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A SOLUTION METHODOLOGY FOR THE VARIABLE-LEVEL SCHEDULING PROBLEM

THESIS

Dennis R. Benson, Captain, USAF

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This study looked at a specific scheduling problem for a Department of Defense agency. A heuristic algorithm was developed to solve a general variable-level scheduling problem and was applied to this specific problem. This heuristic used linear programming and integer programming to find the minimum number of weekly billable hours for five alternative schedules. The best alternative schedule was further developed into a spreadsheet designed, squad level, master schedule. The result of this study was a proposed schedule that would save the United States government 8.2% of their security costs for this one part of the governmental agency. These savings would add up to over $300,000.00 in a period of one year.

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AFIT/GOR/ENS/91M-2

A SOLUTION METHODOLOGY FOR THE VARIABLE-LEVEL SCHEDULING PROBLEM

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

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In Partial Fulfillment of the

Requirements for the Degree of

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Captain, USAF

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Preface

The purpose of the study was to solve a scheduling problem for the Department of Defense. The focus of the study was to find a practical solution to help reduce costs of a security force in the Department of Defense. All of the techniques presented during this degree program were addressed as solution methods to this problem. The best schedule was put in a spreadsheet so that implementation of the solution would be easier to undertake. A schedule was produced which saves this agency about 8% of their current costs and helps with some managerial issues that needed to be addressed.

This research would never have been accomplished without the help of the analysts from the Department of Defense. Dr. Marsh and Mr. Tim Fisher went out of their way to provide me with everything I needed to accomplish this research. I would also like to thank Mr. Pete Paternoster for his help and guidance. My advisors for this project made me work and gave me a wonderful opportunity to have a good educational experience from my thesis. Dr. Yupo Chan and Dr. James Chrissis were my co-advisors on this project and they gave me enough direction to get done, yet I am proud to say that this is my work. A sincere thank-you is directed at these two gentlemen.

As I finish this thesis, my thoughts are to Operation Desert Storm. I dedicate this work to my wife, Captain Lista Benson, who is serving overseas in support of Operation Desert Storm. Lista, thank-you for your support and understanding of my time here at AFIT. Now it is my turn to support you as best I can.

Dennis R. Benson

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Abstract

This study investigated a solution methodology to a variable-level scheduling problem. A variable-level scheduling problem is an assignment problem where the manpower demands vary during specific times over the scheduling period. This research was directed at solving a specific variable-level scheduling problem, the scheduling of security guards for the Department of Defense. Different operations research techniques were applied to the problem, with a linear programming solution to a specific heuristic-driven schedule allocating workers to different shifts providing the primary focus of a solution technique. Several subproblems needed to be solved before an assignment problem was used to put specific workers in specific shifts. These subproblems include the shift requirements problem, the relief guard problem, an allowance for annual leave, and an allowance for sick leave. These problems were specific to proposed schedules based on a heuristic which generated shifts to meet surges in the demand for manpower. With the subproblems completed, the assignment, zero-one integer programming problem could be solved. The results of this were then placed in a spreadsheet so that three further manipulations could be done: getting each employee two consecutive days off, Monday training for as many workers as possible, and grouping the workers into 12-man squads. A schedule was produced with these features that also provided an 8% cost savings from the current DoD scheduling practices.

A SOLUTION METHODOLOGY FOR THE VARIABLE-LEVEL SCHEDULING PROBLEM

Chapter I: Research Problem Statement

Background

The Department of Defense (DoD) has a security force at each of three geographically separated locations or zones. The security force is responsible for personnel, as well as the physical security of DoD assets and resources (10:1). According to Dr. Marsh and Mr. Tim Fisher, analysts for DoD, manpower scheduling for each of the three zones is done manually (9). The current system uses an on-line response team, which may not be the most cost effective utilization of these resources, for emergency security situations (10:1). The analysts further explained that this response team also serves as the relief crew for lunch breaks, personal breaks, and other short diversions for those security personnel who are in specific guard posts during a shift.

DoD wants to manage its security manpower assets more efficiently. They also reported that, in the next few months, DoD will open several new buildings which require additional security personnel in guard posts. The analysts also added that with tight government dollars, DoD would like to meet the new demand with their current security manpower level, if possible, thus avoiding hiring additional security officers for the new posts (9). Another interesting development in this problem is that DoD went through a hiring freeze late in fiscal 1990 and wanted to know the minimum number of security officers required before large amounts of overtime were needed in order to maintain some minimum level of security. What makes this scheduling problem so difficult is the different levels of manpower required during different times during the day, as well as different requirements based on different days of the week (namely weekends versus weekdays).

Another issue with security manpower scheduling is the current evaluation system. This evaluation system is the managerial tool used to measure worker performance. By the current scheduling techniques many supervisors never get a chance to observe their subordinates because they are assigned to different schedules. A schedule that would assign supervisors to the same or similar shifts would help to solve this problem that currently exists with the present evaluation ssystem.

Introduction

This research solves the real world scheduling problem using an integrated operations research approach. This research project outlines a series of research objectives aimed at the breadth of this problem rather than detailing an in-depth study of a single aspect of this problem. This choice of objectives leads to usage of several different concepts in the Operations Research curriculum at the Air Force Institute of Technology. The concepts include mathematical programming of an assignment problem, forecasting techniques, and spreadsheet design.

This research details the objectives of this research project, provides the initial methodology for solving this problem, reviews current literature dealing with this subject, covers the solution methodology in great detail, and reports the results of this research project.

Research Objectives

The purpose of this research project is to provide DoD with an easy-to-use, efficient scheduling system for their security protective force. There are three main results of this research project:

1. A spreadsheet software package for DoD to generate schedules
2. A heuristic model to design future scheduling packages
3. Suggestions to DoD to enhance their security scheduling.

There are two major phases to this research. Phase one methodology is developed to produce an efficient scheduling algorithm that can be applied to each of the three security zones for DoD. The second phase is to implement this algorithm by using a spreadsheet design with an overlay that is the result of phase one. This design interface must be constructed so that a minimal amount of personal computer knowledge is needed to easily produce a 14-day schedule. Should future security requirements change for DoD, a minimal amount of work would be required to update the schedule overlay and let DoD maintain efficient use of its security manpower assets.

To obtain these objectives, an initial methodology was formed to solve the important aspects of this problem. This initial methodology leads to observations and problems with obtaining this overall research objective. These other issues are addressed in the methodology chapter of this research report. The following extended outline is the initial methodology used in this research project.

Data Collection

The first step in this initial methodology is to collect the information on the different issues affecting security manpower. This information includes compiling a list of the different guard posts and their hours of operation from records at DoD. Another important piece of information is the personnel management regulations and policies currently in effect at DoD. This information aids in developing a clear understanding of the current scheduling operaiion. The last piece of data was collected is a list of managerial desires for future schedules of security manpower.

Formulation of the Mathematical Model

The second step in this initial methodology originally appears to be the most formidable and is the basis of this research project: to formulate the mathematical model which assigns the different guards to the various shifts in the 14-day schedule. It is essentially an assignment problem with side constraints. This model is formulated as a minimum cost problem. The thinking behind this decision is that by setting a minimum level of security in the constraints of the problem, DoD would never be undermanned to meet their security requirements. The objective of this model then is to keep costs as low as possible while maintaining this standard of security. Other constraints to this problem include having each person work a minimum of 80 hours each two weeks, to schedule an appropriate amount of training for each guard, and to ensure that a guard has a feasible schedule. This feasibility check ensures that no guard has to work back-to-back shifts or, say, has to work Monday night until 11 PM and then come back to work the following morning at 7 AM. This portion of the problem is explained in detail in the methodology chapter (Chapter 3).

Generating Alternative Schedules

In this minimum cost problem, the basic scheduling system is built into the formulation of the model. This portion of the research is to look at other possible work arrangements, such as 8-hour days versus 10-hour days for the guards. These different formulations would both be subject to the same minimum security requirements, so that a simple comparison of objective function values (total cost) is all that is required to compare these alternative schedules.

Optimal Schedule Analysis

This step in this initial methodology demonstrates that, at this point, an optimal, least-cost schedule has been produced. The analysis here is important because it may identify areas of further savings in security manpower scheduling. It also identifies the minimum number of guards required to maintain this level of security without excessive overtime. This number would be important in a potential hiring freeze situation, not unlike the one that occurred at the end of fiscal 1990. By having this analysis, DoD can then identify a floor for manpower personnel, and hire people based on the reduced cost argument of less overtime. It is also important to note that the optimal schedule can be constructed into a spreadsheet overlay that will be used in the next step of the methodology.

Speadsheet Design

This step takes the overlay of the optimal schedule generated previously and formats it into an easy-to-use fashion for a personal computer user. This step includes the selection of a spreadsheet program based on availability and cost as well as the interface with the user to ensure an easy to use product is produced. Another important aspect of the spreadsheet design is to organize the personnel by squads of 12 - 16 people (this is the supervisor/subordinate working together aspect of the problem). Finally, the design of the spreadsheet should help the scheduler allocate annual leave to the security officers.

Spreadsheet Validation and Verification

This step in the research compares the final product of this research with a current schedule to see if this approach yields real savings in the costs of security manpower. This would validate this algorithm as being a useful way to help schedule personnel in shift work activities to yield savings and provide the results in an easy-to-use format. Finally, verification must ensure that the security requirements are met and that each guard is working the required number of hours in a 14-day schedule.

The methodology of this research is rather diverse and uses many differnet facets of the field of Operations Research. Spreadsheet design, mathematical programming, and statistical analysis will lead to an easy-to-use security scheduling program that will help DoD meet its security requirememtns at lower costs.

Important Assumptions in the Research

There are several important assumptions made in the pursuit of an optimal solution for this research. These assumptions deal with wage issues, minimum manpower requirements, and the size of the employee pool to generate the optimal schedule. In the cost analysis for a particular schedule, an average wage rate of $12.15 is used, based on analysis done by DoD (7:4). For minimum manpower requirements, these levels must be obtained by a schedule without exception. In the recommendations chapter (Chapter 5), these assumptions are questioned for possible future cost savings for the security force. Finally, this research assumes that there is a sufficient employee pool to draw upon to meet the scheduling requirements. This implies that there is not a shortage which would require workers to work extra shifts of overtime to meet the minimum levels of security manpower outlined in the data provided by the security force.

An Overview of the Research

The chapters that follow include a literature review of the current techniques used in a scheduling problem. This is followed by an in depth analysis of the methodology of the research. The results of the research are outlined in chapter four while chapter five addresses recommendations and conclusions. Various appendices provide important insight into the actual schedule produced by this research.

Chapter 2: Literature Review

Introduction

The purpose of a literature review is to survey the state-of-the-art of current methods or give background material that can be used to solve a research problem. There are four topics of discussion for this research project; the general scheduling problem, problem formulation for a variable-level schedule, solution techniques, and spreadsheet selection. This literature review examines these topics in detail and reports on the current state of the art and how it relates to the research herein. The discussion of this review covers the most recent material in problem formulation and solution techniques.

The General Scheduling Problem

To get a sense of direction for this scheduling problem, a quick look at the more general context of scheduling problems is in order. Three ideas associated with scheduling problems include: solving a generalized assignment problem, scheduling and capacity planning using linear programming, as well as personnel planning mathematical models. These ideas are investigated below.

Scheduling problems are often considered a type of assignment problem, where the objective is to minimize the cost of assigning workers to tasks. Davis and McKeown give several examples of assignment problems and demonstrate how they are formulated as integer programming problems (5:423-427). Their discussion also addresses how to handle multiple-choice constraints, such as when a worker has to work five of the seven days in a week (5:427).

Hendrick and Moore address scheduling and capacity planning via linear programming. Their examples are taken from a production setting but can be adapted to the problem associated with this research. One example deals with overtime scheduling in an automobile factory and that also features conditional constraints (8:421-422). This applies to the scheduling problem of determining shift requirements and incorporating overtime into those conditional constraints as well as including an overtime cost component in the objective function. According to Mr. Fisher, overtime costs appear as a considerable source of inefficient scheduling of the current security force scheduling (9). This formulation provides a strong foundation to solve the DoD scheduling problem.

Thierauf addresses personnel planning mathematical models. He states that models should "provide a simplified and logical view of the levels and flows of personnel throughout an organizational system" (17:360-361). By designing a spreadsheet format for the implementation of the optimal schedule, this research incorporates Thierauf's idea so that all of the guards can address the changes made in the schedule and feel comfortable with its results. Providing a master schedule for all of the squads in a security zone clearly illustrates the different manning levels in the DoD scheduling problem.

Problem Formulation

This section addresses the mathematical formulation of the research model and compares it to various models that are repesented in the literature. Many of these ideas provided valueable insight to solve several of the subproblems presented in the methodology chapter of the research.

This research formulates the DoD security scheduling problem as a mathematical programming problem. This mathematical program has many similarities to vehicle routing problems (VRPs), where the "vehicles" in this case are the security officers and the "destinations" are the shift requirements in terms of the number of officers required. Vehicle routing problems are a general class of transportation problems or assignment problems. Vehicle routing problems consist of delivering some commodity to all points that require it at minimum cost. The common example of a trucking company illustrates what a VRP entails. Since this is a scheduling problem as well, a look at some related scheduling problems is also appropriate for this literature review.

Current Vehicle Routing Problem Formulations

In the article, "Vehicle Routing with Stochastic Demands: Properties and Solution Frameworks", Dror, Laporte, and Trudeau, consider problems "with a single depot, a homogenous fleet and where customer demand is the only source of uncertainty. Our problem is therefore a particular case of the stochastic VRP" (6:167). Relating to this research problem, the homogenous fleet consists of security guards and the customer demand is the guard requirements for each shift. Using this idea of a transformation between the VRP and the DoD problem, a mathematical formulation of the research problem can be outlined.

In the article "An Integrated Inventory Allocation and Vehicle Routing Problem", Chien, Balakrishnan, and Wong, note "that this integrated problem might arise as a subproblem while analyzing the multiperiod vehicle routing problem" (3:69). These authors also incorporate a linear penalty function for unsatisfied demand during any period (3:69). Unsatisfied demand in the DoD problem is critical since if manpower requirements are not met during a certain time period, then a possible breach of security could occur. In the DoD problem, one way to address this is with an overtime constraint.

Current Scheduling Problems

The DoD security scheduling problem can be compared to three other scheduling problems found in the current literature. One obvious comparison is "A Break from Tradition for the San Francisco Police: Patrol Officer Scheduling Using an Optimization-Based Decision Support System", by Taylor and Huxley. These authors looked at the SFPD and how it implemented an optimized decision support system to help reduce the cost of the force (16:4). Included in this article is an algebraic formulation to the police scheduling problem (16:21). In "Heuristics for Scheduling Aircraft and Crews during Airlift Operations", Sklar, Armstrong, and Samn address minimizing the number of crews so as to meet airlift requirements (15:64). This formulation has the appeal of minimizing the total the number of crews, which translates to minimizing the total number of security officers DoD will need to meet security requirements.

As an examle of scheduling naval deployments, in "Annual Scheduling of Atlantic Fleet Naval Combatants" Brown, Goodman, and Wood address the objective function question of scheduling criteria for a defense (or security) agency. "The Navy is directed to maximize national defense subject to constrained fleet resources" (1:251). Another issue of problem formulation is addressed in this article; this is the issue of elastic demand. "Necessary violations of constraints, at a cost, are accomodated in the (elastic) formulation where constraint ranges become goals that incur penalties when violated" (1:253).

These problems present valuable information in formulating the DoD security scheduling problem. The SFPD problem shows an algebraic statement for a 24-hour, seven-day a week problem (16:21-22). In the aircrew scheduling problem, the objective to minimize the number of aircrews has a similar objective in the DoD problem of minimizing the number of security guards required by the department (15:64). Finally, in the Navy problem, a slightly different approach to the problem provides some fundamental insight into the DoD problem. By minimizing cost in the DoD problem, only a limited level of security can be provided to DoD. This limited or minimum level of security must be realistic, since it is a critical constraint to the problem.

Solving the Scheduling Problem

Recalling that the primary objective of this research is to generate a security schedule for DoD, the concept of a heuristic method for problem solving emerges. To truly measure the effectiveness of a heuristic, it must be compared to some standard; either the current effectiveness in terms of cost, or an analytically derived optimal solution. For this research, if the heuristic provides similar results (say within 3% of total cost) to the analytical results with less processing, then the heuristic can be considered effective. This part of the literature review concentrates on two solution approaches: heuristic methods and analytical methods.

Heuristic Methods

The Sklar, Armstrong, and Samn article presents a heuristic for scheduling aircrews. According to the authors, "The problem is partioned into two components: scheduling aircraft and then, based on the schedule, assigning crews to flight legs" (15:76). The heuristic continues by alternatingly fixing one component and optimizing the other component until little or no improvement is demonstrated (15:76). This can be applied to the DoD problem by finding the optimal mix of shifts and the number of personnel assigned to each shift, then assigning the guards to these shifts.

Chien, Balakrishnan, and Wong, in "An Integrated Inventory Allocation and Vehicle Routing Problem", use a Lagrangian relaxation-based heuristic to solve their example problem (3:72). The integrated inventory allocation and VRP example used is to "consider, for instance, the supply of a frequently replenished consumable such as heating oil or an industrial chemical from a distribution center to several customers". Their methodology consists of two phases. Phase one consists of solving a Lagrangian subproblem of inventory allocation and customer assignments. Phase two uses a drop procedure to ensure feasibility by eliminating repeated arcs and an add routine to check for possible improvement (3:72). The authors summarize their heuristic by the following:

> This optimization-based procedure is very suitable for day-to-day detailed planning of allocation and delivery activities in private firms that undertake the distribution of their limited amount of goods to customer locations which experience fluctuating demand. Another advantage of having an efficient and accurate procedure is that it makes possible sensitivity analysis which will be very helpful for decision makers. (3:76)

Once again, a two-step heuristic is applied to this type of problem which has many similarities to the DoD problem in this research.

