	3	0	1	0	1	1	20	21	22	22	1
352J	25	28	28	0	11	10	11	1	6	8	6	(2)	1	1	1	0	43	47	47	48	0
352K	9	12	10	(2)	4	2	4	2	2	1	2	1	1	0	1	1	15	15	16	16	1
353A	25	30	26	(4)	10	14	12	(2)	6	3	6	2	1	0	1	1	42	48	45	46	(2)
420A	114	129	119	(10)	48	23	52	29	26	44	27	(17)	7	10	7	(4)	195	206	205	209	3
420C	22	17	23	6	9	15	11	(4)	5	9	5	(4)	1	1	1	(0)	37	42	40	41	(1)
550A	32	36	33	(3)	13	11	14	3	7	9	7	(2)	2	0	2	1	54	56	56	57	1
600A	1	(0)	1	1	0	1	0	(0)	0	3	0	(3)	0	0	0	(0)	1	3	1	1	(2)
640A	30	36	33	(2)	13	14	13	(1)	7	4	7	3	2	0	2	2	52	53	55	56	3
670A	42	54	45	(9)	18	13	19	6	10	7	10	3	2	0	2	2	71	74	76	77	3
880A	42	48	43	(6)	18	16	20	3	10	8	10	2	2	4	2	(2)	71	76	75	76	(0)
881A	50	68	54	(14)	21	18	23	6	12	6	13	6	3	2	3	1	86	94	93	95	1
910A	46	56	49	(7)	20	16	21	4	11	12	12	(0)	3	1	3	1	79	85	84	86	0
911A	0	(6)	0	6	0	3	0	(3)	0	4	0	(4)	0	2	0	(2)	0	3	0	0	(3)
912A	33	25	35	10	14	29	15	(13)	8	12	8	(5)	2	3	2	(1)	56	68	60	61	(7)
913A	34	32	36	5	14	14	15	1	8	14	8	(6)	2	3	2	(1)	58	63	62	63	(0)
914A	26	28	28	(1)	11	14	13	(1)	6	7	6	(1)	2	1	2	0	45	50	48	49	(1)
915A	490	539	517	(22)	207	281	219	(62)	112	75	117	42	28	8	28	21	837	903	881	899	(4)
916A	17	19	18	(1)	7	8	8	(0)	4	3	4	1	1	0	1	1	29	29	31	31	2
917A	28	33	33	(1)	12	16	13	(3)	6	10	6	(3)	2	1	2	1	48	60	54	55	(6)
918A	15	18	16	(2)	6	9	7	(2)	3	2	3	2	1	0	1	1	26	29	27	28	(1)
919A	63	66	70	4	27	35	30	(6)	14	17	16	(1)	4	5	4	(1)	108	124	119	122	(2)
920A	204	238	218	(21)	86	97	94	(3)	47	42	51	9	12	6	12	6	348	382	374	381	(1)
920B	144	194	161	(33)	61	46	67	20	33	25	36	11	8	5	8	3	246	271	272	278	7
921A	27	31	28	(3)	11	11	12	1	6	4	7	3	2	1	2	1	46	48	49	50	2
922A	70	98	77	(21)	29	14	31	17	16	10	17	7	4	2	4	2	119	124	128	131	7
ALL	6,059	6,780	6,588	(192)	2,558	2,816	2,773	(43)	1,388	1,555	1,472	(83)	352	324	352	29	10,357	11,475	11,186	11,410	(65)

	FY '97	BES '97
C BES	11,186	11,410
Auth	10,357	
Avn	5,389	0
Tech	6,086	0
sum	11,475	0
2xNS	0	
BES '97	11,410	0
EOFY	(65)	0

