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A METHODOLOGY TO GENERATE AIR FORCE MATERIEL COMMAND MANPOWER REDUCTION ALTERNATIVES

THESIS

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The purpose of this study is to generate manpower authorization reduction alternatives for Air Force Materiel Command. The advent of low-cost personal computer software applications, such as Excel, has created an assessable tool with the ability to solve linear programming problems. This research examines the manpower resource reduction process of Air Force Materiel Command and models the Resources Allocation - Integrated Process Team (RA-IPT) decision process. A linear programming model is developed to assign these reduction through a weighted sum. The linear programming model is developed as a Microsoft Excel spreadsheet model, the Exercise Support Program (ESP), using Visual Basic macro language. ESP uses the input parameters to generate decision alternatives for the decision makers at the RA-IPT. Test cases are developed to validate the model using known scenarios, and sensitivity analysis is shown for the weight parameters and the constraints. The study reveals that ESP is a viable methodology to generate decision alternatives and to assign manpower reductions in each organization throughout the command.

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A METHODOLOGY TO GENERATE AIR FORCE MATERIEL COMMAND MANPOWER REDUCTION ALTERNATIVES

THESIS

Presented to the Faculty of the Graduate School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

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Steven T. Bishop

Captain, USAF

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Acknowledgments

This thesis is dedicated to my devoted family whose undying devotion to me and my ambitions have kept me sane through these past few months. To my wife, Lauren, willing to follow me to the ends of the earth, I'm indebted to her for the rest of my life. My children, Savannah and Summer, for their love and special ways of saying, "I Love You!". Also, to my parents, who guided me throughout my childhood toward high standards and goals. The encouragement that I have received from these people in my life have made this program a success for me.

After having completed one of the toughest challenges of my life, I think I finally understand the concept of teamwork and support of others. I am forever grateful to the friends that I have made here at AFIT for their support and compassion. The challenges that we faced while here, were faced head on as a team. Not one person was left behind without someone stopping to help them catch up.

Most importantly, I would like to thank my Savior, Jesus Christ, who gave me the strength to make it through every exam, briefing, and late night that I encountered. My faith only has gotten stronger in His love and commitment to us as His children. I can only say thanks for blessing me so much with family and friends, and a career that can allow me to make a difference.

Steven T. Bishop

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Abstract

The Air Force Materiel Command has a requirement to assign manpower reduction allocations within their organization, but no methodology currently exists to allocate these reductions. This research examines the manpower resource reduction process of Air Force Materiel Command and models the Resource Allocation - Integrated Process Team (RA-IPT) decision process. A linear programming model was developed to assign these reductions through a weighted sum. The linear programming model is developed as a Microsoft Excel spreadsheet model, the Exercise Support Program (ESP), using the Visual Basic macro language. ESP uses the input parameters to generate decision alternatives for the decision makers at the RA-IPT. Test cases are developed to validate the model using known scenarios, and sensitivity analysis is shown for the weight parameters and the constraints. The study reveals that ESP is a viable methodology to generate decision alternatives and to assign manpower reductions in each organization throughout the command.

A Methodology to Assign Air Force Materiel Command Manpower Reduction Alternatives

I. Introduction

1.1 Problem Statement

Military decision makers are faced with important decisions that often affect billions of dollars in resources. With declining Air Force resources, decision makers need tools to help prioritize programs and evaluate manpower alternatives. In spite of the importance of the decision, there is currently no standardized methodology available to quantify the effects of the manpower alternatives (3). The Air Force requires a decision aid to provide decision alternatives to decision makers to ensure the utilization of reduced manpower effectively supports the mission accomplishment.

1.2 Background

In the mid-1980s, Congress began to reduce the defense budget and made both manpower and force structure reductions. Controversy abounded regarding the correct way to make these reductions. The Air Force, as well as, other Department of Defense (DoD) Agencies began implementing these reductions.

The manpower reductions were both programmatic and non-programmatic. Programmatic reductions are those reductions involving either an entire program or a portion of a program. Non-programmatic reductions involve no direct connection to a particular program. These reductions are arbitrary in nature and can be applied to any part of the organization.

The current manpower constraints in regard to civilian/military mix and officer-to-enlisted ratios along with security and safety issues made these reductions even more difficult to make. Also, the military leaders attempted to efficiently implement the reductions in order to minimize the loss of military capability.

Organizational restructuring became part of the initial phase of the implementation of the manpower reductions. Since the primary areas of reduction were in the base support areas like logistics, finance, facilities management, and base operations, military leaders were forced to accomplish their missions with fewer authorizations. This was achieved by consolidation of common functions and streamlining of processes. Bases were closed in the United States and overseas. Base missions were realigned to reduce overhead and support costs. Air Force officials hoped that, with these changes, the manpower reductions would have the least impact on mission accomplishment.

1.3 Research Scope and Objectives

The primary objective of this research is to provide a method to analyze manpower resource allocation. This research attempts to capture the constraints and preferences of the leaders tasked to make manpower reduction decisions.

These constraints and preferences are a necessary means for generating acceptable manpower reduction decision alternatives.

This research only addresses the manpower resources of the Air Force Materiel Command (AFMC). The decision support model developed in this research will be used by the research sponsor, Headquarters Air Force Materiel Command (HQAFMC) Manpower Office to assist the Resource Allocation - Integrated Process Team (RA-IPT). The model is intended for Air Force manpower analysts and decision makers to use in creating manpower resource allocation decision alternatives.

This model uses linear programming to allocate manpower reductions among mission elements in an organization while optimizing the manpower authorizations that remain in an organization. The optimization is accomplished after the user assigns weights to specific organizations. The allocation reflects AFMC's organizational hierarchy. Figure 1 depicts the organizational hierarchy of AFMC.

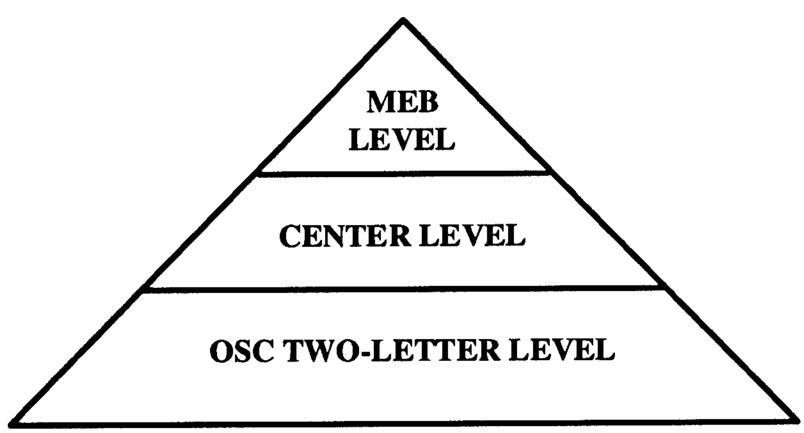

Figure 1. AFMCs Organizational Hierarchy

At the top of the pyramid are the Mission Element Boards (MEBs). There are five MEBs: Base Operating Support (BOS), Product Management (PM), Support and Industrial Operations (S&IO), Science and Technology (S&T), and Test and Evaluation (T&E). Within each of the MEBs are the centers which include the product centers, air logistics centers, laboratories, and the test centers. At the bottom of the pyramid are the Organization Structure Codes (OSC). In the organizational framework of any Air Force organization, the Organization Structure Codes at a two-letter designation provide a roadmap to the chain of command. Letters are added as appropriate to further detail the subordinate organizations of each two-letter OSC. Beneath the two-letter OSCs, the organizations get more specialized. For this research effort, the reduction allocation goes down only to the two-letter OSC.

A secondary objective is to publish these methodologies and the decision model in a 38 series Air Force Manual for Air Force-wide use. This would allow the decision makers at base level to use the model to assist them in providing input on manpower reductions to their major command.

1.4 Resource Allocation Integrated Process Team (RA-IPT)

Air Force Materiel Command has developed a resource allocation governing body called the Resource Allocation - Integrated Process Team (RA-IPT). The composition of this team includes representatives from each of the MEBs. Each MEB has Headquarters Focal Points which are the following:

AFMC/CE represents the BOS MEB, AFMC/DR represents the PM MEB, AFMC/LG represents the S&IO MEB, AFMC/ST represents the S&T MEB, and AFMC/DO represents the T&E MEB. These representatives solicit input from their subordinate centers on the most feasible way of implementing a manpower reduction or resource allocation. Each of the inputs are considered and a solution is formulated for the command.

1.5 Use of Linear Programming

Linear programming is a modeling tool used to solve optimization problems. This tool has been used to solve many different types of problems. For example, transportation problems, scheduling problems, and resource allocation problems. In this research, linear programming techniques are applied to the AFMC manpower reduction allocation problem. Linear programming within a spreadsheet environmant is used to distribute the manpower reductions. With this linear programming approach, decision alternatives can be generated by changing the parameters that are input to the linear programming model.

1.6 Use of Decision Alternatives

Decision alternatives allow the decision makers to examine a reduction problem from many different view points. From these points of view, issues can be discussed and resolved to benefit the entire organization. Each decision maker has restrictions on where manpower reductions can be made. The decision making body can then explore feasible options which do not violate stated constraints. From these decision alternatives, the decision makers can determine the most beneficial option that has the least impact on the organization.

1.7 Overview of Thesis

Chapter II presents a brief history of AFMC's approach to manpower reductions. Then, some recent efforts in developing a resource allocation model for manpower reductions are presented. This chapter also summarizes the current structure of the manpower reduction decision making process and some of the major components of the process.

Chapter III describes the development of the Exercise Support Program (ESP) Decision Support System methodology. Each model variable, model parameter and the assumptions are identified.

Chapter IV is a review of the analytical results obtained with the model. Sensitivity of the model parameters and the behavior of the model are explored.

Finally, Chapter V summarizes the research, presents significant findings, and draws conclusions. Suggestions for further research in the area of manpower reduction allocation are presented as guidance for follow-on studies.

II. Modeling Manpower Resource Reduction Decision Making

Since the mid-1980s, AFMC and its predecessor commands have been tasked to reduce manpower resource levels. This chapter discusses past AFMC manpower reduction decisions and investigates past research into the reduction of manpower and AFMC's current approach to manpower reduction taskings.

2.1 The History of AFMC Reduction Decisions

AFMC has been faced with reductions due to budgetary decreases. Major program deletions and other non-programmatic reductions have forced mission areas to become much more efficient in the accomplishment of the mission. A large part of the non-programmatic reductions have been in the Base Operating Support areas. This has reduced BOS agencies' ability to completely satisfy customer needs because the BOS manpower level is reduced, but the BOS workload does not proportionally decrease.

2.2 Resource Allocation Decision Model (RADM)

Recent manpower reduction studies have produced the Resource Allocation Decision Model (RADM). This model was developed by the Manpower Office at the San Antonio Air Logistics Center. RADM approaches manpower reduction allocation alternatives from a service based point of view. These service based alternatives help direct resources to where they are needed most. They provide a basis for aligning resources with priorities and permit an evaluation of services on a common basis without regard to the organization that provides them (4).

The shortcomings of RADM were identified by the HQAFMC/XPMQ Models Team. They determined that service based alternatives were hard to generate. They require an examination of each customer service to establish priorities and a means of evaluating lots of information quickly. Also, this approach requires extensive data collection (4).

Users at HQAFMC indicated that the RADM was too constrictive. The input parameters were not accessible to the user. Therefore, the decision maker could not bring his or her intuition to bear on the reduction problem.

2.3 Current Methodologies of AFMC for Manpower Reductions

The Air Staff is the originating Air Force agency for resource allocation whether it be dollars, manpower, or force structure. AFMC responds to the taskings of the Air Staff. Manpower reduction taskings come to AFMC/XPM in primarily two forms: programmatic and non-programmatic.

The programmatic reductions are the least difficult of the two taskings. They deal with program-related resources that are identified to support the weapon system or other program. Therefore, the affected authorizations can be deleted in whole or reduced by a percentage to meet the reduced requirement for the program or weapon system. With programmatic reductions, the authorizations to be reduced can usually be identified by the Program Element Code (PEC). PEC Codes identify manpower authorizations in the Command Manpower Data File (CMDS) according to the programs they support.

Non-programmatic reductions are much more difficult to implement since there is no decrease in associated workload. The work must be done, but the dollars are not there to fund the resources required. Therefore, decision makers must take into account the affect of manpower reductions on productivity and mission accomplishment.

Once a reduction tasking is received by AFMC/XPM, they brief the Command Section and forward a copy to the Manpower Requirements Section. The Manpower Requirements Section analyzes the tasking and formulates the constraints on the reduction problem. Most often, a certain number or percentage is associated with a manpower reduction. These numbers or percentages are set by the Air Staff which obtains the Air Force reduction goal from DoD or Congress. The other constraints are based on the type of reduction that is needed and on other organization-specific restrictions. Other constraints in a reduction exercise can confine reductions to a specific group of PECs, to certain MEBs, to only civilians or only military, to a reduced set of command bases, or to a major center.

There also can exist restrictions other than those included in the tasking. Sometimes outside requirements will warrant special attention by decision makers. The Air Force has put certain restrictions on, for example, Officer to Enlisted

Ratios and endstrength requirements. RA-IPT decisions must comply with these restrictions.

AFMC/XPM provides the tasking constraints to the RA-IPT along with any other information that would assist these decision makers. Figure 2 represents the current RA-IPT resource allocation decision making process.

AFMC/XPM submits to the RA-IPT an initial recommendation on where reductions should be made. Also, information that is deemed valuable to the RA-IPT is submitted for consideration in making the decision. This information consists of graphs and summary reports generated from the Command Manpower Data System (CMDS) and other sources.

Once the decision body is aware of the tasking, each decision maker then begins work on what portion of the reduction the decision maker's organization can implement without adversely affecting the mission. Each of the MEB representatives call resource allocation meetings within their MEB to assess their MEB's role in the reduction. From these meetings, the MEB representatives bring back their positions to the RA-IPT. Mostly, the decisions made in a RA-IPT meeting are accomplished using the "squeaky wheel" concept. The position adopted is often that of the MEB whose representative supports the MEB's position the best. This method has no statistical, mathematical, nor analytical basis; therefore, it may not select the best way in which the reductions could be made so as to preserve the productivity levels needed to accomplish the mission.

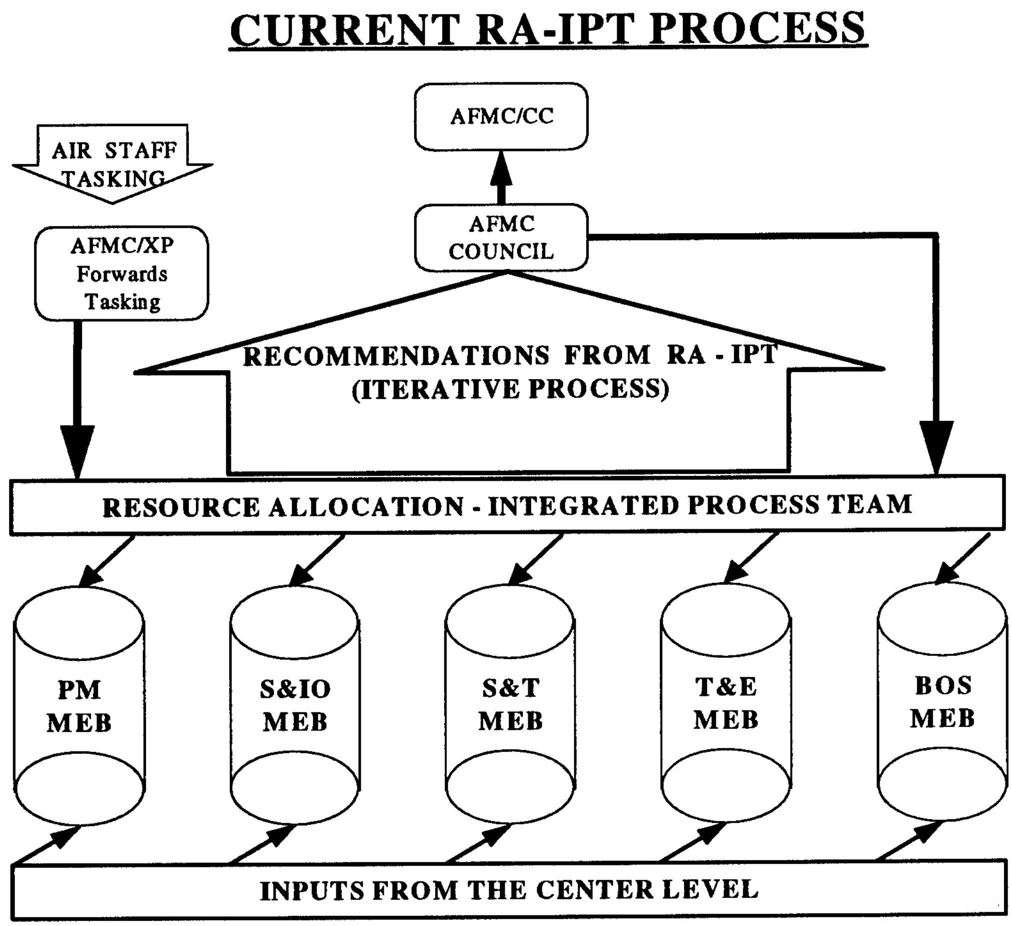

Figure 2. Current RA-IPT Resource Allocation Decision Making Process

Often, the decision comes down to a percentage spread across the affected areas which also may not be the best way to implement the reduction (2).