Bala Shetty's article, "A Heuristic Algorithm for a Network Problem with Variable Upper Bounds", also uses a similar two-step Lagrangian relaxation procedure. The advantage of this method is that it solves two sequences of pure network problems which can be efficiently solved (14:373). Shetty states:

> one sequence yields tighter bounds on the optimal objective value by considering the Lagrangian relaxation in which the VUB (variable upper bound) constraints are dualized. The second sequence yields upper bounds on the optimal value for the problem. The sequence is obtained by considering a reformulation of the VUB problem based on parametric changes in the variable upper bound. (14:373)

As another example of a two-step heuristic for solving the DoD type of scheduling problem, the current literature has shown that a heuristic approach can be very appropriate to solving the variable-level scheduling problem.

The final heuristic procedure deals with the covering salesman problem. Current and Schilling, in "The Covering Salesman Problem", present a heuristic procedure called COVTOUR (4:210). Their heuristic combines two solution methodologies into a single algorithm. One part of the heuristic solves a set covering problem. In the research problem, this is the shift requirements part of the problem. The shift requirements problem finds the least-cost mix of guards needed to fill the minimum security requirements. The second part of the heuristic solves a traveling salesman problem. In the research problem, this corresponds to the assignment of the response guards that relieve other guards during a shift.

Analytical Approaches

These analytical solution methods provide a possible benchmark for comparison for the heuristic solution methods. The Navy scheduling problem, researched by Brown, Goodman, and Wood, presents "an optimization model that automates a substantial part of the employment scheduling problem" (1:249). A similar outcome is the purpose of this research.

In "Vehicle Routing with Stochastic Demands: Properties and Solution Frameworks", Dror, Laporte, and Trudeau present three properties of the traveling salesman problem (abbreviated TSP, it is a minimum cost tour of n cities, starting and stopping at a single point and visiting each city exactly once). The TSP represents a significant subproblem of the DoD scheduling problem, therefore the three properties are presented here:

Property 1: For the Euclidean TSP, the shortest closed path through n given points never intersects itself (i.e., it is a simple polygon unless all of the points are collinear). (6:168)

Property 2: Every Euclidean TSP has an optimal solution in which customers on the boundary of the convex hull of all the customers (including the depot) are visited in the same order in which they appear on the boundary of the convex hull. (6:169)

Property 3: In the case of the optimal TSP tour, the principle of optimization (usually stated in the context of dynamic programming) can be easily verified. It implies that any segment of an optimal TSP tour is optimal (i.e., if the sequence $i_0 = 0, i_1, ..., i_n, 0$ corresponds to the shortest simple cycle through n + 1 points, then any subsequence, say $i_{p+1}, ..., i_{p+q}$, through $q < n + 1$ points also corresponds to the shortest simple path through these q points). (6:169)

These three properties can be used to help find an analytical solution to the TSP portion of the research problem.

Taylor and Huxley's article presented an algebraic statement of the SFPD problem (16:21-22). This formulation produced a linear programming solution using LINDO that took from seven to nine hours of processing time for a ninety officer schedule (16:14). This gives an indication of the complexity of the research problem and the potential to solve this problem using a heuristic.

Spreadsheet Selection

Choosing a software package to construct the scheduling spreadsheet is an important decision in this research. The program should be user-friendly, yet have enough features to be able to hold all of the pertinent information. According to Stephen Cobb, Quattro Pro™, by Borland International, is Lotus 1-2-3™ compatible (version 2.01) yet is faster to load and exit than Lotus 1-2-3™ (2:23). In the Quattro Pro User's Guide, the program is also capable of reading Paradox database files. This would allow a future implementation of the spreadsheet schedule to link the schedule with a relational database (13:215-216). This interaction can provide valuable information to the scheduler as the database can store information such as the number of days of annual leave a guard may have accrued over a long period of time. Quattro Pro™ is the spreadsheet software used in this research with the schedule being stored as both Quattro Pro™ files as well as Lotus 1-2-3™ files.

Summary

This literature review presented current approaches for solving problems that have aspects similar to the DoD scheduling problem. The general scheduling problem was researched to formulate a basic approach to solving the scheduling problem as a large assignment type problem. Some other background information on solution techniques was also reviewed during this portion of the literature review. In terms of formulation of the problem, vehicle routing problems were analyzed for a similar structure by making the idea transfer of treating the response guards as vehicles going from guard post to guard post. Three scheduling problems were also analyzed for their more standard formulation to be used in this research. Two general methods of solving the research problem were also reviewed. The first method was using some heuristic to solve the problem. This may not give the optimal answer to the research problem. To get an optimal answer, an analytical technique could be used, but this would undoubtably have long computational times. The research, then, involving a heuristic algorithm to generate an effective schedule requires an analytical solution against which the heuristic algorithm is measured to determine the effectiveness of the heuristic. Finally, a review of current literature helped in gathering ideas on designing the spreadsheet which forms the user-interface with the algorithm. In the methodology chapter, the different ideas developed from this research are incorporated with the different aspects of Operations Research that can be applied to this DoD scheduling problem.

Chapter 3: Methodology

Introduction

This chapter covers the research methodology for the variable-level scheduling problem in detail. There are two major phases to this methodology. The first phase consists of solving the mathematical programming problem of assigning security personnel to guard shifts in a minimum cost manner. The second phase of the research takes the optimal solution derived in the first phase and puts it into an easy-to-use spreadsheet format.

Figure 1, on the next page, illustrates the relationship of all parts of the methodology. Notice that the diagram is easily broken down into two components, each representing a phase of the research.

Data Collection

The Department of Defense provided data required for this research. There were three significant areas of information to assimilate into this research project. The first and most important area of information is the managerial direction for this project. It is very important for any analyst to have a clear understanding of the current problems before the analyst can decide on a direction to solve the problem. This deals with issues such as trying to minimize overtime payments versus minimizing total costs, and how important an issue is squad grouping. The second area of information that needed to be collected is the data dealing with shift requirements or a minimum standard of security during the different time periods during the day and week. Finally, personnel regulations needed to be summoned in order to make sure that the assumptions and conclusions drawn about different aspects of the scheduling problem were in accordance with current guidelines.

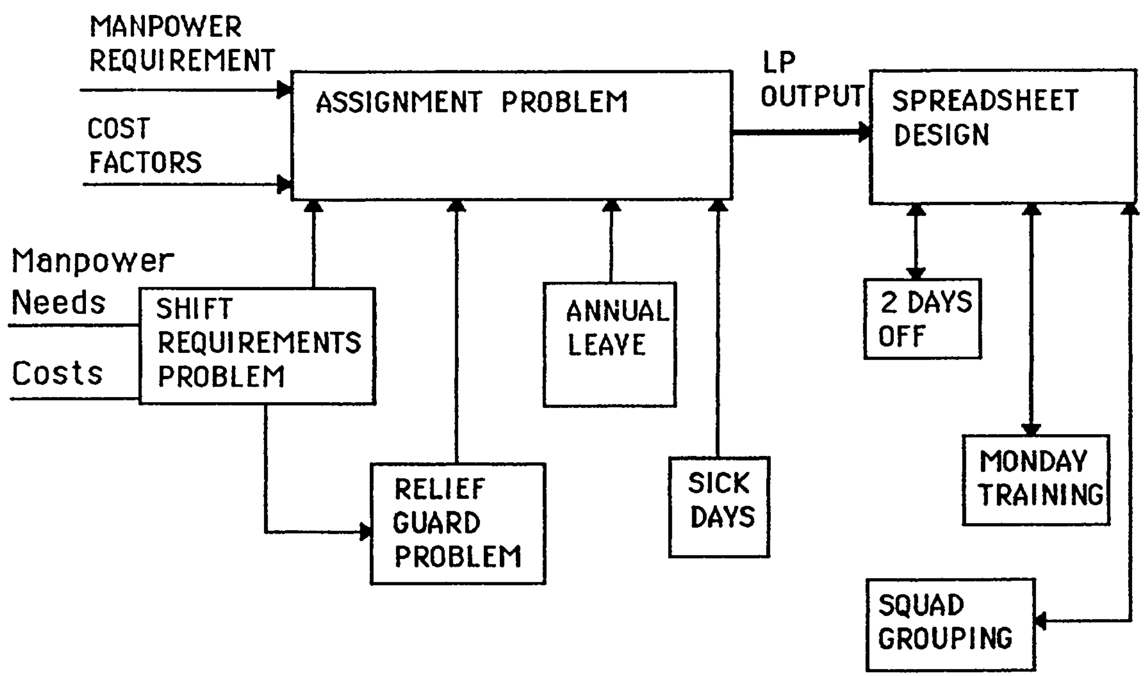

Figure 1. Block Diagram of Research Methodology for Scheduling Problem.

Managerial Objectives

In an original problem statement to the analysts of DoD, security officer John Turrall outlined five concerns that the security force management had with current guidelines. These concerns are summarized below.

The first concern that the security managers expressed deals with the independence of the scheduling process within the organization (18:1). Each zone would construct a schedule for its own zone without regard to any standardization among the different zones. This independent policy results in inconsistent personnel movement: zone to zone, shift to shift, and post to post. As a result, improper planning leads to schedule management by crisis. Turrall suggests that a detailed scheduling policy, enforced by the Operations Commander, is necessary to fix this problem of independence (18:1).

The second concern addressed in this memorandum deals with supervisors observing their subordinates. Under the current system, supervisors do not work with their subordinates on a regular basis, making evaluations of the subordinates difficult due to the lack of personal observation of subordinate's work habits (18:1).

The next concern of security management deals with the irregularity of schedules. Currently, schedules are produced with about a four-week lead time and the security guards only then find out which days they will have off during that 14-day period. A more stable schedule with predictable days off would enhance the security guards' ability to schedule their off-duty time (18:1).

The fourth concern in the initial problem statement addresses management concerns dealing with surpluses and shortages of personnel. Two serious problems result from current scheduling practices: overtime and an excess of response personnel. This is an occasional but nonetheless an extreme problem, particularly with respect to cost, for security management to handle (18:2).

The final concern addressed by the security management deals with the type of shifts which should be scheduled. Management realizes that unequal security requirements throughout the work day leave them with a scheduling decision of multiple 8-hour shifts or 10-hour shifts or even considering the possibility of some 12-hour shifts for any or all of their security guards (18:2).

All of these concerns, which are typical of organizations which have erratic personnel requirements throughout the working day, are addressed in this research methodology. These management concerns provide the direction or a list of informal goals for the methodology for this research project.

Shift Requirements

Handling the shift requirements is a difficult component of this methodology. The shift requirements need to include the number of posts to be filled during a shift, the number of reponse guards during a shift, an allowance for sick days taken as well as an allowance for regular leave time. It is not too difficult from the data presented to get an accurate counting for the number of guard posts that must be manned during a shift. One characteristic of DoD guard posts is the irregularity of some posts times of operation. Calculating the number of response guards to give an adequate amount of break time for all the guards seems to be a difficult problem. Forecasting techniques should provide an approximation that satisfactorily predicts sick days and annual leave.

Personnel requirements are not constant throughout the work day. Table 1 is indicative of the fluctuating number of guard posts that are required to operate at different times in a typical work day.

TABLE 1

PERSONNEL REQUIREMENTS FOR A TYPICAL WEEKDAY IN ZONE #1 (18:4)

Time	/ Number Required	Time	/ Number Required	Time	/ Number Required
0000	/ 21	0800	/ 50	1600	/ 49
0030	/ 19	0830	/ 50	1630	/ 44
0100	/ 18	0900	/ 46	1700	/ 41
0130	/ 18	0930	/ 46	1730	/ 36
0200	/ 18	1000	/ 46	1800	/ 31
0230	/ 18	1030	/ 46	1830	/ 31
0300	/ 18	1100	/ 46	1900	/ 29
0330	/ 18	1130	/ 46	1930	/ 28
0400	/ 18	1200	/ 46	2000	/ 22
0430	/ 23	1230	/ 46	2030	/ 22
0500	/ 29	1300	/ 46	2100	/ 22
0530	/ 35	1330	/ 46	2130	/ 22
0600	/ 44	1400	/ 44	2200	/ 22
0630	/ 50	1430	/ 45	2230	/ 23
0700	/ 50	1500	/ 51	2300	/ 23
0730	/ 50	1530	/ 51	2330	/ 21

This table shows how diverse the requirements for minimum security are during a weekday. Figure 2 is a graphical representation for the zone 1 personnel requirements. Notice that there is a significant increase during the early morning time period and a steady but gradual decrease over several hours in the afternoon.

The minimum security level required is only a start for the information to be collected dealing with shift requirements. Sick leave requirements are also required to accurately account for this occurrence in day-to-day scheduling. By building an adequate buffer for sick days, the security force will not be unexpectedly shorthanded on a regular basis and will reduce costs by not having to pay for expensive overtime. One factor to look for in this data is if the rate of sick days

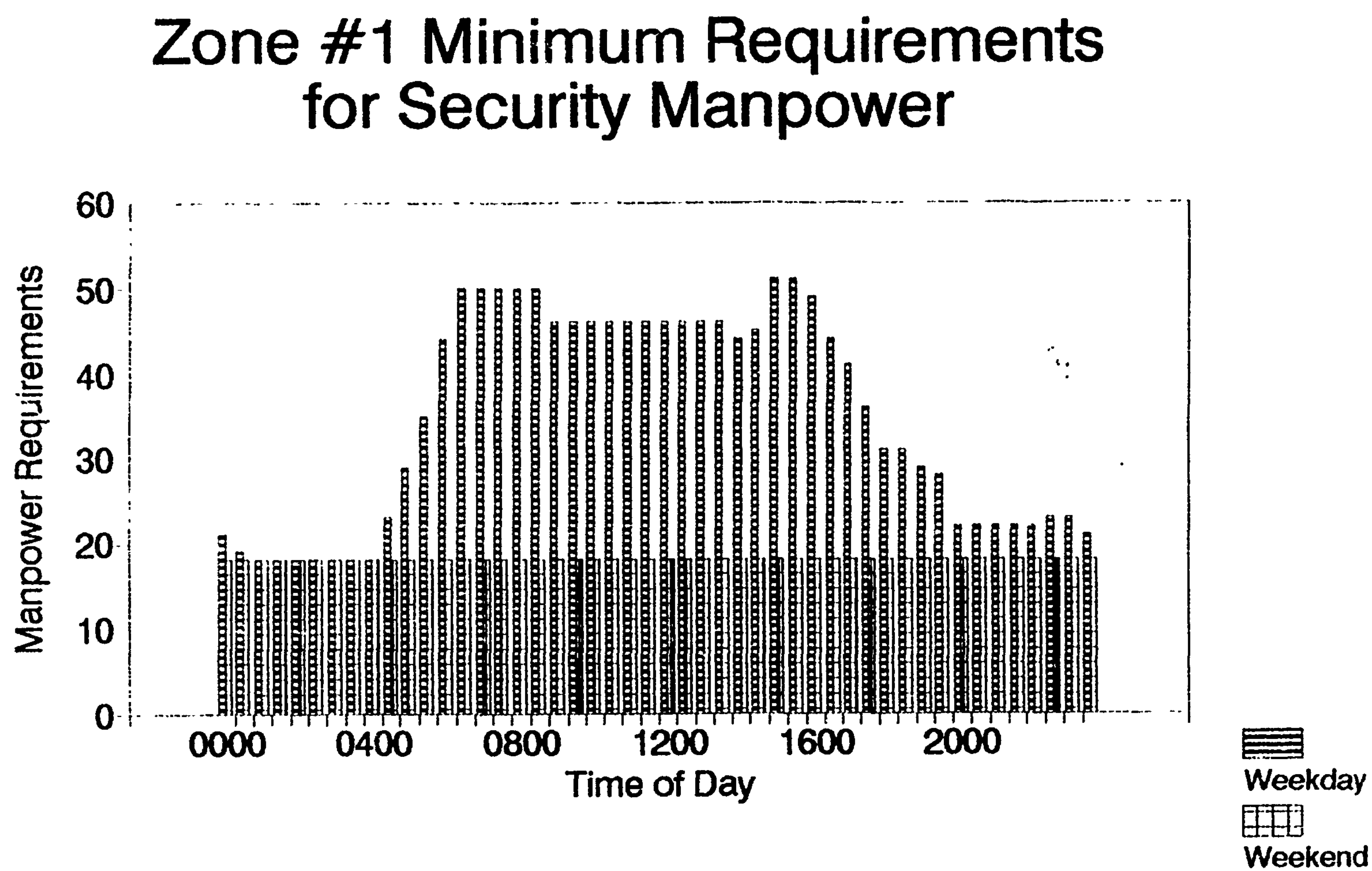

Figure 2. *Zone #1 Minimum Security Manpower Requirements*

varies by different days of the week and by different shifts. This could indicate that incentive pay (for shift differentials, which will be discussed shortly) has an impact on how many people report sick, requiring adjustment in the predictions for the number of people calling in sick for different shifts throughout the 14-day schedule.

Personnel Regulations

Another source for valuable information to this research problem comes from the personnel regulations of DoD. Information dealing with annual leave allocations, shift differentials and overtime pay are all covered in the regulations. Current regulations are cited here for the purpose of better defining the different components of the research problem.

