AD-A087 498 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 16/1

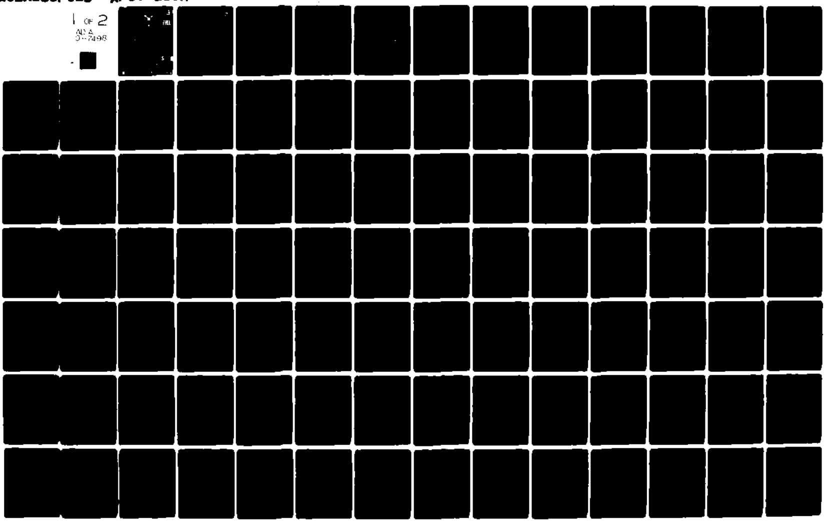
THE FUEL EFFICIENT MISSILE COMBAT CREW ROUTING NETWORK.(U)

JUN 80 E O JACQUES, M G WOOLLEY

UNCLASSIFIED AFIT-LSSR-19-80 NL

1 OF 2

AD A
087498



ADA087498

LEVEL II

DTIC
ELECTE
AUG 5 1980
S D
D

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

80 8 4 014

DDC FILE COPY

Accession For	
NTIS GRA&I	☒
DDC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

3

(9) Master's thesis,

(6) THE FUEL EFFICIENT MISSILE COMBAT CREW ROUTING NETWORK

(11) Jun 80

(10) Edward O./Jacques, Jr./ Captain, USAF
Michael G./Woolley, Captain, USAF

(14) AFIT — LSSR-19-80

(12) 127

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

012

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information are contained therein. Furthermore, the views expressed in the document are those of the author(s) and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the Air Training Command, the United States Air Force, or the Department of Defense.

USAF SCN 75-20B AFIT Control Number LSSR 19-80

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: AFIT/ LSH (Thesis Feedback), Wright-Patterson AFB, Ohio 45433.

1. Did this research contribute to a current Air Force project?

   a. Yes b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

   a. Yes b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

   a. Man-years ________ $ ________ (Contract).

   b. Man-years ________ $ ________ (In-house).

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

   a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments:

________________________ ________________________
Name and Grade Position

________________________ ________________________
Organization Location

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 73236 WASHINGTON D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

AFIT/LSH (Thesis Feedback)
Wright-Patterson AFB OH 45433

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR 19-80	2. GOVT ACCESSION NO. AD-A087 498	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE FUEL EFFICIENT MISSILE COMBAT CREW ROUTING NETWORK		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edward O. Jacques, Jr., Captain, USAF Michael G. Woolley, Captain, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Communication and Humanities AFIT/LSH, WPAFB OH 45433		12. REPORT DATE 9 June 1980
		13. NUMBER OF PAGES 112
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

APPROVED FOR PUBLIC RELEASE AFR 190-17.

Fredric C. Lynch

FREDRIC C. LYNCH, Major, USAF
Director of Public Affairs

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Routing Network
Vehicle Scheduling
Missile Combat Crew Transportation
Fuel Efficiency
Shortest Routes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: Thomas C. Harrington, Major, USAF

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Missile combat crew vehicles are the highest mileage accumulators within SAC and, in the interest of energy conservation, Vice CINCSAC has initiated a long-term study examining utilization of more fuel efficient crew vehicles. This thesis extends the SAC study by determining if alternate dispatch procedures and routes of travel, using currently assigned vehicles, would result in fuel conservation. A network routing model is used to determine the routes of travel for three deployment strategies and five vehicle types at the Minot AFB, ND test base. Fuel efficiency for these fifteen alternatives, measured as gallons of fuel consumed per passenger, is compared with the existing missile combat crew routing network. This study found that ten of the fifteen vehicle/deployment strategy combinations, when employed over the shortest authorized routes of travel that were developed, provided improvement over the fuel efficiency of the MCC routing system that was in effect as of 31 August 1979. The largest potential savings amounted to 52% or 26,255 gallons of fuel per year.

LSSR 19-80

THE FUEL EFFICIENT MISSILE COMBAT CREW ROUTING NETWORK

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Edward O. Jacques, Jr., BA, MBA
Captain, USAF

Michael G. Woolley, BS
Captain, USAF

June 1980

Approved for public release;
distribution unlimited

This thesis, written by

Captain Edward O. Jacques, Jr.

Captain Michael G. Woolley

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 9 June 1980

Thomas C. Harrington

COMMITTEE CHAIRMAN

ACKNOWLEDGMENTS

We wish to express our sincere appreciation to those individuals who have contributed their suggestions, cooperation, and support to this effort. Their contributions have made this document possible.

We dedicate this work to our wives, Sudie and Patricia, and to our children, Andy and Michelle, whose patience, support, and understanding enabled us to weather this very difficult year.

A special thanks is extended to our thesis advisor, Major Tom Harrington, whose delicate guidance and enthusiasm made this educational endeavor an exciting and enjoyable experience.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION TO RESEARCH

Background

Each day within the Strategic Air Command (SAC), missile combat crews (MCCs) dispatch from each of the nine strategic missile wing support bases (SMSBs) to launch control facilities (LCFs) in the surrounding area (Figure 1-1). Normal dispatch procedures have these MCCs drive government

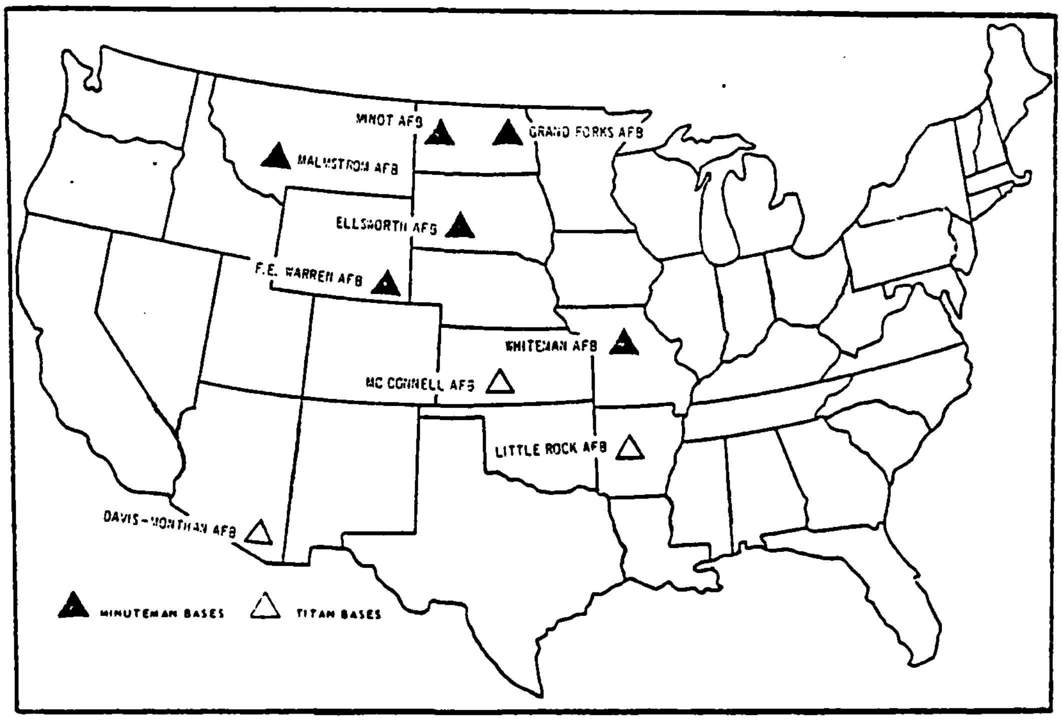


Figure 1-1 SAC Missile Bases

vehicles as their means of transportation from the strategic missile support base to and from the LCF. Because of the large number of miles driven each year by the SAC MCCs, the transport of these MCCs has arrived in the limelight of our nation's energy conservation efforts.

Problem Statement

During these days of increased emphasis on the efficient use of energy, everyone should be conscious of ways to make maximum use of the available vehicle fuel we possess because of its limited availability and rapidly rising cost. Recent presidential memorandums have addressed the necessity to reduce energy consumption within the federal government (21). These memorandums dictate the need for an overall review of government vehicle programs in an effort to find ways to increase usage utility, while at the same time reducing total energy consumption. Such a review requires special emphasis in areas of operation that accumulate high mileage. Because the transport of MCCs is the highest mileage accumulator within SAC, this area of high energy consumption requires special attention within the overall energy conservation effort (22:1).

Excessive fuel consumption associated with the transportation of missile combat crews can be caused by a combination of using vehicles with inefficient fuel consumption characteristics over transportation networks that do not minimize distances traveled. In the equipment area, the Vice Commander In Chief of SAC has recently initiated a study into more fuel efficient vehicles for deploying MCCs which also encompasses the investigation of more fuel efficient engines and alternative vehicle fuels. This study is a long-term effort specifically designed to upgrade the fuel efficiency of those vehicles used in the transporting of MCCs, but will also aid in upgrading the fuel efficiency of all vehicles in the SAC fleet. Because this study is a long-term effort whose benefits will not be realized for several years, there is the immediate short-term problem that concerns the most efficient use of the vehicles that are presently on hand. These vehicles will continue to be used until replacement is required and more fuel efficient vehicles can be procured. The purpose of this research is to look at this short-term aspect of fuel efficiency. A routing network algorithm will be used to determine if the MCC routing system that was in use as of 31 August 1979 at Minot AFB, ND is the most energy efficient means, in terms of gallons of fuel per passenger, for dispatching the MCCs to the various LCFs. It is anticipated that this method of analysis used to study the situation at Minot AFB could be applied to any missile wing's routing network through incorporation of wing-peculiar variables.

Overview

Standard station wagons were the primary mode of transporting missile combat crews to the LCFs at all missile bases until 1972. This type of vehicle had a life expectancy of 70,000 to 90,000 miles, but had poor operating characteristics (i.e., poor steering, vehicle sway, and frequent bottoming-out when fully loaded with passengers and related equipment) (24:1). The low-silhouette carryall was selected as the replacement for the station wagon and has remained the primary missile combat crew transport vehicle because of its flexibility, reliability, and long life of 170,000 to 200,000 miles. Although this vehicle has proved to be ideal for this transportation requirement, increased Environmental Protection Agency requirements have resulted in larger engines and increased antipollution components which adversely affected fuel consumption. The 1979 model year low-silhouette carryalls are averaging only 9.5 miles per gallon as compared to prior year models which averaged over 12.0 miles per gallon (25:1).

Current MCC transport requirements vary from base to base. Each Titan base dispatches four-man MCCs to each of their 18 LCFs on a daily basis. Three to five of these MCCs are also accompanied by two-man Security Police Alert Response Teams. Each Minuteman base also dispatches a MCC to each of their 15 or 20 LCFs on a daily basis. The dispatch may include one two-man MCC destined for one LCF; two two-man MCCs destined for two separate LCFs; or one two-man MCC, accompanied by a cook and a facility manager (FM), destined for one LCF. The literature review, personal experience, and discussion with responsible personnel did not indicate that quantitative approaches have been used as decision-aiding tools for the development of dispatch routes designed to minimize distances traveled in the transportation network. Apparently, dispatch routes have evolved through the years based on qualitative criteria such as maintaining squadron integrity and the quality of life of the MCCs.