Once the decisions have been made by the RA-IPT, AFMC/XPM forwards the results to the Command Section, and if the input is approved, AFMC/XPM updates the CMDS to reflect the reductions.

2.4 The Command Manpower Data System (CMDS)

The CMDS is a computer system that the Manpower Offices use at command levels to track and audit the manpower authorizations allocated to them by the Air Staff. The Command Manpower Datafile (CMDF) contains all of the information about each of the authorizations; the type, skill level, grade, and specialty. Also, the CMDF contains the locations where the authorizations are funded and assigned (1).

The CMDS tracks 29 quarters of data, beginning with the current quarter. This information is used by the Manpower Offices to forecast changes in the number of authorizations. The authorization levels are determined by the missions and the funding for each organization.

The CMDF is segregated down to the Base Manpower Datafile. This allows the base-level Manpower Offices to track their respective base manpower authorization levels. Changes generated at the base level are forwarded back up to the command level for approval and altering of the CMDF.

2.5 Decision Support Systems

A decision support system provides a decision maker with a tool to use in making important decisions (6:285-286). A decision support system can be a powerful tool to assist a decision maker.

With automated decision support systems, the decision maker can generate differing alternatives based upon the input to the system. These inputs could be supply levels, acceptable risk levels, or available manpower levels. When these parameters are altered, the decision alternative produced by the system changes. This gives the decision maker a group of options to choose from. The decision maker is then able to examine the options and selects the best alternative to match the situation.

Chapter III presents a decision support system designed to aide decision makers with difficult manpower reduction decisions. The decision support system developed is named the Exercise Support Program (ESP) and it provides decision makers with a tool that generates manpower reduction alternatives.

III. Exercise Support Program (ESP) Model

This chapter presents a method which can be used to generate alternative manpower reduction scenarios for the Air Force Materiel Command Resource Allocation Integrated Process Team (RA-IPT). The ESP Model uses linear programming techniques and was developed to provide decision alternatives to the decision makers. Additionally, the model was developed to enhance the information available to the decision maker in a manpower resource allocation exercise. A scenario was devised to use in the development of the model.

3.1 Development of the Linear Programming Model for ESP

The major effort of this research was the development of a linear programming model to determine the resulting manpower level after a manpower reduction. The data generated from the Command Manpower Data System (CMDS) consisted of the five MEBs, their subordinate centers, and each center's subordinate two-letter OSCs. The breakout of the data was according to the total number of officer, enlisted, and civilian authorizations in each two-letter OSC for the current year, Y(C), and the following five years, Y(1) through Y(5). The data used for this research was from September 1994. An excerpt of this data appears in Appendix A.

The linear program solver that was used was the Microsoft Excel Solver Add-in routine supplied with Excel 5.0. The limitations of Excel and the Solver caused a few problems in the development of the linear programs. Solver is limited to 200 variables and a maximum of 100 constraints for each optimization. Excel is limited to 16,148 database records in one spreadsheet (5:80).

The data from the CMDS for AFMC had 1048 records to input to ESP. Because of the magnitude of the data, the linear programming model had to be decomposed into problems that Excel could handle. This resulted in optimum solutions within each linear program, but an optimal solution is not guaranteed for the final manpower reduction decision alternative. An optimal decision solution is not the goal of ESP. Its goal is the generation of decision alternatives which satisfy the reduction requirements and comply with the constraints.

The following are the linear programming models presented in the three steps taken to formulate a manpower reduction alternative for the RA-IPT. The linear program in each step is a weighted sum over the appropriate AFMC hierarchal organizational level. The indices are as follows:

m = 1 ... # Mission Elements

c = 1 ... # Centers subordinate to the MEBs

t = 1 ... # Two-Letter OSCs subordinate to the Centers

r = Grades: Officer, Enlisted, or Civilian

y = Year(C), Year(1), Year(2), Year(3), Year(4), or Year(5)

Step 1 in the manpower reduction process occurs at the MEB Level.

Let $\mathbf{X_{mry}}$ = Number of Manpower Authorizations in each MEB m by Grade r for each Year y **after** the reductions

$\mathbf{(\tilde{X})_{mry}}$ = Parameter Designated for the Authorized Manpower in each MEB m by Grade r for each Year y **before** the reductions

$\mathbf{w_{my}}$ = Nonnegative Parameter Designated for the Weight Assigned to each MEB m by Year y

$\mathbf{N_y}$ = Number to be Reduced from the Current Authorized Manpower by Year y

$\mathbf{L_{ry}}$ = Parameter Designated for the Percentage of Authorized Manpower **Allowed** to be Reduced by Grade r for each Year y

$\mathbf{R_y}$ = Parameter Designated for the Officer-to-Enlisted Ratio

$$\text{MAX} \quad \text{STRENGTH} = \sum_m \left(w_{my} \sum_r X_{mry}\right)$$

SUBJECT TO

$$\sum_r \sum_m X_{mry} = \sum_r \sum_m (\tilde{X})_{mry} - N_y \qquad \text{for each y}$$

$$(1 - L_{ry})(\tilde{X})_{mry} \le X_{mry} \le (\tilde{X})_{mry} \qquad \text{for each m,r,y}$$

$$\sum_r \left(X_{(1)ry} + X_{(2)ry} + X_{(3)ry} + X_{(4)ry} + X_{(5)ry}\right) =$$

$$\sum_m \left(X_{m(civ)y} + X_{m(enl)y} + X_{m(off)y}\right) \qquad \text{for all y}$$

$$R_y \sum_m X_{m(off)y} \le \sum_m X_{m(enl)y} \qquad \text{for all y}$$

$$X_{mry} \ge 0 \qquad \text{for all m,r,y}$$

The function that is maximized at Step 1 is a weighted sum of the levels of manpower authorizations remaining after the reduction is taken. These weights correspond to the "value" that a decision maker places upon a particular organization's mission. Organizations with higher weight values would receive less of the manpower reduction than organizations with lower weight value. The defaults for these weights, w_{my}, are the respective organization's percentage of the total authorized manpower. These default weights are indicative of the revealed preferences of the command on the mission of the organization and assume more manpower resources are placed in those areas of most importance.

The first constraint,

$$\sum_r \sum_m X_{mry} = \sum_r \sum_m (X^{\sim})_{mry} - N_y \qquad \text{for each y}$$

states that the sum of the reduced strength for the MEBs over Grade r for each Year y will be <u>equal</u> to the sum of the current strength over Grade r for each Year y for the MEBs minus the number of manpower authorizations that the RA-IPT is tasked to reduce for each Year y. This constraint ensures the required reduction is indeed applied to the current authorized manpower levels.

The second constraint provides an upper and lower bound on the values the decision variables can take.

$$(1 - L_{ry})(X^{\sim})_{mry} \le X_{mry} \le (X^{\sim})_{mry} \qquad \text{for each m,r,y}$$

The upper bound is simply the current number of manpower authorizations in each of the organizations. This ensures that the reduction cannot exceed the current manpower levels in an organization. The lower bound is an input parameter from the user. It corresponds to the amount allowed to be reduced in each of the Grades. For example, if a decision maker is only willing to reduce 10% of the current authorized civilian manpower in Year y, then $L_{(civ)y} = 0.10$ and the lower bound is $0.90(X^{\sim})_{m(civ)y}$ and this value is input into the model for the lower bound on the civilian reduction.

The third constraint in the linear model is a "sanity" check.

$$\sum_r (X_{(1)ry} + X_{(2)ry} + X_{(3)ry} + X_{(4)ry} + X_{(5)ry}) = \sum_m (X_{m(civ)y} + X_{m(enl)y} + X_{m(off)y}) \qquad \text{for all } y$$

This constraint sums over the Grades for each of the MEBs and sets it equal to the sum over the MEBs for each Grade. It is required to ensure that the sum of the elements in one column of the ESP spreadsheet does equal the sum of the elements in the appropriate row.

The fourth constraint in Step 1,

$$R_y \sum_m X_{m(off)y} \leq \sum_m X_{m(enl)y} \qquad \text{for all } y$$

is the Officer-to Enlisted Ratio constraint. The Officer-to Enlisted Ratio is set at the Air Staff level to control the balance of the officers in any one command-level organization as compared to the number of enlisted. This constraint ensures that at the highest level in the organizational hierarchy, the pre-set ratio is met.

Step 2 in the manpower reduction process occurs at the center level.

Let $\mathbf{X_{mcry}}$ = Number of Manpower Authorizations in each Center c by Grade r for each MEB m by Year y **after** the reduction

$\mathbf{(X^{\sim})_{mcry}}$ = Parameter Designated for the Authorized Manpower in each Center c by Grade r for each MEB m by Year y **before** the reduction

$\mathbf{w_{mcy}}$ = Nonnegative Parameter Designated for the Weight Assigned to each Center c within each MEB m for each Year y

$\mathbf{(N^{\sim})_{mry}}$ = Number to be Reduced from the Current Authorized Manpower in each Center c as determined in Step 1 for each MEB m by Grade r for each Year y

$\mathbf{L_{ry}}$ = Parameter Designated for the Percentage of Authorized Manpower **Allowed** to be Reduced by Grade r for each Year y

$$\text{MAX} \quad \text{STRENGTH} = \sum_{c}\left(w_{mcy}\sum_{r} X_{mcry}\right)$$

SUBJECT TO

$$\sum_{r}\sum_{c} X_{mcry} = \sum_{r}\sum_{c} (X^{\sim})_{mcry} - (N^{\sim})_{mry} \qquad \text{for each m,y}$$

$$(1-L_{ry})(X^{\sim})_{mcry} \le X_{mcry} \le (X^{\sim})_{mcry} \qquad \text{for each m,c,r,y}$$

$$\sum_{r}(X_{m(1)ry} + X_{m(2)ry} + \ldots + X_{mcry}) =$$

$$\sum_{c}(X_{mc(civ)y} + X_{mc(enl)y} + X_{mc(off)y}) \qquad \text{for all m,y}$$

$$X_{mcry} \ge 0 \qquad \text{for all m,c,r,y}$$

The objective function in Step 2 is a weighted sum of X_{mcry}. The weights are just as they were in the Step 1 linear program. Again, higher weights indicate greater "value".

In Step 2, the center level, the first constraint,

$$\sum_{r}\sum_{c} X_{mcry} \quad = \quad \sum_{r}\sum_{c} (X^{\sim})_{mcry} - (N^{\sim})_{mry} \qquad \text{for each m,y}$$

also ensures that the proper number of manpower resources are reduced from the current authorized manpower levels, but the number reduced from each of the centers varies according to the amount that was reduced from each Grade r at the MEB level in Step 1. Before beginning Step 2, the reduction for each MEB by Grade must be computed. The reduction is $(N^{\sim})_{mry} = (X^{\sim})_{mry} - X_{mry}$ for each m,r, and y. The parameter $(N^{\sim})_{mry}$ acts as a link between Step 1 and Step 2 and ensures that the reductions are properly administered to each grade within each center. That is, the number reduced as determined from the optimization in Step 1 for each of the MEBs is then spread across its subordinate centers in the optimization at the center level in Step 2.

The second constraint sets the upper and lower bounds on the decision variable, X_{mcry}. The third constraint in the linear model is again a "sanity" check.

$$\sum_{r}(X_{m(1)ry} + X_{m(2)ry} + \ldots + X_{mcry}) \quad =$$

$$\sum_{c}(X_{mc(civ)y} + X_{mc(enl)y} + X_{mc(off)y}) \qquad \text{for all m,y}$$

This constraint sums over the grades for each of the centers and sets it equal to the sum over the centers for each grade.

The Officer/Enlisted Ratio constraint that appeared in Step 1 does not apply at this level in AFMC's organizational hierarchy. The varying officer requirements at this organizational hierarchy level makes the satisfaction of the ratio impossible.

Step 3 in the manpower reduction procss occurs at the two-letter OSC level.

Let $\mathbf{X}_{\mathbf{mctry}}$ = Number of Manpower Authorizations in each Two-Letter OSC t by Grade r for each Center c within each MEB m by Year y **after** the reductions are taken

$(\mathbf{X}^{\sim})_{\mathbf{mctry}}$ = Parameter Designated for the Authorized Manpower in each Two-Letter OSC for each Center c within each MEB m by Year y **before** the reductions are taken

$\mathbf{w}_{\mathbf{mcty}}$ = Nonnegative Parameter Designated for the Weight Assigned to each Two-Letter OSC t within each Center c and MEB m for each Year y

$(\mathbf{N}^{\sim})_{\mathbf{mcry}}$ = Number to be Reduced from the Current Authorized Manpower in each Two-Letter OSC as determined in Step 2 for each Grade r within each Center c and MEB m by Year y

$\mathbf{L}_{\mathbf{ry}}$ = Parameter Designated for the Percentage of Authorized Manpower **Allowed** to be Reduced by Grade r for each Year y

$$\text{MAX} \quad \text{STRENGTH} = \sum_{t}(w_{mcty} \sum_{r} X_{mctry})$$

SUBJECT TO

$$\sum_{r}\sum_{t} X_{mctry} = \sum_{r}\sum_{t}(X^{\sim})_{mctry} - (N^{\sim})_{mcry} \qquad \text{for each m,c,y}$$

$$(1-L_{ry})(X^{\sim})_{mctry} \le X_{mctry} \le (X^{\sim})_{mctry} \qquad \text{for each m,c,t,r,y}$$

$$\sum_{r}(X_{mc(1)ry} + X_{mc(2)ry} + \ldots + X_{mctry}) =$$
$$\sum_{t}(X_{mct(civ)y} + X_{mct(enl)y} + X_{mct(off)y}) \qquad \text{for all m,c,y}$$

$$X_{m,c,t,r,y} \ge 0 \qquad \text{for all m,c,t,r,y}$$

The objective function in Step 3, the two-letter OSC level, is similar to the objective function of Step 1 and Step 2. The weighted sum is now over the two-letter OSCs for each center. Also, the constraints in Step 3 function the same as those in Step 2. The number to be reduced from each of the centers is spread over its subordinate two-letter OSCs.

The first constraint,

$$\sum_{r}\sum_{t} X_{mctry} = \sum_{r}\sum_{t}(X^{\sim})_{mctry} - (N^{\sim})_{mcry} \qquad \text{for each m,c,y}$$

again ensures that the proper number of manpower resources are reduced from the current authorized manpower, but the number reduced from each of the two-letter OSCs varies according to the amount that was reduced at the center level in Step

2. The parameter $(N^{-})_{mcry}$ acts as a link between Step 2 and Step 3, and just as in Step 2, it ensures that the reductions are properly administered.

The second constraint sets the upper and lower bounds on the decision variable, X_{mctry}. The third constraint in the linear model is again a "sanity" check.

$$\sum_{r}(X_{mc(1)ry} + X_{mc(2)ry} + \ldots + X_{mctry}) =$$
$$\sum_{t}(X_{mct(civ)y} + X_{mct(enl)y} + X_{mct(off)y}) \qquad \text{for each m,c,y}$$

This constraint sums over the grades for each of the two-letter OSCs and sets it <u>equal</u> to the sum over the two-letter OSCs for each grade. The Officer/Enlisted Ratio constraint that appeared in Step 1 does not apply at this level in AFMC's organizational hierarchy. For Steps 2 and 3, this constraint is not applicable because according to the specialization of an organization, this ratio may be higher or lower than the prescribed ratio set for the command.

Step 1 consists of six optimization problems; all of the MEBs over each of the six years. This is done to permit reductions which are taken over a period of years. For example, if a fixed number of authorizations were specified to be reduced from each of the six years, ESP would determine the allocation of the reduction for Y(C). The reductions identified would then be taken from the current programmed manpower authorizations over the five remaining years. Then, the reduction specified for Y(1) would be determined. Again, those manpower reductions would be taken from the programmed authorizations over the remaining four years. This process continues until all of the specified reductions have been identified for the six year period.