For overtime pay considerations, DoD Personnel Management Manual 30-2, Chapter 362, Section 1 (later referred to as PMM 362.X where X is the section), paragraph g discusses how overtime will be paid to the guards. Overtime refers to those hours worked by the employee in excess of 8 hours in a day, or 40 hours in a calendar week, whichever is the greater number of hours. Therefore, if an employee works four 10-hour days in a week, that employee has accrued eight hours of overtime, even though the employee only worked a total of 40 hours in the week (12:3). Section 3-5 of the regulation discusses overtime rates for the employees of DoD. For the most part, overtime is paid at 1.5 times the basic wage rate for the shift where overtime occurred (11:10). One exception exists for this rule occurs on Sundays and holidays; on these occasions overtime is paid at a rate equivalent to the rate paid on a 10% differential day (11:10).

Another pay-related area that is addressed in the DoD regulations deals with night differentials and Sunday premium pay. These pays are refered to as shift differentials for the remainder of this research. The regulation, PMM 362, mentions that premium pay is authorized for several situations but does not mention exact amounts. According to Mr. Fisher, these shift differentials are a 10% differential for each hour worked betwee. 300 and 0600 (night differential) and 25% for any hour worked on Sunday (9). PMM 362 calls the Sunday differential premium pay. These are important numbers for the computation of how much a guard is paid in calculating total cost for the security force.

The final area of information from personnel regulations deals with annual leave. Leave is accrued on an hourly basis, meaning that leave is charged for the number of hours an employee misses work (11:8). An assumption will be made in this research dealing with annual leave; each guard can take up to 30 days of annual leave per year so that each guard can miss at ieast 8.33 % (1/12th) of the time allocated for work.

Formulation of the Mathematical Model

This is the largest and most complex portion of the methodology for this project. This part of the methodology consists of formulating a mathematical program that assigns a security guard to a series of shifts for a 14-day period. This part of the methodology is illustrated in figure 3 shown on the next page.

There are five parts to solving this portion of the methodology problem. The first problem deals with the shift requirements problem. This assigns the correct number of guards to each shift during the 14-day schedule. This portion is simplified in that it does not include annual leave, sick days, or training requirements. This simply optimizes the number of guards assigned various shifts during the 14-days in a minimum cost linear programming problem.

The next part of the overall math program deals with the relief guard problem. This proved to be the most difficult portion of the research project,

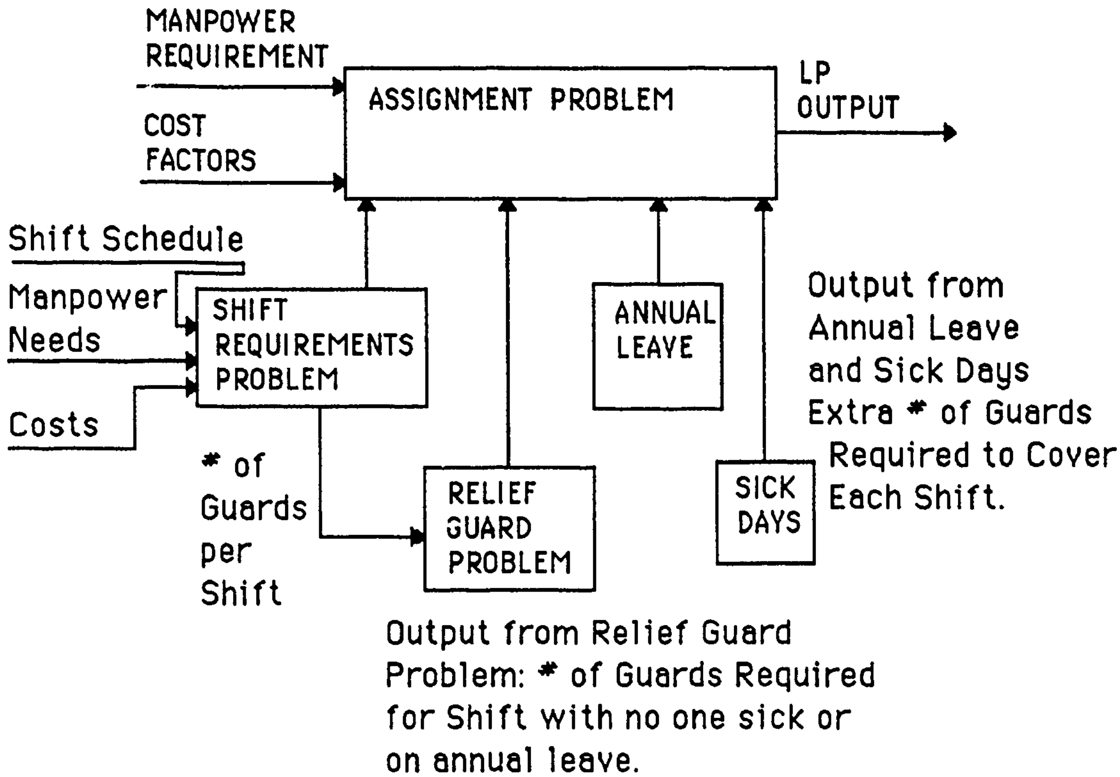

Figure 3. Assignment Problem Methodology with Subproblems.

since it was necessary to ensure that a fairness standard was attained so that each security guard has adequate break time to maintain high morale and that personnel regulations are met. The minimum requirements presented for zone #1 included response guards in each half-hour time block. Therefore the issue of assigning guards to a reduced number of response guard posts is not addressed in the DoD problem, but this methodology suggests that the response guards be modeled using a VRP (Vehicle Routing Problem) format as suggested in the previous chapter.

The third portion of the math program problem is forecasting the number of sick people taking a day off. It is important to predict the percentage of people who would report sick on a given day or given shift to make sure that there is still adequate coverage of all of the guard posts during the shift. The alternative here would be to call in someone on a day off and pay them overtime (as well as shift differentials, if they apply) to cover for a sick day.

The fourth part of the math program problem is to allow for the security guards to take annual leave. This is allocated to the guards per personnel regulations and this methodology builds this into the schedule as an overage for each shift.

The fifth and final part of this problem is bringing all of these individual components together to construct a mathematical model that will evaluate different schedules and find the least-cost alternative. The cost result from the shift requirements problem should indicate which of the schedules will have an overall minimum cost since the schedules are adjusted fairly equally.

Shift Requirements Problem

This portion of the math program deals with finding the optimal (least cost) assignment of officers to different shifts in a 14-day period. To get this optimal assignment of security guards to the various shifts, this research uses a linear program formulation. This result is essential for solving other portions of the math program, such as the relief guard problem and the sick days sub-problem. Therefore this problem needs to be solved first in this methodology. This section describes the decision variables in the linear program as well as the objective function and the constraints. Finally, before actually solving the linear program, analysis of the constraints leads to reducing the size of the linear programming problem which results in a more efficient solution to this linear program. These reduction techniques are described in this section of the research methodology.

The decision variables used in this linear program consist of the number of guards assigned to different shifts during a 14-day period as well as the number of guards that are required to work either one or two hours of overtime to meet minimum security requirements. The first set of variables consists of the regular shifts during the two-week period and are represented as S_i where i is the particular shift during the 14-day schedule period. The other set of variables consists of overtime requirements to meet the minimum security requirements. These variables are A_i and B_i and represent the number of guards working one hour of overtime during shift i (A_i) and two hours of overtime during shift i (B_i).

Two assumptions are made with this formulation. The first assumption is that only a maximum of two hours of overtime can be scheduled for any one shift. The second assumption is that either one hour of overtime is scheduled, or two hours of overtime are scheduled, not one and one half hours (but this can be pointed out and corrected in the constraint analysis described later). Therefore the total number of decision variables for this linear programming problem is three times the number of shifts for the entire two-week period. One drawback from this methodology is that these shifts are predetermined in order to create these decision variables. This drawback is addressed when generating alternative schedules using a heuristic search for finding the optimal starting times for shifts in the 14-day period.

The objective function for this linear program is not very difficult to construct. The objective function represents the cost of the number of guards assigned to the different shifts, and therefore makes this a minimization problem. By taking the number of hours associated with the shift as well as any shift differential that applies to that shift, the coefficients of the objective function can be constructed. For instance, a regular eight hour shift during a weekday with no shift differential may have a coefficient of 8 while a Friday afternoon / early evening shift that has 4 hours of a 10% shift differential would have a 8.4 coefficient in the objective function. Overtime decision variables would have a 1.5 coefficient (for time and a half) plus any shift differentials factored into them. For example, a Sunday overtime of two hours during shift 54 (54 is an arbitrary label for the shift) where the Sunday differential is 25% would result in the following portion of the objective function: $10\ S_{54} + 1.65\ A_{54} + 1.65\ B_{54}$ (10 is the result of 8 x 1.25 for the 25% differential; 1.65 is the result of 1.5 x 1.10 for the 10% differential). The resulting measure of this objective function then is the number of billable hours that all of the guards work to maintain minimum security levels. By factoring in the shift differentials and overtime as described above with their adjusting coefficients, the objective function value represents the number of hours that all of the guards work without any adjustments for overtime or shift differentials during the schedule.

There are two types of constraints to this linear program. The first set of constraints deals with the minimum number of guards required during each half-hour period during the 14-day period. The number of constraints then is 14 days times 24 hours times 2 half-hours per hour for 672 (14 x 24 x 2) constraints. Each constraint has a left-hand-side that consists of the shifts that are working during that thirty minute period while the right-hand-side consists of the minimum number of guards that are required to be working. These are greater than or equal to constraints. The second set of constraints keeps the number of workers on overtime correct. For each shift i, there would be two constraints. The first ensures that the number of guards working one hour of overtime does not exceed the number of guards working the regular shift while the second constraint ensures that the number of guards working a second hour of overtime does not exceed the number of guards working one hour of overtime. For shift number one for example, these constraints would be

$$S_1 - A_1 \geq 0 \text{ and } A_1 - B_1 \geq 0.$$

Therefore the number of constraints in this portion of the problem is 2 times the number of shifts in the 14-day period. The total number of constraints then is 672 + 2 x N (where N equals the number of shifts in a 14-day period).

After looking at the decision variables, the objective function and the constraints to this linear programming problem, this is not a small linear programming problem. However, with some analysis of the constraints the size of the problem can be reduced. Reducing the size of the problem results in faster solution times. The number of constraints can be reduced significantly by looking at blocks of time where the same shifts are on duty. A second technique reduces the number of overtime variables that are required, which reduces the size of the objective function as well.

There is significant redundancy inherent in the constraints of the problem. While the same shifts are on duty and as long as there is no change in the number of guards required, the constraints are identical. By eliminating these constraints, the size of the problem is reduced. Looking at time periods where the same shifts were on duty, and taking the highest number of guards required during that time period, those constraints are dominating constraints. All of the other constraints during that time period are unnecessary and therefore can be eliminated from the linear program. As a result, instead of 672 constraints for minimum requirements, fewer than 100 are actually required. An example of the magnitude of this reduction can be found in Appendix A. In Appendix A, all 672 time periods are listed for the two-week time period as well as though time periods which form nondominated constraints (or constraints which cannot be eliminated by this method of problem reduction).

Another way of reducing the size of this linear program is to eliminate those overtime variables where overtime is not necessary. By looking at the left hand side of those constraints where only a regular shift is present during that 30 minute time period and comparing it with the left hand side of the constraints where the same shift is supplemented by overtime employees, the analyst should note that if the left hand side is larger (or at least equal to) from the dominating constraint where only the regular shift is working, then the overtime variables will go to zero. Consider for instance the case where, in zone 1 on Saturday afternoon, a constant force of 18 officers are required. When the Saturday morning shift is relieved by the Saturday afternoon force, there is no requirement for the morning shift to pull overtime because the afternoon shift is adequate by itself. This would eliminate the two overtime variables associated with the Saturday morning shift, as well as two constraints in the time portion of the problem and the two overtime constraints associated with keeping the overtime straight. Therefore each time it can be determined that overtime is not required by using this technique, two variables and four constraints can be eliminated.

Relief Guard Problem

This sub-problem deals with scheduling lunch breaks and personal breaks during a particular guard shift. The minimum requirements for the zone includes the number of guards required for this portion of the problem. This area needs to be addressed after the shift requirements problem is completed, to identify the amount of extra guards available of various times during a shift to possibly reduce the size of the surplus during certain times of the shift. A reduction in the number of guards required would lead to solving another series of shift requirements problems. This could then possibly change the optimal mix of the guards required and generate even more reductions in the total number of guards. This is unlikely, though, in the sense that the percentage of relief guards is not dominating the solution to the shift requirements problem and the total number of guards should be pretty stable because not that many extra guards are required with these fluctuating minimum levels of manpower security.

Sick Days Problem

This sub-problem tries to forecast an adequate amount of personnel to cover for those reporting sick during a particular shift. This outline shows the logical progression of how this subproblem was solved using STATGRAPHICS.

The first step was to partition the data into an initial set and a test set. The convention used is to make the initial set consist of the first 90% of the data, while the test set consists of the remaining 10%. The data itself is a percentage of workers who report sick and cannot work during a 36-week period. Therefore with this in mind, the first 33 weeks of data (231 days) is used to predict a test set consisting of the last three weeks of data (21 days of the 252 days in the complete data set).

The second step is to get summary statistics on the complete initial data set as well as for each day of the week. A comparison of the means and variances can be done to see if the sick day rate is different by various days of the week. This can be done by hypothesis testing.

The third step for predicting the number of sick days is to break each day of the week into a percentile analysis. By choosing some appropriate level that the cumulative percentage of sick days is less than, for instance 90%, then only 10% of the time is there a need to call in a worker on a day off for extra overtime. This also presumes that all of the workers who could be on annual leave status are in fact on annual leave.

The final step in predicting the amount of sick days is to take the test set described earlier and use the predictions formulated by the percentile analysis and see how many times an underestimation of the number of people who called in sick actually occurs. If this number is less than 10%, then this prediction methodology is appropriate for this data set. If it is greater than 10%, then more data points are required or a higher percentile must be chosen to adequately predict the number of guards who will report in sick.

Allowance for Annual Leave

This final sub-problem is based on the personnel regulation requirement to allow the security guards to take their alloted amount of annual leave during a 14-day schedule. As mentioned in the data collection portion of the research methodology, it is assumed that 8.33% of the time a DoD employee can take annual leave. By allowing up to 12.5% of the work force to have annual leave during a schedule there should be adequate opportunities for the guards to request time off and have it granted.

Bringing it all together: The Assignment Problem

This section incorporates the information from the sub-problems and puts it together into a mathematical program problem. To set up this model, some

assumptions have been made and will be clearly explained; an initial guess for the minimum number of guards that are required must be derived as well.
uired must be derived as well.

For decision variables, the notation is x_{ij} where the subscript i represents worker i and the subscript j represents shift j during a two week schedule. More clearly,

x_{ij} = 1 if worker i is assigned shift j to work

= 0 otherwise.

The objective function has three components which consist of a regular pay cost component for 80 hours of work in two weeks, an overtime cost component, and a shift differential cost component. These costs are calculated for each guard. The objective function for minimizing cost can be expressed as:

$$\sum_{i}\{(1.5 * [\sum_{j}(x_{ij} * L_j)] - 40) * w_i + (0.1 * w_i) [\sum_{j \varepsilon J^1} x_{ij}] + (0.25 * w_i) [\sum_{j \varepsilon J^2} x_{ij}]\}$$

where: L_j - length in time of number of hours in shift j.

w_i - wage rate of worker i.

J^1 - subset of shifts with 10% wage differential.

J^2 - subset of shifts with 25% wage differential.

The first term of the summation expresses both the regular and overtime cost components. The regular cost component is

$$\sum(x_{ij} * L_j) * w_i.$$

The overtime cost component looks like

$$\{0.5 * \Sigma [(x_{ij} * L_j) - 80]\} * w_i.$$

which pays 1.5 times the base pay for any overtime a guard accrues over a 14-day schedule. Combining the two terms yields the first term in the objective function:

$$\{(1.5 * [\Sigma(x_{ij} * L_j)] - 40) * w_i \}$$

The other two terms of the summation account for the shift differential costs that are above the regular pay component. These shifts consist of subsets J^1 and J^2. Shift differentials are premium payments to workers for working during the evening and the weekend.

An interesting aspect of this objective function is how the wage rate is defined. Using w_i, this formulation is generalized for any variable-level scheduling problem. Recall that the assumption here is that each worker is scheduled based on an average wage rate of $12.15.

Shift constraints are the most complex component of this methodology. These constraints consist of the results of the different subproblems of the phase 1 methodology. The shift constraints need to include the number of posts to be filled during a shift, the number of reponse guards during a shift, an allowance for sick days taken as well as an allowance for regular leave time. It is not too difficult from the data presented to get an accurate counting of the number of guard posts that must be manned during a shift. One aspect with DoD guard posts is the irregularity of some posts times of operation. Calculating the number of response guards to give the correct amount of break time for all the guards seems to be a difficult problem. Forecasting techniques should provide an approximation that satisfactorily predicts sick days and regular leave.

The first component of the shift constraints is to generate the right hand side of the constraints. This number represents the basic number of guards that are required to fill all of the posts during the shift. These numbers are the result of the shift requirements problem of allocating guards to the different shifts so as to have the lowest cost while meeting minimum manpower requirements.

The second component that must be predicted is the number of response guards required during a shift. One way to model this aspect of the problem, is to use a Vehicle Routing Problem formulation that shows a response guard going from post to post with a set dwell time at each post (the length of the break) and then moving on to the next post. This formulation preserves the manning requirements of all the posts and provides all of the guards with their required break time. The travel time between posts could be set at ten minutes which would give adequate time for the guards to get from one post to another. Then by using a VRP minimum fleet size solution technique, this would minimize the number of guards that are required for response duty during each shift. The number of response guards was incorporated in the input data for the shift requirements problem for this research problem for DoD.