The SAC study currently underway is concerned with the long-run fuel efficiency problem. Study members recognize that the low-silhouette carryall has proven to be an excellent vehicle with a good maintenance record, overall low cost per miles driven and high mileage life expectancy. However, the low fuel efficiency and variable crew/cargo composition of many dispatches no longer justifies the use of the low-silhouette carryall in all situations. Therefore, "the most desirable mode of transportation may have to become secondary to the most fuel efficient mode [22:2]."

SAC is approaching the study from several different perspectives. First, SAC has tasked the nine missile wings with using assigned compact station wagons and sedans for MCC transport whenever possible. These vehicles can be supplemented by low-silhouette carryalls when passenger/cargo requirements or inclement weather conditions dictate (22:2). Second, a test program with six types of leased subcompacts at four missile bases is underway to evaluate this range of vehicles in different climatic conditions. The ultimate goal is to identify vehicles for future incorporation in a vehicle mix with low-silhouette carryalls (28:1). Third, SAC has asked HQ AFLC/LO to help in the procurement of more fuel efficient vehicles and to explore the possibility of more fuel efficient engines which could be used in the present fleet as replacement engines are required (25:1). SAC has also asked for assistance in raising the initial vehicle acquisition price ceiling based on fuel efficiency considerations within a life cycle cost framework for the procurement of these vehicles (25:2). Finally, SAC is investigating diesel powered vehicles as well as alternative fuels that might be used to supplement or replace gasoline (24:4).

SAC's study is primarily oriented towards a long-term improvement in fuel efficiency of the SAC vehicle fleet. The dividends of this study are years away. In the mean time, managers must attempt to maximize the use of our available gasoline resources. The identification of the best routing network for the transport of MCCs will pay dividends both now and in the future. By establishing the routing network with the lowest gallons of fuel per passenger ratio, our present vehicle utility is maximized and a solid foundation is established that will be enhanced by the use of more fuel efficient vehicles in the future.

Scope

In the realm of fuel efficiency there are a myriad of aspects to consider. The study initiated by the Vice Commander In Chief of SAC is an in-depth analysis concerned with improving the existing fuel efficiency of the vehicles used to transport missile combat crews to the launch control facilities. The study is investigating the potential use of more efficient vehicles in the transport process, the possibility of retrofitting existing gasoline-engine carryalls, and the use of other fuels (propane, gasahol, and natural gas) to power these vehicles. Furthermore, it is considering these aspects in conjunction with other related factors that include:

(1) Missile Combat Crew "Quality of Life",

(2) Severe Weather Conditions,

(3) Vehicle Dispatch Mix,

(4) Vehicle Ground Clearance,

(5) Vehicle Maintenance and Acquisition Costs,

(6) Unimproved and Paved Roads,

(7) Crew Travel Related Time Costs,

(8) Personnel and Cargo Volume, and

(9) Weight Carrying Capability (7).

These aspects and related factors are beyond the scope of this research. In addition, non-routine MCC travel in response to standardization evaluations, training, or helicopter dispatches will not be addressed.

The SAC study does not address the specific dispatch procedures and routes of travel to and from each LCF because these factors are under the control of each individual missile wing commander. It is within this area that we wish to extend the study of fuel efficiency by looking at the routing networks used to dispatch the MCCs to the LCFs. This study will first develop:

(1) The shortest authorized routes from the SMSB to the LCFs.

(2) The shortest authorized route from any LCF to any other LCF.

Using this information, this study will then consider several routing networks to determine:

(1) The shortest authorized route from the SMSB to several LCFs with subsequent return to the SMSB.

(2) The routing networks for available vehicles, given the constraints of the number of passengers demanded by the authorized route and the passenger/gear capacity of the vehicle.

The criterion for measurement of the various routing networks will be gallons of fuel used per passenger.

Through this criterion, the various routing networks generated will be compared, in terms of fuel efficiency, to the present MCC routing network at the Minot AFB, ND test base. It was recognized that during the course of this research, modifications might occur in the existing system due to changes in dispatch procedures, road closings, or due to any number of other reasons. Therefore, in order to establish a single standard for comparison and to isolate out the interaction effects of future network modifications, the present MCC routing network is hereafter defined as that network and associated dispatch procedures in effect as of 31 August 1979.

Research Question

The following research question was developed to provide direction for this research: Is the present missile combat crew routing network at Minot AFB the most fuel efficient method in terms of gallons of fuel per passenger using the existing vehicles assigned to the base?

Survey of Principle Techniques

The MCC routing problem is one which falls within the scope of the well known sequencing theory problem called the Traveling Salesman Problem (TSP). The prototype TSP involves an individual who wishes to visit each of several given cities once and only once, and who also wishes to return to the starting point of his journey. The TSP has been given a great deal of study, and the literature reviewed has presented many treatises and analyses on the subject that deal with different methods to solve various TSPs. Two surveys of TSP literature were extremely helpful in directing the researchers to studies that might be applicable to the MCC routing problem. A general synopsis of the studies presented in these surveys is presented here; however, more in-depth reviews of particular methods or procedures are contained in Chapter 2 in order to maintain continuity with the subject matter being presented.

R. H. Mole, in his article that surveys routing methodology (30), indicated that Pierce (31) and Christofides (6) describe some strategies that can be used in TSP partial enumeration schemes to ensure vehicle and route feasibility. Mole further stated that Eilon and Christofides (13) utilized a 3-optimality improvement routine on several initial feasible sets of routes and selected the best one. Dantzig and Ramser (10) developed procedures which rely on successive aggregation of a large number of very elementary routes to minimize the miles traveled at each stage. Later these procedures were developed into a "savings" algorithm. Mole also pointed out that Yellow (37) used a simple segmentation into quadrants before the sequential generation of routes.

Bellmore and Nemhauser also performed a survey of TSP literature (2). They provided a general classification of solution techniques, and also provided a description of some of the proven methods (2:538). Karg and Thompson (23) developed a method for the solution of TSPs using a "nearest neighbor" rule. In contrast, Dantzig, Fulkerson, and Johnson (9) used integer programming in the solution of

TSPs. Gomory looked further at integer programming procedures using "cutting plane" constraints (15). From Gomory's contribution, Miller, Tucker, and Zemlin (29) experimented with a "cutting plane" algorithm to solve TSPs.

Bellmore and Nemhauser also addressed dynamic programming and branch and bound algorithms. Dynamic programming solution methods were developed by Bellman (1), Gonzales (16) and Held and Karp (20), while Eastman (12), Little, Murty, Sweeny, and Karel (27), Shapiro (33), and Hatfield and Pierce (18) developed branch and bound algorithms. Subtour elimination methods were conceptualized by Eastman (12) and Shapiro (33) and Gilmore and Gomory (14). Tour-to-tour improvement algorithms were prepared by Reiter and Sherman (32) and Lin (26).

Textbooks by Budnick, Mojena, and Vollman (4; 5) and Bradley, Hax, and Magnanti (3) also gave further insight into the application of some of the above-mentioned solution techniques. In addition, other potentially useful studies that were investigated are Heidler's (19) closed circuit problem and Whiting and Hillier's (36) shortest route analysis.

Chapter 2

METHODOLOGY

Introduction

As previously stated, MCC transport requirements vary from base to base. This study will concentrate on the existing MCC routing system at Minot AFB, ND, to determine if this system is the most energy efficient means, in terms of gallons of fuel per passenger, for dispatching the MCCs to the various LCFs.

The authors are closely acquainted with the routing of MCCs to the LCFs at Minot AFB because of their combined 7 years of missile combat crew experience (spanning the time frame of November 1973 to May 1979) at that base. Their combined MCC experience, their familiarity with the present MCC routing system, and their familiarity with the overall operation of the strategic missile wing, provide them with an enhanced insight into the existing routing system.

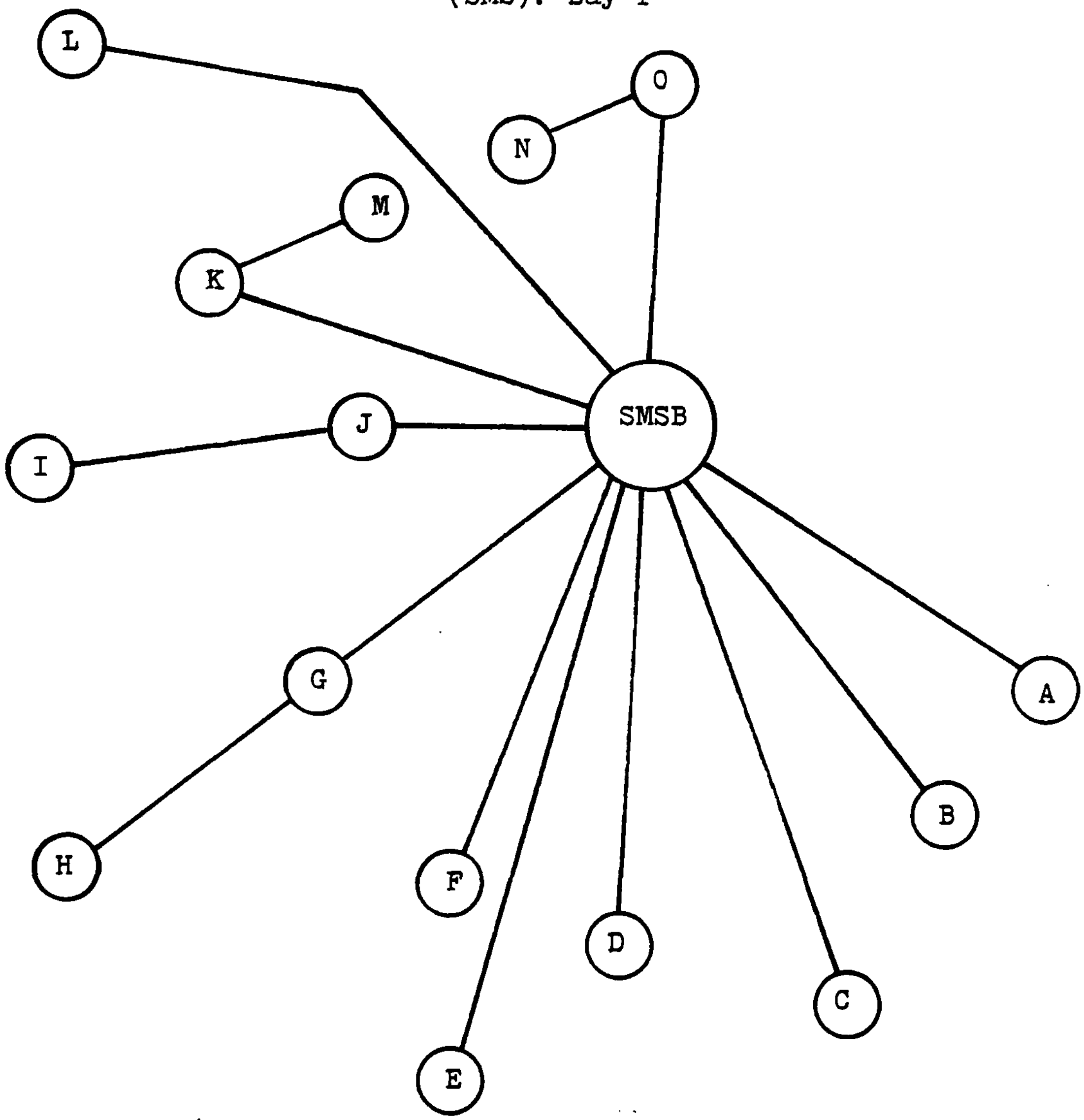
The Present MCC Routing System

The MCC routing system in use at Minot AFB as of 31 August 1979, is within the guidelines established by the 91st Strategic Missile Wing, Deputy Commander for Operations, Operating Instruction 77-2 (38). In order to strike a balance between fuel and manhour conservation, this operating instruction specifies the primary and alternate routes of travel to be used by MCCs when traveling to the LCFs. In the interest of fuel consumption, specific vehicle dispatch schedules are also identified for each of three possible dispatch requirements (38:1-2).