At the center level, in Step 2, there are two optimizations for each of the six years. The first optimization involves the BOS MEB centers and the second optimization involves the remaining MEB centers; PM, S&IO, S&T, and T&E. As in Step 1, reductions identified for a specific year are flowed through the remaining years in the database.

For Step 3, the two-letter OSC organizations were grouped by center with as many two-letter OSCs as possible in each optimization. This resulted in 132 different optimizations with 22 optimizations for each of the six years. Again, reductions for a particular year are flowed through the following years.

3.2 Assumptions

The development of the ESP Model included some simplifying assumptions. The first assumption was that the current RA-IPT decision framework is constant. That is, there are only five MEBs and the number of centers and two-letter OSCs will remain constant. The second assumption was that the focus of manpower reductions will always be according to the organizational hierarchy of AFMC.

3.3 The Exercise Support Program's (ESP) Role

In Figure 3, ESP's role in the RA-IPT manpower reduction allocation process is shown. ESP is a decision support system used to formulate decision alternatives for consideration in allocating manpower authorization reductions. The model begins where the tasking is given to AFMC/XPM and they collect the required information and formulate an initial alternative for use in the RA-IPT meeting.

The type of information required by RA-IPT decision makers to make an informed decision about the reduction of manpower resources is based on the current manpower authorizations assigned to their respective organizations. Table 1 shows a generic list of information options available from ESP.

The first type of output generated from the ESP Model, the spreadsheet report, queries the Command Manpower Data System (CMDS) and reports the output in a columnarized format. These reports are controlled by the user. Reports such as the number of manpower authorizations in each MEB, sub-sorted by major center, over the current year and the following five years can be generated. This allows the decision maker to view the programmed manpower authorization levels in the out years. Often there are non-related reductions on authorizations in the future that may affect the manpower reduction decision for the more current years.

SPREADSHEET REPORTS	SUMMARY REPORTS	GRAPHIC OUTPUT
Sorted by MEB	by MEB	by MEB
Sorted by Center	by Center	by Center
Sorted by Two-Letter OSC	by Two-Letter OSC	by Two-Letter OSC
Sorted by GRADE	by GRADE	by GRADE

Table 1. Sample of Information Provided to RA-IPT by ESP

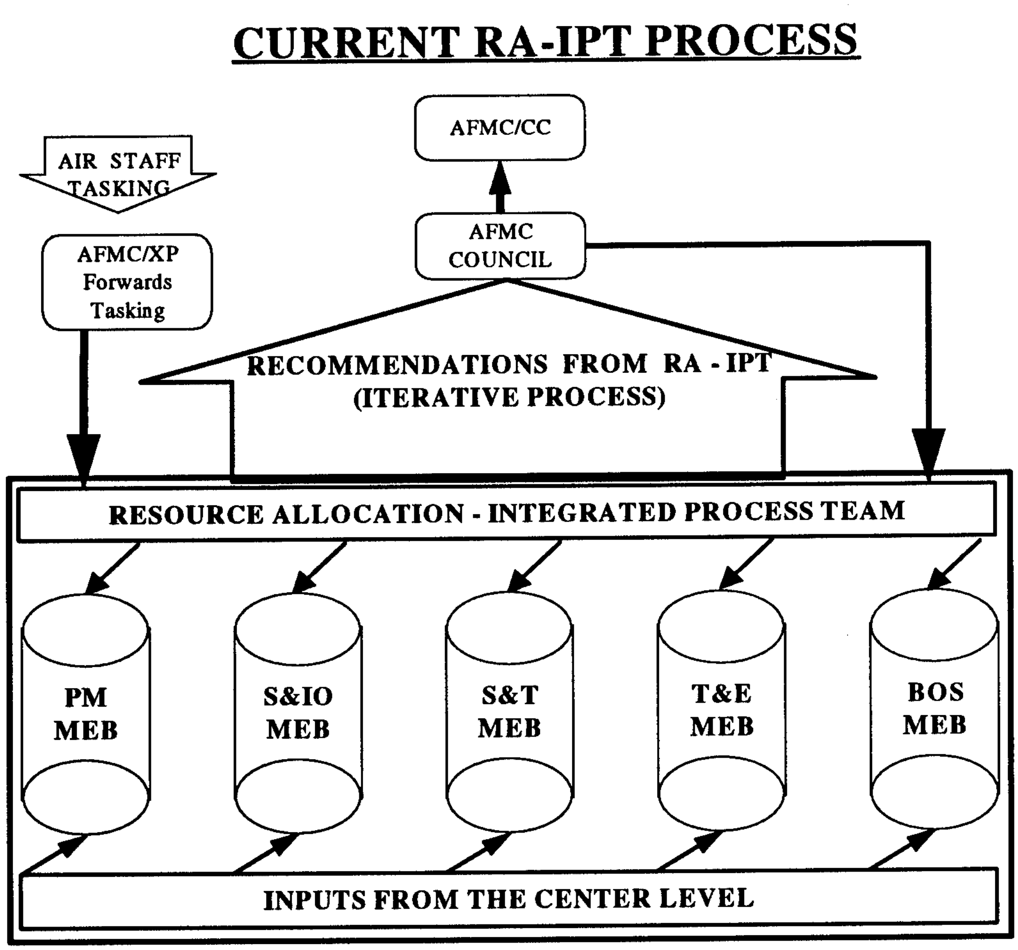

Figure 3. ESP's Portion of Current RA-IPT Process

Large amounts of data are used in a manpower reduction. Reports to summarize large amounts of data are provided as options to the user of the ESP Model. These reports would be used to compare the relevant manpower strengths by desired level of organization. Often the decision maker is not interested in the details of a spreadsheet report, but instead, is more interested in the bottom-line totals. This provides the decision maker with the option to receive a less detailed picture of their organizational level.

Graphical output is also provided as an option when required. Some decision makers prefer tables and lists to gather information, but others may prefer to see graphs and charts. The ESP model framework is in Microsoft Excel. Therefore, the decision makers have the option to present data in several graphical formats (i.e., bar charts, pie charts, trend lines, etc.). Comparisons can be made among the MEBs or centers to help determine potential options to explore for manpower reductions.

The alternative that is generated by AFMC/XPM for the initial alternative to use as a basis for the discussion of the manpower reductions at the RA-IPT can take many forms. It can be based upon either of two options: Percentage Spread Reduction or User-Defined Reduction. These options are available in any of the output formats previously discussed.

As a default, ESP can generate a manpower reduction alternative in the form of a Percentage Spread Reduction. The weights in the objective functions of the linear programming models correspond to these percentages, and the percentages are based upon the total percent of current manpower authorizations each organization currently has. These percentages are updated with each CMDS data update. AFMC refers to this option as a “Peanut Butter Spread”.

The second form of alternative generation is the User-Defined Reduction. This type of alternative is based upon the input parameters to the model: w_{my}, w_{mcy}, w_{mcty}, L_{ry}, and R_y. These parameters are intended to reflect, as much as possible, the restrictions to the model that were not included in the manpower reduction tasking. For example, if a particular MEB were not involved in the manpower reduction, the weight, w_{my}, corresponding to it would be set to a high value while the other MEBs involved in the reduction would be given much lower weight values. Therefore, the manpower reduction alternative would be less likely to be deducted from this MEB; the majority of the reduction would then fall to the remaining MEBs. This outcome depends on the weights assigned to the other MEBs and the manpower authorization levels in those MEBs. If the other MEBs involved in the reduction have enough authorizations to satisfy the reduction requirement, the excluded MEB will not receive any of the reduction. Another example would be a totally military manpower authorization reduction. In this case, the percentage allowed to be reduced from the civilian manpower authorizations would be set to zero. This sets the lower bound on the civilian decision variables equal to the current level. Since the upper and lower bounds are equal, the reduction will not be taken from the authorized civilian population. At optimality, this constraint must be satisfied.

The next portion of the RA-IPT process that ESP models is the iterative decision process that the decision makers go through during a RA-IPT meeting. AFMC/XPM can use ESP to generate different alternatives. The informational outputs are again available to present the positions of each of the MEBs.

In the preliminary RA-IPT meeting, ESP is used to solve Step 1 in the model process. The command tasking is evaluated and a feasible alternative regarding the distribution of the reduction among the MEBs is attained. The MEB representative then gathers input from the center level and below to formulate a feasible alternative regarding the manpower reduction spread among the centers. Step 2 of ESP is used to again optimize a manpower reduction alternative at the center level for input to the MEB representative. Step 3, at the two-letter OSC level, is performed if the decision requires that much detail. The alternatives are consolidated and returned to the MEB-level RA-IPT and evaluated for incorporation into the overall decision alternative. This process is repeated until a consensus is reached on the most acceptable decision alternative.

For any of these levels, the user has the ability to change the constraint parameters and other user inputs to the model; and therefore, compare differing manpower reduction alternatives. The overall process is meant to be iterative. What this means is that at each level, a reduction iteration is performed and forwarded up to the next level of management. Each subordinate level is consolidated and evaluated from the parent organization's perspective. If at that time, the decision maker is not satisfied or an acceptable alternative is not obtained, the reduction process returns to the ESP model.

The RA-IPT forwards the consolidated decision up through the AFMC Council and the Command Section for approval. If the Council is not satisfied with the alternative, it is returned to the RA-IPT for reconsideration. Again, ESP can be used to formulate other alternatives.

Once the decision has been made on where the manpower reductions will be taken, AFMC/XPM retrieves the decision solution from ESP and the CMDS is updated to reflect these changes.

3.4 Requirements of the Exercise Support Program

1. Microsoft Excel Version 5.0 with Visual Basic Add-in
2. Microsoft Solver (Add-in for Excel)
3. Input From The User
    - Tasking Constraints and External Constraints/Restrictions
    - Weights For Responsible Areas in the Reduction Exercise
    - Graphical and/or Summary Report User Requirements
4. Current Command Manpower Datafile (CMDF) from AFMC/XPM
5. Other Requirements of User
    - Basic Knowledge of Spreadsheets and Windows Functions
    - Understanding of the Overall Process of a Reduction Exercise

3.5 Use of Microsoft Excel 5.0

The decision to use Microsoft Excel 5.0 to model this manpower reduction allocation problem was made because the sponsor, AFMC/XPM, had the software readily available. The advantages of using Excel were the graphical and spreadsheet report formats that most people are used to working with. The Visual Basic macro language allowed the presentation of user required information to the user to be easily generated by a menu item choice. Much of this graphical and spreadsheet report information can be used by the decision maker to get a detailed picture of the results.

3.6 Summary

Resource allocation decisions made at any level of management must be based upon sound information. The ESP Model provides the required information to the decision making body, the RA-IPT. With this information, a decision maker can discuss and display various decision alternatives.

The ESP Model was developed in a Microsoft Excel 5.0 workbook as a series of cross-linked spreadsheets. The control of the model is accomplished through a Visual Basic macro language. The macros retrieve the data from the CMDS, constrict the data for the particular manpower reduction, and provide the necessary outputs and decision alternatives as the user requests them. The model is menu-driven with its own "ESP" menu item.

The flow of the model data and parameters is automatic. The most important parameters are entered into their own dedicated spreadsheet; i.e., the weights associated with the MEBs, centers, or two-letter OSCs. ESP then sorts, analyzes, and reports on the reduction to provide the decision maker with the results of the chosen alternative. This output can then be compared with other alternatives previously generated. This cross-linking of data eases scenario and model analysis.

IV. Analysis of Results

Chapter IV develops a basecase scenario for use in the development and testing of the ESP model. The results from the basecase scenario are also presented in this chapter. These results were verified and sensitivity analysis performed on the input weight parameters and constraints at the MEB level. The ESP model was then validated using test cases in which the results were known. The research analysis will stop at the second tier in the organizational hierarchy because of the magnitude of the problem at the center and two-letter OSC level.

4.1 Development of Basecase Scenario

In the development of ESP, a basecase scenario was used to test the model. Table 2 shows the inputs for the ESP model that generated the basecase results. This reduction scenario included 2000 manpower authorizations being taken from the programmed authorized AFMC manpower levels for the current year and for each of the next five years. This resulted in a total of 12,000 manpower authorizations reduced for the six years over and above any programmed reductions. The Officer/Enlisted Ratio equaled 2.2358 for each of the six years. For each grade, 20% of the current manpower levels are allowed to be reduced, so the parameter, L_{ry}, input to the model is 0.20. The weights for each of the MEBs are set to 0.2 giving equal weight to each MEB. Therefore, the coefficients of the linear program objective function summed to one. Table 3 presents the manpower presents the manpower authorization levels before the basecase scenario reduction is processed through ESP. The differences between the authorized manpower levels in each year are due to the programmatic reductions already accounted for in the CMDS.

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Reduction Amount	2000	2000	2000	2000	2000	2000
Off/Enl Ratio	2.2358	2.2358	2.2358	2.2358	2.2358	2.2358
% Allowed Reduced:						
Civilian	20 %	20 %	20 %	20 %	20 %	20 %
Enlisted	20 %	20 %	20 %	20 %	20 %	20 %
Officer	20 %	20 %	20 %	20 %	20 %	20 %
Weights:						
BOS	0.2	0.2	0.2	0.2	0.2	0.2
PM	0.2	0.2	0.2	0.2	0.2	0.2
S&IO	0.2	0.2	0.2	0.2	0.2	0.2
S&T	0.2	0.2	0.2	0.2	0.2	0.2
T&E	0.2	0.2	0.2	0.2	0.2	0.2

Table 2. Input Parameters to ESP for Basecase Scenario

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Manpower Levels:						
BOS	41447	41526	40659	40500	40440	40361
PM	12149	11694	11167	11105	11053	10999
S&IO	47055	44263	41864	41046	40711	40325
S&T	7201	6703	6575	6575	6575	6575
T&E	9110	8650	8197	8094	8016	7987
Grand Totals	116962	112836	108462	107320	106795	106247

Table 3. The Manpower Levels of Each MEB Before Basecase Scenario

4.2 Initial ESP Results

The results of the basecase scenario are presented in Table 4 through Table 15. The parameters input to the ESP model in Table 2 show the required reduction amount, 2000, the percent allowed to be reduced from each grade, the Officer/Enlisted Ratio, and the weights assigned to each MEB. Tables 4, 6, 8, 10, 12, and 14 present the reduced manpower levels after the 2000 authorization reduction in each year. Tables 5, 7, 9, 11, 13, and 15 show the updated total manpower levels for each MEB from Table 3 following the reduction in each year. The reductions taken in any one year are flowed to the subsequent years where they are taken from the programmed manpower totals.