The third component requires forecasting sick days and regular leave time (vacation days). This analysis is broken down into days of the week through a multiple regression analysis of previous sick days and leave requests. Through this analysis, a certain percentage of overage will be built into each shift in the schedule to accomodate requests for days off and sick days.

Worker constraints also have three different aspects to them. First, the workers are required to work 80 hours every two weeks. This constraint is expressed as

$$\Sigma(x_{ij} * L_j) \geq 80 \quad \text{for all workers } i$$

The next aspect of the assignment problem worker constraints deals with no back-to-back shift scheduling. This constraint looks like:

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} \leq 1$$
$$x_{12} + x_{13} + x_{14} + x_{15} + x_{16} \leq 1 .$$

This shows how a guard cannot be working more than one shift during any 24 hour period. This also needs to be done for each guard and therefore constitutes the number of guards times the number of shifts constraints. This number can be extremely large, for instance there are at least 42 shifts in a two week period and over 180 security officers. The result is over 7500 constraints for this part of the problem. By assuming that a guard will work only during a specific shift, the need for this back-to-back restriction is not required. This assumption, while reasonable, may lead to excess guards being needed to fulfill a single shift during a two week schedule. The remaining shifts this guard works during the two weeks during this time period is unnecessary for the remainder of the schedule and therefore is inefficient.

A similar constraint, though, does need to be addressed. This third worker constraint is a multiple choice type constraint where the worker works only five days in a week. This constraint is

$$\Sigma\, x_{i,j} \leq 5 \quad \text{for each worker } i \text{ and for all shifts } j \text{ in weeks 1 and 2.}$$

This ensures that each worker has at least two days off each week. These days may not be consecutive. The solution method for changing the two days off into two consecutive days off in a week is handled in the second phase of the methodology and is done by a swapping type algorithm.

Generating Alternative Schedules

The mathematical programming model is dependent on a schedule of shift start times introduced by the analyst. This portion of the methodology finds the optimal starting times for various shifts during the week.

To generate these alternative schedules five different possibilities were explored. Since DoD needs round-the-clock security, all five schedules have three 8-hour shifts, seven days a week. The start times for these shifts are assumed to be the same as the current start times at DoD. The reason for this assumption is that to implement a change in the schedule there needs to be a consistency with the current schedule. The first schedule will consist solely of these three 8-hour shifts each day. Also, by keeping this set of eight hour shifts, not too many people would be moved to other shifts so that those workers who wanted to keep their current arrangements for such things as child care and other requirements would not be affected by a new schedule. This will be known as schedule A.

The next schedule is the three 8-hour shifts plus a weekday 8-hour shift from 1000 to 1800 hours. Presently, this is the current scheduling scheme being implemented by DoD. It should be noted right away that the manpower requirements in the late afternoon drop off rather dramatically in zone one (recall figure 2 on page 23) so there appears to be quite some excess built into this schedule. This will be known as schedule B.

The next three schedules all start with the three 8-hour shifts of the first schedule and then add various shifts on top of that to take care of surges in manpower requirements. With this in mind, schedule C has two extra 8-hour shifts to cover the surge of manpower from 0400 to 2000. The first shift covers the first eight hours from 0400 to 1200, while the second extra shift goes from 1200-2000.

Schedule D has one extra 10-hour shift that goes from 0600 to 1600. These ten hours during the day have the highest consecutive amount of manpower requirements and was thus chosen with that in mind.

The fifth and final schedule to be considered is schedule E which is similar to schedule D but has one extra 12-hour shift which commences at 0600 and goes until 1800. Therefore there are five schedules being generated by this research to look for an optimal schedule.

Spreadsheet Design

Phase two begins with this step in the research methodology. Looking at this block diagram for phase two, notice there are three important components to this portion of the methodology. This diagram is on the next page (figure 4). The three blocks under the spreadsheet design are the two consecutive days off problem, the Monday training problem, and the squad grouping problem. The problems are individually discussed after the characteristics of the spreadsheet are described.

The spreadsheet design for a master schedule is included because a master schedule could be copied and then adapted for each individual two-week schedule. Each squad could be looked at individually which would facilitate analysis of the schedule by each squad leader to ensure supervision of activities would take place for each of his subordinates in every two-week period.

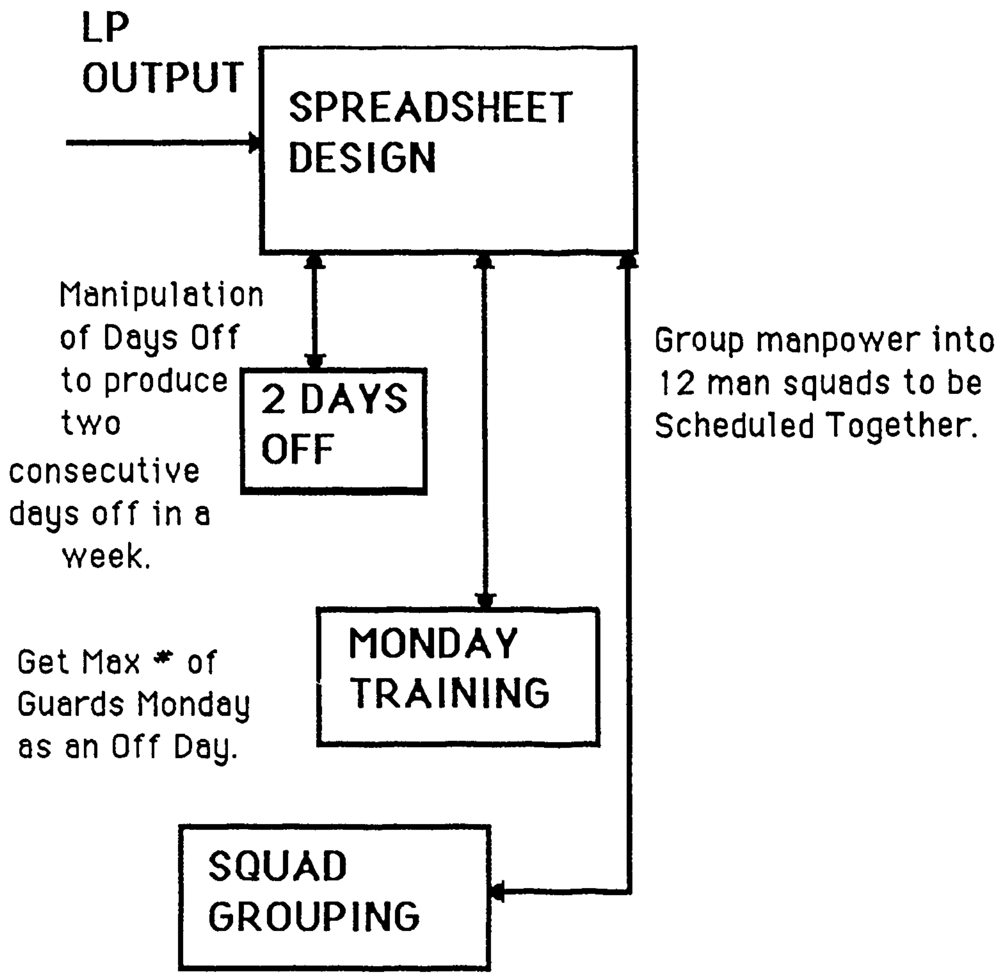

Figure 4. Postprocessing Methodology in Spreadsheet

The input into the spreadsheet design methodology is the result of the assignment problem. This result has multiple optima. This result is exploited by swapping different shifts among the workers. The number of multiple optima is large in this research due to the assumption that each guard is assumed to make the same wage rate. In fact, there are N! similar cost results (where N is the number of guards) since each guard could substitute his entire schedule with any other guard. For example, suppose there are 192 guards. Guard number one could have any of the 192 schedules. Then guard number two then has a choice of the remaining 191 schedules. The objective function result of the assignment problem does not change since it consists of the number of billable hours for each schedule without regard to who is assigned to that schedule.

The result of the optimal schedule portion of the research may or may not have two consecutive days off in a particular week. The optimal schedule does ensure, though, that two days off are available each week. A swapping heuristic is done for those workers who have similar shifts during a week to get the desired two consecutive day off result. The swapping idea ensures an improvement in the two consecutive day off problem without losing any optimality, because each worker is considered to make an average wage in the assumptions presented in chapter one. By swapping one person for one person in this heuristic, the total cost is not affected since the wage rate has been assumed to be a constant and therefore shift differentials will have similar effects on different workers. This methodology may not guarantee that all workers will have two consecutive days off each week and maintain optimality, but will come very close to obtaining a schedule that produces the desired affect.

The next subproblem on the design side of the methodology deals with the Monday training idea. The goal of this subproblem is to maximize the number of workers who have Monday training during the two-week period. The idea behind this thought is the number of federal holidays each worker is entitled to plus the number of current training days annually is about 21 (9). With 26 two-week scheduling periods during the year, each guard would have either a holiday or training during each two-week schedule. Since most federal holidays occur on Monday, it would help the scheduler give credit for the holiday to the maximum number of guards if the scheduler simply cancels training for that two-week period. This thought would try to incorporate the idea that the two consecutive days off for employees would not include Monday, and thus all workers not required on Monday and not on their two day off period, could then be scheduled for training. One shortcoming of this idea is that those workers who work overnight on Sunday would not be available for Monday training and thus may have to be scheduled to have Monday off. To facilitate this, segregation of days off into distinct pairs needs to be incorporated in the consecutive day off swapping procedure. These pairs include Saturday and Sunday, Tuesday and Wednesday, and a third pair of Thursday and Friday. This helps in assigning the maximum number of people for Monday training.

The final subproblem with this design phase of the methodology deals with the grouping of workers into squads of roughly 12 people. Twelve is significant since it would capture the annual leave and sick day components of the phase 1 methodology and have the scheduler capable of having up to two people sick or on annual leave on any particular day from each squad and still meet minimum requirements. On weekends and overnight the number of people out can increase by one per squad to meet the lower requirements for minimum manpower. This is significant since it reduces the possibility of being short-handed during the more expensive night and weekend shifts.

With these subproblems complete, a schedule that addresses the concerns of management can be put together that would address all of the workers' needs as well. The final schedule then is produced using the results of these sub-problems in a series of spreadsheets. The scheduler then can look through the different squads and generate the number of people who are sick or on annual leave and be able to instantly see if any extra workers need to be brought in for overtime due to a large number of people sick.

This methodology is very segmented in that there are several small problems which require a solution. Once a single schedule has been formulated, it will be very easy to copy and use over and over again. If manpower requirements change, only a quick rerun of the shift requirements subproblem is needed to see if the rest of the process has to be accomplished. This methodology is beneficial to the user if there are not a significant number of changes in the near future or a single large change which would require the entire problem to be resolved.

Chapter 4: Research Results

There are two major results of this research project. The first result deals with the development of a useful heuristic for generating a schedule for different minimum requirements throughout some time period. The second area of results deals with the DoD scheduling problem in more detail and follows the methodology presented previously.

The Variable-Level Scheduling Heuristic

As a result of this research, a heuristic algorithm is presented as a starting point for finding a minimum-cost schedule where different levels of manpower are required. This heuristic incorporates many of the ideas presented in the methodology outlined in the previous chapter. This heuristic is designed for the analyst rather than a nontechnical manager. The heuristic consists of ten steps, some of which require solving linear programming problems, so the use of a computer with a linear programming package is encouraged. For small and medium size schedules (less than 200 employees), a personal computer solver would be sufficient. The heuristic is presented in its entirety with each step throughly explained and then summarized in a list for quick reference. This is the variable-level scheduling heuristic. Each step is explained using the DoD problem as an example.

In step one, simple data collection of the minimum worker requirements is obtained. The time periods can be diverse, in this research, a 30 minute interval was used throughout a two-week time period. A more common case may be one-hour intervals for a five day work week. The detail of the problem and length of the schedule are the two factors to be considered by the analyst. This step requires a consultation with management about the minimum levels. In the security scheduling problem, it consists of all of the guard posts and response guards required to be manned during each half hour during the work day.

The second step of the heuristic addresses a baseline schedule requirement. This is simply the answer to the question of "What is the minimum number of workers required for all time periods considered ?" For the DoD problem, the answer is 18, since 18 guards are required on weekends and overnight. Notice however that 21 guards are required from 2000 hours to 2400 hours and this can be established as a secondary baseline for that time period.

In the third step, appropriate start times must be addressed. Guidance can come from personnel regulations, worker requests, or from the result of step 2, after the subtraction of the baseline schedule. In the DoD problem, the 8-hour shifts that go around the clock are continuations of current policy. Therefore, other start times would be driven by the variable-level manning requirements to provide maximal coverage of the surges in manpower requirements.

In step four, the baseline number of workers are removed from the total to address the time periods where surges in manpower are actually required. By subtracting the baseline from the total requirement, the result should eliminate large portions of time that need to be scheduled, since a baseline schedule of consistent manning levels will take care of that portion of the schedule. This idea is adapted from a reverse thinning concept taken from monte-carlo simulation (5:621).

Step five is an important part of this heuristic heuristic. The shift-time heuristic used in this step is a common sense approach to take care of surges in the schedule. The resulting hours of assignment for the surge shifts is based on overtime worth 1.5 times regular pay, a traditional premium associated in the American marketplace for overtime wage compensation. The shift-time heuristic is presented as follows:

a. Add the total number of consecutive hours where surge shifts are required. If this number is less than two hours at the end of each shift, pay overtime and do not create a new shift.

b. If total number of hours is between two and five hours, consider part-time workers with a premium of up to 50% over regular pay. This would meet requirements at a lower cost and then try to trim requirements during this time period for cost effectiveness. If part-time is not possible, then add a single eight hour shift centered on the desired surge time.

c. From 5-9 consecutive hours add one 8-hour shift to overlay peak demand.

d. From 9-11 consecutive hours add one 10-hour shift to overlay peak demand.

e. From 11-14 consecutive hours add one 12-hour shift to overlay peak demand.

f. From 14-17 consecutive hours add two 8-hour shifts to overlay peak demand.

g. From 17-19 consecutive hours add one 8-hour shift and one 10-hour shift to overlay peak demand.

h. From 19-21 consecutive hours add one 10-hour shifts to overlay peak demand.

i. From 21-23 consecutive hours add one 10-hour shift and one 12-hour shift to overlay peak demand.

j. Over 23 consecutive hours add three 8-hour shifts to overlay peak demand.

This is the shift-time heuristic which generates alternative schedules for cost comparison.

Step six deals with the shift requirements allocation problem. For each individual alternative shift scheme, this problem generates the optimal mix of people assigned to various shifts throughout the scheduling time period. In the DoD problem, the time period is two weeks with five different schedules (as outlined in the methodology chapter). The result is a weekly cost figure of paying regular time plus overtime to minimize costs and maintain minimum requirements. The objective function is the number of billable hours in a one-week time frame. One week is all that is required in this research problem because the requirements are static from week to week. The variables in this problem are the number of workers allocated for each shift, as well as the number of workers for one hour of overtime and two hours of overtime. This provides an excellent point of comparison between various shift alternatives. Several alternatives may be eliminated while the rest of the heuristic may be pursued with only the most promising alternatives.

The next step, step seven, compiles the result from step six and organizes the various shifts together for the assignment problem. This is based on the assumption that workers need to work on the same or similar shifts throughout the time period. Otherwise a constraint needs to be added in the assignment problem in step nine to ensure that a worker does not have to work back-to-back shifts. Another advantage to this assumption is that the size of the problem in step 9 is reduced because the problem can be reduced to individual assignments to certain shifts.

Step eight addresses collective shift requirements. This accounts for excess scheduling for personal breaks if work cannot be interrupted, sick days and for annual vacations of employees. Some methods for adjustment are to add a flat percentage for each category, or an overall percentage for all categories which contribute to collective shift requirements.

Step nine deals with the assignment of workers to these shift allocations which have been adjusted to meet collective shift requirements. Minimum cost drives the zero-one integer programming problem of assigning worker i to shift j. Each worker is required to work a minimum amount of time during a schedule. These are incorporated in the minimum worker requirements constraints. The collective requirement constraints ensure each shift is adequately manned. Finally, two days a week off are built into the last series of constraints. An important feature of this step is that if the similar shift assumption is made (i.e. a worker will work a similar shift throughout the period), then the assignment problem can be further broken down by similar shifts over the scheduled period. For instance, all of the morning shifts could be considered in a separate assignment problem.

Step ten, the final step in this heuristic heuristic, manipulates the days off produced by the assignment step (which ordinarily have multiple optimal solutions) to have the days as consecutive days off. This requires the identification of days off between workers on the same shift. Then a simple greedy type heuristic of sequentially starting at one end of the list and trading with the other end of the list to produce the desired two consecutive days off seemed to work well in the DoD research example. An optimal solution without this condition could exist but could be scaled down such that less than ten percent of the work force on any one shift would not have the desired result of two consecutive days off. Also in the DoD problem, Monday training forced pairs of days to be considered for the consecutive days off aspect of the problem. This reduces the size of the problem by considering only three possible two consecutive day off patterns versus the normal seven possibilities.

The heuristic is now summarized to show more clearly the interaction of the different steps of the variable-level scheduling heuristic algorithm.

Step 1: Determine minimum level requirements over time. This may require some consultation with management.

Step 2: Establish a baseline for certain portions of the time period. This can be important to reduce the size of the problem later on.

Step 3: Using guidelines, find appropriate start times for baseline.

Step 4: Subtract baseline from minimum level requirements. Identify the length of time required for extra shifts to be added.

Step 5: Using shift-time heuristic (presented earlier), identify possible extra shifting to be added to baseline shifting.

Step 6: Solve shift requirements integer linear programming problem (for a specific schedule) as follows.

min Σ (Cost of $shift_i$ / worker) * (Number of workers on $Shift_j$)

s.t. $\sum_i$ (Number of workers on $shift_i$ during time t) $\geq$ minimum level of workers at time t $\forall$ t.