These three possible vehicle dispatch schedules are based on the requirement for facility manager and cook changeover at each LCF in a specific squadron and a desire to have these personnel travel with the MCC going to the same LCF. Each day, one of the three strategic missile squadrons (740th SMS, 741st SMS, or 742nd SMS) has a scheduled changeover of facility managers and cooks. This fluctuating requirement necessitates a flexible vehicle dispatch procedure. Therefore, each of the three possible vehicle dispatch schedules are specifically identified, and the proper schedule for any particular day is contingent on which strategic missile squadron has the scheduled changeover of facility managers and cooks (38).

Figures 2-1, 2-2, and 2-3 show the three dispatch schedules of crew vehicles at Minot. Under the present vehicle dispatch scheduling system, a backtracking procedure is used. Each vehicle proceeds from the base to one or more LCFs to deliver relief personnel, and returns over the same route to pick up relieved personnel. Each vehicle presently carries one two-man MCC, two two-man MCCs, or one two-man MCC

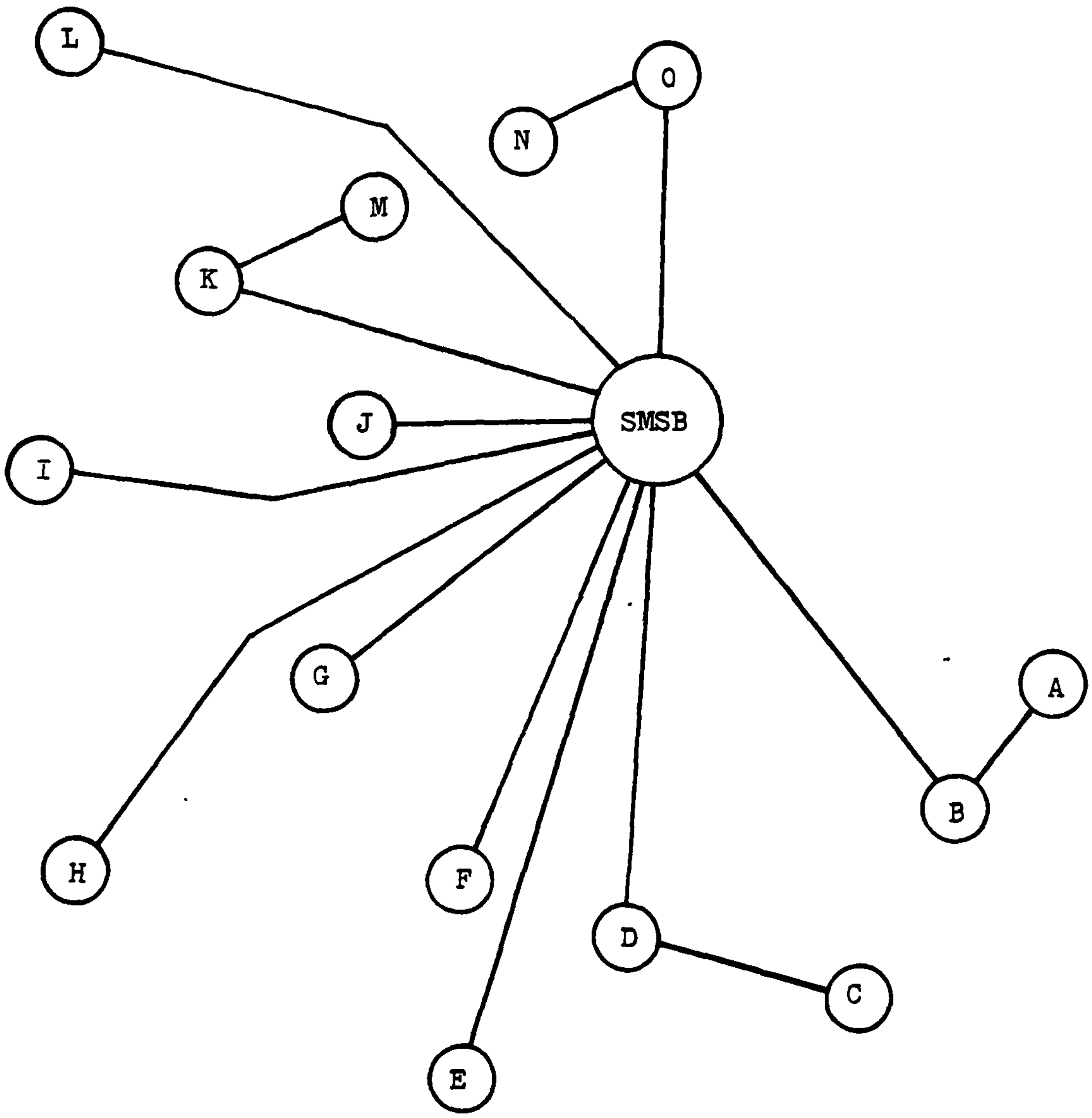
Vehicle Dispatch Schedule When Facility Manager And Cook Changeover Is In The 740th Strategic Missile Squadron (SMS): Day 1



740th SMS composed of LCFs: A,B,C,D, and E.
741st SMS composed of LCFs: F,G,H,I, and J.
742nd SMS composed of LCFs: K,L,M,N, and O.

Figure 2-1 Vehicle Dispatch Schedule - Day 1

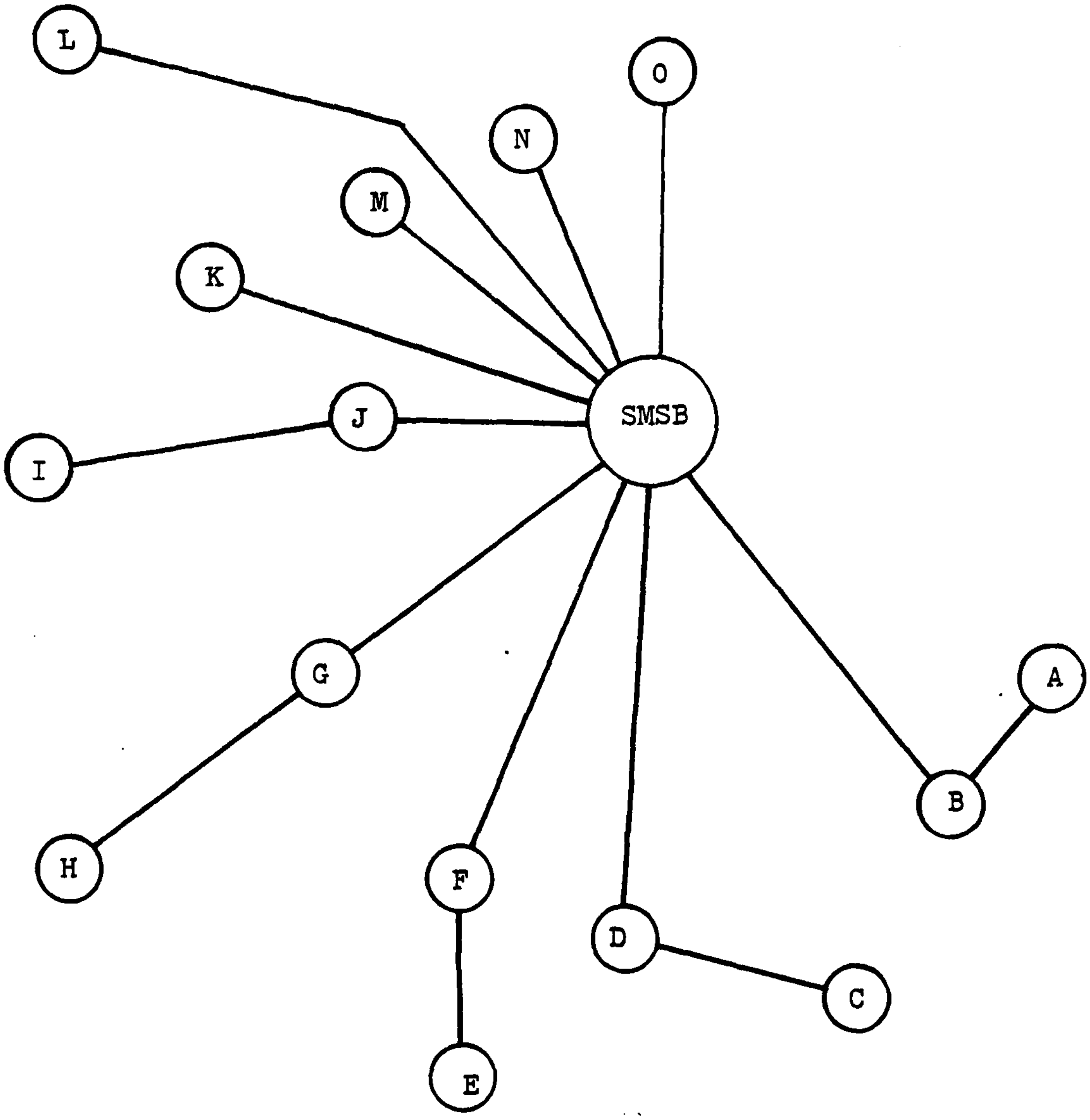
Vehicle Dispatch Schedule When Facility Manager And Cook Changeover Is In The 741st Strategic Missile Squadron (SMS): Day 2



740th SMS composed of LCFs: A,B,C,D, and E.
741st SMS composed of LCFs: F,G,H,I, and J.
742nd SMS composed of LCFs: K,L,M,N, and O.

Figure 2-2 Vehicle Dispatch Schedule - Day 2

Vehicle Dispatch Schedule When Facility Manager And Cook Changeover Is In The 742nd Strategic Missile Squadron (SMS): Day 3



740th SMS composed of LCFs: A,B,C,D, and E.
741st SMS composed of LCFs: F,G,H,I, and J.
742nd SMS composed of LCFs: K,L,M,N, and O.

Figure 2-3 Vehicle Dispatch Schedule - Day 3

accompanied by a facility manager and cook (38). Although the low-silhouette carryall crew vehicle can carry six personnel and their related gear, the present procedure never calls for more than four passengers in any vehicle on a regularly scheduled basis. This procedure provides flexibility for additional passenger requirements (training crew, evaluation crew, etc.) or additional equipment/housekeeping supplies. The present vehicle scheduling system satisfies driver requirements by using the MCC members in that capacity.

Because the 91st Strategic Missile Wing has three separate vehicle dispatch schedules, it was determined that the current gallons of fuel per passenger ratio could only be computed by looking at the total number of miles traveled over an entire 3-day changeover cycle. Each of the three schedules was reviewed, and distances were computed for the primary authorized routes of travel using the 91st Strategic Missile Wing (Wing III) Transport-Erector Route Book. The Transport-Erector Route Book was developed by the 91st Strategic Missile Wing's Civil Engineering Squadron and Safety Office to specifically identify the available authorized routes of travel that can be used by different types of military vehicles. This document presents the entire road network that exists within the confines of the 91st Strategic Missile Wing (35). These routes were developed jointly by the Federal Highway Administration, the North Dakota

Dakota Highway Department, the United States Air Force, and local government officials during the initial development and construction of the missile wing complex (8).