Year (YC)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19942**	**17567**	**3938**	41447
PM	**7117**	**897**	**4135**	12149
S&IO	**43251**	**1849**	**1031**	46131
S&T	**4306**	**685**	**1134**	6125
T&E	**4435**	**3815**	**860**	9110
Grand Total	79051	24813	11098	114962

Table 4. Basecase Results for MEB Level at Year (C)

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Manpower Levels:						
BOS	41447	41526	40659	40500	40440	40361
PM	11036	10581	10054	9992	9940	9886
S&IO	47055	44263	41864	41046	40711	40325
S&T	7201	6703	6575	6575	6575	6575
T&E	8223	7763	7310	7207	7129	7100
Grand Totals	114962	110836	106462	105320	104795	104247

Table 5. Updated Manpower Levels of Each MEB After Y(C)

Year (Y1)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19976**	**17600**	**3950**	41526
PM	**5611**	**773**	**4004**	10387
S&IO	**39613**	**1818**	**1025**	42456
S&T	**4886**	**690**	**1127**	6703
T&E	**3232**	**3672**	**859**	7763
Grand Total	73318	24553	10965	108836

Table 6. Basecase Results for MEB Level at Year (1)

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Manpower Levels:						
BOS	41447	41526	40659	40500	40440	40361
PM	11036	10387	9861	9799	9747	9693
S&IO	47055	42456	40057	39239	38904	38518
S&T	7201	6703	6575	6575	6575	6575
T&E	8223	7763	7310	7207	7129	7100
Grand Totals	114962	108836	104462	103320	102795	102247

Table 7. Updated Manpower Levels of Each MEB After Y(1)

Year (Y2)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19515**	**17231**	**3913**	40659
PM	**5442**	**569**	**3708**	9719
S&IO	**36117**	**1676**	**986**	38780
S&T	**4774**	**676**	**1125**	6575
T&E	**2321**	**3543**	**866**	6730
Grand Total	68169	23695	10598	102462

Table 8. Basecase Results for MEB Level at Year (2)

Manpower Levels:	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
BOS	41447	41526	40659	40500	40440	40361
PM	11036	10387	9719	9657	9605	9551
S&IO	47055	42456	38780	37961	37626	37240
S&T	7201	6703	6575	6575	6575	6575
T&E	8223	7763	6730	6627	6549	6520
Grand Totals	114962	108836	102462	101320	100795	100247

Table 9. Updated Manpower Levels of Each MEB After Y(2)

Year (Y3)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19368**	**17226**	**3812**	40406
PM	**5397**	**460**	**2948**	8805
S&IO	**35342**	**1339**	**757**	37438
S&T	**4774**	**542**	**899**	6215
T&E	**2237**	**3541**	**679**	6457
Grand Total	67118	23107	9095	99320

Table 10. Basecase Results for MEB Level at Year (3)

Manpower Levels:	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
BOS	41447	41526	40659	40406	40346	40267
PM	11036	10387	9719	8805	8753	8699
S&IO	47055	42456	38780	37438	37103	36717
S&T	7201	6703	6575	6215	6214	6214
T&E	8223	7763	6730	6457	6379	6350
Grand Totals	114962	108836	102462	99320	98795	98246

Table 11. Updated Manpower Levels of Each MEB After Y(3)

Year (Y4)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19305**	**17229**	**3049**	39583
PM	**4919**	**364**	**2938**	8221
S&IO	**35013**	**1073**	**598**	36685
S&T	**4774**	**433**	**719**	5927
T&E	**2238**	**3469**	**674**	6379
Grand Total	66249	22568	7977	96795

Table 12. Basecase Results for MEB Level at Year (4)

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Manpower Levels:						
BOS	41447	41526	40659	40406	39583	39504
PM	11036	10387	9719	8805	8221	8167
S&IO	47055	42456	38780	37438	36685	36298
S&T	7201	6703	6575	6215	5927	5927
T&E	8223	7763	6730	6457	6379	6350
Grand Totals	114962	108836	102462	99320	96795	96246

Table 13. Updated Manpower Levels of Each MEB After Y(4)

Year (Y5)	GRD			
MEB	CIV	ENL	OFF	Grand Total
BOS	**19230**	**17225**	**2440**	38895
PM	**4893**	**351**	**2923**	8167
S&IO	**34651**	**1014**	**467**	36132
S&T	**4774**	**347**	**719**	5840
T&E	**1825**	**2721**	**667**	5213
Grand Total	65374	21657	7216	94247

Table 14. Basecase Results for MEB Level at Year (5)

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Manpower Levels:						
BOS	41447	41526	40659	40406	39583	38895
PM	11036	10387	9719	8805	8221	8167
S&IO	47055	42456	38780	37438	36685	36132
S&T	7201	6703	6575	6215	5927	5840
T&E	8223	7763	6730	6457	6379	5213
Grand Totals	114962	108836	102462	99320	96795	94247

Table 15. Updated Manpower Levels of Each MEB After Y(5)

	Y (C)	**Y (1)**	**Y (2)**	**Y (3)**	**Y (4)**	**Y (5)**	**Totals**
Reductions:							
BOS	0	0	0	94	763	609	1466
PM	1113	194	142	852	532	0	2833
S&IO	0	1807	1277	523	418	166	4191
S&T	0	0	0	360	287	87	734
T&E	887	0	580	170	0	1137	2774
Grand Totals	2000	2001	1999	1999	2000	1999	11998

Table 16. Summary of Manpower Reductions From Basecase Scenario

The bold numbers in each year represent the manpower authorizations remaining after the 2000 manpower authorizations were reduced from AFMC. The X_{mry} variables are in terms of the MEBs, the grade, and the year. For each year, the optimality conditions were met. That is, all of the constraints noted in Chapter III for Step 1 are satisfied. Since the reductions are generated by a linear programming model, all results are noninteger. The results have been rounded for presentation in the tables. Table 16 presents the summary of the 2000 per year after reduction totals in Table 5 reveals that 2000 manpower authorizations were reduced from Y(C) and then those authorizations were taken from the subsequent five years. Again in Year (1), shown in Table 6, 2000 manpower authorizations were reduced from the updated manpower level for Y(1) and these reductions were taken from the programmed manpower levels in the following years. This process continued for each of the following years. Also, the "sanity" constraints are satisfied for each year. The sum of the Grade column totals does equal the Grand Total column total. The Officer/Enlisted Ratio constraint was also met in the basecase scenario. In each year, if the reduced level of officers is multiplied by 2.2358, the result is less than or equal to the enlisted levels for the year.

Figure 4 - Figure 9 presents the difference between the before-reduction strength and the after reduction strength for each of the years. In Year (C), the reductions were taken from the PM and T&E MEBs. In Year (1), PM and S&IO MEBs absorbed the reduction. This pattern of different combinations of MEBs being reduced continued over each of the years.

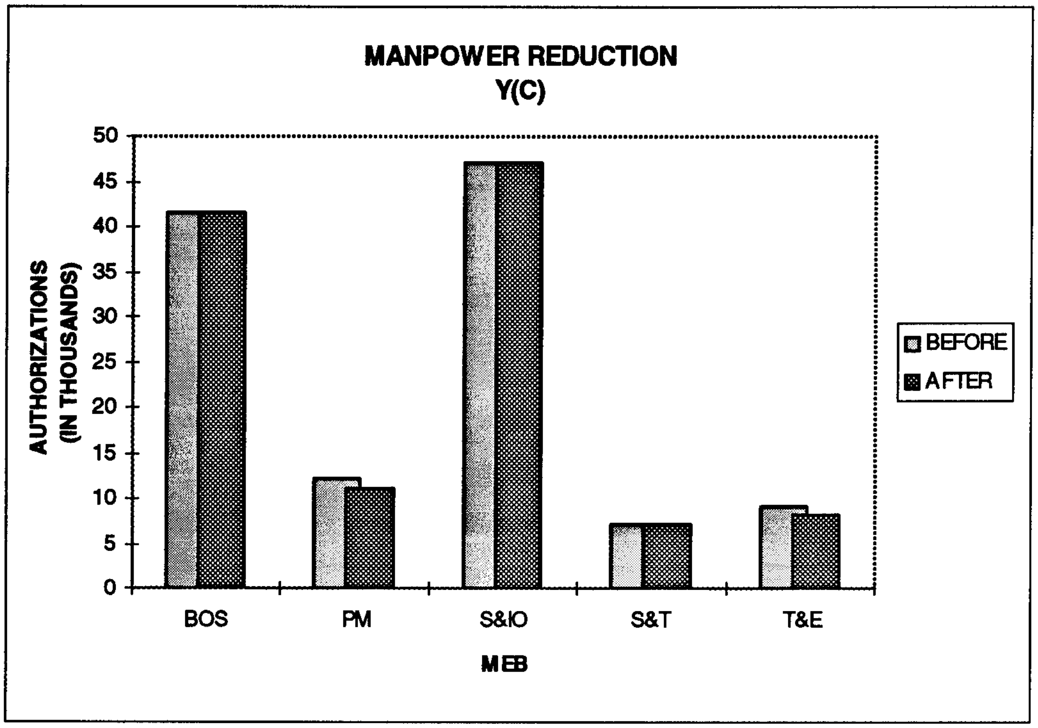

Figure 4. Basecase Reduced Manpower Strength for Year (C)

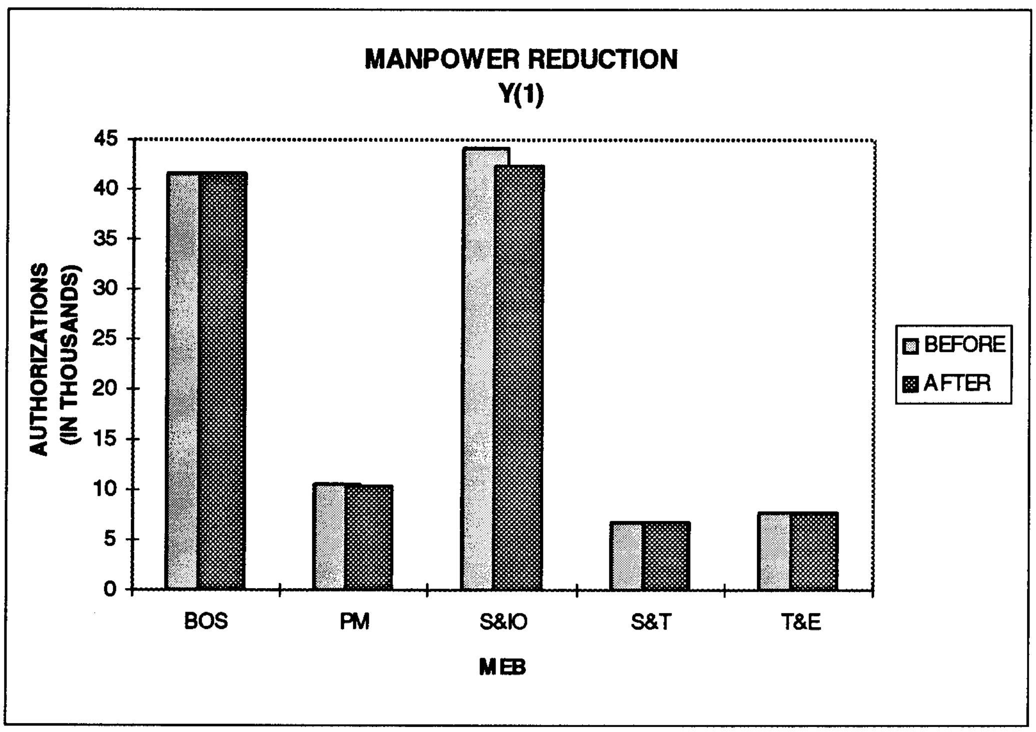

Figure 5. Basecase Reduced Manpower Strength for Year (1)

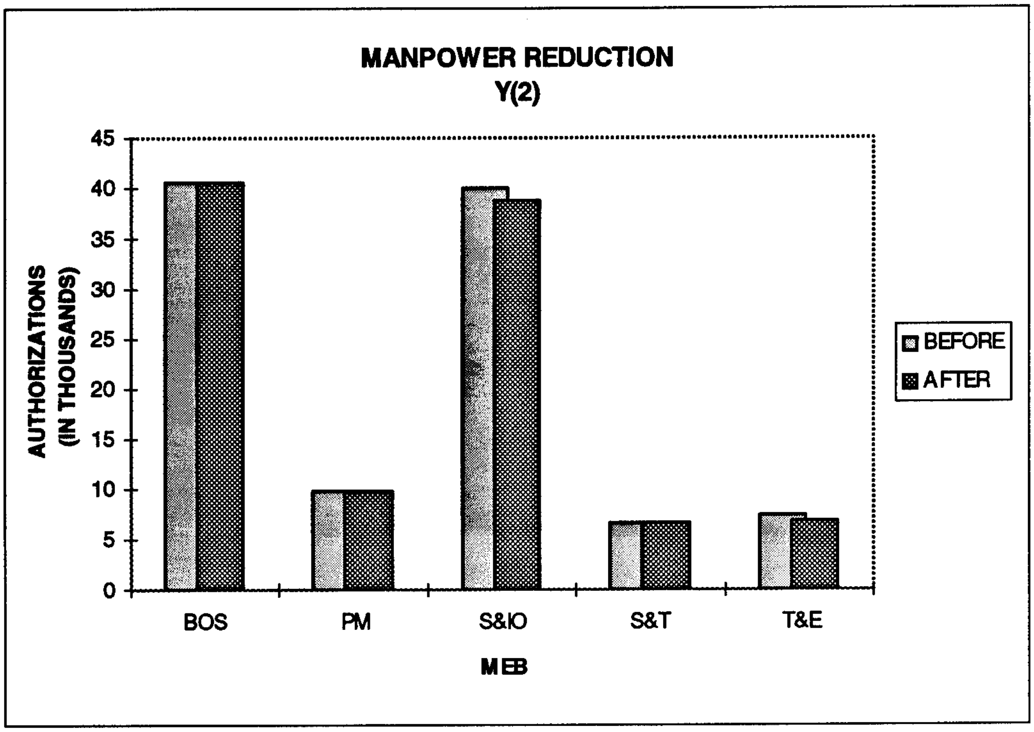

Figure 6. Basecase Reduced Manpower Strength for Year (2)

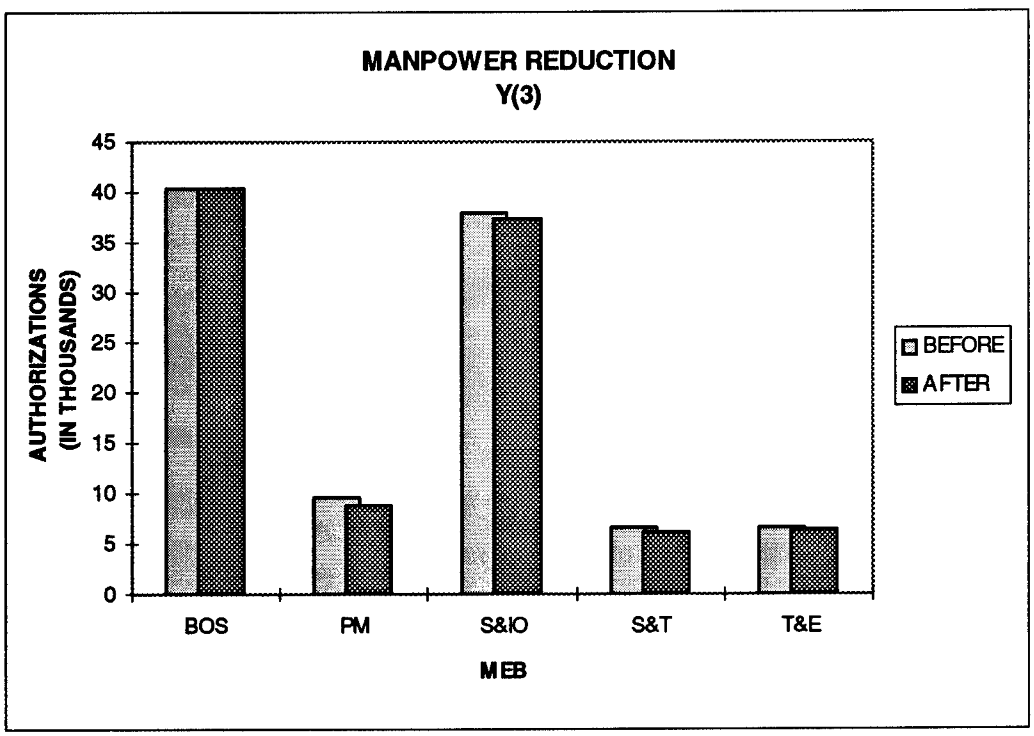

Figure 7. Basecase Reduced Manpower Strength for Year (3)

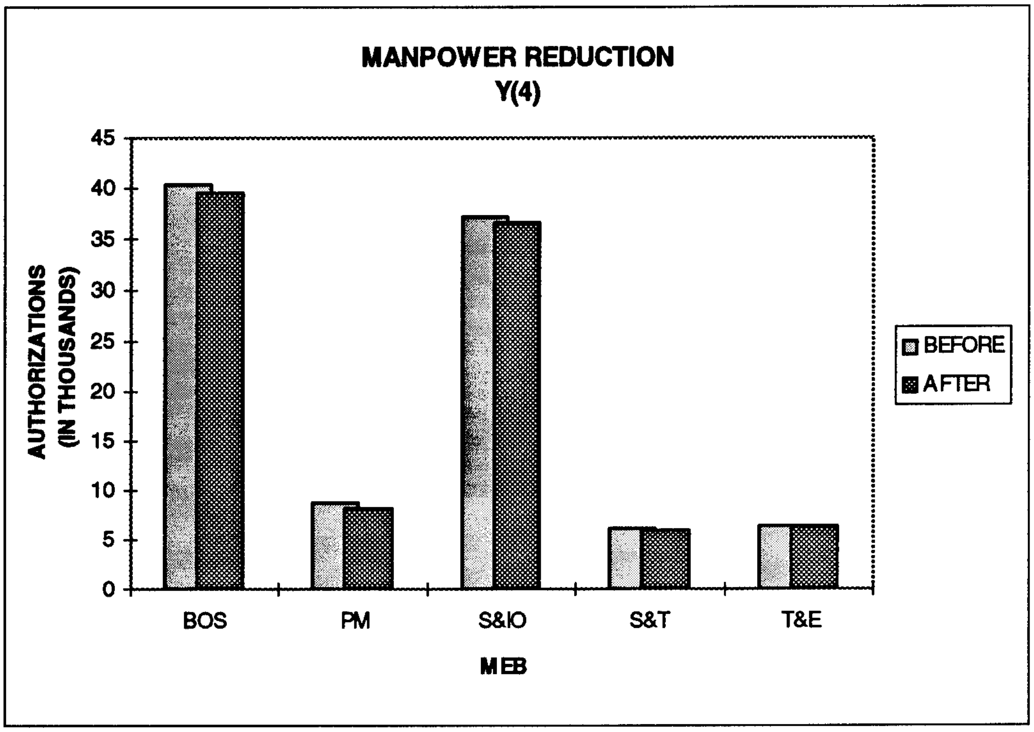

Figure 8. Basecase Reduced Manpower Strength for Year (4)