{Known as minimum level constraints}

(Number of workers on $shift_j$) - (Number of workers on first hour of overtime) $\geq$ 0

(Number of workers on first hour of overtime on $shift_j$) - (Number of workers on second hour of overtime on $shift_j$) $\geq$ 0

{Known as overtime constraints}

Variables: (Number of workers on $shift_j$) are nonnegative integers.

Step 7: Take results of integer linear programming problem of step 6 and segregate into different shifts. This is to take advantage of the assumption of the workers being assigned to a similar shift throughout the time period. Otherwise in assignment problem (step 9) formulate no back-to-back shifting requirement constraints (as described in the methodology chapter).

Step 8: Add to shift requirements results from integer linear programming problem allowances for training, sick days, and personal breaks. These numbers will vary by different organizations. Only the personal breaks problem can be optimized. These are known as collective shift requirements.

Step 9: Solve assignment problem (for a specific schedule)

min Σ $wage_i$ * $shift_{i,j}$ i- worker #i; j- shift #j.

s.t. $\sum_j$ (Number of hours in $shift_j$) * ($shift_{i,j}$) $\geq$ minimum number of hours $\forall$ i (worker requirements)

$\sum_i$ $Shift_{i,j}$ $\geq$ Collective shift requirement for shift j $\forall$ j (minimum manning level requirements)

$$\sum_{j=1,7 \,\&\, 8,14} Shift_{i,j} \leq 5 \quad \forall i$$ (each worker gets two days a week off)

The result of step 9 is a feasible set of shift schedules which meets minimum requirements at minimum cost. Remember that overtime allocation was accomplished during step 6 of the heuristic and therefore needs to added to the cost result of step 9 to garner a true minimum cost of the schedule.

Step 10: A desirable scheduling feature is to have two consecutive days off. A swappping procedure is performed to accomplish this feature.

Specific Results of this Research

This research was able to develop a schedule that could save about 8% annually and meet many of management's desires for squad grouping and consecutive days off. The results are broken down into three specific areas: preliminary information; shift requirements linear programming results for the five schedules proposed; and the final schedule for the security personnel to follow in zone #1.

Preliminary information results combines the sick days and annual leave subproblems. The methodology in this esearch made an allowance for annual leave of 12.5%. This means that for every eight security officers scheduled during a shift, an additional guard needs to be scheduled for the annual leave allowance. For sick days, a comparison of the means and variances of the percentage of guards calling in sick showed no significant statistical significance between different shifts. A percentile analysis showed that an allowance of 6% of the guards calling in sick was an adequate allowance over 90% of the time. In fact, on the test set of data described in the methodology chapter, this 6% allowance was adequate for 93.6% of the shifts (only 4 shifts of 63 in the test set required additional guards). Combining these two results, a total allowance of 18.5% is required to account for these two subproblems.

The second result that needs to be addressed is the result of the minimum-cost shift requirements analysis. Here schedule C performed the best, followed by schedule E, then schedule D, schedule B (the current DoD schedule), and finally, schedule A. An interesting observation is that the more "extra hours" associated with a schedule, the better it seemed to perform. Looking at the numbers of the weekly cost in schedule C versus schedule B, there is an 8.6% savings. Schedule B is the baseline for comparison in this analysis since it reflects the best possible combination of shift allocation for the current DoD schedule. Finally, after going to phase two of the methodology, there is not much loss in optimality to achieve squad grouping and Monday holidays as well as two consecutive days off each week. The shift requirements problem results are summarized in table 2 below.

TABLE 2

SHIFT REQUIREMENTS PROBLEM RESULTS

Shift Schedule	Weekly Billable Hours (Minimum)
A	6658.8
B	6628.8
C	6058.0
D	6251.3
E	6202.8

Taking schedule C and moving to phase two of the methodology added less than 27 billable hours a week to solve the three subproblems of phase 2 of the methodology. Table 3 on the next page shows the result of phase two of the methodology and its effect on cost.

TABLE 3

SCHEDULE C COST ANALYSIS

Shift Number	Number Working	Number of 1st Hour Overtime	Number of 2nd Hour Overtime	Shift Cost
1	36	1	1	291.0
2	23	2	2	199.8
3	21	0	0	184.8
4	36	1	1	291.0
5	23	2	2	199.8
6	21	0	0	184.8
7	36	1	1	291.0
8	23	2	2	199.8
9	21	0	0	184.8
10	36	1	1	291.0
11	23	2	2	199.8
12	21	0	0	184.8
13	36	1	1	291.0
14	23	5	5	209.7
15	18	0	0	158.4
16	18	0	0	158.4
17	18	0	0	158.4
18	18	0	0	174.6
19	18	0	0	180.0
20	18	0	0	180.0
21	21	0	0	191.1
43	14	0	0	114.8
44	27	0	0	221.4
45	14	0	0	114.8
46	27	0	0	221.4
47	14	0	0	114.8
48	27	0	0	221.4
49	14	0	0	114.8
50	27	0	0	221.4
51	14	0	0	114.8
52	27	0	0	221.4

The third result is the actual schedule for zone one. Each of the sixteen squads have their own schedule with very little separation of the squad during working hours. In fact, the most is two hours in any day, while all training is grouped together for the entire squad. These results are included in Appendix B.

Chapter 5: Recommendations and Conclusions

Recommendations

This research leads to a single schedule for DoD to implement. This is schedule C as described earlier in this paper. This schedule gives management many of the features it was trying to accomplish as well as save a significant amount of money. After manipulation of phase two of the methodology, this schedule yields a total of 6084.8 billable hours each week. This is the result of adding the cost column of table 3. The minimum number of billable hours for the current DoD schedule (schedule B in this research) is 6628.8 hours a week. Schedule C saves 544 billable hours each week or a savings of 8.2%. Note that the 6084.8 billable hours is less than any alternative after the shift requirements portion of the problem. The 544 billable hours multiplied by the average wage yields a savings of $6,609.60 each week and, if extended for a period of one year would result in a savings of $343,699.20. Therefore, schedule C should be implemented as the zone #1 schedule. Implementation would not be difficult since the basic-around-the-clock eight hour shifts have not changed.

Another recommendation is built into this schedule. This would tie the idea of Monday training with the observance of Federal holidays. If a Federal holiday is scheduled during a two week time period, there would be no need to track who received credit for the holiday if the training day is simply substituted for the holiday.

To reduce costs even further, the following times should be analyzed by DoD to see if some posts could be eliminated. This would reduce the number of billable hours significantly since it would translate to whole shifts of eight hours being eliminated if implemented. On Monday through Friday, the early morning surge from 0630 to 0900 of 50 officers should possibly be reduced to 46. Only 46 security officers are required until 1400 on weekdays, therefore four 8-hour shifts could be eliminated each weekday. This would save 160 additional billable hours a week. During the late afternoon weekday surge from 1500 to 1700, a high of 51 officers are required in zone #1. If these numbers can be reduced to 41, additional significant savings can be realized. These are difficult times to cut officers since they are involved in traffic control, but an investigation of part-time workers for these surge periods could result in some additional savings.

A single recommendation for follow-on research would look more closely at the response guard problem. An algorithm which could quickly solve this portion of the variable-level scheduling problem could possibly reveal even more savings for the security force.

Conclusions

The key subproblem that led to these dramatic results is the shift requirements linear programming subproblem of phase 1 of the methodology. By measuring the number of weekly billable hours between schedules, it is easy to determine a minimum-cost variable-level schedule.

This has been an interesting analysis of a real world scheduling problem. This research has investigated this problem using many different ideas from operations research and developed a heuristic algorithm to solve a variable-level scheduling problem in the future. By putting the results in a spreadsheet format, an analyst is not needed to use the results of the research on a day-to-day basis. This research also kept the wishes of management, as well as a concern for the workers, in mind, in order to develop a system which is easy to implement.

Appendix A: Schedule C Minimum Requirements Printout

The following pages show the overlapping of shifts for schedule C matched with the minimum requirements for each 30 minute time period during a 14-day schedule. This format was used to determine the binding constraints for the shift requirements problem as outlined in chapter 3, the methodology chapter (see pages 29-31). These binding constraints are illustrated with an " * " in the last column. A regular shift is annotated as SXX where XX is the shift number. The first hour of overtime is labeled as AXX for shift XX. Similarly, the second hour of overtime is labeled as BXX. For instance, on shift number 3, S3 represents the number of guards required during normal shift hours which extend from 2200 on the first Monday to 0600 on Tuesday morning. A3 represents the number of guards required for one hour of overtime, or from the time period of 0600 to 0700 on Tuesday morning. B3 then represents the number of guards required for a second hour of overtime which would be from 0700 to 0800 on Tuesday morning. This analysis reduces the size of the shift requirements problem by reducing the number of constraints by over 50%.

SCHEDULE C Time	Day	Regular Shifts	Overtime Shifts	Number Required	Time	Non-Dominated Constraints
0000	Monday	S42		21	0000	*
0030	Monday	S42		19	0030	
0100	Monday	S42		18	0100	
0130	Monday	S42		18	0130	
0200	Monday	S42		18	0200	
0230	Monday	S42		18	0230	
0300	Monday	S42		18	0300	
0330	Monday	S42		18	0330	
0400	Monday	S42,S43		18	0400	
0430	Monday	S42,S43		23	0430	
0500	Monday	S42,S43		29	0500	
0530	Monday	S42,S43		35	0530	*
0600	Monday	S1,S43	A42	44	0600	
0630	Monday	S1,S43	A42	50	0630	*
0700	Monday	S1,S43	B42	50	0700	*
0730	Monday	S1,S43	B42	50	0730	
0800	Monday	S1,S43		50	0800	*
0830	Monday	S1,S43		50	0830	
0900	Monday	S1,S43		46	0900	
0930	Monday	S1,S43		46	0930	
1000	Monday	S1,S43		46	1000	
1030	Monday	S1,S43		46	1030	
1100	Monday	S1,S43		46	1100	
1130	Monday	S1,S43		46	1130	
1200	Monday	S1,S44	A43	46	1200	*
1230	Monday	S1,S44	A43	46	1230	
1300	Monday	S1,S44	B43	46	1300	*
1330	Monday	S1,S44	B43	46	1330	
1400	Monday	S2,S44	A1	44	1400	
1430	Monday	S2,S44	A1	45	1430	*
1500	Monday	S2,S44	B1	51	1500	*
1530	Monday	S2,S44	B1	51	1530	
1600	Monday	S2,S44		49	1600	*
1630	Monday	S2,S44		44	1630	
1700	Monday	S2,S44		41	1700	
1730	Monday	S2,S44		36	1730	
1800	Monday	S2,S44		31	1800	
1830	Monday	S2,S44		31	1830	
1900	Monday	S2,S44		29	1900	
1930	Monday	S2,S44		28	1930	
2000	Monday	S2	A44	22	2000	*
2030	Monday	S2	A44	22	2030	
2100	Monday	S2	B44	22	2100	*
2130	Monday	S2	B44	22	2130	
2200	Monday	S3	A2	22	2200	*
2230	Monday	S3	A2	23	2230	
2300	Monday	S3	B2	23	2300	*

2330	Monday	S3	B2	21	2330	
0000	Tuesday	S3		21	0000	*
0030	Tuesday	S3		19	0030	
0100	Tuesday	S3		18	0100	
0130	Tuesday	S3		18	0130	
0200	Tuesday	S3		18	0200	
0230	Tuesday	S3		18	0230	
0300	Tuesday	S3		18	0300	
0330	Tuesday	S3		18	0330	
0400	Tuesday	S3,S45		18	0400	
0430	Tuesday	S3,S45		23	0430	
0500	Tuesday	S3,S45		29	0500	
0530	Tuesday	S3,S45		35	0530	*
0600	Tuesday	S4,S45	A3	44	0600	
0630	Tuesday	S4,S45	A3	50	0630	*
0700	Tuesday	S4,S45	B3	50	0700	*
0730	Tuesday	S4,S45	B3	50	0730	
0800	Tuesday	S4,S45		50	0800	*
0830	Tuesday	S4,S45		50	0830	
0900	Tuesday	S4,S45		46	0900	
0930	Tuesday	S4,S45		46	0930	
1000	Tuesday	S4,S45		46	1000	
1030	Tuesday	S4,S45		46	1030	
1100	Tuesday	S4,S45		45	1100	
1130	Tuesday	S4,S45		46	1130	
1200	Tuesday	S4,S46	A45	46	1200	*
1230	Tuesday	S4,S46	A45	46	1230	
1300	Tuesday	S4,S46	B45	46	1300	*
1330	Tuesday	S4,S46	B45	46	1330	
1400	Tuesday	S5,S46	A4	44	1400	
1430	Tuesday	S5,S46	A4	45	1430	*
1500	Tuesday	S5,S46	B4	51	1500	*
1530	Tuesday	S5,S46	B4	51	1530	
1600	Tuesday	S5,S46		49	1600	*
1630	Tuesday	S5,S46		44	1630	
1700	Tuesday	S5,S46		41	1700	
1730	Tuesday	S5,S46		36	1730	
1800	Tuesday	S5,S46		31	1800	
1830	Tuesday	S5,S46		31	1830	
1900	Tuesday	S5,S46		29	1900	
1930	Tuesday	S5,S46		28	1930	
2000	Tuesday	S5	A46	22	2000	*
2030	Tuesday	S5	A46	22	2030	
2100	Tuesday	S5	B46	22	2100	*
2130	Tuesday	S5	B46	22	2130	
2200	Tuesday	S6	A5	22	2200	*

2230	Tuesday	S6	A5	23	2230	
2300	Tuesday	S6	B5	23	2300	*
2330	Tuesday	S6	B5	21	2330	
0000	Wednesday	S6		21	0000	*
0030	Wednesday	S6		19	0030	
0100	Wednesday	S6		18	0100	
0130	Wednesday	S6		18	0130	
0200	Wednesday	S6		18	0200	
0230	Wednesday	S6		18	0230	
0300	Wednesday	S6		18	0300	
0330	Wednesday	S6		18	0330	
0400	Wednesday	S6,S47		18	0400	
0430	Wednesday	S6,S47		23	0430	
0500	Wednesday	S6,S47		29	0500	
0530	Wednesday	S6,S47		35	0530	*
0600	Wednesday	S7,S47	A6	44	0600	
0630	Wednesday	S7,S47	A6	50	0630	*
0700	Wednesday	S7,S47	B6	50	0700	*
0730	Wednesday	S7,S47	B6	50	0730	
0800	Wednesday	S7,S47		50	0800	*
0830	Wednesday	S7,S47		50	0830	
0900	Wednesday	S7,S47		46	0900	
0930	Wednesday	S7,S47		46	0930	
1000	Wednesday	S7,S47		46	1000	
1030	Wednesday	S7,S47		46	1030	
1100	Wednesday	S7,S47		46	1100	
1130	Wednesday	S7,S47		46	1130	
1200	Wednesday	S7,S48	A47	46	1200	*
1230	Wednesday	S7,S48	A47	46	1230	
1300	Wednesday	S7,S48	B47	46	1300	*
1330	Wednesday	S7,S48	B47	46	1330	
1400	Wednesday	S8,S48	A7	44	1400	
1430	Wednesday	S8,S48	A7	45	1430	*
1500	Wednesday	S8,S48	B7	51	1500	*
1530	Wednesday	S8,S48	B7	51	1530	
1600	Wednesday	S8,S48		49	1600	*
1630	Wednesday	S8,S48		44	1630	
1700	Wednesday	S8,S48		41	1700	
1730	Wednesday	S8,S48		36	1730	
1800	Wednesday	S8,S48		31	1800	
1830	Wednesday	S8,S48		31	1830	
1900	Wednesday	S8,S48		29	1900	
1930	Wednesday	S8,S48		28	1930	
2000	Wednesday	S8	A48	22	2000	*
2030	Wednesday	S8	A48	22	2030	
2100	Wednesday	S8	B48	22	2100	*

2130	Wednesday	S8	B48	22	2130	
2200	Wednesday	S9	A8	22	2200	*
2230	Wednesday	S9	A8	23	2230	
2300	Wednesday	S9	B8	23	2300	*
2330	Wednesday	S9	B8	21	2330	
0000	Thursday	S9		21	0000	*
0030	Thursday	S9		19	0030	
0100	Thursday	S9		18	0100	
0130	Thursday	S9		18	0130	
0200	Thursday	S9		18	0200	
0230	Thursday	S9		18	0230	
0300	Thursday	S9		18	0300	
0330	Thursday	S9		18	0330	
0400	Thursday	S9,S49		18	0400	
0430	Thursday	S9,S49		23	0430	
0500	Thursday	S9,S49		29	0500	
0530	Thursday	S9,S49		35	0530	*
0600	Thursday	S10,S49	A9	44	0600	
0630	Thursday	S10,S49	A9	50	0630	*
0700	Thursday	S10,S49	B9	50	0700	*
0730	Thursday	S10,S49	B9	50	0730	
0800	Thursday	S10,S49		50	0800	*
0830	Thursday	S10,S49		50	0830	
0900	Thursday	S10,S49		46	0900	
0930	Thursday	S10,S49		46	0930	
1000	Thursday	S10,S49		46	1000	
1030	Thursday	S10,S49		46	1030	
1100	Thursday	S10,S49		46	1100	
1130	Thursday	S10,S49		46	1130	
1200	Thursday	S10,S50	A49	46	1200	*
1230	Thursday	S10,S50	A49	46	1230	
1300	Thursday	S10,S50	B49	46	1300	*
1330	Thursday	S10,S50	B49	46	1330	
1400	Thursday	S11,S50	A10	44	1400	
1430	Thursday	S11,S50	A10	45	1430	*
1500	Thursday	S11,S50	B10	51	1500	*
1530	Thursday	S11,S50	B10	51	1530	
1600	Thursday	S11.S50		49	1600	*
1630	Thursday	S11,S50		44	1630	
1700	Thursday	S11,S50		41	1700	
1730	Thursday	S11,S50		36	1730	
1800	Thursday	S11,S50		31	1800	
1830	Thursday	S11,S50		31	1830	
1900	Thursday	S11,S50		29	1900	
1930	Thursday	S11,S50		28	1930	
2000	Thursday	S11	A50	22	2000	*