The two specific types of authorized routes identified within the 91st Strategic Missile Wing (Wing III) Transport-Erector Route Book are transport-erector routes and general access routes. Transport-erector routes are those routes that were constructed to meet the weight and safety demands required by a transport-erector vehicle (8). This type of vehicle is used to transport a missile to various destinations within the missile wing complex. It is approximately 110 feet long, 8 feet wide, and has a gross weight of approximately 250,000 pounds when fully loaded (17). General access routes are those routes available for use by all other military traffic (35). MCCs can travel over either type of route and this study will use both types in the determination of the most efficient MCC deployment strategy.

The route book contains all authorized routes overlayed with a one square mile grid network. The distances between the SMSB and the LCFs, and the distances between the LCFs, were computed from this document. First, the distances for the existing routing system were computed (Table 2-1) by applying a mechanical divider to the routes of travel specified in the aforementioned Operating Instruction 77-2. However, these distances may or may not be the shortest

TABLE 2-1

PRESENT MCC ROUTING SYSTEM DISTANCES

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	116.00	4
SMSB - B - SMSB	101.00	4
SMSB - C - SMSB	120.50	4
SMSB - D - SMSB	93.00	4
SMSB - E - SMSB	134.50	4
SMSB - F - SMSB	114.50	2
SMSB-G-H-G-SMSB	194.50	4
SMSB-J-I-J-SMSB	118.50	4
SMSB-K-M-K-SMSB	126.50	4
SMSB - L - SMSB	142.00	2
SMSB-O-N-O-SMSB	93.00	4
	1354.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB-B-A-B-SMSB	156.00	4
SMSB-D-C-D-SMSB	132.00	4
SMSB - E - SMSB	134.50	2
SMSB - F - SMSB	114.50	4
SMSB - G - SMSB	150.00	4
SMSB - H - SMSB	154.50	4
SMSB - I - SMSB	120.00	4
SMSB - J - SMSB	64.00	4
SMSB-K-M-K-SMSB	126.50	4
SMSB - L - SMSB	142.00	2
SMSB-O-N-O-SMSB	93.00	4
	1387.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB-B-A-B-SMSB	156.00	4
SMSB-D-C-D-SMSB	132.00	4
SMSB-F-E-F-SMSB	134.50	4
SMSB-G-H-G-SMSB	194.50	4
SMSB-J-I-J-SMSB	118.50	4
SMSB - K - SMSB	88.50	4
SMSB - L - SMSB	142.00	4
SMSB - M - SMSB	112.00	4
SMSB - N - SMSB	73.00	4
SMSB - O - SMSB	56.00	4
	1207.00	40

distances between two specific points. Therefore, a "straight-line" methodology was applied to the Transport-Erector Route Book map of the 91st Strategic Missile Wing complex to determine the shortest distance between two points. With this "straight-line" methodology, a straight edge was placed on the map to link any two desired points. The shortest route between these two points was then determined by following a route of travel over authorized routes that correspond as closely as possible with the straight line connecting the two nodes. After determination of the shortest routes, the distances for these routes were computed as before using a divider and the Transport-Erector Route book. These shortest distances will be used as data inputs in the problem formulation.

Measure of Efficiency

The efficiency formula used within this study will be one relating the number of gallons of fuel used to transport each MCC member, facility manager, or cook to the LCF. Its basic formulation is as follows:

(1) Compute the total number of miles (M_{total}) driven for each deployment strategy.

(2) Divide the total number of miles driven by the fuel efficiency of the vehicle used in the deployment strategy. The fuel efficiency of each vehicle is measured by

the vehicle's miles per gallon (MPG) ratio. The result will be the total number of gallons (Gal_{total}) used within each deployment strategy/vehicle combination.

(3) The final step is to divide the total number of gallons of fuel used for each deployment strategy/vehicle combination by the total number of passengers ($Pass_{total}$) moved within the deployment strategy.

(4) Symbolically, these efficiency formulas are:

(a)
$$M_{total} = \sum_{i=1}^{3} M_i \qquad \text{Eq. 2-1}$$

(b)
$$Gal_{total} = \frac{M_{total}}{MPG} \qquad \text{Eq. 2-2}$$

(c)
$$Pass_{total} = \sum_{i=1}^{3} P_i \qquad \text{Eq. 2-3}$$

(d)
$$\text{Gallons per passenger} = \frac{Gal_{total}}{Pass_{total}} \qquad \text{Eq. 2-4}$$

where, M_i = Miles driven on day i (i=1, 2, 3) for a particular deployment strategy/vehicle combination.

M_{total} = Total miles driven for each deployment strategy.

Gal_{total} = Total gallons used within a deployment strategy/vehicle combination.

P_i = Passengers transported on day i for a particular deployment strategy/vehicle combination.

$Pass_{total}$ = Total passengers transported for each deployment strategy.

The present MCC routing system has an efficiency ratio of 3.46 gallons per passenger. It was computed using the information contained in Table 2-1 as follows:

(1) $M_{total} = 1354.00 + 1387.00 + 1207.00 = 3948.00$

(2) $Gal_{total} = \dfrac{3948.00 \text{ miles}}{9.5 \text{ MPG for low-silhouette carryall}} = 415.58$

(3) $Pass_{total} = 40 + 40 + 40 = 120$

(4) $\text{Gallons per passenger} = \dfrac{415.58 \text{ gallons}}{120 \text{ passengers}} = 3.46$

The objective of this research is to determine if the present MCC routing system is the most efficient means, in terms of gallons per passenger, of transporting MCCs and related personnel to the LCFs. This analysis will look at several alternative deployment strategies and at several alternative vehicles for use within these deployment strategies. Our objective is to find the shortest routes of travel for the various deployment strategies and vehicles used within the strategies. From these routes, we will compute the gallons per passenger ratio to determine if there is a more fuel efficient system for routing the MCCs than the routing system presently used.

This study will focus on the types of vehicles that are presently available at Minot AFB (Table 2-2).

TABLE 2-2

PRESENTLY AVAILABLE VEHICLES

Vehicle Type (7)	MPG Rating (7)	Estimated * Passenger Capacity
Low-silhouette Carryall	9.5	6
Compact Station Wagon	18.0	4
15 Passenger Commuter Van	7.0	12 **
29 Passenger Bus	6.0	22 **
45 Passenger Bus	3.5	36 **

*This includes MCCs, FMs, and cooks only. Motor pool drivers needed for Decision Strategy III are considered to be integral to the vehicle in use and do not impact on the estimated passenger capacity of any vehicle.

**Passenger capacity modification would be required to enable the vehicle to also carry the personal gear associated with each crew member, facility manager, and cook (technical order bag, survival gear, and/or personal items), survival kits, and periodic housekeeping supplies carried by the facility managers. The rear seat would be removed in the vans, while the last row and one of the two seats in the second-to-last row would be removed in the two types of buses.

Although there may not presently be sufficient numbers of each type of vehicle on hand for use in the MCC routing process, it is assumed that because these vehicles have previously met the test of congressional price ceilings, that additional vehicles of these types could be procured as replacements are required.

Deployment Strategies

This study will look at three basic deployment strategies. The first deployment strategy (DS I) employs an "arrive and return" procedure called backtracking. With this strategy a vehicle proceeds from the SMSB to a location, or to a series of locations, and returns over the same path. The present MCC routing system at Minot AFB follows the premise of this deployment strategy. Figures 2-1, 2-2, and 2-3 show the backtracking routes for each day of the 3-day changeover cycle. In some situations, a vehicle departs the SMSB to one LCF and returns over the same route with the relieved personnel. In other situations, a vehicle departs the SMSB with two destinations. The vehicle proceeds to the first LCF and drops off the MCC. This delivery process entails approximately five minutes. The vehicle then proceeds to its second destination. After the crew changeover has been completed at the second LCF, which takes approximately one hour, the relieved MCC backtracks the route to pick up the relieved crew at the first destination and the two MCCs return to the SMSB. The apparent advantages to this strategy are that crewmembers can accomplish the driving to and from the LCF without the need of a separate driver and that a complete wing changeover can be accomplished each day. The apparent disadvantage is that the number of vehicles required to accomplish the wing changeover is greater than with other deployment strategies under investigation.

The second deployment strategy (DS II) does not employ the concept of backtracking, but rather an "arrive and wait" procedure. With this strategy, a vehicle departs the SMSB to an LCF. Upon arrival, the vehicle "waits" for the newly delivered MCC to replace the on-duty MCC. This changeover process takes approximately one hour. The relieved MCC then accompanies the vehicle to the next LCF. This "arrive and wait" process is repeated until all desired locations have been visited, and then the vehicle returns to the SMSB. This process does not allow for the return to any previously visited LCFs. Its apparent advantages are that crewmembers can accomplish the driving to and from the LCF and that the total number of miles is reduced. However, its apparent disadvantage is that the process results in one hour waits at each LCF visited that are in addition to the required travel time. This reduces the number of LCFs that could be visited each day and might adversely affect crew availability for future alert scheduling requirements.

The third deployment strategy (DS III) that will be investigated is one that uses a trailing vehicle. A vehicle driven by a motor pool driver dispatches from the SMSB carrying MCCs destined for several LCFs. The vehicle proceeds to each LCF and drops off a MCC. As previously mentioned, this delivery process takes approximately five minutes. The vehicle continues to the next location and delivers the MCC. The process continues until all MCCs are deployed. At this point the vehicle returns to the SMSB without any relieved MCCs. One hour (the approximate length of a MCC changeover) after the first vehicle departed to deliver the new MCCs, a second vehicle is dispatched over the same route to pick up the relieved MCCs and return them to the SMSB. The apparent advantages of this procedure are that the MCCs are promptly and efficiently picked up for return to the SMSB and more LCFs could be visited each day with fewer vehicles. The apparent disadvantages of this procedure are that motor pool drivers would be required to drive the vehicles and the total number of miles driven would increase.

The important thing to recognize in evaluating the advantages and disadvantages of these deployment strategies is that they must be viewed in context with the whole model. Although total miles may increase with the selection of a strategy, they may be more than offset by use of a vehicle with a much higher miles per gallon ratio. This study will evaluate these strategies in terms of the entire effect of the strategy and the associated vehicles on the gallons per passenger ratio.

<u>Problem Formulation</u>

The minimum distance TSP can be formulated as a 0-1 integer programming problem. The decision variable X_{ij} is an indicator variable that represents whether or not the link from node i to node j is included in the minimum tour (the shortest route through the network). X_{ij} equals one (1) if the tour includes the link from node i to node j, and X_{ij} equals zero (0) when the link from node i to node j is not included in the minimum tour. C_{ij} is the distance or "cost" associated with including the link from node i to node j in the tour. The objective is to minimize the tour distance or "cost", and becomes in general form:

$$\text{Minimize } Z = \sum_{i}^{n} \sum_{j}^{n} C_{ij} X_{ij} \qquad \text{Eq. 2-5}$$

where n equals the number of nodes (including the starting point) in the network.

There are three sets of constraints typically associated with the Traveling Salesman Problem (4:286). The first set of constraints is introduced to assure each city is visited exactly one time. The general formula for these constraints is:

$$\sum_{\substack{i=1 \\ i \neq j}}^{n} X_{ij} = 1 \quad \text{for } j = 1,2,\ldots\ldots,n. \qquad \text{Eq. 2-6}$$

The second set of constraints assures there is exactly one departure from each of the n nodes. The general formula for these constraints is:

$$\sum_{\substack{j=1 \\ j \neq i}}^{n} X_{ij} = 1 \quad \text{for } i = 1,2,\ldots\ldots,n. \qquad \text{Eq. 2-7}$$

The third set of constraints is used in order to prevent subtours (a tour which does not visit each node in the system at least once). These constraints state that if the link from node i to node j is included in the tour, then the link from j to i is excluded. For example, to prevent a subtour between nodes 1 and 2, the constraint:

$$X_{12} + X_{21} \leq 1 \qquad \text{Eq. 2-8}$$

would be used.