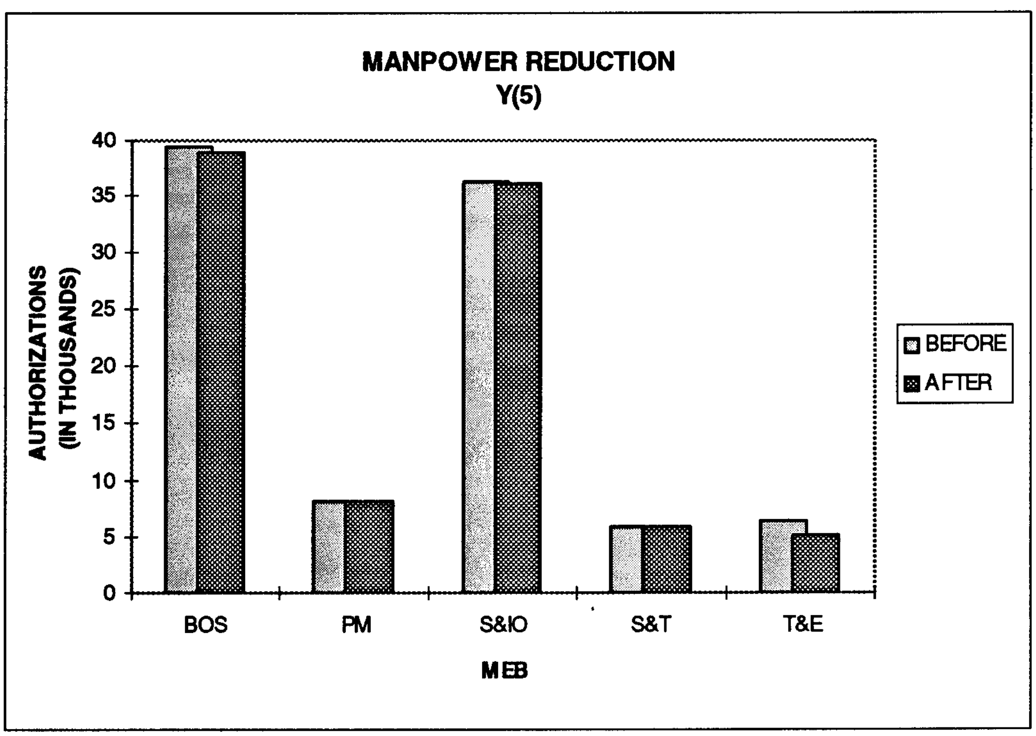

Figure 9. Basecase Reduced Manpower Strength for Year (5)

4.3 Sensitivity Analysis

The next step in analyzing the ESP model was to test the sensitivity of the weights assigned to each of the organizations. Each weight was shifted from its basecase value to an upper and lower bound while holding the other weights constant. The results were compared to determine which of the weights could be changed the most without altering the solution. The sensitivity analysis results are presented in Appendix B.

The sensitivity analysis results indicate that the optimal solutions obtained by Microsoft Excel Solver are highly sensitive to the weights assigned the organizations. For this basecase scenario, most of the weights can be either decreased to zero or increased by a large number, as indicated in Appendix B, but not both without altering the reduction allocation represented in the solution. There were seven weight parameters to which the solution was the most sensitive. Table 16 presents these sensitive weight parameters by year. These weights, if changed by any amount, would change the allocation of the reduction, and therefore, either increase or decrease the optimal value of the objective function.

In terms of alternative generation, a different alternative can be generated by altering the weights in the direction of their sensitivity. If a decision variable's weight can be increased by a large amount without changing the solution, but it cannot be decreased, then by decreasing the decision variable weight, a different alternative will be generated. If a value can be decreased a large amount, without changing the solution, but it cannot be increased, then by increasing the decision variable weight a different alternative will also be generated.

Year	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Y(C)	S&IO CIV	43251.4	0	0.2	0	0
Y(C)	T&E OFF	860	0	0.2	0	0
Y(1)	PM ENL	873.6	0	0.2	0	0
Y(2)	S&IO ENL	1571.5	0	0.2	0	0
Y(4)	S&IO ENL	1498.4	0	0.2	0	0
Y(5)	BOS CIV	16035.6	0	0.2	0	0
Y(5)	T&E OFF	830	0	0.2	0	0

Table 17. Most Sensitive Weights from Analysis

4.4 Linear Program Constraint Analysis

In Appendix C, the status of the constraints at optimality are shown. The information in the report is whether or not a constraint in the program is binding or nonbinding at optimality. For those constraints that are binding, the slack value is zero, and for those constraints that are nonbinding, the slack value corresponds to the difference between the right-hand side value and the final value.

For those constraints which impose the upper and lower bounds on the decision variables, each of the bounds are modeled separately. If the upper bound constraint on a variable is binding then the corresponding lower bound on the same variable will be nonbinding while if the lower bound on a decision variable is binding, then the upper bound will be nonbinding. If the upper limit is nonbinding and the lower limit is also nonbinding, then the final value is somewhere between the upper and lower bounds.

4.5 Development of the Test Cases

The development of the test cases was done to validate the ESP model. The benefit of this analysis was to see how the input parameters affected the optimal solution and, if different input parameters would generate a solution that was already known.

The first test case was the scenario presented in Table 17. It included a 2000 reduction in manpower authorizations for each of the six years. The percent allowed to be reduced from each of the grades was set to 20 percent and the Officer/Enlisted Ratio was not changed from the basecase scenario. For each of the MEBs, except S&IO, the weights assigned, w_{my} ,were equal to 1.0. S&IO's assigned weight was set to zero. For this scenario, the expected outcome was that all of the 2000 authorizations to be reduced from the current manpower levels for each year would be deducted from the S&IO MEB. Figures 10 through 15 show the results of the alternative generated by ESP. For each of the six years, the S&IO MEB took a reduction of 2000 manpower authorizations while the other MEB's manpower levels remained constant.

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Reduction Amount	2000	2000	2000	2000	2000	2000
Off/Enl Ratio	2.2358	2.2358	2.2358	2.2358	2.2358	2.2358
% Allowed Reduced:						
Civilian	20%	20%	20%	20%	20%	20%
Enlisted	20%	20%	20%	20%	20%	20%
Officer	20%	20%	20%	20%	20%	20%
Weights:						
BOS	1	1	1	1	1	1
PM	1	1	1	1	1	1
S&IO	0	0	0	0	0	0
S&T	1	1	1	1	1	1
T&E	1	1	1	1	1	1

Table 18. Input Parameters to ESP for First Test Case Scenario

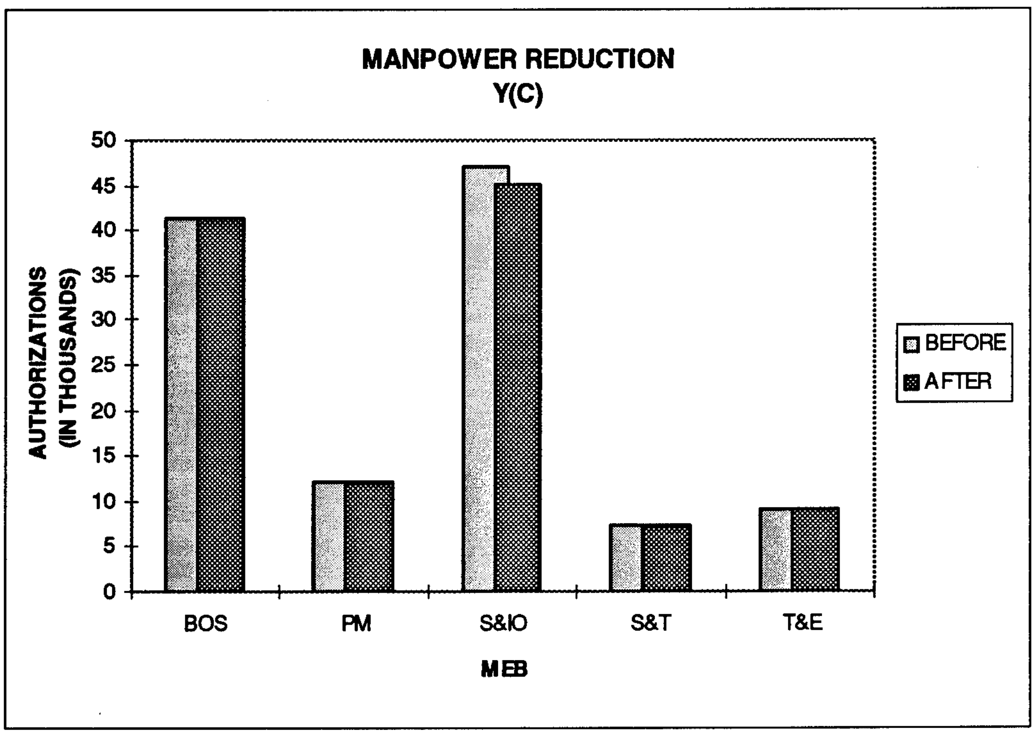

Figure 10. 1st Test Case MEB Levels Before and After Reduction Y(C)

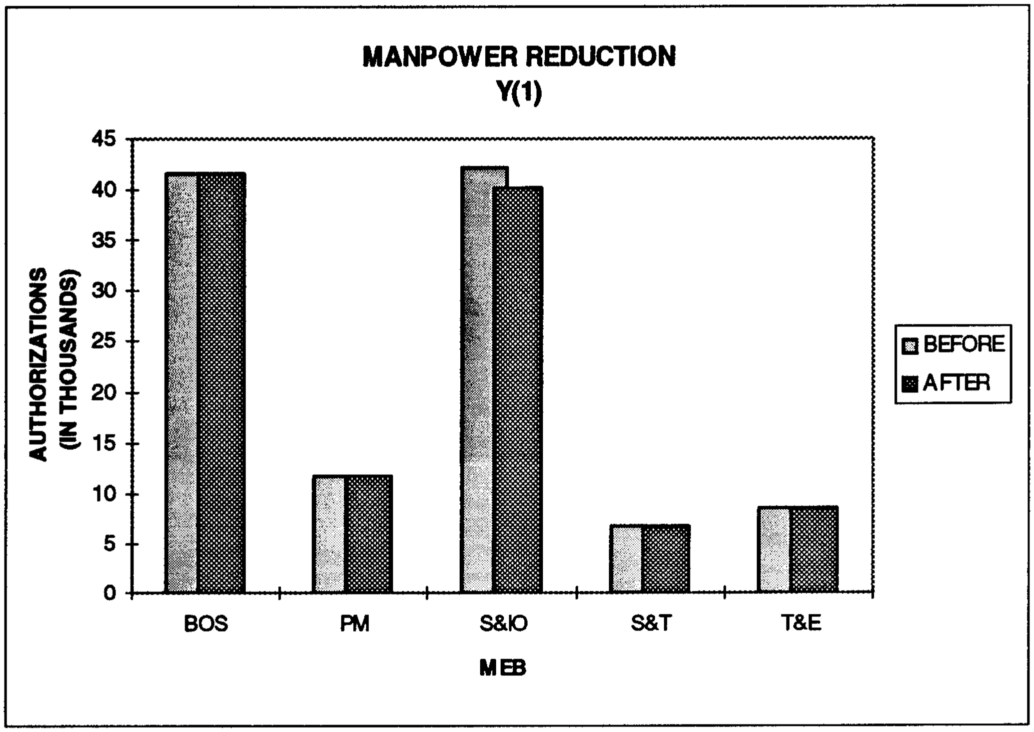

Figure 11. 1st Test Case MEB Levels Before and After Reduction Y(1)

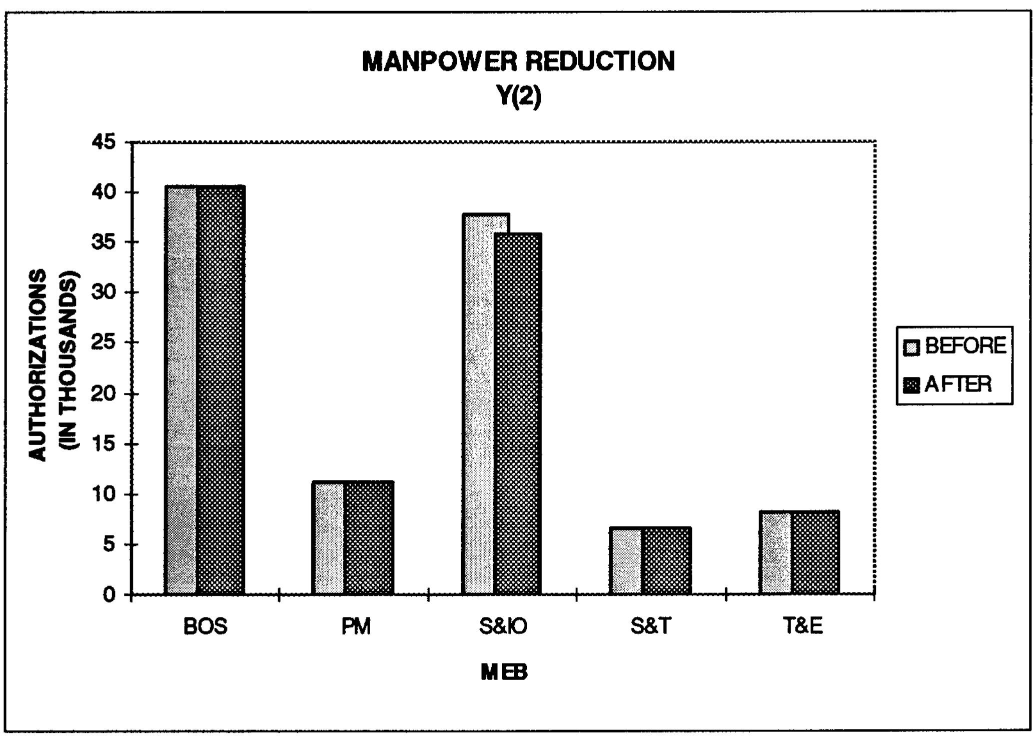

Figure 12. 1st Test Case MEB Levels Before and After Reduction Y(2)

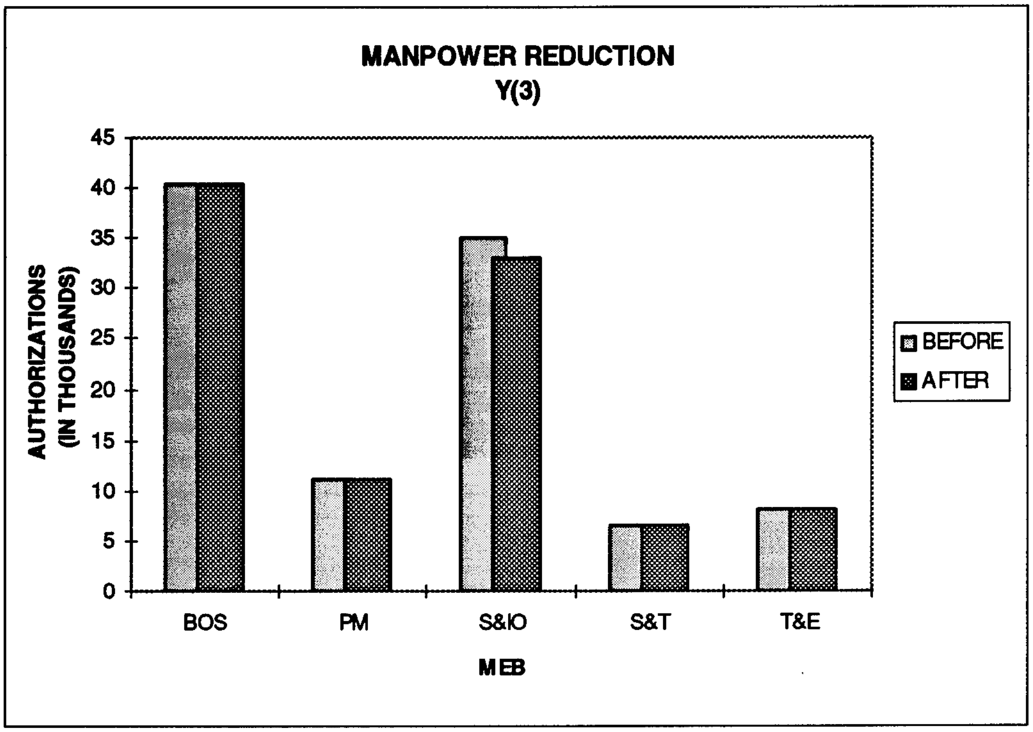

Figure 13. 1st Test Case MEB Levels Before and After Reduction Y(3)