2030	Thursday	S11	A50	22	2030	
2100	Thursday	S11	B50	22	2100	*
2130	Thursday	S11	B50	22	2130	
2200	Thursday	S12	A11	22	2200	*
2230	Thursday	S12	A11	23	2230	
2300	Thursday	S12	B11	23	2300	*
2330	Thursday	S12	B11	21	2330	
0000	Friday	S12		21	0000	*
0030	Friday	S12		19	0030	
0100	Friday	S12		18	0100	
0130	Friday	S12		18	0130	
0200	Friday	S12		18	0200	
0230	Friday	S12		18	0230	
0300	Friday	S12		18	0300	
0330	Friday	S12		18	0330	
0400	Friday	S12,S51		18	0400	
0430	Friday	S12,S51		23	0430	
0500	Friday	S12,S51		29	0500	
0530	Friday	S12,S51		35	0530	*
0600	Friday	S13,S51	A12	44	0600	
0630	Friday	S13,S51	A12	50	0630	*
0700	Friday	S13,S51	B12	50	0700	*
0730	Friday	S13,S51	B12	50	0730	
0800	Friday	S13,S51		50	0800	*
0830	Friday	S13,S51		50	0830	
0900	Friday	S13,S51		46	0900	
0930	Friday	S13,S51		46	0930	
1000	Friday	S13,S51		46	1000	
1030	Friday	S13,S51		46	1030	
1100	Friday	S13,S51		46	1100	
1130	Friday	S13,S51		46	1130	
1200	Friday	S13,S52	A51	46	1200	*
1230	Friday	S13,S52	A51	46	1230	
1300	Friday	S13,S52	B51	46	1300	*
1330	Friday	S13,S52	B51	46	1330	
1400	Friday	S14,S52	A13	44	1400	
1430	Friday	S14,S52	A13	45	1430	*
1500	Friday	S14,S52	B13	51	1500	*
1530	Friday	S14,S52	B13	51	1530	
1600	Friday	S14,S52		49	1600	*
1630	Friday	S14,S52		44	1630	
1700	Friday	S14,S52		41	1700	
1730	Friday	S14.S52		36	1730	
1800	Friday	S14,S52		31	1800	
1830	Friday	S14,S52		31	1830	
1900	Friday	S14,S52		29	1900	

1930	Friday	S14,S52		28	1930	
2000	Friday	S14	A52	22	2000	*
2030	Friday	S14	A52	22	2030	
2100	Friday	S14	B52	22	2100	*
2130	Friday	S14	B52	22	2130	
2200	Friday	S15	A14	22	2200	
2230	Friday	S15	A14	23	2230	*
2300	Friday	S15	B14	23	2300	*
2330	Friday	S15	B14	21	2330	
0000	Saturday	S15		18	0000	*
0030	Saturday	S15		18	0030	
0100	Saturday	S15		18	0100	
0130	Saturday	S15		18	0130	
0200	Saturday	S15		18	0200	
0230	Saturday	S15		18	0230	
0300	Saturday	S15		18	0300	
0330	Saturday	S15		18	0330	
0400	Saturday	S15		18	0400	
0430	Saturday	S15		18	0430	
0500	Saturday	S15		18	0500	
0530	Saturday	S15		18	0530	
0600	Saturday	S16	A15	18	0600	*
0630	Saturday	S16	A15	18	0630	
0700	Saturday	S16	B15	18	0700	*
0730	Saturday	S16	B15	18	0730	
0800	Saturday	S16		18	0800	*
0830	Saturday	S16		18	0830	
0900	Saturday	S16		18	0900	
0930	Saturday	S16		18	0930	
1000	Saturday	S16		18	1000	
1030	Saturday	S16		18	1030	
1100	Saturday	S16		18	1100	
1130	Saturday	S16		18	1130	
1200	Saturday	S16		18	1200	
1230	Saturday	S16		18	1230	
1300	Saturday	S16		18	1300	
1330	Saturday	S16		18	1330	
1400	Saturday	S17	A16	18	1400	*
1430	Saturday	S17	A16	18	1430	
1500	Saturday	S17	B16	18	1500	*
1530	Saturday	S17	B16	18	1530	
1600	Saturday	S17		18	1600	*
1630	Saturday	S17		18	1630	
1700	Saturday	S17		18	1700	
1730	Saturday	S17		18	1730	
1800	Saturday	S17		18	1800	

1830	Saturday	S17		18	1830	
1900	Saturday	S17		18	1900	
1930	Saturday	S17		18	1930	
2000	Saturday	S17		18	2000	
2030	Saturday	S17		18	2030	
2100	Saturday	S17		18	2100	
2130	Saturday	S17		18	2130	
2200	Saturday	S18	A17	18	2200	*
2230	Saturday	S18	A17	18	2230	
2300	Saturday	S18	B17	18	2300	*
2330	Saturday	S18	B17	18	2330	
0000	Sunday	S18		18	0000	*
0030	Sunday	S18		18	0030	
0100	Sunday	S18		18	0100	
0130	Sunday	S18		18	0130	
0200	Sunday	S18		18	0200	
0230	Sunday	S18		18	0230	
0300	Sunday	S18		18	0300	
0330	Sunday	S18		18	0330	
0400	Sunday	S18		18	0400	
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0500	Sunday	S18		18	0500	
0530	Sunday	S18		18	0530	
0600	Sunday	S19	A18	18	0600	*
0630	Sunday	S19	A18	18	0630	
0700	Sunday	S19	B18	18	0700	*
0730	Sunday	S19	B18	18	0730	
0800	Sunday	S19		18	0800	*
0830	Sunday	S19		18	0830	
0900	Sunday	S19		18	0900	
0930	Sunday	S19		18	0930	
1000	Sunday	S19		18	1000	
1030	Sunday	S19		18	1030	
1100	Sunday	S19		18	1100	
1130	Sunday	S19		18	1130	
1200	Sunday	S19		18	1200	
1230	Sunday	S19		18	1230	
1300	Sunday	S19		18	1300	
1330	Sunday	S19		18	1330	
1400	Sunday	S20	A19	18	1400	*
1430	Sunday	S20	A19	18	1430	
1500	Sunday	S20	B19	18	1500	*
1530	Sunday	S20	B19	18	1530	
1600	Sunday	S20		18	1600	*
1630	Sunday	S20		18	1630	
1700	Sunday	S20		18	1700	

1730	Sunday	S20		18	1730	
1800	Sunday	S20		18	1800	
1830	Sunday	S20		18	1830	
1900	Sunday	S20		18	1900	
1930	Sunday	S20		18	1930	
2000	Sunday	S20		18	2000	
2030	Sunday	S20		18	2030	
2100	Sunday	S20		18	2100	
2130	Sunday	S20		18	2130	
2200	Sunday	S21	A20	18	2200	*
2230	Sunday	S21	A20	18	2230	
2300	Sunday	S21	B20	18	2300	*
2330	Sunday	S21	B20	18	2330	
0000	Monday	S21		21	0000	*
0030	Monday	S21		19	0030	
0100	Monday	S21		18	0100	
0130	Monday	S21		18	0130	
0200	Monday	S21		18	0200	
0230	Monday	S21		18	0230	
0300	Monday	S21		18	0300	
0330	Monday	S21		18	0330	
0400	Monday	S21,S53		18	0400	
0430	Monday	S21,S53		23	0430	
0500	Monday	S21,S53		29	0500	
0530	Monday	S21,S53		35	0530	*
0600	Monday	S22,S53	A21	44	0600	
0630	Monday	S22,S53	A21	50	0630	*
0700	Monday	S22,S53	B21	50	0700	*
0730	Monday	S22,S53	B21	50	0730	
0800	Monday	S22,S53		50	0800	*
0830	Monday	S22,S53		50	0830	
0900	Monday	S22,S53		46	0900	
0930	Monday	S22,S53		46	0930	
1000	Monday	S22,S53		46	1000	
1030	Monday	S22,S53		46	1030	
1100	Monday	S22,S53		46	1100	
1130	Monday	S22,S53		46	1130	
1200	Monday	S22,S54	A53	46	1200	*
1230	Monday	S22,S54	A53	46	1230	
1300	Monday	S22,S54	B53	46	1300	*
1330	Monday	S22,S54	B53	46	1330	
1400	Monday	S23,S54	A22	44	1400	
1430	Monday	S23,S54	A22	45	1430	*
1500	Monday	S23,S54	B22	51	1500	*
1530	Monday	S23,S54	B22	51	1530	
1600	Monday	S23,S54		49	1600	*

1630	Monday	S23,S54		44	1630	
1700	Monday	S23,S54		41	1700	
1730	Monday	S23,S54		36	1730	
1800	Monday	S23,S54		31	1800	
1830	Monday	S23,S54		31	1830	
1900	Monday	S23,S54		29	1900	
1930	Monday	S23,S54		28	1930	
2000	Monday	S23	A54	22	2000	*
2030	Monday	S23	A54	22	2030	
2100	Monday	S23	B54	22	2100	*
2130	Monday	S23	B54	22	2130	
2200	Monday	S24	A23	22	2200	*
2230	Monday	S24	A23	23	2230	
2300	Monday	S24	B23	23	2300	*
2330	Monday	S24	B23	21	2330	
0000	Tuesday	S24		21	0000	*
0030	Tuesday	S24		19	0030	
0100	Tuesday	S24		18	0100	
0130	Tuesday	S24		18	0130	
0200	Tuesday	S24		18	0200	
0230	Tuesday	S24		18	0230	
0300	Tuesday	S24		18	0300	
0330	Tuesday	S24		18	0330	
0400	Tuesday	S24,S55		18	0400	
0430	Tuesday	S24,S55		23	0430	
0500	Tuesday	S24,S55		29	0500	
0530	Tuesday	S24,S55		35	0530	*
0600	Tuesday	S25,S55	A24	44	0600	
0630	Tuesday	S25,S55	A24	50	0630	*
0700	Tuesday	S25,S55	B24	50	0700	*
0730	Tuesday	S25,S55	B24	50	0730	
0800	Tuesday	S25,S55		50	0800	*
0830	Tuesday	S25,S55		50	0830	
0900	Tuesday	S25,S55		46	0900	
0930	Tuesday	S25,S55		46	0930	
1000	Tuesday	S25,S55		46	1000	
1030	Tuesday	S25,S55		46	1030	
1100	Tuesday	S25,S55		46	1100	
1130	Tuesday	S25,S55		46	1130	
1200	Tuesday	S25,S56	A55	46	1200	*
1230	Tuesday	S25,S56	A55	46	1230	
1300	Tuesday	S25,S56	B55	46	1300	*
1330	Tuesday	S25,S56	B55	46	1330	
1400	Tuesday	S26,S56	A25	44	1400	
1430	Tuesday	S26,S56	A25	45	1430	*
1500	Tuesday	S26,S56	B25	51	1500	*

1530	Tuesday	S26,S56	B25	51	1530	
1600	Tuesday	S26,S56		49	1600	*
1630	Tuesday	S26,S56		44	1630	
1700	Tuesday	S26,S56		41	1700	
1730	Tuesday	S26,S56		36	1730	
1800	Tuesday	S26,S56		31	1800	
1830	Tuesday	S26,S56		31	1830	
1900	Tuesday	S26,S56		29	1900	
1930	Tuesday	S26,S56		28	1930	
2000	Tuesday	S26	A56	22	2000	*
2030	Tuesday	S26	A56	22	2030	
2100	Tuesday	S26	B56	22	2100	*
2130	Tuesday	S26	B56	22	2130	
2200	Tuesday	S27	A26	22	2200	*
2230	Tuesday	S27	A26	23	2230	
2300	Tuesday	S27	B26	23	2300	*
2330	Tuesday	S27	B26	21	2330	
0000	Wednesday	S27		21	0000	*
0030	Wednesday	S27		19	0030	
0100	Wednesday	S27		18	0100	
0130	Wednesday	S27		18	0130	
0200	Wednesday	S27		18	0200	
0230	Wednesday	S27		18	0230	
0300	Wednesday	S27		18	0300	
0330	Wednesday	S27		18	0330	
0400	Wednesday	S27,S57		18	0400	
0430	Wednesday	S27,S57		23	0430	
0500	Wednesday	S27,S57		29	0500	
0530	Wednesday	S27,S57		35	0530	*
0600	Wednesday	S28,S57	A27	44	0600	
0630	Wednesday	S28,S57	A27	50	0630	*
0700	Wednesday	S28,S57	B27	50	0700	*
0730	Wednesday	S28,S57	B27	50	0730	
0800	Wednesday	S28,S57		50	0800	*
0830	Wednesday	S28,S57		50	0830	
0900	Wednesday	S28,S57		46	0900	
0930	Wednesday	S28,S57		46	0930	
1000	Wednesday	S28,S57		46	1000	
1030	Wednesday	S28,S57		46	1030	
1100	Wednesday	S28,S57		46	1100	
1130	Wednesday	S28,S57		46	1130	
1200	Wednesday	S28,S58	A57	46	1200	*
1230	Wednesday	S28,S58	A57	46	1230	
1300	Wednesday	S28,S58	B57	46	1300	*
1330	Wednesday	S28,S58	B57	46	1330	
1400	Wednesday	S29,S58	A28	44	1400	

1430	Wednesday	S29,S58	A28	45	1430	*
1500	Wednesday	S29,S58	B28	51	1500	*
1530	Wednesday	S29,S58	B28	51	1530	
1600	Wednesday	S29,S58		49	1600	*
1630	Wednesday	S29,S58		44	1630	
1700	Wednesday	S29,S58		41	1700	
1730	Wednesday	S29,S58		36	1730	
1800	Wednesday	S29,S58		31	1800	
1830	Wednesday	S29,S58		31	1830	
1900	Wednesday	S29,S58		29	1900	
1930	Wednesday	S29,S58		28	1930	
2000	Wednesday	S29	A58	22	2000	*
2030	Wednesday	S29	A58	22	2030	
2100	Wednesday	S29	B58	22	2100	*
2130	Wednesday	S29	B58	22	2130	
2200	Wednesday	S30	A29	22	2200	*
2230	Wednesday	S30	A29	23	2230	
2300	Wednesday	S30	B29	23	2300	*
2330	Wednesday	S30	B29	21	2330	
0000	Thursday	S30		21	0000	*
0030	Thursday	S30		19	0030	
0100	Thursday	S30		18	0100	
0130	Thursday	S30		18	0130	
0200	Thursday	S30		18	0200	
0230	Thursday	S30		18	0230	
0300	Thursday	S30		18	0300	
0330	Thursday	S30		18	0330	
0400	Thursday	S30,S59		18	0400	
0430	Thursday	S30,S59		23	0430	
0500	Thursday	S30,S59		29	0500	
0530	Thursday	S30,S59		35	0530	*
0600	Thursday	S31,S59	A30	44	0600	
0630	Thursday	S31,S59	A30	50	0630	*
0700	Thursday	S31,S59	B30	50	0700	*
0730	Thursday	S31,S59	B30	50	0730	
0800	Thursday	S31,S59		50	0800	*
0830	Thursday	S31,S59		50	0830	
0900	Thursday	S31,S59		46	0900	
0930	Thursday	S31,S59		46	0930	
1000	Thursday	S31,S59		46	1000	
1030	Thursday	S31,S59		46	1030	
1100	Thursday	S31,S59		46	1100	
1130	Thursday	S31,S59		46	1130	
1200	Thursday	S31,S60	A59	46	1200	*
1230	Thursday	S31,S60	A59	46	1230	
1300	Thursday	S31,S60	B59	46	1300	*

1330	Thursday	S31,S60	B59	46	1330	
1400	Thursday	S32,S60	A31	44	1400	
1430	Thursday	S32,S60	A31	45	1430	*
1500	Thursday	S32,S60	B31	51	1500	*
1530	Thursday	S32,S60	B31	51	1530	
1600	Thursday	S32,S60		49	1600	*
1630	Thursday	S32,S60		44	1630	
1700	Thursday	S32,S60		41	1700	
1730	Thursday	S32,S60		36	1730	
1800	Thursday	S32,S60		31	1800	
1830	Thursday	S32,S60		31	1830	
1900	Thursday	S32,S60		29	1900	
1930	Thursday	S32,S60		28	1930	
2000	Thursday	S32	A60	22	2000	*
2030	Thursday	S32	A60	22	2030	
2100	Thursday	S32	B60	22	2100	*
2130	Thursday	S32	B60	22	2130	
2200	Thursday	S33	A32	22	2200	*
2230	Thursday	S33	A32	23	2230	
2300	Thursday	S33	B32	23	2300	*
2330	Thursday	S33	B32	21	2330	
0000	Friday	S33		21	0000	*
0030	Friday	S33		19	0030	
0100	Friday	S33		18	0100	
0130	Friday	S33		18	0130	
0200	Friday	S33		18	0200	
0230	Friday	S33		18	0230	
0300	Friday	S33		18	0300	
0330	Friday	S33		18	0330	
0400	Friday	S33,S61		18	0400	
0430	Friday	S33,S61		23	0430	
0500	Friday	S33,S61		29	0500	
0530	Friday	S33,S61		35	0530	*
0600	Friday	S34,S61	A33	44	0600	
0630	Friday	S34,S61	A33	50	0630	*
0700	Friday	S34,S61	B33	50	0700	*
0730	Friday	S34,S61	B33	50	0730	
0800	Friday	S34,S61		50	0800	*
0830	Friday	S34,S61		50	0830	
0900	Friday	S34,S61		48	0900	
0930	Friday	S34,S61		46	0930	
1000	Friday	S34,S61		46	1000	
1030	Friday	S34,S61		46	1030	
1100	Friday	S34,S61		46	1100	
1130	Friday	S34,S61		46	1130	
1200	Friday	S34,S62	A61	46	1200	*