In problems where the number of nodes (n) is even, the number of constraints needed to prevent subtours increases at an increasing rate corresponding to the formula (5:131):

$$\frac{n!}{(n-2)!2} + \frac{n!}{(n-3)!3} + \ldots\ldots\ldots\ldots + \frac{n}{(n-\frac{n}{2})!\frac{n}{2}} \qquad \text{Eq. 2-9}$$

Equation 2-9 indicates that for an n of 16 (15 LCFs and the SMSB), 74,179,552 of the third type of constraints would be required. In problems where the number of nodes is odd, the number of subtour constraints required is even greater.

There are two integer programming programs in the Honeywell library that were available to the researchers. INTØ1 can handle only 11 constraints and INTLP can handle only 16 constraints (34). Because of these limitations on problem size, neither of these programs could handle the 74,179,552 subtour constraints required in the MCC routing problem. The search was then directed towards finding another type of algorithm which could be employed to solve the MCC routing system problem. A "branch and bound algorithm", developed by Little, Murty, Sweeney, and Karel to solve TSPs, was found that showed promise (26). It is a tour-building algorithm that calculates the minimum distance (lower bound) through a matrix reduction procedure. Because of the similarity of the Traveling Salesman Problem and DS II, this TSP algorithm will be applied to the DS II phase of our MCC analysis.

Two problems exist within DS II. The first is the passenger/gear capacity of presently available vehicles at Minot AFB. The maximum passenger/gear capacity is maintained by a bus that can transport thirty-six passengers and their associated gear. Because the daily changeover requirement at Minot AFB is 40 personnel, the largest vehicle is not adequate to deploy all relief personnel in one trip. The second problem is one of time. Because it takes approximately one hour for MCC changeover, DS II will entail 15 hours of "waiting time" in addition to the time required for driving the total circuit. A rough estimate of the mileage from the base through all the LCFs and back to the base is 425 miles. If travel could be accomplished at a constant 55 miles per hour (which is not possible because some travel would be required on gravel roads where a 25 miles per hour speed limit is in force), it would take approximately 23 hours to complete the circuit. In addition to the excessive delay for relieved MCCs, current directives only allow a driver 8 hours of driving per 24-hour period (11).

To alleviate the problems of vehicle capacity and excessive time to complete the circuit, the network will be partitioned into smaller segments based on the number of LCFs a vehicle can transit in a day and their geographical locations. According to Bellmore and Nemhauser's survey of TSP literature (2), no algorithms have been developed that obtain optimality through use of a partitioning procedure. However, Held and Karp give some rules for selecting good partitions, and develop two partitioning procedures called local partitioning and global partitioning that can be used to obtain approximate minimum distance solutions (20).

Held and Karp's partitioning procedures were developed to permit the rapid direct solution of problems of smaller proportion. Algorithms are combined through a method of successive approximation to provide a systematic procedure for handling large-scale problems (20:202). This procedure results in a sequence of permutations where each permutation is obtained from its predecessor by the solution of a derived subproblem of moderate size with the same structure as the given problem (20:202).

> Given a permutation $P = (1\ i_2 \ldots i_n)$ representing a route through n cities, the cities may be partitioned into U ordered sets, each consisting of cities which occur successively in P, and maintaining the same order as in P. A U-city TSP is solved in which each ordered set is treated as a city, and the cost of going from the set $(i_j\ i_{j+1} \ldots . i_{k-1}\ i_k)$ to $(i_1\ i_{1+1} \ldots . i_{m-1} i_m)$ is $A_{i_k i_1}$. The solution implies a reordering P' of P, with P' having cost less than or equal to that of P. Two types of partitioning proved to be especially useful. In local partitioning, all of the ordered sets but one consist of a single element. Therefore, the tours associated with P and P' differ only locally if they differ at all. At the other extreme, a global partition takes the U sets as nearly equal in size as possible, so that, if changes are made, they tend to be of a global nature [20:230].

Another approach to partitioning has been formulated by Karg and Thompson. Their tour building heuristic centers on a proposition that the optimal distance tour approximates a convex set in two-dimensional Euclidean space (23:230). The reader is directed to the original source document for additional treatment of this partitioning procedure.

The partitioning procedure this study will use is a tour-building heuristic that centers on the geographical distribution of the SMSB and the LCFs. The authors determined the personnel requirements and the number of LCFs that can be visited by each vehicle under consideration and, with their familiarity of the geographical placement of the LCFs within the missile wing complex, derived the partitions necessary for each vehicle. A more detailed description of the partitioning process is contained in Chapter 3. This geographical partitioning procedure is similar to Held and Karp's global partitioning procedure. Held and Karp used partitioning because of the large number of nodes in the particular TSP they were investigating (20:202), while this study used partitioning because of vehicle passenger/gear capacity and travel time constraints.

It is noted that the TSP algorithm will also be applied to the DS III phase of our MCC analysis. That is, the optimal route as determined by the TSP algorithm for the lead vehicle will also be used for the trailer vehicle.

Algorithm Application

The computer program (Appendix A) that this study will use in the analysis of the MCC routing network is the Closed Circuit Problem written by Captain Claire D. Heidler, USAF, as modified by Woolley/Jacques to permit repetitive iterations (19). Captain Heidler's Closed Circuit Problem is the computerization of an algorithm commonly known as the Little Branch and Bound Algorithm (19). This algorithm was developed to aid in the solution of traveling salesman problems. A general summary of the algorithm follows; however, the interested reader is referred to Little (27) for an in-depth analysis of the algorithm.

The traveling salesman or closed circuit problem involves an individual who wishes to visit each of several given cities once and only once and to return to the starting point of his journey (26:2245). This procedure is descriptive of DS II and DS III. The objective is to determine the proper visiting order of the cities that will minimize the total distance he must travel. To determine the optimum route, the distances (or other measurements such as cost or time) between all cities or nodes must be known (26:2245).

An explanation of the algorithm that will be used in this study will be centered around the narrative explanation of a practical example. This example includes specific distances so that the reader may more easily follow the computational flow within the algorithm. To lend reality to the example situation, a portion of the Minot AFB complex will be used. The following computational procedures are paraphrased from Heidler's Closed Circuit Problem (19) using the example data.

Step 1: Establish a distance matrix (Figure 2-4). In this example the distances between Minot AFB, and Alpha (A), Bravo (B), and Charlie (C) LCFs will be used.

	SMSB	A	B	C
SMSB	M	58.00	50.50	60.25
A	58.00	M	27.50	46.50
B	50.50	27.50	M	19.00
C	60.25	46.50	19.00	M

Figure 2-4. Initial Matrix

An M (representing infinity) is placed on the main diagonal as a penalty to insure that a "traveler" entering a node must depart that node.

<u>Step 2</u>: Reduce the initial matrix by determining the shortest distance in each row and subtracting that shortest distance from every other element in the row being investigated. This reduction operation creates at least one "zero" entry in each row. Now determine the shortest distance in each column, including the zeros resulting from the row reduction. Subtract the smallest distance in each column from every distance in the column being investigated. The result of the matrix reduction is shown in Figure 2-5.

	SMSB	A	B	C	Amount Subtracted From Its Row	
SMSB	M	0	0	9.75	50.50	
A	0	M	0	19.00	27.50	
B	1	1	M	0	19.00	
C	10.75	20.00	0	M	19.00	
Amount Subtracted From Its Column	30.50	7.5	0	0		38.00
					116.00	154.00

Figure 2-5. Matrix After Reduction

Additionally, the distances that are subtracted from their rows and their columns should be annotated on the matrix (Figure 2-5) and summed to provide a "lower bound" or minimum distance for all tours. The "lower bound" sum can also be annotated on a pictorial representation of the iteration process called a branching diagram (Figure 2-9).

Step 3: Identify the zero (0) cells in the reduced matrix presented in Figure 2-5. For each zero (0) cell located, identify the smallest distance, other than the zero itself, in the cell's associated row and column. In Figure 2-5, a zero (0) is found on the bottom row for the (C,B) cell. The smallest distances are 10.75 for the row and 0 for the column. These two distances represent minimum penalties for not choosing the zero cell. These two distances should be summed and annotated in the zero cell associated with the calculation. Therefore, the penalty for cell (C,B) is 10.75 + 0 = 10.75. Figure 2-6 shows the matrix with the penalties for each zero cell.

	SMSB	A	B	C
SMSB	M	0 ^{1}	0 ^{0}	9.75
A	0 ^{1}	M	0 ^{0}	19.00
B	1	1	M	0 $^{10.75}$
C	10.75	20.00	0 $^{10.75}$	M

Figure 2-6. Matrix With Penalties

Step 4: In order to minimize overall circuit distance, the objective is to avoid incurring large penalties. The penalties represent the extra mileage incurred if that particular route is not taken. Therefore, the first tour link is determined by selecting the zero cell with the highest penalty. Because the matrix is symmetrical around the main diagonal, the routes with the highest penalty of 10.75 are actually both the same and reflect a tour link of B to C or C to B. In the case of ties, the algorithm allows one to arbitrarily choose among the ties. Therefore, in our example, the route from B to C is chosen. After selection of the highest penalty, add the penalty to the "lower bound" on the branching diagram and delete the associated row and column for that tour link from the matrix. This procedure is seen in Figures 2-7 and 2-9.

	SMSB	A	B
SMSB	M	0	0
A	0	M	0
C	10.75	20.00	0

Figure 2-7. Matrix With Column and Row Deleted

Step 5: Now assign an infinite distance to the reverse of the tour link generated in Step 4. Because we selected a tour link from B to C in the example, the tour link from C to B, cell (C,B), would be assigned an infinite distance (M) to preclude choosing the same link. Figure 2-8 shows the results of this manipulation.

	SMSB	A	B
SMSB	M	0	0
A	0	M	0
C	10.75	20.00	M

Figure 2-8. Matrix After Step 5

<u>Step 6</u>: This completes the first iteration of the algorithm. To continue the process and generate the next tour link, return to Step 2 with the Step 5 matrix and re-iterate the process until only one link remains in the matrix.

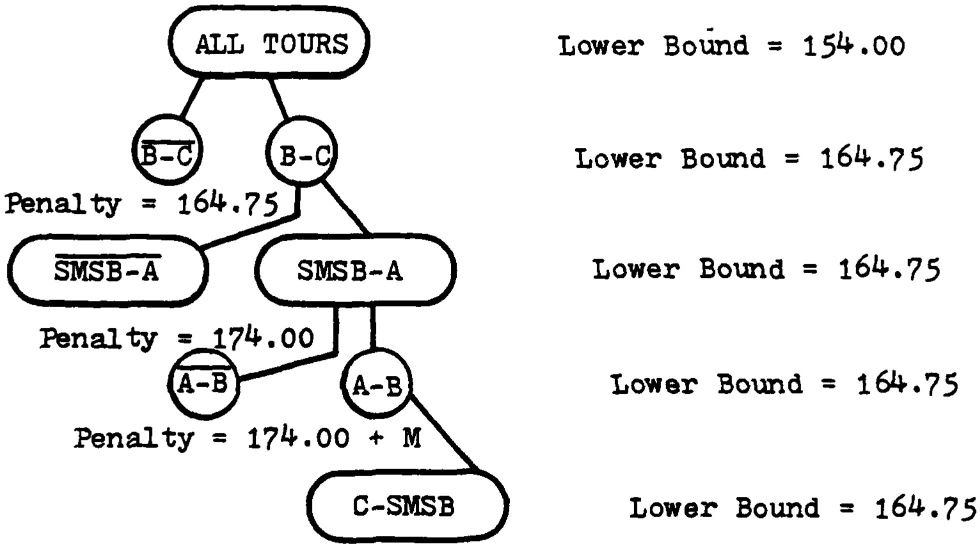


Figure 2-9. Branching Diagram

The shortest tour is SMSB-A-B-C-SMSB.