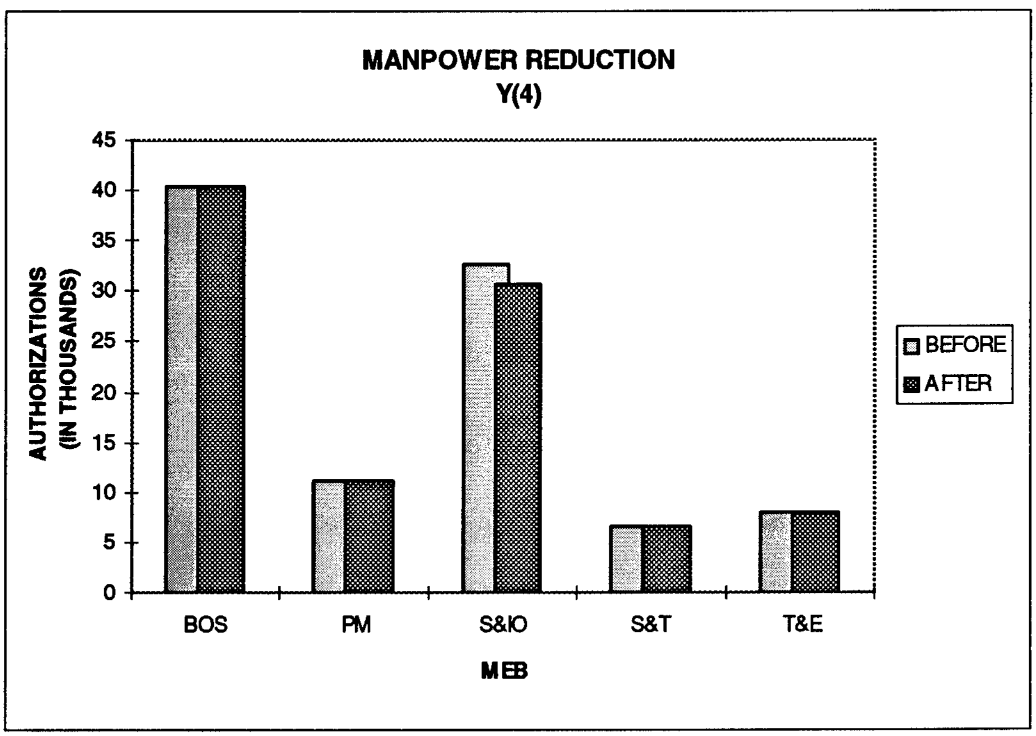

Figure 14. 1st Test Case MEB Levels Before and After Reduction Y(4)

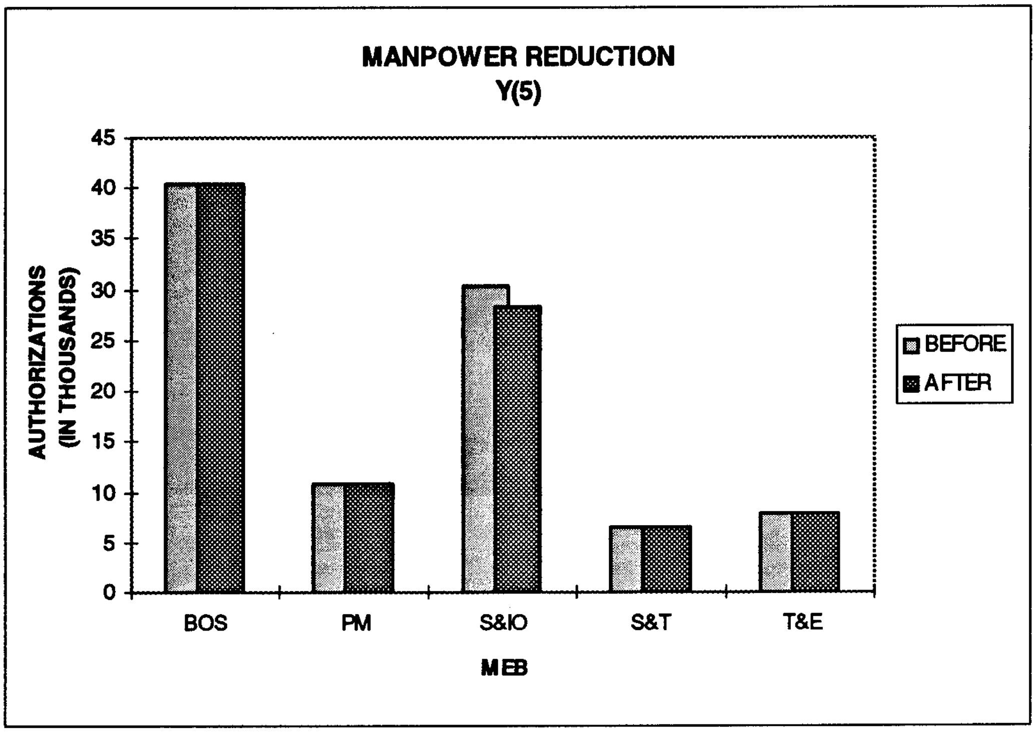

Figure 15. 1st Test Case MEB Levels Before and After Reduction Y(5)

The second test case was the scenario presented in Table 18. It included a 2000 reduction in manpower authorizations for each of the six years. The percent allowed to be reduced from each of the grades was set to 20% and the Officer/Enlisted Ratio was not changed from the basecase scenario. For each of the MEBs, except S&IO, the weights assigned w_{my} were equal to zero. S&IO's assigned weight was set to 1.0. For this test case, the expected outcome was that the S&IO authorization would remain constant after the reduction, and the remaining MEBs would incur the reduction allocation. Figures 16 through 21 show that the manpower levels of the S&IO MEB remained constant while the reductions were taken from the remaining MEBs.

	Year (C)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Reduction Amount	2000	2000	2000	2000	2000	2000
Off/Enl Ratio	2.2358	2.2358	2.2358	2.2358	2.2358	2.2358
% Allowed Reduced:						
Civilian	20%	20%	20%	20%	20%	20%
Enlisted	20%	20%	20%	20%	20%	20%
Officer	20%	20%	20%	20%	20%	20%
Weights:						
BOS	0	0	0	0	0	0
PM	0	0	0	0	0	0
S&IO	1	1	1	1	1	1
S&T	0	0	0	0	0	0
T&E	0	0	0	0	0	0

Table 19. Input Parameters to ESP for Second Test Case Scenario

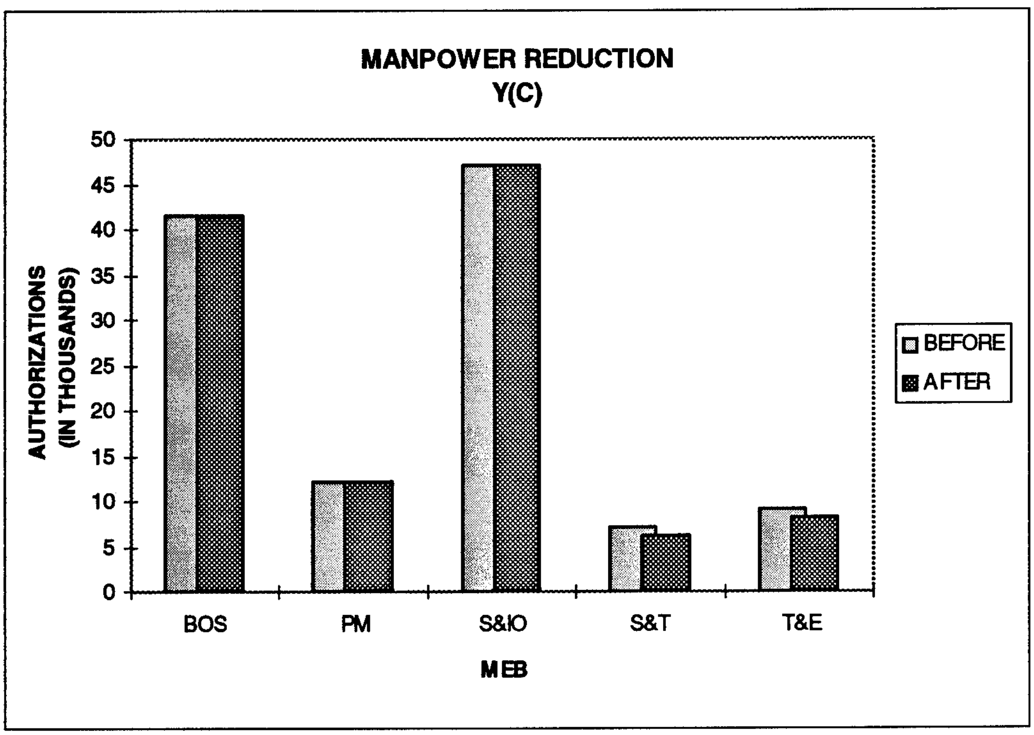

Figure 16. 2nd Test Case MEB Levels Before and After Reduction Y(C)

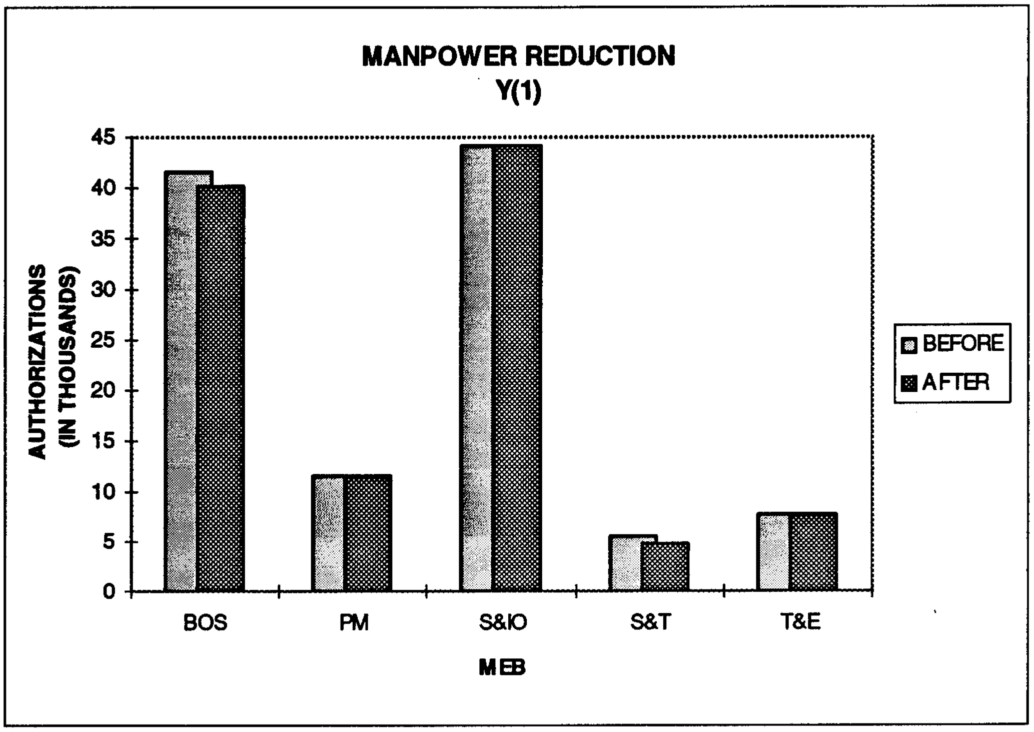

Figure 17. 2nd Test Case MEB Levels Before and After Reduction Y(1)

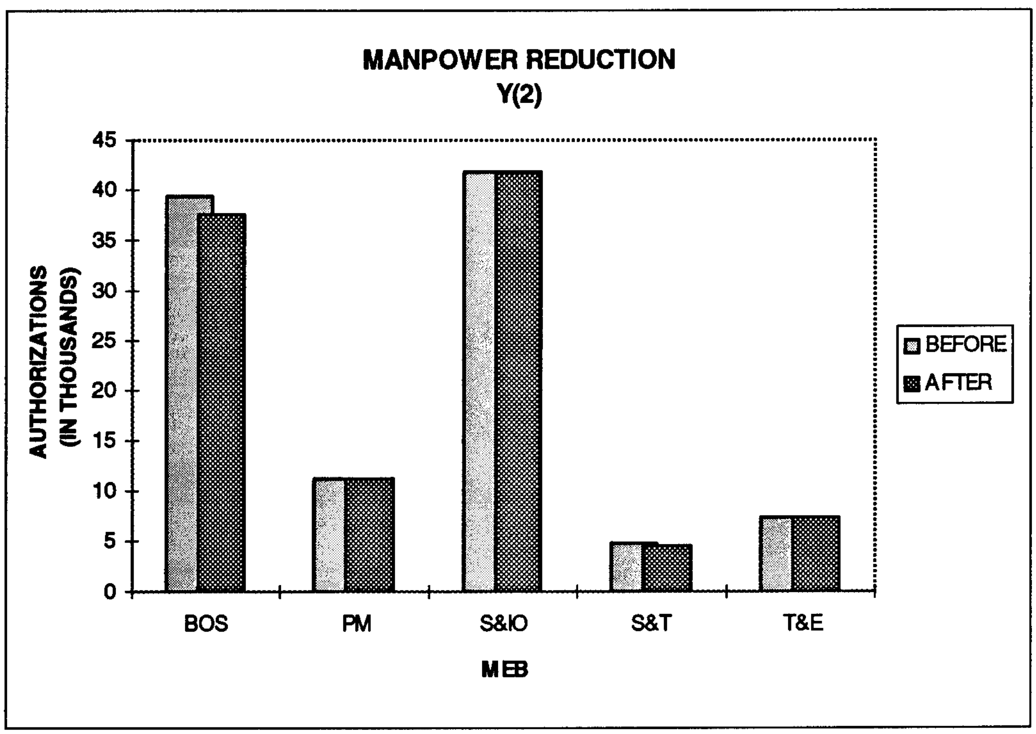

Figure 18. 2nd Test Case MEB Levels Before and After Reduction Y(2)

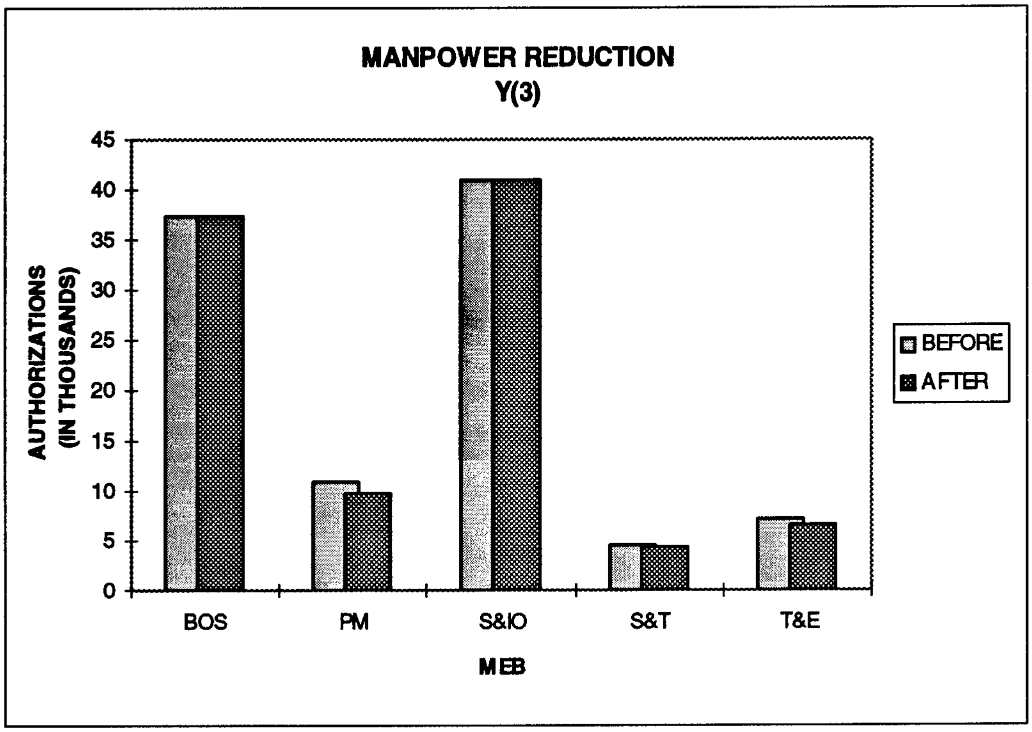

Figure 19. 2nd Test Case MEB Levels Before and After Reduction Y(3)