1230	Friday	S34,S62	A61	46	1230	
1300	Friday	S34,S62	B61	46	1300	*
1330	Friday	S34,S62	B61	46	1330	
1400	Friday	S35,S62	A34	44	1400	
1430	Friday	S35,S62	A34	45	1430	*
1500	Friday	S35,S62	B34	51	1500	*
1530	Friday	S35,S62	B34	51	1530	
1600	Friday	S35,S62		49	1600	*
1630	Friday	S35,S62		44	1630	
1700	Friday	S35,S62		41	1700	
1730	Friday	S35,S62		36	1730	
1800	Friday	S35,S62		31	1800	
1830	Friday	S35,S62		31	1830	
1900	Friday	S35,S62		29	1900	
1930	Friday	S35,S62		28	1930	
2000	Friday	S35	A62	22	2000	*
2030	Friday	S35	A62	22	2030	
2100	Friday	S35	B62	22	2100	*
2130	Friday	S35	B62	22	2130	
2200	Friday	S36	A35	22	2200	
2230	Friday	S36	A35	23	2230	*
2300	Friday	S36	B35	23	2300	*
2330	Friday	S36	B35	21	2330	
0000	Saturday	S36		18	0000	*
0030	Saturday	S36		18	0030	
0100	Saturday	S36		18	0100	
0130	Saturday	S36		18	0130	
0200	Saturday	S36		18	0200	
0230	Saturday	S36		18	0230	
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0330	Saturday	S36		18	0330	
0400	Saturday	S36		18	0400	
0430	Saturday	S36		18	0430	
0500	Saturday	S36		18	0500	
0530	Saturday	S36		18	0530	
0600	Saturday	S37	A36	18	0600	*
0630	Saturday	S37	A36	18	0630	
0700	Saturday	S37	B36	18	0700	*
0730	Saturday	S37	B36	18	0730	
0800	Saturday	S37		18	0800	*
0830	Saturday	S37		18	0830	
0900	Saturday	S37		18	0900	
0930	Saturday	S37		18	0930	
1000	Saturday	S37		18	1000	
1030	Saturday	S37		18	1030	
1100	Saturday	S37		18	1100	

1130	Saturday	S37		18	1130	
1200	Saturday	S37		18	1200	
1230	Saturday	S37		18	1230	
1300	Saturday	S37		18	1300	
1330	Saturday	S37		18	1330	
1400	Saturday	S38	A37	18	1400	*
1430	Saturday	S38	A37	18	1430	
1500	Saturday	S38	B37	18	1500	*
1530	Saturday	S38	B37	18	1530	
1600	Saturday	S38		18	1600	*
1630	Saturday	S38		18	1630	
1700	Saturday	S38		18	1700	
1730	Saturday	S38		18	1730	
1800	Saturday	S38		18	1800	
1830	Saturday	S38		18	1830	
1900	Saturday	S38		18	1900	
1930	Saturday	S38		18	1930	
2000	Saturday	S38		18	2000	
2030	Saturday	S38		18	2030	
2100	Saturday	S38		18	2100	
2130	Saturday	S38		18	2130	
2200	Saturday	S39	A38	18	2200	*
2230	Saturday	S39	A38	18	2230	
2300	Saturday	S39	B38	18	2300	*
2330	Saturday	S39	B38	18	2330	
0000	Sunday	S39		18	0000	*
0030	Sunday	S39		18	0030	
0100	Sunday	S39		18	0100	
0130	Sunday	S39		18	0130	
0200	Sunday	S39		18	0200	
0230	Sunday	S39		18	0230	
0300	Sunday	S39		18	0300	
0330	Sunday	S39		18	0330	
0400	Sunday	S39		18	0400	
0430	Sunday	S39		18	0430	
0500	Sunday	S39		18	0500	
0530	Sunday	S39		18	0530	
0600	Sunday	S40	A39	18	0600	*
0630	Sunday	S40	A39	18	0630	
0700	Sunday	S40	B39	18	0700	*
0730	Sunday	S40	B39	18	0730	
0800	Sunday	S40		18	0800	*
0830	Sunday	S40		18	0830	
0900	Sunday	S40		18	0900	
0930	Sunday	S40		18	0930	
1000	Sunday	S40		18	1000	

1030	Sunday	S40		18	1030	
1100	Sunday	S40		18	1100	
1130	Sunday	S40		18	1130	
1200	Sunday	S40		18	1200	
1230	Sunday	S40		18	1230	
1300	Sunday	S40		18	1300	
1330	Sunday	S40		18	1330	
1400	Sunday	S41	A40	18	1400	*
1430	Sunday	S41	A40	18	1430	
1500	Sunday	S41	B40	18	1500	*
1530	Sunday	S41	B40	18	1530	
1600	Sunday	S41		18	1600	*
1630	Sunday	S41		18	1630	
1700	Sunday	S41		18	1700	
1730	Sunday	S41		18	1730	
1800	Sunday	S41		18	1800	
1830	Sunday	S41		18	1830	
1900	Sunday	S41		18	1900	
1930	Sunday	S41		18	1930	
2000	Sunday	S41		18	2000	
2030	Sunday	S41		18	2030	
2100	Sunday	S41		18	2100	
2130	Sunday	S41		18	2130	
2200	Sunday	S42	A41	18	2200	*
2230	Sunday	S42	A41	18	2230	
2300	Sunday	S42	B41	18	2300	*
2330	Sunday	S42	B41	18	2330	

Appendix B: Master and Squad Level Schedules

Shown below is a master schedule for the 16 squads to follow for schedule C. If there is an (X) following a squad letter, then X number of guards should report two hours earlier than the rest of their squad for duty. This schedule is followed on the next few pages with a squad by squad breakdown of this 14-day master schedule.

Shift Start Times	WEEK 1 Monday	Tuesday	Wednesday	Thursday	Friday	Saturday Sunday
0400	A,D(4)	A,D(4)	A,D(4)	A,D(4)	A,D(4)	
0600	B,C,D,E	B,C,D,E	B,C,D,E	C,D,F,G	B,D,F,G	F,G
1200	H,L,I(7)	H,L,I(7)	H,L,I(7)	M,L,I(7)	E,M,I(7)	
1400	I,J,K	I,J,K	I,J,K	I,J,K	I,J,L	H,M
2200	N,O	N,O	N,O	N,P	N,P	O,P
Day Off	P	F,G,M,P	F,G,M	H,O	H,O	ABCDE IJKLN
Train	F,G,M		P	B,E	C,K	

Shift Start Times	WEEK 2 Monday	Tuesday	Wednesday	Thursday	Friday	Saturday Sunday
0400	B,C(4)	B,C(4)	B,C(4)	B,C(4)	B,C(4)	
0600	A,C,D,E	A,C,D,E	A,C,D,E	A,C,F,G	C,D,F,G	F,G
1200	F,G,K(7)	H,I,K(7)	H,I,K(7)	E,I,K(7)	E,I,K(7)	
1400	J,K,L	J,K,L	J,K,L,	J,K,M	K,L,M	H,M
2200	M,O	N,O	N,P	N,P	N,P	O,P
Day Off	P	F,G,M,P	F,G,M,O	H,O	H	ABCDE IJKLN
Train	H,I,N			D,L	A,J,O	

SQUAD LEVEL WORK SCHEDULE
SQUAD A

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
A1	0400	0400	0400	0400	0400	OFF	OFF
A2	0400	0400	0400	0400	0400	OFF	OFF
A3	0400	0400	0400	0400	0400	OFF	OFF
A4	0400	0400	0400	0400	0400	OFF	OFF
A5	0400	0400	0400	0400	0400	OFF	OFF
A6	0400	0400	0400	0400	0400	OFF	OFF
A7	0400	0400	0400	0400	0400	OFF	OFF
A8	0400	0400	0400	0400	0400	OFF	OFF
A9	0400	0400	0400	0400	0400	OFF	OFF
A10	0400	0400	0400	0400	0400	OFF	OFF
A11	0400	0400	0400	0400	0400	OFF	OFF
A12	0400	0400	0400	0400	0400	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
A1	0600	0600	0600	0600	TRG	OFF	OFF
A2	0600	0600	0600	0600	TRG	OFF	OFF
A3	0600	0600	0600	0600	TRG	OFF	OFF
A4	0600	0600	0600	0600	TRG	OFF	OFF
A5	0600	0600	0600	0600	TRG	OFF	OFF
A6	0600	0600	0600	0600	TRG	OFF	OFF
A7	0600	0600	0600	0600	TRG	OFF	OFF
A8	0600	0600	0600	0600	TRG	OFF	OFF
A9	0600	0600	0600	0600	TRG	OFF	OFF
A10	0600	0600	0600	0600	TRG	OFF	OFF
A11	0600	0600	0600	0600	TRG	OFF	OFF
A12	0600	0600	0600	0600	TRG	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD B

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
B1	0600	0600	0600	TRG	0600	OFF	OFF
B2	0600	0600	0600	TRG	0600	OFF	OFF
B3	0600	0600	0600	TRG	0600	OFF	OFF
B4	0600	0600	0600	TRG	0600	OFF	OFF
B5	0600	0600	0600	TRG	0600	OFF	OFF
B6	0600	0600	0600	TRG	0600	OFF	OFF
B7	0600	0600	0600	TRG	0600	OFF	OFF
B8	0600	0600	0600	TRG	0600	OFF	OFF
B9	0600	0600	0600	TRG	0600	OFF	OFF
B10	0600	0600	0600	TRG	0600	OFF	OFF
B11	0600	0600	0600	TRG	0600	OFF	OFF
B12	0600	0600	0600	TRG	0600	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
B1	0400	0400	0400	0400	0400	OFF	OFF
B2	0400	0400	0400	0400	0400	OFF	OFF
B3	0400	0400	0400	0400	0400	OFF	OFF
B4	0400	0400	0400	0400	0400	OFF	OFF
B5	0400	0400	0400	0400	0400	OFF	OFF
B6	0400	0400	0400	0400	0400	OFF	OFF
B7	0400	0400	0400	0400	0400	OFF	OFF
B8	0400	0400	0400	0400	0400	OFF	OFF
B9	0400	0400	0400	0400	0400	OFF	OFF
B10	0400	0400	0400	0400	0400	OFF	OFF
B11	0400	0400	0400	0400	0400	OFF	OFF
B12	0400	0400	0400	0400	0400	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD C

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
C1	0600	0600	0600	0600	TRG	OFF	OFF
C2	0600	0600	0600	0600	TRG	OFF	OFF
C3	0600	0600	0600	0600	TRG	OFF	OFF
C4	0600	0600	0600	0600	TRG	OFF	OFF
C5	0600	0600	0600	0600	TRG	OFF	OFF
C6	0600	0600	0600	0600	TRG	OFF	OFF
C7	0600	0600	0600	0600	TRG	OFF	OFF
C8	0600	0600	0600	0600	TRG	OFF	OFF
C9	0600	0600	0600	0600	TRG	OFF	OFF
C10	0600	0600	0600	0600	TRG	OFF	OFF
C11	0600	0600	0600	0600	TRG	OFF	OFF
C12	0600	0600	0600	0600	TRG	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
C1	0400	0400	0400	0400	0400	OFF	OFF
C2	0400	0400	0400	0400	0400	OFF	OFF
C3	0400	0400	0400	0400	0400	OFF	OFF
C4	0400	0400	0400	0400	0400	OFF	OFF
C5	0600	0600	0600	0600	0600	OFF	OFF
C6	0600	0600	0600	0600	0600	OFF	OFF
C7	0600	0600	0600	0600	0600	OFF	OFF
C8	0600	0600	0600	0600	0600	OFF	OFF
C9	0600	0600	0600	0600	0600	OFF	OFF
C10	0600	0600	0600	0600	0600	OFF	OFF
C11	0600	0600	0600	0600	0600	OFF	OFF
C12	0600	0600	0600	0600	0600	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD D

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
D1	0400	0400	0400	0400	0400	OFF	OFF
D2	0400	0400	0400	0400	0400	OFF	OFF
D3	0400	0400	0400	0400	0400	OFF	OFF
D4	0400	0400	0400	0400	0400	OFF	OFF
D5	0600	0600	0600	0600	0600	OFF	OFF
D6	0600	0600	0600	0600	0600	OFF	OFF
D7	0600	0600	0600	0600	0600	OFF	OFF
D8	0600	0600	0600	0600	0600	OFF	OFF
D9	0600	0600	0600	0600	0600	OFF	OFF
D10	0600	0600	0600	0600	0600	OFF	OFF
D11	0600	0600	0600	0600	0600	OFF	OFF
D12	0600	0600	0600	0600	0600	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
D1	0600	0600	0600	TRG	0600	OFF	OFF
D2	0600	0600	0600	TRG	0600	OFF	OFF
D3	0600	0600	0600	TRG	0600	OFF	OFF
D4	0600	0600	0600	TRG	0600	OFF	OFF
D5	0600	0600	0600	TRG	0600	OFF	OFF
D6	0600	0600	0600	TRG	0600	OFF	OFF
D7	0600	0600	0600	TRG	0600	OFF	OFF
D8	0600	0600	0600	TRG	0600	OFF	OFF
D9	0600	0600	0600	TRG	0600	OFF	OFF
D10	0600	0600	0600	TRG	0600	OFF	OFF
D11	0600	0600	0600	TRG	0600	OFF	OFF
D12	0600	0600	0600	TRG	0600	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD E

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
E1	0600	0600	0600	TRG	1200	OFF	OFF
E2	0600	0600	0600	TRG	1200	OFF	OFF
E3	0600	0600	0600	TRG	1200	OFF	OFF
E4	0600	0600	0600	TRG	1200	OFF	OFF
E5	0600	0600	0600	TRG	1200	OFF	OFF
E6	0600	0600	0600	TRG	1200	OFF	OFF
E7	0600	0600	0600	TRG	1200	OFF	OFF
E8	0600	0600	0600	TRG	1200	OFF	OFF
E9	0600	0600	0600	TRG	1200	OFF	OFF
E10	0600	0600	0600	TRG	1200	OFF	OFF
E11	0600	0600	0600	TRG	1200	OFF	OFF
E12	0600	0600	0600	TRG	1200	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
E1	0600	0600	0600	1200	1200	OFF	OFF
E2	0600	0600	0600	1200	1200	OFF	OFF
E3	0600	0600	0600	1200	1200	OFF	OFF
E4	0600	0600	0600	1200	1200	OFF	OFF
E5	0600	0600	0600	1200	1200	OFF	OFF
E6	0600	0600	0600	1200	1200	OFF	OFF
E7	0600	0600	0600	1200	1200	OFF	OFF
E8	0600	0600	0600	1200	1200	OFF	OFF
E9	0600	0600	0600	1200	1200	OFF	OFF
E10	0600	0600	0600	1200	1200	OFF	OFF
E11	0600	0600	0600	1200	1200	OFF	OFF
E12	0600	0600	0600	1200	1200	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD F

START NAME	TIMES MONDAY	WEEK TUES	ONE WED	THUR	FRI	SAT	SUN
F1	TRG	OFF	OFF	0600	0600	0600	0600
F2	TRG	OFF	OFF	0600	0600	0600	0600
F3	TRG	OFF	OFF	0600	0600	0600	0600
F4	TRG	OFF	OFF	0600	0600	0600	0600
F5	TRG	OFF	OFF	0600	0600	0600	0600
F6	TRG	OFF	OFF	0600	0600	0600	0600
F7	TRG	OFF	OFF	0600	0600	0600	0600
F8	TRG	OFF	OFF	0600	0600	0600	0600
F9	TRG	OFF	OFF	0600	0600	0600	0600
F10	TRG	OFF	OFF	0600	0600	0600	0600
F11	TRG	OFF	OFF	0600	0600	0600	0600
F12	TRG	OFF	OFF	0600	0600	0600	0600

START NAME	TIMES MONDAY	WEEK TUES	TWO WED	THUR	FRI	SAT	SUN
F1	1200	OFF	OFF	0600	0600	0600	0600
F2	1200	OFF	OFF	0600	0600	0600	0600
F3	1200	OFF	OFF	0600	0600	0600	0600
F4	1200	OFF	OFF	0600	0600	0600	0600
F5	1200	OFF	OFF	0600	0600	0600	0600
F6	1200	OFF	OFF	0600	0600	0600	0600
F7	1200	OFF	OFF	0600	0600	0600	0600
F8	1200	OFF	OFF	0600	0600	0600	0600
F9	1200	OFF	OFF	0600	0600	0600	0600
F10	1200	OFF	OFF	0600	0600	0600	0600
F11	1200	OFF	OFF	0600	0600	0600	0600
F12	1200	OFF	OFF	0600	0600	0600	0600