PROJECTED INVENTORY AS OF EOFY '98																					
WO1/CW2					CW3				CW4				CW5					Total			
PMOS	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Auth	Inventory	BES	diff	Autr	Inventory	BES	diff	Tot Auth	Inventory	C-BES	A-BES	diff
000A	0	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)	0	0	0
001A	0	(1)	0	1	0	0	0	0	0	1	0	(1)	0	0	0	0	0	0	0	0	(0)
003A	0	0	0	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)
004A	0	0	0	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(0)
130A	0	(1)	0	1	0	1	0	(1)	0	0	0	0	0	0	0	0	0	0	0	0	(0)
130B	0	(1)	0	1	0	0	0	(0)	0	0	0	(0)	0	0	0	0	0	0	0	0	(0)
131A	101	159	107	(52)	42	17	46	29	23	9	25	16	6	3	6	4	172	188	185	188	(0)
132A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140A	11	18	12	(6)	4	3	7	4	2	0	2	2	1	0	1	0	18	22	22	22	0
140B	34	41	38	(3)	14	13	16	3	8	11	9	(2)	2	1	2	2	58	66	65	66	0
140D	6	4	7	3	3	3	3	(0)	1	3	2	(2)	0	2	0	(1)	11	12	12	12	(0)
140E	73	106	79	(27)	31	25	34	10	17	9	20	11	4	0	5	5	125	140	137	140	0
151A	106	116	112	(4)	45	50	50	(0)	24	23	26	3	6	8	7	(1)	181	198	195	198	0
152B/153	107	123	129	6	45	3	50	47	25	84	26	(58)	6	6	7	1	183	216	212	216	0
152C	42	52	47	(5)	18	15	20	4	10	12	12	(0)	2	3	3	0	72	82	81	82	(0)
152D	338	419	391	(29)	143	164	153	(10)	77	67	82	15	20	8	21	13	578	658	647	658	0
152F	508	347	555	208	215	371	225	(146)	116	201	120	(81)	30	27	30	3	869	947	931	947	(0)
152G	95	18	106	88	40	69	44	(25)	22	79	23	(56)	6	16	6	(10)	163	182	179	182	0
153A	80	154	95	(59)	34	0	34	34	18	0	20	20	5	3	5	2	136	157	154	157	0
153B	267	315	304	(11)	113	53	120	67	61	119	64	(55)	16	26	16	(10)	456	513	505	513	0
153D	893	883	964	82	377	491	415	(76)	204	260	217	(43)	52	46	55	10	1,526	1,680	1,652	1,680	(0)
154C	269	109	283	174	114	172	123	(49)	62	165	64	(102)	16	48	16	(32)	460	495	486	495	(0)
155A	11	14	11	(4)	4	1	4	3	2	2	3	1	1	2	1	(1)	18	19	19	19	(0)
155D	41	58	45	(13)	17	9	19	11	9	10	11	1	2	2	3	1	70	79	78	79	0
155E	105	(1)	119	121	44	98	53	(45)	24	84	26	(58)	6	28	7	(21)	180	209	205	209	(0)
156A	9	(20)	12	32	4	13	5	(8)	2	23	2	(20)	1	4	1	(4)	16	20	19	20	(0)
180A	214	277	231	(46)	90	58	97	39	49	61	49	(12)	12	0	12	12	365	396	390	396	0
210A	20	27	23	(4)	9	8	10	2	5	3	5	1	1	2	1	(1)	35	39	38	39	(0)
213A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215D	15	13	15	2	6	6	7	0	3	7	3	(4)	1	0	1	0	25	27	26	27	(0)
250A	93	102	99	(3)	39	39	42	3	21	27	23	(4)	5	5	6	1	159	173	170	173	0
250B	43	48	45	(4)	18	21	20	(1)	10	9	10	1	3	0	3	3	74	78	77	78	(0)
251A	52	64	55	(9)	22	18	23	5	12	11	12	1	3	2	3	1	89	95	93	95	0
256A	127	149	136	(13)	54	54	58	4	29	30	30	0	7	3	8	5	217	236	232	236	0
311A	232	313	247	(66)	98	83	106	23	53	29	56	26	13	4	14	10	396	430	422	430	0
350B	76	89	80	(10)	32	30	34	4	17	15	17	2	4	3	4	1	130	138	136	138	0
350D	51	57	52	(5)	21	23	25	2	12	13	12	(1)	3	1	3	2	87	93	92	93	0
350L	29	35	33	(1)	12	10	13	3	7	10	7	(3)	2	0	2	1	49	56	55	56	0
351B#	178	245	190	(55)	75	66	80	14	41	19	46	26	10	2	12	9	304	333	328	333	0
351C#	37	42	39	(3)	16	18	17	(1)	8	6	9	3	2	2	2	0	63	68	67	68	0
351E#	76	110	80	(29)	32	18	36	18	17	13	19	6	4	1	5	4	130	142	140	142	0
352C	92	134	100	(35)	39	30	41	11	21	12	26	15	5	0	7	6	158	177	174	177	0
352D	4	4	4	(0)	2	2	2	(0)	1	1	1	0	0	0	0	0	7	7	7	7	0
352G	31	33	35	2	13	19	14	(5)	7	7	9	1	2	1	2	1	53	61	60	61	0
352H	12	16	13	(3)	5	4	6	2	3	3	3	0	1	0	1	1	20	22	22	22	0
352J	25	28	28	1	11	9	11	2	6	9	6	(3)	1	1	1	0	43	47	47	47	(0)
352K	9	12	10	(2)	4	2	4	2	2	2	2	(0)	1	0	1	1	15	16	16	16	0
353A	25	29	26	(3)	10	13	12	(1)	6	3	6	2	1	0	1	1	42	46	45	46	0
420A	114	144	119	(25)	48	18	52	34	26	37	27	(10)	7	9	7	(2)	195	209	205	209	0
420C	22	17	23	6	9	14	11	(4)	5	8	5	(3)	1	2	1	(0)	37	41	40	41	0
550A	32	36	33	(3)	13	11	14	3	7	9	7	(2)	2	1	2	1	54	57	56	57	0
600A	1	(1)	1	2	0	0	0	0	0	2	0	(2)	0	0	0	(0)	1	1	1	1	0
640A	30	37	32	(4)	13	14	13	(1)	7	5	7	2	2	0	2	2	51	55	54	55	0
670A	41	57	44	(13)	17	12	19	7	9	7	9	3	2	0	2	2	70	76	74	76	(0)
880A	42	51	43	(9)	18	15	20	5	10	7	10	4	2	4	3	(1)	71	76	75	76	(0)
881A	50	73	54	(19)	21	15	23	9	12	6	13	7	3	2	3	2	86	95	93	95	(0)
910A	46	59	49	(10)	20	14	21	6	11	11	12	0	3	1	3	2	79	86	84	86	0
911A	0	(7)	0	7	0	2	0	(2)	0	3	0	(3)	0	2	0	(2)	0	0	0	0	(0)
912A	33	16	35	19	14	28	15	(13)	8	14	8	(6)	2	3	2	(1)	56	61	60	61	0
913A	34	34	36	3	14	13	15	3	8	13	8	(5)	2	3	2	(1)	58	63	62	63	0
914A	26	29	28	(1)	11	12	13	0	6	6	6	0	2	2	2	(0)	45	49	48	49	(0)
915A	491	577	519	(58)	207	249	220	(29)	113	68	117	49	29	7	30	23	840	901	886	901	0
916A	17	21	18	(4)	7	7	8	0	4	2	4	2	1	0	1	1	29	31	31	31	(0)
917A	28	21	33	12	12	20	13	(7)	6	12	6	(6)	2	1	2	1	48	55	54	55	(0)
918A	15	15	16	1	6	10	7	(3)	3	3	3	1	1	0	1	1	26	28	27	28	0
919A	63	72	70	(1)	27	30	30	(1)	14	15	16	1	4	5	4	(1)	108	122	120	122	0
920A	205	264	219	(45)	86	80	94	14	47	33	51	18	12	6	13	7	350	384	377	384	0
920B	144	211	161	(50)	61	37	67	29	33	24	36	12	8	5	9	4	246	278	273	278	0
921A	27	35	28	(6)	11	10	12	2	6	5	7	3	2	1	2	1	46	50	49	50	0
922A	71	110	78	(32)	30	12	31	20	16	8	17	9	4	3	4	2	121	133	130	133	0
ALL	6,066	6,612	6,596	(16)	2,561	2,730	2,776	46	1,390	1,754	1,474	(279)	353	315	374	59	10,370	11,410	11,220	11,410	(0)