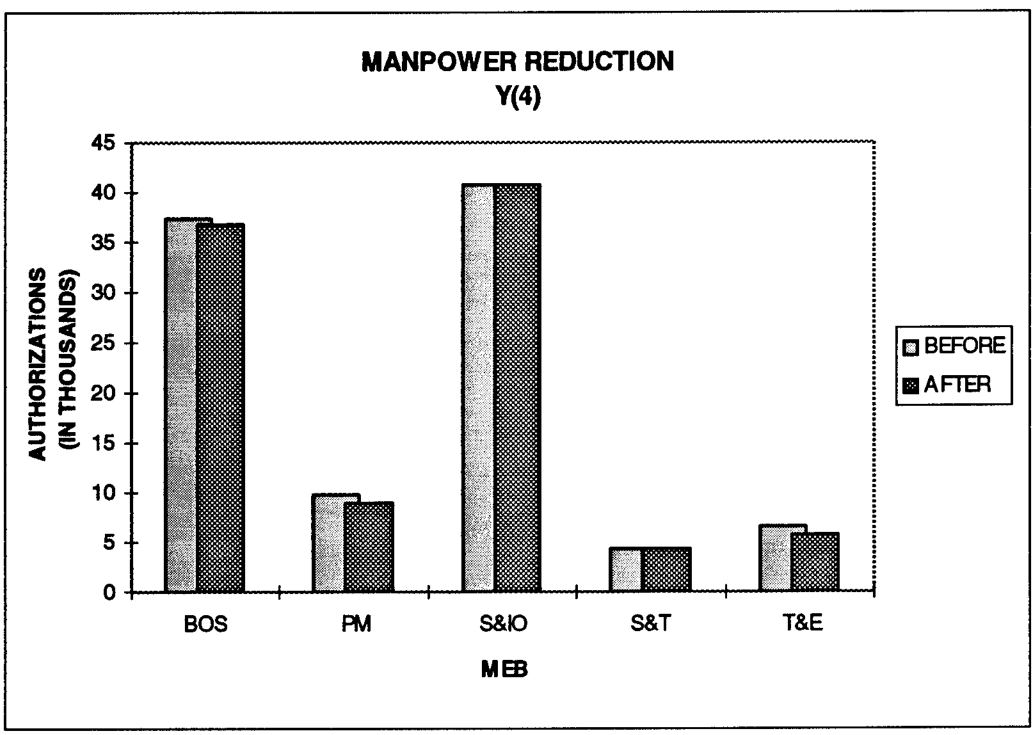

Figure 20. 2nd Test Case MEB Levels Before and After Reduction Y(4)

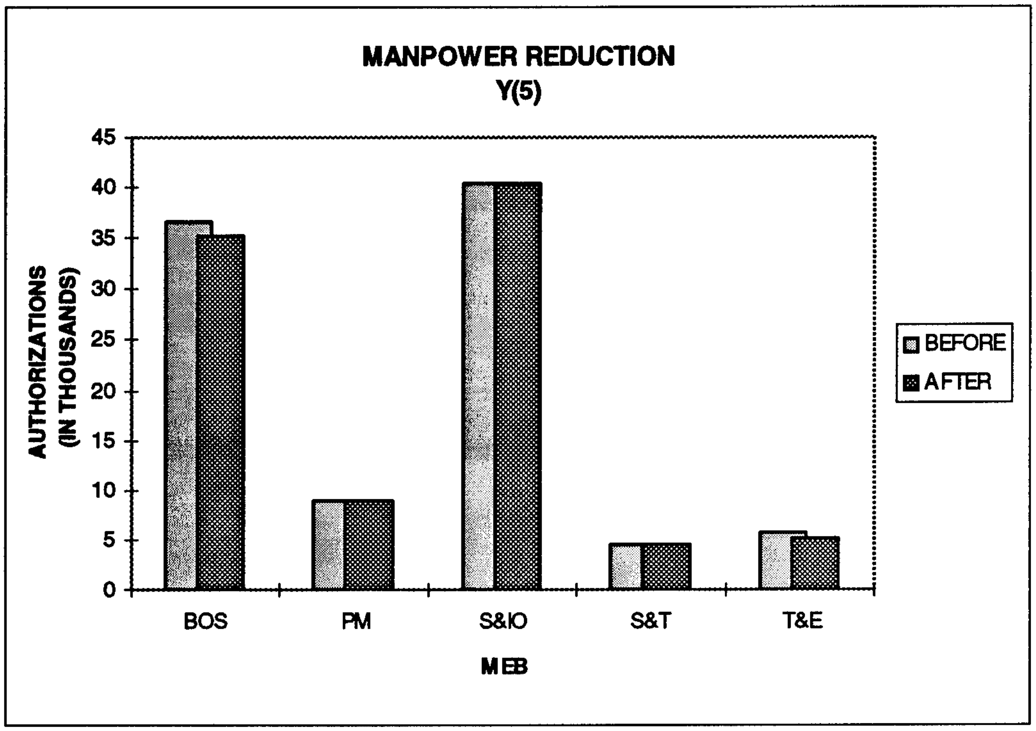

Figure 21. 2nd Test Case MEB Levels Before and After Reduction Y(5)

These two test cases show that the model reacts to the input parameters as expected.

4.6 Summary of ESP Results

Through the use of the ESP decision support model, a decision maker can indeed generate differing decision alternatives. These alternatives are based upon the model input parameters. The weight parameters drive the solution since they are the objective function coefficients. Therefore, the solution is sensitive to the weight parameters.

The analysis of the basecase scenario revealed that ESP does provide manpower reduction allocation decision alternatives to the decision maker. The results indicated that all constraints were being satisfied by the optimal solution. Therefore, the model produces feasible manpower reduction alternatives for decision makers.

The sensitivity analysis revealed high sensitivities to changes in the weight parameters of the decision variables. The sensitivity analysis in relation to the decision variables indicate where the input parameters can be changed to affect the decision alternative.

Test cases were used to validate the ESP model to ensure that the model behaved correctly in situations where certain results were expected. The first test case set the S&IO MEB weight to zero while all other MEB weights were set to 1.0. The second test case set all of the MEB weights equal to zero, except S&IO whose weight was set to 1.0. The results of these test cases were consistent with the expected reductions, therefore, the model is well behaved.

V. Conclusions and Recommendations

This final chapter discusses conclusions based on the results of analysis of the ESP decision support system, and proposes issues for further research.

5.1 Conclusions

The primary objective of this research was to provide a method to rationally approach manpower resource allocation decisions. The study concludes that ESP is a viable method of determining these allocations. ESP also provides an audit trail of the decision process.

Another objective of the research was the development of a method to generate a set of decision alternatives to use while making manpower reduction decisions. ESP allows the user to generate differing decision alternatives. The outputs of each alternative can then be compared and contrasted with other decision alternatives to determine the most agreeable alternative.

A secondary objective was to publish these methodologies and the decision model in a 38 series Air Force Manual for Air Force-wide use. The research identified such flexibility in the model that ESP can be easily altered for use by other organizations in the Air Force.

5.2 Recommendations

This research identifies a means to apply a manpower resource reduction to AFMC. However, during the course of this study, AFMC has been developing a new concept for the RA-IPT. Instead of viewing manpower reductions through the MEBs, the new concept views the reductions across the MEBs and oriented to the programs that they support. With some modifications, ESP can be adapted for use in this new approach to manpower reductions.

The problems experienced in the development of the linear programming model for ESP has indicated that a better linear programming solver should be used to generate the decision alternatives. The recommendation is to use a solver that still interfaces with Microsoft Excel, but has more computing power than the Excel Solver used in this study.

Finally, this research has now provided a methodology for decision makers to exploit in decision making regarding manpower resource reductions. The use of ESP will indicate improvements to the model and its outputs. Further study into improvements of these aspects of ESP can only enhance the capabilities available to decision makers and better the Air Force in the process.

Appendix A. Exerpt From September 1994 Database

The data used in this research came from the September 1994 end of month datafile from the CMDS. This data is readily available from the Manpower Office at AFMC. The dataset used with ESP only contains those datafields applicable to the manpower reduction process. Table 20 presents the exerpt from the September 1994 datafile.

Table 20. Exerpt from September 1994 CMDS

Sum of Sum(YC)			GRD			
MEB	CENTER	OSC2LTR	CIV	ENL	OFF	Grand Total
BOS	AFDTC	CE	437	491	10	938
		FM	29	17	1	47
		HC	2	7	8	17
		HO	3	0	0	3
		JA	1	0	0	1
		LG	230	498	14	742
		MO	14	4	0	18
		XP	19	6	3	28
		XR	1	0	0	1
	ASC	CE	697	303	8	1008
		HC	1	11	11	23
		IG	3	0	0	3
		JA	13	12	9	34
		LG	401	150	40	591
		MO	29	1	1	31
		XP	25	1	0	26
	HQAFMC	CE	66	6	21	93
		DO	28	25	43	96
		DP	97	27	31	155
		FM	151	4	31	186
		HC	1	4	3	8
		HO	9	0	0	9
		IG	12	5	34	51
		JA	11	2	9	22
		LG	204	24	32	260
		SG	8	11	19	38
		XP	98	3	34	135
		XR	148	12	70	230

	SMC	CE	351	233	10	594
		DO	2	13	1	16
		DP	64	41	10	115
		FM	63	58	7	128
		HC	2	9	8	19
		HO	0	1	0	1
		JA	12	13	18	43
		LG	51	106	2	159
		MO	22	3	1	26
		RM	173	0	0	173
		XP	5	6	5	16
		XR	1	0	0	1
	WR-ALC	CE	432	297	12	741
		DO	0	3	0	3
		DP	192	45	3	240
		FM	67	12	4	83
		HC	1	4	5	10
		JA	16	5	5	26
		LG	224	27	1	252
		MO	25	0	1	26
		XP	13	3	0	16
PM	ASC	FM	77	1	24	102
		IG	1	0	4	5
		LG	1	0	0	1
	SMC	CE	5	0	0	5
		DO	1	1	2	4
		DP	4	2	4	10
		FM	183	6	117	306
		HO	4	0	0	4
		JA	12	2	3	17
		LG	4	0	0	4
		RM	7	0	0	7
		XP	0	2	0	2
		XR	45	26	166	237
	WR-ALC	CE	0	0	2	2
		LG	1	0	0	1
S&IO	AFDTC	CE	0	6	0	6
	ASC	FM	2	0	0	2
		LG	30	0	0	30
	HQAFMC	XR	0	0	0	0
	SMC	CE	0	17	0	17
	WR-ALC	CE	4	0	0	4
		DO	0	9	11	20
		DP	44	0	0	44
		FM	183	0	5	188
		HO	3	1	0	4
		IG	7	0	1	8
		LG	488	8	2	498

			47	1	0	48
S&T	ASC	FM	6	0	1	7
		SG	8	3	14	25
	SMC	DO	187	61	12	260
		DP	50	0	0	50
		FM	41	0	8	49
		JA	3	0	0	3
		XP	73	5	22	100
T&E	AFDTC	CE	5	43	1	49
		DO	34	473	49	556
		FM	41	0	1	42
		JA	11	8	10	29
		LG	263	462	5	730
		XP	43	6	4	53
		XR	35	1	7	43
	ASC	FM	2	0	2	4

Appendix B. Weight Parameter Sensitivity Analysis

The weight parameter sensitivity analysis results for the basecase scenario in Chapter IV is presented in Table 21 through Table 26. These weight parameters correspond to the objective function coefficients. For values that appear as 1E+30, this indicates that the decision variable can increase or decrease by a large number before the MEBs being reduced changes.

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B18	BOS CIV	19942	0	0.2	1E+30	0
C18	BOS ENL	17567	0	0.2	1E+30	0
D18	BOS OFF	3938	0	0.2	1E+30	0
B19	PM CIV	7117	0	0.2	1E+30	0
C19	PM ENL	897	0	0.2	1E+30	0
D19	PM OFF	4135	0	0.2	1E+30	0
B20	S&IO CIV	43251.4	0	0.2	0	0
C20	S&IO ENL	1849	0	0.2	1E+30	0
D20	S&IO OFF	1031	0	0.2	1E+30	0
B21	S&T CIV	4305.6	0	0.2	0	1E+30
C21	S&T ENL	685	0	0.2	1E+30	0
D21	S&T OFF	1134	0	0.2	1E+30	0
B22	T&E CIV	4435	0	0.2	1E+30	0
C22	T&E ENL	3815	0	0.2	1E+30	0
D22	T&E OFF	860	0	0.2	0	0

Table 21. Weight Parameter Sensitivity Analysis Results Y(C)

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B43	BOS CIV	19792.0825	0	0.2	1E+30	0
C43	BOS ENL	17600	0	0.2	1E+30	0
D43	BOS OFF	3950	0	0.2	1E+30	0
B44	PM CIV	6724	0	0.2	1E+30	0
C44	PM ENL	873.6375023	0	0.2	0	0
D44	PM OFF	4004	0	0.2	1E+30	0
B45	S&IO CIV	40496.4	0	0.2	1E+30	0
C45	S&IO ENL	1818	0	0.2	1E+30	0
D45	S&IO OFF	1025	0	0.2	1E+30	0
B46	S&T CIV	3047.68	0	0.2	0	1E+30
C46	S&T ENL	552	0	0.2	0	1E+30
D46	S&T OFF	1127	0	0.2	1E+30	0
B47	T&E CIV	3295.2	0	0.2	0	1E+30
C47	T&E ENL	3672	0	0.2	1E+30	0
D47	T&E OFF	859	0	0.2	1E+30	0

Table 22. Weight Parameter Sensitivity Analysis Results Y(1)

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B68	BOS CIV	17557.62413	0	0.2	1E+30	0
C68	BOS ENL	17231	0	0.2	1E+30	0
D68	BOS OFF	3913	0	0.2	1E+30	0
B69	PM CIV	6555	0	0.2	1E+30	0
C69	PM ENL	811.6375023	0	0.2	1E+30	0
D69	PM OFF	3708	0	0.2	1E+30	0
B70	S&IO CIV	38156.4	0	0.2	1E+30	0
C70	S&IO ENL	1571.458371	0	0.2	0	0
D70	S&IO OFF	986	0	0.2	1E+30	0
B71	S&T CIV	2935.68	0	0.2	1E+30	0
C71	S&T ENL	538	0	0.2	1E+30	0
D71	S&T OFF	1125	0	0.2	1E+30	0
B72	T&E CIV	2964.2	0	0.2	1E+30	0
C72	T&E ENL	3543	0	0.2	1E+30	0
D72	T&E OFF	866	0	0.2	1E+30	0

Table 23. Weight Parameter Sensitivity Analysis Results Y(2)

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B93	BOS CIV	16820.42413	0	0.2	1E+30	0
C93	BOS ENL	17226	0	0.2	1E+30	0
D93	BOS OFF	3906	0	0.2	1E+30	0
B94	PM CIV	5208	0	0.2	0	1E+30
C94	PM ENL	817.6375023	0	0.2	1E+30	0
D94	PM OFF	3685	0	0.2	1E+30	0
B95	S&IO CIV	37381.4	0	0.2	1E+30	0
C95	S&IO ENL	1568.458371	0	0.2	1E+30	0
D95	S&IO OFF	946	0	0.2	1E+30	0
B96	S&T CIV	2935.68	0	0.2	1E+30	0
C96	S&T ENL	431.2	0	0.2	0	1E+30
D96	S&T OFF	1124	0	0.2	1E+30	0
B97	T&E CIV	2880.2	0	0.2	1E+30	0
C97	T&E ENL	3541	0	0.2	1E+30	0
D97	T&E OFF	849	0	0.2	1E+30	0

Table 24. Weight Parameter Sensitivity Analysis Results Y(3)

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B118	BOS CIV	16757.42413	0	0.2	1E+30	0
C118	BOS ENL	17229	0	0.2	1E+30	0
D118	BOS OFF	3906	0	0.2	1E+30	0
B119	PM CIV	4136.8	0	0.2	0	1E+30
C119	PM ENL	812.6375023	0	0.2	1E+30	0
D119	PM OFF	3675	0	0.2	1E+30	0
B120	S&IO CIV	37052.4	0	0.2	1E+30	0
C120	S&IO ENL	1498.37623	0	0.2	0	0
D120	S&IO OFF	937	0	0.2	1E+30	0
B121	S&T CIV	2348.544	0	0.2	0	1E+30
C121	S&T ENL	431.2	0	0.2	1E+30	0
D121	S&T OFF	1124	0	0.2	1E+30	0
B122	T&E CIV	2575.618141	0	0.2	1E+30	0
C122	T&E ENL	3469	0	0.2	1E+30	0
D122	T&E OFF	842	0	0.2	1E+30	0

Table 25. Weight Parameter Sensitivity Analysis Results Y(4)

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B143	BOS CIV	16035.55072	0	0.2	0	0
C143	BOS ENL	17225	0	0.2	1E+30	0
D143	BOS OFF	3906	0	0.2	1E+30	0
B144	PM CIV	3288.64	0	0.2	0	1E+30
C144	PM ENL	799.6375023	0	0.2	1E+30	0
D144	PM OFF	3660	0	0.2	1E+30	0
B145	S&IO CIV	36690.4	0	0.2	1E+30	0
C145	S&IO ENL	1489.37623	0	0.2	1E+30	0
D145	S&IO OFF	922	0	0.2	1E+30	0
B146	S&T CIV	2348.544	0	0.2	1E+30	0
C146	S&T ENL	431.2	0	0.2	1E+30	0
D146	S&T OFF	1124	0	0.2	1E+30	0
B147	T&E CIV	2095.694513	0	0.2	0	1E+30
C147	T&E ENL	3401	0	0.2	1E+30	0
D147	T&E OFF	829.9570386	0	0.2	0	0

Table 26. Weight Parameter Sensitivity Analysis Results Y(5)

Appendix C. Constraint Sensitivity Analysis Results

The basecase scenario used to develop ESP was processed as described in Chapter IV. Table 27 through Table 33 presents the results of the sensitivity analysis on the constraints to the linear programming model.