SQUAD LEVEL WORK SCHEDULE
SQUAD G

START NAME	TIMES MONDAY	WEEK TUES	ONE WED	THUR	FRI	SAT	SUN
G1	TRG	OFF	OFF	0600	0600	0600	0600
G2	TRG	OFF	OFF	0600	0600	0600	0600
G3	TRG	OFF	OFF	0600	0600	0600	0600
G4	TRG	OFF	OFF	0600	0600	0600	0600
G5	TRG	OFF	OFF	0600	0600	0600	0600
G6	TRG	OFF	OFF	0600	0600	0600	0600
G7	TRG	OFF	OFF	0600	0600	0600	0600
G8	TRG	OFF	OFF	0600	0600	0600	0600
G9	TRG	OFF	OFF	0600	0600	0600	0600
G10	TRG	OFF	OFF	0600	0600	0600	0600
G11	TRG	OFF	OFF	0600	0600	0600	0600
G12	TRG	OFF	OFF	0600	0600	0600	0600

START NAME	TIMES MONDAY	WEEK TUES	TWO WED	THUR	FRI	SAT	SUN
G1	1200	OFF	OFF	0600	0600	0600	0600
G2	1200	OFF	OFF	0600	0600	0600	0600
G3	1200	OFF	OFF	0600	0600	0600	0600
G4	1200	OFF	OFF	0600	0600	0600	0600
G5	1200	OFF	OFF	0600	0600	0600	0600
G6	1200	OFF	OFF	0600	0600	0600	0600
G7	1200	OFF	OFF	0600	0600	0600	0600
G8	1200	OFF	OFF	0600	0600	0600	0600
G9	1200	OFF	OFF	0600	0600	0600	0600
G10	1200	OFF	OFF	0600	0600	0600	0600
G11	1200	OFF	OFF	0600	0600	0600	0600
G12	1200	OFF	OFF	0600	0600	0600	0600

SQUAD LEVEL WORK SCHEDULE
SQUAD H

START NAME	TIMES MONDAY	WEEK TUES	ONE WED	THUR	FRI	SAT	SUN
H1	1200	1200	1200	OFF	OFF	1400	1400
H2	1200	1200	1200	OFF	OFF	1400	1400
H3	1200	1200	1200	OFF	OFF	1400	1400
H4	1200	1200	1200	OFF	OFF	1400	1400
H5	1200	1200	1200	OFF	OFF	1400	1400
H6	1200	1200	1200	OFF	OFF	1400	1400
H7	1200	1200	1200	OFF	OFF	1400	1400
H8	1200	1200	1200	OFF	OFF	1400	1400
H9	1200	1200	1200	OFF	OFF	1400	1400
H10	1200	1200	1200	OFF	OFF	1400	1400
H11	1200	1200	1200	OFF	OFF	1400	1400
H12	1200	1200	1200	OFF	OFF	1400	1400

START NAME	TIMES MONDAY	WEEK TUES	TWO WED	THUR	FRI	SAT	SUN
H1	TRG	1200	1200	OFF	OFF	1400	1400
H2	TRG	1200	1200	OFF	OFF	1400	1400
H3	TRG	1200	1200	OFF	OFF	1400	1400
H4	TRG	1200	1200	OFF	OFF	1400	1400
H5	TRG	1200	1200	OFF	OFF	1400	1400
H6	TRG	1200	1200	OFF	OFF	1400	1400
H7	TRG	1200	1200	OFF	OFF	1400	1400
H8	TRG	1200	1200	OFF	OFF	1400	1400
H9	TRG	1200	1200	OFF	OFF	1400	1400
H10	TRG	1200	1200	OFF	OFF	1400	1400
H11	TRG	1200	1200	OFF	OFF	1400	1400
H12	TRG	1200	1200	OFF	OFF	1400	1400

SQUAD LEVEL WORK SCHEDULE
SQUAD I

START NAME	TIMES MONDAY	WEEK TUES	ONE WED	THUR	FRI	SAT	SUN
I1	1200	1200	1200	1200	1200	OFF	OFF
I2	1200	1200	1200	1200	1200	OFF	OFF
I3	1200	1200	1200	1200	1200	OFF	OFF
I4	1200	1200	1200	1200	1200	OFF	OFF
I5	1200	1200	1200	1200	1200	OFF	OFF
I6	1200	1200	1200	1200	1200	OFF	OFF
I7	1200	1200	1200	1200	1200	OFF	OFF
I8	1400	1400	1400	1400	1400	OFF	OFF
I9	1400	1400	1400	1400	1400	OFF	OFF
I10	1400	1400	1400	1400	1400	OFF	OFF
I11	1400	1400	1400	1400	1400	OFF	OFF
I12	1400	1400	1400	1400	1400	OFF	OFF

START NAME	TIMES MONDAY	WEEK TUES	TWO WED	THUR	FRI	SAT	SUN
I1	TRG	1200	1200	1200	1200	OFF	OFF
I2	TRG	1200	1200	1200	1200	OFF	OFF
I3	TRG	1200	1200	1200	1200	OFF	OFF
I4	TRG	1200	1200	1200	1200	OFF	OFF
I5	TRG	1200	1200	1200	1200	OFF	OFF
I6	TRG	1200	1200	1200	1200	OFF	OFF
I7	TRG	1200	1200	1200	1200	OFF	OFF
I8	TRG	1200	1200	1200	1200	OFF	OFF
I9	TRG	1200	1200	1200	1200	OFF	OFF
I10	TRG	1200	1200	1200	1200	OFF	OFF
I11	TRG	1200	1200	1200	1200	OFF	OFF
I12	TRG	1200	1200	1200	1200	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD J

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
J1	1400	1400	1400	1400	1400	OFF	OFF
J2	1400	1400	1400	1400	1400	OFF	OFF
J3	1400	1400	1400	1400	1400	OFF	OFF
J4	1400	1400	1400	1400	1400	OFF	OFF
J5	1400	1400	1400	1400	1400	OFF	OFF
J6	1400	1400	1400	1400	1400	OFF	OFF
J7	1400	1400	1400	1400	1400	OFF	OFF
J8	1400	1400	1400	1400	1400	OFF	OFF
J9	1400	1400	1400	1400	1400	OFF	OFF
J10	1400	1400	1400	1400	1400	OFF	OFF
J11	1400	1400	1400	1400	1400	OFF	OFF
J12	1400	1400	1400	1400	1400	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
J1	1400	1400	1400	1400	TRG	OFF	OFF
J2	1400	1400	1400	1400	TRG	OFF	OFF
J3	1400	1400	1400	1400	TRG	OFF	OFF
J4	1400	1400	1400	1400	TRG	OFF	OFF
J5	1400	1400	1400	1400	TRG	OFF	OFF
J6	1400	1400	1400	1400	TRG	OFF	OFF
J7	1400	1400	1400	1400	TRG	OFF	OFF
J8	1400	1400	1400	1400	TRG	OFF	OFF
J9	1400	1400	1400	1400	TRG	OFF	OFF
J10	1400	1400	1400	1400	TRG	OFF	OFF
J11	1400	1400	1400	1400	TRG	OFF	OFF
J12	1400	1400	1400	1400	TRG	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD K

START NAME	TIMES MONDAY	WEEK TUES	ONE WED	THUR	FRI	SAT	SUN
K1	1400	1400	1400	1400	TRG	OFF	OFF
K2	1400	1400	1400	1400	TRG	OFF	OFF
K3	1400	1400	1400	1400	TRG	OFF	OFF
K4	1400	1400	1400	1400	TRG	OFF	OFF
K5	1400	1400	1400	1400	TRG	OFF	OFF
K6	1400	1400	1400	1400	TRG	OFF	OFF
K7	1400	1400	1400	1400	TRG	OFF	OFF
K8	1400	1400	1400	1400	TRG	OFF	OFF
K9	1400	1400	1400	1400	TRG	OFF	OFF
K10	1400	1400	1400	1400	TRG	OFF	OFF
K11	1400	1400	1400	1400	TRG	OFF	OFF
K12	1400	1400	1400	1400	TRG	OFF	OFF

START NAME	TIMES MONDAY	WEEK TUES	TWO WED	THUR	FRI	SAT	SUN
K1	1200	1200	1200	1200	1200	OFF	OFF
K2	1200	1200	1200	1200	1200	OFF	OFF
K3	1200	1200	1200	1200	1200	OFF	OFF
K4	1200	1200	1200	1200	1200	OFF	OFF
K5	1200	1200	1200	1200	1200	OFF	OFF
K6	1200	1200	1200	1200	1200	OFF	OFF
K7	1200	1200	1200	1200	1200	OFF	OFF
K8	1400	1400	1400	1400	1400	OFF	OFF
K9	1400	1400	1400	1400	1400	OFF	OFF
K10	1400	1400	1400	1400	1400	OFF	OFF
K11	1400	1400	1400	1400	1400	OFF	OFF
K12	1400	1400	1400	1400	1400	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD L

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
L1	1200	1200	1200	1200	1400	OFF	OFF
L2	1200	1200	1200	1200	1400	OFF	OFF
L3	1200	1200	1200	1200	1400	OFF	OFF
L4	1200	1200	1200	1200	1400	OFF	OFF
L5	1200	1200	1200	1200	1400	OFF	OFF
L6	1200	1200	1200	1200	1400	OFF	OFF
L7	1200	1200	1200	1200	1400	OFF	OFF
L8	1200	1200	1200	1200	1400	OFF	OFF
L9	1200	1200	1200	1200	1400	OFF	OFF
L10	1200	1200	1200	1200	1400	OFF	OFF
L11	1200	1200	1200	1200	1400	OFF	OFF
L12	1200	1200	1200	1200	1400	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
L1	1400	1400	1400	TRG	1400	OFF	OFF
L2	1400	1400	1400	TRG	1400	OFF	OFF
L3	1400	1400	1400	TRG	1400	OFF	OFF
L4	1400	1400	1400	TRG	1400	OFF	OFF
L5	1400	1400	1400	TRG	1400	OFF	OFF
L6	1400	1400	1400	TRG	1400	OFF	OFF
L7	1400	1400	1400	TRG	1400	OFF	OFF
L8	1400	1400	1400	TRG	1400	OFF	OFF
L9	1400	1400	1400	TRG	1400	OFF	OFF
L10	1400	1400	1400	TRG	1400	OFF	OFF
L11	1400	1400	1400	TRG	1400	OFF	OFF
L12	1400	1400	1400	TRG	1400	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD M

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
M1	TRG	OFF	OFF	1200	1200	1400	1400
M2	TRG	OFF	OFF	1200	1200	1400	1400
M3	TRG	OFF	OFF	1200	1200	1400	1400
M4	TRG	OFF	OFF	1200	1200	1400	1400
M5	TRG	OFF	OFF	1200	1200	1400	1400
M6	TRG	OFF	OFF	1200	1200	1400	1400
M7	TRG	OFF	OFF	1200	1200	1400	1400
M8	TRG	OFF	OFF	1200	1200	1400	1400
M9	TRG	OFF	OFF	1200	1200	1400	1400
M10	TRG	OFF	OFF	1200	1200	1400	1400
M11	TRG	OFF	OFF	1200	1200	1400	1400
M12	TRG	OFF	OFF	1200	1200	1400	1400

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
M1	2200	OFF	OFF	1400	1400	1400	1400
M2	2200	OFF	OFF	1400	1400	1400	1400
M3	2200	OFF	OFF	1400	1400	1400	1400
M4	2200	OFF	OFF	1400	1400	1400	1400
M5	2200	OFF	OFF	1400	1400	1400	1400
M6	2200	OFF	OFF	1400	1400	1400	1400
M7	2200	OFF	OFF	1400	1400	1400	1400
M8	2200	OFF	OFF	1400	1400	1400	1400
M9	2200	OFF	OFF	1400	1400	1400	1400
M10	2200	OFF	OFF	1400	1400	1400	1400
M11	2200	OFF	OFF	1400	1400	1400	1400
M12	2200	OFF	OFF	1400	1400	1400	1400

SQUAD LEVEL WORK SCHEDULE
SQUAD N

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
N1	2200	2200	2200	2200	2200	OFF	OFF
N2	2200	2200	2200	2200	2200	OFF	OFF
N3	2200	2200	2200	2200	2200	OFF	OFF
N4	2200	2200	2200	2200	2200	OFF	OFF
N5	2200	2200	2200	2200	2200	OFF	OFF
N6	2200	2200	2200	2200	2200	OFF	OFF
N7	2200	2200	2200	2200	2200	OFF	OFF
N8	2200	2200	2200	2200	2200	OFF	OFF
N9	2200	2200	2200	2200	2200	OFF	OFF
N10	2200	2200	2200	2200	2200	OFF	OFF
N11	2200	2200	2200	2200	2200	OFF	OFF
N12	2200	2200	2200	2200	2200	OFF	OFF

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
N1	TRG	2200	2200	2200	2200	OFF	OFF
N2	TRG	2200	2200	2200	2200	OFF	OFF
N3	TRG	2200	2200	2200	2200	OFF	OFF
N4	TRG	2200	2200	2200	2200	OFF	OFF
N5	TRG	2200	2200	2200	2200	OFF	OFF
N6	TRG	2200	2200	2200	2200	OFF	OFF
N7	TRG	2200	2200	2200	2200	OFF	OFF
N8	TRG	2200	2200	2200	2200	OFF	OFF
N9	TRG	2200	2200	2200	2200	OFF	OFF
N10	TRG	2200	2200	2200	2200	OFF	OFF
N11	TRG	2200	2200	2200	2200	OFF	OFF
N12	TRG	2200	2200	2200	2200	OFF	OFF

SQUAD LEVEL WORK SCHEDULE
SQUAD O

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
O1	2200	2200	2200	OFF	OFF	2200	2200
O2	2200	2200	2200	OFF	OFF	2200	2200
O3	2200	2200	2200	OFF	OFF	2200	2200
O4	2200	2200	2200	OFF	OFF	2200	2200
O5	2200	2200	2200	OFF	OFF	2200	2200
O6	2200	2200	2200	OFF	OFF	2200	2200
O7	2200	2200	2200	OFF	OFF	2200	2200
O8	2200	2200	2200	OFF	OFF	2200	2200
O9	2200	2200	2200	OFF	OFF	2200	2200
O10	2200	2200	2200	OFF	OFF	2200	2200
O11	2200	2200	2200	OFF	OFF	2200	2200
O12	2200	2200	2200	OFF	OFF	2200	2200

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
O1	2200	2200	OFF	OFF	TRG	2200	2200
O2	2200	2200	OFF	OFF	TRG	2200	2200
O3	2200	2200	OFF	OFF	TRG	2200	2200
O4	2200	2200	OFF	OFF	TRG	2200	2200
O5	2200	2200	OFF	OFF	TRG	2200	2200
O6	2200	2200	OFF	OFF	TRG	2200	2200
O7	2200	2200	OFF	OFF	TRG	2200	2200
O8	2200	2200	OFF	OFF	TRG	2200	2200
O9	2200	2200	OFF	OFF	TRG	2200	2200
O10	2200	2200	OFF	OFF	TRG	2200	2200
O11	2200	2200	OFF	OFF	TRG	2200	2200
O12	2200	2200	OFF	OFF	TRG	2200	2200

SQUAD LEVEL WORK SCHEDULE
SQUAD P

START	TIMES	WEEK	ONE				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
P1	OFF	OFF	TRG	2200	2200	2200	2200
P2	OFF	OFF	TRG	2200	2200	2200	2200
P3	OFF	OFF	TRG	2200	2200	2200	2200
P4	OFF	OFF	TRG	2200	2200	2200	2200
P5	OFF	OFF	TRG	2200	2200	2200	2200
P6	OFF	OFF	TRG	2200	2200	2200	2200
P7	OFF	OFF	TRG	2200	2200	2200	2200
P8	OFF	OFF	TRG	2200	2200	2200	2200
P9	OFF	OFF	TRG	2200	2200	2200	2200
P10	OFF	OFF	TRG	2200	2200	2200	2200
P11	OFF	OFF	TRG	2200	2200	2200	2200
P12	OFF	OFF	TRG	2200	2200	2200	2200

START	TIMES	WEEK	TWO				
NAME	MONDAY	TUES	WED	THUR	FRI	SAT	SUN
P1	OFF	OFF	2200	2200	2200	2200	2200
P2	OFF	OFF	2200	2200	2200	2200	2200
P3	OFF	OFF	2200	2200	2200	2200	2200
P4	OFF	OFF	2200	2200	2200	2200	2200
P5	OFF	OFF	2200	2200	2200	2200	2200
P6	OFF	OFF	2200	2200	2200	2200	2200
P7	OFF	OFF	2200	2200	2200	2200	2200
P8	OFF	OFF	2200	2200	2200	2200	2200
P9	OFF	OFF	2200	2200	2200	2200	2200
P10	OFF	OFF	2200	2200	2200	2200	2200
P11	OFF	OFF	2200	2200	2200	2200	2200
P12	OFF	OFF	2200	2200	2200	2200	2200

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Vita

Capt Dennis R Benson was born on 16 February 1962 in Danbury, Connecticut. He graduated from New Fairfield High School in New Fairfield, Connecticut in 1980 and attended the United States Air Force Academy, graduating with a Bachelor of Science in Mathematical Science in May 1984. Upon graduation, he received a regular commision in the USAF and served his first tour at Whiteman AFB, Missouri. He began as a deputy missile crew commander in the 510th Strategic Missile Squadron and progressed through various positions in the squadron and wing to become the Senior Flight Commander of the 510th Strategic Missile Squadron in June 1988. There he was responsible for the day-to-day operation of the squadron command post and the interaction of squadron staff with the forty-four missile launch officers of the squadron. In September 1988, he finished his Master of Business Administration degree in Management Information Systems from the University of Missouri-Columbia. In May 1989, he led Whiteman AFB to the Blanchard trophy as the best missile wing in SAC with the highest operations score in Eighth Air Force during the annual Missile Competition held at Vandenberg AFB, Caliafornia. He later was named by the Chief of Staff of the Air Force as the best overall missile combat crew commander in SAC. He entered the School of Engineering, Air Force Institute of Technology, in August 1989.

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