A brief summary of the overall route determination sequence is provided for the reader.

Step 1: Establish the distance matrix.

Step 2: Reduce the matrix - rows first, then columns. Then sum the distances subtracted in the reduction process. Annotate this sum on the branching diagram.

Step 3: Calculate penalties for each zero (0) cell.

Step 4: Select the cell possessing the highest penalty as the next tour link, and delete its row and column from the matrix. Add the penalty to the lower bound and annotate the branching diagram.

Step 5: Assign an infinite distance to the reverse of the link generated to establish a new matrix.

Step 6: Repeat Steps 2 through 5 until only one link remains.

Figure 2-9 shows the results of the continuation of the example. The process has indicated that the shortest route that will encompass all four points and return to the starting point is based on a tour from SMSB-A-B-C-SMSB that encompasses 164.75 miles. However, this is only one solution. There is a remote possibility that the left branch generated on the first iteration can branch to a better solution. This is only true if the lower bound for the first left branch is less than the final lower bound calculated by continually branching to the right. An interesting phenomenon is that "if the TSP is symmetric and t is any tour, another tour with the same cost is obtained by traversing the circuit in the reverse direction [26:484]." Therefore, if the initial matrix at Step 1 is symmetrical, then not only is the tour produced by the algorithm optimal, but the reverse tour is also optimal. In the example the tour was SMSB-A-B-C-SMSB. Thus, since the initial matrix is symmetrical, the tour SMSB-C-B-A-SMSB is also optimal. For a more detailed description of the computer program's logic, the interested reader can reference the original source document (19).

When the geographical partitioning procedure is used, the segmentation of the network will be accomplished prior to the input of the distance matrix into the computer program. The input of the distance matrix applicable only to a particular segment will ensure an optimal solution for that partition.

As stated earlier, Little's Branch and Bound Algorithm and Heidler's Closed Circuit Problem aid in the solution of problems within DS II and DS III. Heidler's model solves the general Traveling Salesman Problem where a vehicle proceeds from a starting point and visits each node only once and subsequently returns to the starting point. However, Heidler's computer model does not solve the "arrive and return" procedure (backtracking) inherent to DS I. With the backtracking procedure of DS I, a vehicle proceeds from a starting point and visits each node. The vehicle stops at the last node in the network and returns to the starting point via the reverse route. Figure 2-10 and Figure 2-11 give pictorial representations of these concepts.

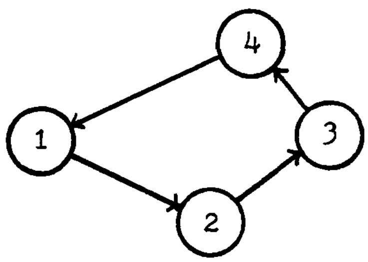


Figure 2-10. Traveling Salesman

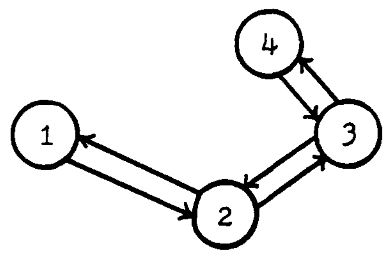


Figure 2-11. Backtracking

The authors have developed the following heuristic to handle the multiple visits required by the backtracking procedure. It is based on the symmetrical property of Little's Branch and Bound Algorithm.

Step 1: Solve the routing problem using the Heidler computer program. It will yield two equivalent solutions because of the symmetric property.

Step 2: Select the solution that has the longest last link (the link from the last LCF back to the SMSB).

Step 3: Subtract the last link from that solution. This provides the shortest tour that visits all nodes without returning to the starting point.

Step 4: Multiply the result by two. This will incorporate the "backtrack" and will provide the least total distance for that routing problem.

Using the previous example from Figure 2-4, we found the optimal tour was SMSB-A-B-C-SMSB (solution 1) or SMSB-C-B-A-SMSB (solution 2). The total distance for both solutions was 164.75 miles. The link C-SMSB (solution 1) is 60.25 miles while the link A-SMSB (solution 2) is 58.00 miles. Subtracting the longer link of C-SMSB (solution 1) from 164.75 gives 104.50 miles.

<u>Summary</u>

The objective of this research is to determine if the present MCC routing system is the most efficient means, in terms of gallons per passenger, of transporting MCCs and related personnel to the LCFs. Three alternate deployment strategies will be examined for each of the five vehicle types presently available at Minot AFB. Deployment strategy I involves an "arrive and return" procedure called backtracking, where a vehicle visits each LCF in the tour discharging relief personnel and backtracks over the same route picking up relieved personnel. Deployment strategy II incorporates an "arrive and wait" procedure where the vehicle waits at each LCF for crew change and returns to the SMSB from the last LCF visited. Deployment strategy III is similar to DS II; however, a trailing vehicle is used to pick up relieved personnel. An appropriate algorithm will be used to develop the shortest route network for each deployment strategy. Heidler's computer code of the Little Branch and

Bound algorithm will be used to determine the shortest route network for DS II and DS III. This program, together with the heuristic developed to handle multiple LCF visits, will be used to determine the shortest route network for DS I. Geographic partitioning will be used to determine which LCF will be included in the network being analyzed under each deployment strategy/vehicle type combination.

Once the shortest routes are determined for each vehicle type/deployment strategy, the gallons per passenger measure of efficiency will be computed to determine if there is a more fuel efficient system for routing the MCCs than the routing system presently used. Table 2-3 summarizes the 15 vehicle type/deployment strategy combinations that will be investigated where the response variable gal/pax$_{ij}$ is the gallon per passenger measure of efficiency of vehicle type i (i = 1,...,5) and deployment strategy j (j = I,...,III).

TABLE 2-3

GALLONS PER PASSENGER MEASURES OF EFFICIENCY

VEHICLE TYPES	DEPLOYMENT STRATEGIES		
	DS I	DS II	DS III
Low-Silhouette Carryall	Gal/Pax$_{1I}$	Gal/Pax$_{1II}$	Gal/Pax$_{1III}$
Compact Station Wagon	Gal/Pax$_{2I}$	Gal/Pax$_{2II}$	Gal/Pax$_{2III}$
Commuter Van	Gal/Pax$_{3I}$	Gal/Pax$_{3II}$	Gal/Pax$_{3III}$
29 Passenger Bus	Gal/Pax$_{4I}$	Gal/Pax$_{4II}$	Gal/Pax$_{4III}$
40 Passenger Bus	Gal/Pax$_{5I}$	Gal/Pax$_{5II}$	Gal/Pax$_{5III}$

Chapter 3

DATA COMPUTATION AND ANALYSIS

Data Computation

The straight-line methodology was applied to the Transport-Erector Route Book map of the 91st Missile Wing complex (Figure B-1 in Appendix B provides a facsimile map of the 91st Strategic Missile Wing complex) to determine the shortest distance between two specific points over authorized routes. The routes of travel between the SMSB and the LCFs were determined, as well as the routes of travel between all combinations of LCFs. From these shortest authorized routes of travel, the distances between the SMSB and the LCFs, as well as between all combinations of LCFs, were computed. These shortest authorized routes of travel and corresponding distances are detailed in Tables C-1 through C-16 in Appendix C and the routes of travel distances for the entire wing complex are summarized in Table D-1 in Appendix D. Due to the scale of the Transport-Erector Route Book map and the accuracy of the mechanical divider, the authors recognize a potential measurement error of approximately one-half (½) mile per every 100 miles. However, since this constitutes a measurement error of only Ø.5%, study results are not significantly affected.

Because of vehicle capacity constraints and the travel time constraints to complete the circuit, the wing complex was partitioned into smaller segments. A geographical partitioning procedure was used which considered the geographical location of the LCFs, the personnel requirements for the LCFs on each day of the 3-day changeover cycle, and the personnel capacity restrictions of the vehicle under study. The authors evaluated these factors and developed partitions that would maximize vehicle capacity (to reduce the total number of vehicles required) as much as possible.

After development of the required partitions, the appropriate algorithm was used to develop the shortest authorized route network for each deployment strategy. For DS II, the appropriate distances associated with the shortest authorized routes between the SMSB and the LCFs and between the LCFs were input into Heidler's computer program of the Little Branch and Bound algorithm to determine the shortest authorized route networks and the route distances. Because of the "trailing vehicle" concept of DS III, the shortest authorized route networks for DS III were the same as those for DS II, but the route distances were twice that of DS II. The heuristic developed in Chapter 2 to handle multiple LCF visits was used to determine the shortest authorized route network for DS I. The partitions, route network sequences, route network distances, and the numbers of people transported in each vehicle for each vehicle/deployment strategy combination are contained in Tables E-1 through E-15 in Appendix E.

The total distances, number of gallons of fuel used, and the gallons per passenger efficiency formulation for each vehicle/deployment strategy combination for each 3-day changeover cycle are summarized in Tables 3-1, 3-2, and 3-3. The results of the investigation indicate that 10 of the 15 vehicle/deployment strategy combinations provide greater fuel efficiency than the 3.46 gal/pax of the present MCC routing system.

TABLE 3-1

VEHICLE/DEPLOYMENT STRATEGY SUMMARY - TOTAL MILES

Type of Vehicle	DS I	DS II	DS III
Carryall	3,265.00	2,961.00	5,922.00
Station Wagon	3,635.50	3,511.75	7,023.25
Van	2,500.50	1,894.75	3,789.50
29 Pax Bus	2,266.00	1,424.50	2,849.00
45 Pax Bus	2,166.00	1,353.00	2,706.00

TABLE 3-2

VEHICLE/DEPLOYMENT STRATEGY SUMMARY-GALLONS OF FUEL CONSUMED

Type of Vehicle	DS I	DS II	DS III
Carryall	343.68	311.68	623.37
Station Wagon	201.97	195.10	390.18
Van	357.21	270.68	541.36
29 Pax Bus	377.67	237.42	474.83
45 Pax Bus	618.86	386.57	773.14

TABLE 3-3

VEHICLE/DEPLOYMENT STRATEGY SUMMARY-GALLONS PER PASSENGER

Type of Vehicle	DS I	DS II	DS III
Carryall	2.86	2.60	5.19
Station Wagon	1.68	1.63	3.25
Van	2.98	2.26	4.51
29 Pax Bus	3.15	1.98	3.96
45 Pax Bus	5.16	3.22	6.44

Analysis of Data

Table 3-4 provides a comparison of the potential savings of the fifteen vehicle/deployment strategy combinations over the MCC routing system in effect as of 31 August 1979. The table includes the number of gallons of fuel saved (lost) and the percent savings (percent loss) by conversion to the particular vehicle/deployment strategy combination. The number of gallons of fuel saved (lost) and the percent savings (percent loss) were derived as follows:

$$\begin{matrix}\text{Gallons of fuel} \\ \text{consumed with} \\ \text{present system}\end{matrix} - \begin{matrix}\text{Gallons of fuel} \\ \text{consumed with} \\ \text{proposed system}\end{matrix} = \begin{matrix}\text{Gallons saved} \\ \text{(Gallons lost)}\end{matrix} \qquad \text{Eq. 4-1}$$

$$1 - \frac{\text{Proposed system efficiency ratio}}{\text{Present system efficiency ratio}} \times 100\% = \begin{matrix}\text{Percent saved} \\ \text{(Percent lost)}\end{matrix} \qquad \text{Eq. 4-2}$$

TABLE 3-4

POTENTIAL SAVINGS PER 3-DAY CHANGEOVER
CYCLE-GALLONS OF FUEL/PERCENT SAVINGS

Vehicle Type	DS I	DS II	DS III
Carryall	71.9/17%	103.00/25%	(207.79)/(50%)
Station Wagon	213.61/51%	220.48/53%	25.40 / 6%
Van	58.37/14%	144.90/35%	(125.78)/(30%)
29 Pax Bus	37.91/ 9%	178.16/43%	-(59.25)/(14%)
45 Pax Bus	(203.28)/(49%)	29.01/ 7%	(357.56)/(86%)

Our analysis indicates that five vehicle/deployment strategy combinations are less efficient than the present MCC routing system and are excluded from further consideration. These combinations include Carryall/DS III, Van/DS III, 29 Pax Bus/DS III, 45 Pax Bus/DS I, and 45 Pax Bus/DS III.