	FY '98	BES '99
C BES	11,220	11,410
Auth	10,370	
Avn	5,257	0
Tech	6,153	0
sum	11,410	0
2xNS	0	
BES '98	11,410	0
EOFY	(0)	0

Appendix C

Historical accession plan for 1994. Optimized accession plan for projection years 1995 to 1998.

Accessions					
PMOS	'94	'95	'96	'97	'98
000A	0	(15)	(15)	(15)	(15)
001A	0	(1)	(1)	(1)	(1)
003A	0	(1)	(1)	(1)	(1)
004A	0	(0)	(0)	(0)	(0)
130A	0	(0)	(0)	(0)	(0)
130B	0	0	0	0	0
131A	9	37	37	37	37
132A	0	0	0	0	0
140A	1	5	5	5	5
140B	6	8	8	8	8
140D	0	2	2	2	2
140E	8	24	24	24	24
151A	10	26	26	26	26
152B/3C	176	112	112	112	112
152C	0	14	14	14	14
152D	0	(22)	(22)	(22)	(22)
152F	0	(1)	(1)	(1)	(1)
152G	0	58	58	58	58
153A	0	31	31	31	31
153B	202	165	165	165	165
153D	0	(26)	(26)	(26)	(26)
154C	0	(42)	(42)	(42)	(42)
155A	0	3	3	3	3
155D	0	29	29	29	29
155E	0	(62)	(62)	(62)	(62)
156A	0	(7)	(7)	(7)	(7)
180A	59	41	41	41	41
210A	3	5	5	5	5
213A	0	0	0	0	0
215D	2	2	2	2	2
250A	15	18	18	18	18
250B	5	6	6	6	6
251A	8	15	15	15	15
256A	23	21	21	21	21
311A	31	73	73	73	73
350B	9	19	19	19	19
350D	5	8	8	8	8
350L	6	7	7	7	7
351B#	33	37	37	37	37
351C#	0	2	2	2	2
351E#	9	24	24	24	24
352C	15	29	29	29	29
352D	1	0	0	0	0
352G	3	5	5	5	5
352H	1	4	4	4	4
352J	4	3	3	3	3
352K	1	2	2	2	2
353A	4	4	4	4	4
420A	18	39	39	39	39
420C	2	1	1	1	1
550A	4	5	5	5	5
600A	0	(1)	(1)	(1)	(1)
640A	3	6	6	6	6
670A	6	10	10	10	10
880A	9	7	7	7	7
881A	10	9	9	9	9
910A	5	15	15	15	15
911A	0	(2)	(2)	(2)	(2)
912A	5	(1)	(1)	(1)	(1)
913A	4	8	8	8	8
914A	3	6	6	6	6
915A	63	110	110	110	110
916A	2	3	3	3	3
917A	12	(4)	(4)	(4)	(4)
918A	2	0	0	0	0
919A	8	15	15	15	15
920A	33	58	58	58	58
920B	23	73	73	73	73
921A	3	8	8	8	8
922A	13	38	38	38	38
ALL	877	1,082	1,082	1,082	1,082