Cell	Name	Cell Value	Bound	Status	Slack
B18	BOS CIV	19942	UPPER	Binding	0
C18	BOS ENL	17567	UPPER	Binding	0
D18	BOS OFF	3938	UPPER	Binding	0
B19	PM CIV	7117	UPPER	Binding	0
C19	PM ENL	897	UPPER	Binding	0
D19	PM OFF	4135	UPPER	Binding	0
B20	S&IO CIV	43251.4	UPPER	Not Binding	923.6
C20	S&IO ENL	1849	UPPER	Binding	0
D20	S&IO OFF	1031	UPPER	Binding	0
B21	S&T CIV	4305.6	UPPER	Not Binding	1076.4
C21	S&T ENL	685	UPPER	Binding	0
D21	S&T OFF	1134	UPPER	Binding	0
B22	T&E CIV	4435	UPPER	Binding	0
C22	T&E ENL	3815	UPPER	Binding	0
D22	T&E OFF	860	UPPER	Binding	0
B18	BOS CIV	19942	LOWER	Not Binding	3988.4
C18	BOS ENL	17567	LOWER	Not Binding	3513.4
D18	BOS OFF	3938	LOWER	Not Binding	787.6
B19	PM CIV	7117	LOWER	Not Binding	1423.4
C19	PM ENL	897	LOWER	Not Binding	179.4
D19	PM OFF	4135	LOWER	Not Binding	827
B20	S&IO CIV	43251.4	LOWER	Not Binding	7911.4
C20	S&IO ENL	1849	LOWER	Not Binding	369.8
D20	S&IO OFF	1031	LOWER	Not Binding	206.2
B21	S&T CIV	4305.6	LOWER	Binding	0
C21	S&T ENL	685	LOWER	Not Binding	137
D21	S&T OFF	1134	LOWER	Not Binding	226.8
B22	T&E CIV	4435	LOWER	Not Binding	887
C22	T&E ENL	3815	LOWER	Not Binding	763
D22	T&E OFF	860	LOWER	Not Binding	172

Table 27. Bounding Constraint Sensitivity Analysis Y(C)

Cell	Name	Cell Value	Bound	Status	Slack
B43	BOS CIV	19792.0825	UPPER	Not Binding	183.9175023
C43	BOS ENL	17600	UPPER	Binding	0
D43	BOS OFF	3950	UPPER	Binding	0
B44	PM CIV	6724	UPPER	Binding	0
C44	PM ENL	873.6375023	UPPER	Not Binding	92.36249775
D44	PM OFF	4004	UPPER	Binding	0
B45	S&IO CIV	40496.4	UPPER	Binding	0
C45	S&IO ENL	1818	UPPER	Binding	0
D45	S&IO OFF	1025	UPPER	Binding	0
B46	S&T CIV	3047.68	UPPER	Not Binding	761.92
C46	S&T ENL	552	UPPER	Not Binding	138
D46	S&T OFF	1127	UPPER	Binding	0
B47	T&E CIV	3295.2	UPPER	Not Binding	823.8
C47	T&E ENL	3672	UPPER	Binding	0
D47	T&E OFF	859	UPPER	Binding	0
B43	BOS CIV	19792.0825	LOWER	Not Binding	3811.282498
C43	BOS ENL	17600	LOWER	Not Binding	3520
D43	BOS OFF	3950	LOWER	Not Binding	790
B44	PM CIV	6724	LOWER	Not Binding	1344.8
C44	PM ENL	873.6375023	LOWER	Not Binding	100.8375023
D44	PM OFF	4004	LOWER	Not Binding	800.8
B45	S&IO CIV	40496.4	LOWER	Not Binding	8099.28
C45	S&IO ENL	1818	LOWER	Not Binding	363.6
D45	S&IO OFF	1025	LOWER	Not Binding	205
B46	S&T CIV	3047.68	LOWER	Binding	0
C46	S&T ENL	552	LOWER	Binding	0
D46	S&T OFF	1127	LOWER	Not Binding	225.4
B47	T&E CIV	3295.2	LOWER	Binding	0
C47	T&E ENL	3672	LOWER	Not Binding	734.4
D47	T&E OFF	859	LOWER	Not Binding	171.8

Table 28. Bounding Constraint Sensitivity Analysis Y(1)

Cell	Name	Cell Value	Bound	Status	Slack
B68	BOS CIV	17557.62413	UPPER	Not Binding	1773.458371
C68	BOS ENL	17231	UPPER	Binding	0
D68	BOS OFF	3913	UPPER	Binding	0
B69	PM CIV	6555	UPPER	Binding	0
C69	PM ENL	811.6375023	UPPER	Binding	0
D69	PM OFF	3708	UPPER	Binding	0
B70	S&IO CIV	38156.4	UPPER	Binding	0
C70	S&IO ENL	1571.458371	UPPER	Not Binding	226.5416291
D70	S&IO OFF	986	UPPER	Binding	0
B71	S&T CIV	2935.68	UPPER	Binding	0
C71	S&T ENL	538	UPPER	Binding	0
D71	S&T OFF	1125	UPPER	Binding	0
B72	T&E CIV	2964.2	UPPER	Binding	0
C72	T&E ENL	3543	UPPER	Binding	0
D72	T&E OFF	866	UPPER	Binding	0
B68	BOS CIV	17557.62413	LOWER	Not Binding	2092.758129
C68	BOS ENL	17231	LOWER	Not Binding	3446.2
D68	BOS OFF	3913	LOWER	Not Binding	782.6
B69	PM CIV	6555	LOWER	Not Binding	1311
C69	PM ENL	811.6375023	LOWER	Not Binding	162.3275005
D69	PM OFF	3708	LOWER	Not Binding	741.6
B70	S&IO CIV	38156.4	LOWER	Not Binding	7631.28
C70	S&IO ENL	1571.458371	LOWER	Not Binding	133.0583709
D70	S&IO OFF	986	LOWER	Not Binding	197.2
B71	S&T CIV	2935.68	LOWER	Not Binding	587.136
C71	S&T ENL	538	LOWER	Not Binding	107.6
D71	S&T OFF	1125	LOWER	Not Binding	225
B72	T&E CIV	2964.2	LOWER	Not Binding	592.84
C72	T&E ENL	3543	LOWER	Not Binding	708.6
D72	T&E OFF	866	LOWER	Not Binding	173.2

Table 29. Bounding Constraint Sensitivity Analysis Y(2)

Cell	Name	Cell Value	Bound	Status	Slack
B93	BOS CIV	16820.42413	UPPER	Not Binding	590.2
C93	BOS ENL	17226	UPPER	Binding	0
D93	BOS OFF	3906	UPPER	Binding	0
B94	PM CIV	5208	UPPER	Not Binding	1302
C94	PM ENL	817.6375023	UPPER	Binding	0
D94	PM OFF	3685	UPPER	Binding	0
B95	S&IO CIV	37381.4	UPPER	Binding	0
C95	S&IO ENL	1568.458371	UPPER	Binding	0
D95	S&IO OFF	946	UPPER	Binding	0
B96	S&T CIV	2935.68	UPPER	Binding	0
C96	S&T ENL	431.2	UPPER	Not Binding	107.8
D96	S&T OFF	1124	UPPER	Binding	0
B97	T&E CIV	2880.2	UPPER	Binding	0
C97	T&E ENL	3541	UPPER	Binding	0
D97	T&E OFF	849	UPPER	Binding	0
B93	BOS CIV	16820.42413	LOWER	Not Binding	2891.924825
C93	BOS ENL	17226	LOWER	Not Binding	3445.2
D93	BOS OFF	3906	LOWER	Not Binding	781.2
B94	PM CIV	5208	LOWER	Binding	0
C94	PM ENL	817.6375023	LOWER	Not Binding	163.5275005
D94	PM OFF	3685	LOWER	Not Binding	737
B95	S&IO CIV	37381.4	LOWER	Not Binding	7476.28
C95	S&IO ENL	1568.458371	LOWER	Not Binding	313.6916742
D95	S&IO OFF	946	LOWER	Not Binding	189.2
B96	S&T CIV	2935.68	LOWER	Not Binding	587.136
C96	S&T ENL	431.2	LOWER	Binding	0
D96	S&T OFF	1124	LOWER	Not Binding	224.8
B97	T&E CIV	2880.2	LOWER	Not Binding	576.04
C97	T&E ENL	3541	LOWER	Not Binding	708.2
D97	T&E OFF	849	LOWER	Not Binding	169.8

Table 30. Bounding Constraint Sensitivity Analysis Y(3)

Cell	Name	Cell Value	Bound	Status	Slack
B118	BOS CIV	16757.42413	UPPER	Binding	0
C118	BOS ENL	17229	UPPER	Binding	0
D118	BOS OFF	3906	UPPER	Binding	0
B119	PM CIV	4136.8	UPPER	Not Binding	1034.2
C119	PM ENL	812.6375023	UPPER	Binding	0
D119	PM OFF	3675	UPPER	Binding	0
B120	S&IO CIV	37052.4	UPPER	Binding	0
C120	S&IO ENL	1498.37623	UPPER	Not Binding	73.08214092
D120	S&IO OFF	937	UPPER	Binding	0
B121	S&T CIV	2348.544	UPPER	Not Binding	587.136
C121	S&T ENL	431.2	UPPER	Binding	0
D121	S&T OFF	1124	UPPER	Binding	0
B122	T&E CIV	2575.618141	UPPER	Not Binding	305.5818592
C122	T&E ENL	3469	UPPER	Binding	0
D122	T&E OFF	842	UPPER	Binding	0
B118	BOS CIV	16757.42413	LOWER	Not Binding	3351.484825
C118	BOS ENL	17229	LOWER	Not Binding	3445.8
D118	BOS OFF	3906	LOWER	Not Binding	781.2
B119	PM CIV	4136.8	LOWER	Binding	0
C119	PM ENL	812.6375023	LOWER	Not Binding	162.5275005
D119	PM OFF	3675	LOWER	Not Binding	735
B120	S&IO CIV	37052.4	LOWER	Not Binding	7410.48
C120	S&IO ENL	1498.37623	LOWER	Not Binding	241.2095333
D120	S&IO OFF	937	LOWER	Not Binding	187.4
B121	S&T CIV	2348.544	LOWER	Binding	0
C121	S&T ENL	431.2	LOWER	Not Binding	86.24
D121	S&T OFF	1124	LOWER	Not Binding	224.8
B122	T&E CIV	2575.618141	LOWER	Not Binding	270.6581408
C122	T&E ENL	3469	LOWER	Not Binding	693.8
D122	T&E OFF	842	LOWER	Not Binding	168.4

Table 31. Bounding Constraint Sensitivity Analysis Y(4)

Cell	Name	Cell Value	Bound	Status	Slack
B143	BOS CIV	16035.55072	UPPER	Not Binding	646.8734106
C143	BOS ENL	17225	UPPER	Binding	0
D143	BOS OFF	3906	UPPER	Binding	0
B144	PM CIV	3288.64	UPPER	Not Binding	822.16
C144	PM ENL	799.6375023	UPPER	Binding	0
D144	PM OFF	3660	UPPER	Binding	0
B145	S&IO CIV	36690.4	UPPER	Binding	0
C145	S&IO ENL	1489.37623	UPPER	Binding	0
D145	S&IO OFF	922	UPPER	Binding	0
B146	S&T CIV	2348.544	UPPER	Binding	0
C146	S&T ENL	431.2	UPPER	Binding	0
D146	S&T OFF	1124	UPPER	Binding	0
B147	T&E CIV	2095.694513	UPPER	Not Binding	523.9236282
C147	T&E ENL	3401	UPPER	Binding	0
D147	T&E OFF	829.9570386	UPPER	Not Binding	7.04296135
B143	BOS CIV	16035.55072	LOWER	Not Binding	2689.611415
C143	BOS ENL	17225	LOWER	Not Binding	3445
D143	BOS OFF	3906	LOWER	Not Binding	781.2
B144	PM CIV	3288.64	LOWER	Binding	0
C144	PM ENL	799.6375023	LOWER	Not Binding	159.9275005
D144	PM OFF	3660	LOWER	Not Binding	732
B145	S&IO CIV	36690.4	LOWER	Not Binding	7338.08
C145	S&IO ENL	1489.37623	LOWER	Not Binding	297.875246
D145	S&IO OFF	922	LOWER	Not Binding	184.4
B146	S&T CIV	2348.544	LOWER	Not Binding	469.7088
C146	S&T ENL	431.2	LOWER	Not Binding	86.24
D146	S&T OFF	1124	LOWER	Not Binding	224.8
B147	T&E CIV	2095.694513	LOWER	Binding	0
C147	T&E ENL	3401	LOWER	Not Binding	680.2
D147	T&E OFF	829.9570386	LOWER	Not Binding	160.3570386

Table 32. Bounding Constraint Sensitivity Analysis Y(5)

Year	Name	Cell Value	Status	Slack
Y(C)	Reduction = Current - Reduction Amt	114962	Binding	0
Y(C)	Sum of Rows = Sum of Columns	114962	Binding	0
Y(C)	Officer/Enlisted Ratio	24813	Not Binding	24813
Y(1)	Reduction = Current - Reduction Amt	108836	Binding	0
Y(1)	Sum of Rows = Sum of Columns	108836	Binding	0
Y(1)	Officer/Enlisted Ratio Grand Total	24516	Not Binding	24516
Y(2)	Reduction = Current - Reduction Amt	102462	Binding	0
Y(2)	Sum of Rows = Sum of Columns	102462	Binding	0
Y(2)	Officer/Enlisted Ratio Grand Total	23695	Not Binding	23695
Y(3)	Reduction = Current - Reduction Amt	99320	Binding	0
Y(3)	Sum of Rows = Sum of Columns	99320	Binding	0
Y(3)	Officer/Enlisted Ratio Grand Total	23498	Not Binding	23670
Y(4)	Reduction = Current - Reduction Amt	96795	Binding	0
Y(4)	Sum of Rows = Sum of Columns	96795	Binding	0
Y(4)	Officer/Enlisted Ratio Grand Total	23440	Not Binding	23440
Y(5)	Reduction = Current - Reduction Amt	94247	Binding	0
Y(5)	Sum of Rows = Sum of Columns	94247	Binding	0
Y(5)	Officer/Enlisted Ratio Grand Total	23346	Not Binding	23346

Table 33. Constraint Sensitivity Analysis

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Vita

Captain Steven T. Bishop was born in 1966 in Talladega, Alabama. He was active in scholastic activities and earned numerous academic awards. Following graduation from Talladega High School in Talladega, Alabama, he accepted an Air Force ROTC scholarship and entered Samford University in Birmingham, Alabama in 1985. He met his wife, Lauren, and they married in 1987. In 1989, he graduated with a Mathematics degree and a Biology degree with a minor degree in Chemistry, was commissioned, and entered active duty at Sheppard Technical Training Center at Sheppard AFB, Texas in 1990. While at Sheppard he worked with the Manpower Office developing manpower standards, advising management on efficiency and effectiveness issues, and incorporating Quality Air Force to Sheppard. Also, he developed a software tool to aid in the tracking of Air Force suggestions in 1992 which was incorporated in the Air Force Suggestion Program. In 1993, he entered the Graduate School of Engineering, Air Force Institute of Technology.

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