Closer analysis of the remaining ten vehicle/deployment strategies indicates that although a vehicle/deployment strategy is more efficient in terms of gallons per passenger, the choice of that combination may necessitate additional resource requirements that are beyond the existing capabilities of the base resources and may result in incremental costs which prove prohibitive.

The Station Wagon/DS III combination has a fuel efficiency ratio of 3.25 gallons per passenger. While this combination provides improvement over the present MCC routing system's 3.46 gallons per passenger, twenty vehicles would be required as well as twenty drivers to ferry the vehicles to the LCFs and back. These vehicle and manpower resource requirements may result in prohibitive incremental costs.

Inspection of the 29 Pax Bus/DS II combination indicates that the longest network that the bus would be required to follow encompasses 307.50 miles. At an average of 35 miles-per-hour, an approximation to account for travel over pavement and gravel roads, the network would require 8.79 hours of continuous travel. Because of the "arrive and wait" nature of DS II, the 8.79 hours of travel time would be augmented by one-hour waits at each of the 10 LCFs visited in the network. The total "travel" time of the longest network thus becomes 18.79 hours, and the first MCC relieved or the last MCC to be delivered could possibly spend approximately 17 hours on the bus. This long transit time, combined with the required "crew rest" period, could reduce the number of wing crews available for duty on the next duty and negatively impact crew scheduling requirements. Also, because MCC members would be required to drive the bus after a

24-hour alert tour, driving safety might be impacted. Although the 1.98 gallons per passenger is a 43% improvement over the present MCC routing system's 3.46 gallons per passenger, the potential disadvantages associated with this vehicle/deployment strategy combination must be thoroughly evaluated by wing personnel to determine if these disadvantages outweigh the advantages.

The 45 Pax Bus/DS II combination has the same disadvantages as the 29 Pax Bus/DS II combination. Its largest network of 260 miles and visits to 8 LCFs would result in a "total" travel time of 15.43 hours. While its 3.22 gallons per passenger efficiency ratio is a 7% improvement over the present MCC routing system, its potential disadvantages must also be thoroughly evaluated by wing personnel in comparison with the potential advantages.

The Van/DS II combination experiences the same types of problems. The longest network for the Van/DS II combination entails 213.00 miles and visits to 5 LCFs. At an average of 35 miles-per-hour, the "total" travel time would be 11.09 hours. While the 2.26 gallons per passenger efficiency ratio represents a 35% improvement, the potential disadvantages associated with the length of time required to tour the longest network and the necessity for a relieved MCC member to drive the van must be evaluated by wing personnel in conjunction with the potential advantages.

The Van/DS I and 29 Pax Bus/DS I combinations reflect the same disadvantages inherent with DS II combinations.

The Van/DS I combination's longest network is 291.50 miles with 9 stops required during the backtracking associated with visits to 5 LCFs. At an average of 35 miles-per-hour, with 5 minute stops at each of the 9 stopping points, the total travel time would be 9.08 hours. The 29 Pax Bus/DS I combination's longest network encompasses 527.00 miles and 19 stops at 10 LCFs. Its "total" travel time for the longest network would require 16.66 hours. The 14% and 9% improvements associated with these combinations must be evaluated by wing personnel against their lengthy travel times.

Although wing personnel must evaluate the disadvantages associated with the Station Wagon/DS III, 29 Pax Bus/DS II, 45 Pax Bus/DS II, Van/DS II, Van/DS I, and 29 Pax Bus/DS I combinations, the authors believe that the potential lengthy travel times, driving safety factor, vehicle and manpower resource requirements, and prohibitive incremental costs associated with these six vehicle/deployment strategy combinations are more disadvantageous than advantageous. Therefore, the authors propose that the Station Wagon/DS III, 29 Pax Bus/DS II, 45 Pax Bus/DS II, Van/DS II, Van/DS I, and 29 Pax Bus/DS I combinations should not be considered unless constrained gasoline or vehicle resources force the use of one of these combinations.

The authors believe that the four remaining vehicle/deployment strategy combinations are all acceptable and preferable alternatives to the present MCC routing system.

The Carryall/DS I combination is similar to the present MCC dispatching system. The 17% improvement to 2.86 gallons per passenger is the result of increased passenger capacity from four to six, and the development of the shortest authorized routes of travel that replace the present emphasis on the use of paved roads. The Carryall/DS II combination provides a 25% savings by using shorter routes of travel and the "arrive and wait" procedure. The additional time associated with DS II adds only two hours to the "total" travel time of any network (resulting from the additional wait at two LCFs). The Station Wagon/DS I combination provides potential fuel savings of 51% as the result of its 18 miles-per-gallon rating and the shorter authorized routes of travel. Even though the total number of miles per 3-day changeover cycle for this combination is the largest of the four acceptable combinations, the increased fuel economy of the station wagon provides the second-best fuel efficiency ratio of 1.68 gallons per passenger. The Station Wagon/DS II combination provides the best overall results and provides a potential 53% fuel savings over the present MCC routing system. The "arrive and wait" nature of this combination would only result in the addition of one hour to the "total" travel time of the tour provided in the Station Wagon/DS I combination.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The authors believe that the Station Wagon/DS II vehicle/deployment strategy (coupled with travel over the shortest authorized routes of travel), and its potential 52% fuel savings, would be the best choice to replace the present MCC routing system at Minot AFB, North Dakota.

The following analysis demonstrates the potential benefits of this recommendation when considered over a one year time horizon. The present MCC routing system uses 415.58 gallons of fuel for each 3-day changeover cycle, as compared to 195.10 gallons with the Station Wagon/DS II combination. The net potential savings are 220.48 gallons for each 3-day changeover cycle. With 121.67 3-day changeover cycles per year, the potential fuel savings amount to 26,826 gallons of fuel per year. With the present escalation in the price of fuel, the impact of the quantity of fuel saved is magnified by its potential savings in fuel costs. The potential yearly fuel savings for the four acceptable vehicle/deployment strategy combinations were similarly computed and are summarized in Table 4-1.

TABLE 4-1

POTENTIAL YEARLY SAVINGS OF FUEL IN GALLONS

Vehicle Type	DS I	DS II
Carryall	8,748	12,642
Station Wagon	25,990	26,826

It must be remembered that these potential results were a composite of the effects of the vehicle/deployment strategies, the miles-per-gallon rating of the vehicle, and the development of the shortest authorized routes of travel. These potential savings must be tempered by a recognition that these potential savings are based on day-to-day use of the shortest authorized routes of travel and the transporting of only the required LCF personnel. Severe weather, gravel and paved road conditions, and additional LCF personnel (training crews, standardization crews, visitors, etc.) may all have negative impacts on the potential savings of any of the four acceptable vehicle/deployment strategy combinations. Thus, the flexibility to meet these contingencies may prevent the actual attainment of the estimated potential savings for any vehicle/deployment strategy combination that would be used in conjunction with the shortest authorized routes of travel. However, following the shortest authorized routes of travel as often as possible will reduce overall fuel consumption.

Recommendations for Implementation

The next step in the comparison of the present MCC routing system with the four acceptable alternatives should be to independently implement the four alternatives on a trial basis to see if practical application of the procedures described in this study perform in the same manner as the study predicts. Because Minot AFB's forty-seven carryalls (7) are enough to effect wing-wide implementation of the Carryall/DS I or Carryall/DS II combinations, practical tests of these MCC routing systems over the shortest authorized routes could be done throughout the entire wing or just with a segment (such as a squadron) of the wing. Because Minot AFB's eight station wagons (7) do not meet the needs of eleven vehicles for the Station Wagon/DS I or Station Wagon/DS II combinations, the practical tests of these MCC routing systems over the shortest authorized routes could be done through rotating segments that will aggregate to a test of the entire wing. If the results correspond to the research results, all available compact station wagons could be dedicated to the routing of MCCs, with the less efficient carryalls picking up the vacated transportation responsibilities, and additional compact station wagons could be purchased as existing vehicle assets required replacement.

Recommendations for Further Study

Although the SAC study is investigating many related factors such as alternative fuels, alternative vehicle types, and MCC "quality of life" factors, several areas appear to be logical extensions of this research. An increase in the number of passengers carried in a vehicle might reduce the total number of miles and the number of vehicles required. This might be achieved through the use of cargo roof racks or other vehicle modifications. An example of the potential of this area of study can be seen by modifying the compact station wagon to carry 6 personnel. The compact station wagon could then follow the same routes as the Carryall and the fuel efficiency ratios for DS I, DS II, and DS III would drop to 1.51 gal/pax, 1.37 gal/pax, and 2.74 gal/pax respectively. These lower fuel efficiency ratios would enhance the fuel savings to 28,471 gallons, 30,561 gallons and 10,559 gallons for DS I, DS II, and DS III.

Another area that could be investigated is the dispatching of Security Police personnel with the other LCF personnel. This would be another excellent means to cut down on overall miles traveled, fuel consumption, and vehicle requirements. Since Security Police personnel transit to the same LCFs as the MCCs, FMs, and cooks, the potential for additional wing savings might occur by coordinating the movement of all required LCF personnel in the same vehicle rather than continuing the present system of multiple vehicle visits to the same LCF.

A third potential area for investigation is the concept of a vehicle mix. While the SAC study encompasses the concept of vehicle mix with new vehicles, a mix of the vehicles presently on hand should be analyzed to see if further economies can be achieved by using the best vehicle for each particular situation or network.

A fourth area that may be investigated is an elimination of the requirements for facility manager and cook changeover by squadrons. For example, after the present research was well underway, it came to our attention that the 91 SMW changed the present deployment strategy, which was used for comparison purposes in our research, to remove squadron integrity in facility manager and cook changeovers. The authors recognize that the resultant increased utilization of the carryall with six passengers can save gasoline resources, but that use of the same routes that were in effect as of 31 August 1979 does not result in maximizing fuel savings. It is recommended that this recent change to the present MCC routing system at Minot AFB be analyzed in conjunction with use of the shortest authorized routes developed in this study to determine if further savings can be achieved.

A final area for potential investigation is to change the 24-hour alert tour to a 48 or 72-hour alert tour. A decrease in fuel consumption would directly correspond with these longer alerts. For example, an increase to a 48-hour alert tour would cut gasoline consumption for comparable MCC routing systems by one-half, while an increase to a 72-hour alert tour would cut gasoline consumption by two-thirds. Such changes in dispatch procedures would further enhance the results identified in this research. However, the reduced gasoline requirements would have to be weighed against behavioral and physical factors such as crew member morale and fatigue to determine if the benefits of such a change outweigh the costs.

As stated in the scope, this study attempted to look at the short-term problem of using the existing vehicle types at Minot AFB in the most efficient manner possible. Through the development of the shortest authorized routes of travel and fifteen vehicle/deployment strategy combinations, this study has demonstrated the potential for fuel savings of up to 53% in routing MCCs to the LCFs at Minot AFB, North Dakota. In addition, the development of the shortest authorized routes of travel should complement and enhance the findings of the SAC study by providing the shortest distances for any new or modified vehicles in the future.

The potential for savings at each missile base exists, and the methodology developed in this study appears to be capable of implementation at any of them. Any opportunity for potential fuel savings cannot be overlooked, and other SAC missile bases should consider applying this methodology in an effort to reduce their gallons per passenger fuel efficiency ratio.

APPENDIXES

APPENDIX A

COMPUTER CODE FOR HEIDLER'S CLOSED CIRCUIT PROBLEM (19)

```
      CHARACTER FLNAME*50
      COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
      COMMON PEN(18,18,30),J1,J2,L
       COMMON N(50),IS
      COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
      COMMON NX(40),IP
   500 NX(1)=0
      IS=0
      DFDR=0.0;INDX=1;DFDR1=0.0;MS=0
       M=1
       SUM(M)=0.0
        PRINT 50
    50  FORMAT(//,5X,"HOW MANY ROWS AND COLUMNS?")
      READ, K1,L1
       KEND=K1
       LEND=L1
    100 PRINT 110
    110 FORMAT(//,"WHAT IS THE MODE OF THE DATA INPUT (TELETYPE=1)"
&          "(PERMENENT FILE=2, HALT=3)")
        READ, IANS
        IFC=05
       IF(IANS.LT.1.OR.IANS.GT.3)GO TO 100
        IF(IANS.EQ.1)GO TO 130
        IF(IANS.EQ.3)GO TO 245
        PRINT 120
    120 FORMAT(//)
        IFC=15
        PRINT, "INPUT DATA FILE NAME IN THE FORM   USERID/FILENAME;"
        PRINT, "END YOUR INPUT WITH A SEMICOLON(;)"
        PRINT, "EXAMPLE   75B/INPUT;"
        PRINT 120
        READ, FLNAME
        CALL ATTACH(15,FLNAME,1,0,IOK,)
        DO 90 K=1,K1
        READ(IFC,1110)LN,(T(K,L,M),L=1,L1)
    90  CONTINUE
    1110 FORMAT(V)
        GO TO 25
    130 PRINT 51
    51  FORMAT(//,5X,"ENTER MATRIX BY ROWS AFTER=")
        READ, ((T(K,L,M),L=1,L1),K=1,K1)
     25 IF(INDX.EQ.2)CALL RESET
        IF(INDX.EQ.3)GO TO 45
    14 DO 1 K=1,K1
        DO 2 L=1,L1
        IF(K.EQ.L)T(K,L,M)=1000000000.0
     2  CONTINUE
        TEMP(K)=T(K,1,M)
       DO 3 J=1,L1
       IF(T(K,J,M).GE.1000000.)GO TO 3
```

```
      IF(T(K,J,M).LE.TEMP(K))TEMP(K)=T(K,J,M)
    3 CONTINUE
     IF(TEMP(K).GE.1000000.)TEMP(K)=0.0
    1 CONTINUE
      DO 4 K=1,K1
      DO 5 L=1,L1
     IF(T(K,L,M).GE.1000000.)GO TO 5
      IF(K.EQ.L)GO TO 5
     T(K,L,M)=T(K,L,M)-TEMP(K)
    5 CONTINUE
    4 CONTINUE
      DO 6 L=1,L1
      TEMP2(L)=T(1,L,M)
     DO 7 K=1,K1
     IF(T(K,L,M).GE.1000000.)GO TO 7
      IF(L.EQ.K)GO TO 7
      IF(T(K,L,M).LE.TEMP2(L))TEMP2(L)=T(K,L,M)
    7 CONTINUE
     IF(TEMP2(L).GE.1000000.)TEMP2(L)=0.0
    6 CONTINUE
      DO 8 L=1,L1
     DO 9 K=1,K1
     IF(T(K,L,M).GE.1000000.)GO TO 9
      IF(L.EQ.K)GO TO 9
      T(K,L,M)=T(K,L,M)-TEMP2(L)
    9 CONTINUE
    8 CONTINUE
   10 FORMAT(5(F12.2,2X))
      DO 11 K=1,K1
      SUM(M)=SUM(M)+TEMP(K)
   11 CONTINUE
     DO 12 L=1,L1
      SUM(M)=SUM(M)+TEMP2(L)
   12 CONTINUE
     IF(INDX.EQ.2.AND.SUM(M).GT.DFDR)GO TO 25
     IF(INDX.EQ.2)GO TO 49
      PRINT 13,SUM(M)
   13 FORMAT(///,15X,"THE LOWER BOUND IS ",F7.2)
   49 CALL PENLTY
     IF(INDX.EQ.2)GO TO 46
      SUM(M+1)=SUM(M)+PEN(J1,J2,M)
     PRINT 24,J1,J2
   24 FORMAT(//,10X,"TAKE ROUTE ",I2," TO ",I2)
      PEN(J1,J2,M+1)=PEN(J1,J2,M)
      DO 18 K=1,K1
      DO 19 L=1,L1
     T(K,L,M+1)=T(K,L,M)
   19 CONTINUE
   18 CONTINUE
   46 CALL XOUT
      IF(KEND.LT.2.AND.LEND.LT.2)GO TO 20
```

```
  KEND=KEND-1
  LEND=LEND-1
    GO TO 14
20 IF(INDX.LT.2)GO TO 40
   DFDR1=SUM(M)
   DO 27 ID=1,IS,2
     PRINT 13,SUM(IM+2+ID)
28 FORMAT(//,10X,"TAKE ROUTE ",I2," TO ",I2)
   PRINT 28,N(ID),N(ID+1)
27 CONTINUE
40 DO 21 K=1,K1
    DO 22 L=1,L1
    IF(T(K,L,M).GE.1000000000.)GO TO 22
23  PRINT 24,K,L
 22  CONTINUE
 21  CONTINUE
   DFDR=SUM(M)
   IF(INDX.GE.2)GO TO 38
   ID1=IS+1
   ID=ID1+IS-1
   IS=1
   DO 35 IL=ID1,ID
   N(IL)=N(IS)
   IS=IS+1
35 CONTINUE
   IF(INDX.LE.1)IM=M
38 INDX=2
    CALL RTSUM
   GO TO 25
45 IF(DFDR1.LE.0.0)GO TO 41
   GO TO 26
41 PRINT 42
42 FORMAT(///,10X,"NO BETTER SOLUTION FOUND")
26  PRINT 43
43  FORMAT(////,10X,"THIS IS THE FINAL SOLUTION")
    CALL DETACH(15,IOK,)
GO TO 500
245 STOP
   END
   SUBROUTINE RESET
   COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
   COMMON PEN(18,18,30),J1,J2,L
  COMMON N(50),IS
   COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
  COMMON NX(40),IP
    M1=IM+3
   M=MS+2
    IF(M.EQ.2)PRINT 7
 7  FORMAT(///,15X,"BEGINNING LEFT NODE SEARCH")
    IF(SUM(M).GT.DFDR)INDX=3
    IF(M.EQ.M1-2)INDX=3
```

```
      IF(INDX.GE.3)GO TO 3
     SUM(M1)=SUM(M-1)
     KEND=K1
      MS=M
     LEND=L1
      DO 1 K=1,K1
      DO 2 L=1,L1
      T(K,L,M1)=T(K,L,M)
    2 CONTINUE
    1 CONTINUE
      IS=M-2
       IF(IS.GT.2)JJ=JJ+1
       IF(IS-2)5,5,6
    6  IT=ID1
       DO 4 KK=1,M-JJ
       N(KK)=N(IT)
       IT=IT+1
    4  CONTINUE
    5  IF(IS.EQ.2)JJ=3
       IF(IS.EQ.2)N(1)=N(ID1)
       IF(IS.EQ.2)IS=1
       M=M1
    MT=MS
     IF(IS.EQ.0)MS=100000
      CALL PENLTY
     T(J1,J2,M)=1000000000.
    MS=MT
   3  RETURN
      END
      SUBROUTINE TRACX
      COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
      COMMON PEN(18,18,30),J1,J2,L
     COMMON N(50),IS
     COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
     COMMON NX(40),IP
      TEMP2(L)=1000000.
      DO 2 J3=1,K1
      IF(J3.EQ.J1.AND.L.EQ.J2)GO TO 2
      IF(T(J3,L,M).LE.TEMP2(L))TEMP2(L)=T(J3,L,M)
   2  CONTINUE
      IF(KEND.LT.3)GO TO 3
      IF(TEMP2(L).GE.1000000.)TEMP2(L)=0.0
   3  RETURN
      END
     SUBROUTINE ROSCAN
      COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
      COMMON PEN(18,18,30),J1,J2,L
     COMMON N(50),IS
     COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
     COMMON NX(40),IP
      TEMP(J1)=1000000.
```

```
      DO 2 J4=1,L1
      IF(T(J1,J4,M).GE.1000000.)GO TO 2
      IF(J1.EQ.J4)GO TO 2
      IF(J4.EQ.J2)GO TO 2
     IF(T(J1,J4,M).LE.TEMP(J1))TEMP(J1)=T(J1,J4,M)
2     CONTINUE
     IF(KEND.LT.3)GO TO 1
     IF(TEMP(J1).GE.1000000.)TEMP(J1)=0.0
1     CONTINUE
      RETURN
      END
      SUBROUTINE PENLTY
      COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
      COMMON PEN(18,18,30),J1,J2,L
     COMMON N(50),IS
    COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
     COMMON NX(40),IP
      DO 1 K=1,K1
      DO 2 L=1,L1
      PEN(K,L,M)=-1.
      IF(K.EQ.L)GO TO 2
     IF(T(K,L,M).GE.1000000.)GO TO 2
      IF(T(K,L,M).LE.0.0)GO TO 3
      GO TO 2
3     J1=K
      J2=L
      CALL TRACX
     CALL ROSCAN
      PEN(J1,J2,M)=TEMP(J1)+TEMP2(L)
2     CONTINUE
1     CONTINUE
      PTEMP=PEN(1,2,M)
      DO 4 K=1,K1
      DO 5 L=1,L1
     IF(T(K,L,M).GE.1000000.)GO TO 5
      IF(K.EQ.L)GO TO 5
      IF(PEN(K,L,M).LT.0.0)GO TO 5
      IF(PEN(K,L,M).GE.PTEMP)GO TO 6
      GO TO 5
6     PTEMP=PEN(K,L,M)
      J1=K
      J2=L
5     CONTINUE
4     CONTINUE
     IF(MS.GT.10000)GO TO 7
     IS=IS+1
     N(IS)=J1
     IS=IS+1
      N(IS)=J2
      PEN(J1,J2,M)=PTEMP
7    RETURN
```

```
      END
       SUBROUTINE XOUT
       COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
       COMMON PEN(18,18,30),J1,J2,L
      COMMON N(50),IS
     COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
      COMMON NX(40),IP
       M=M+2
       DO 1 K=1,K1
       DO 2 L=1,L1
       T(K,L,M)=T(K,L,M-2)
       IF(K.EQ.J1)T(K,L,M)=1000000000.
       IF(L.EQ.J2)T(K,L,M)=1000000000.
     2 CONTINUE
     1 CONTINUE
      CALL DBACK
     5  SUM(M)=SUM(M-2)
       RETURN
       END
        SUBROUTINE DBACK
       COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
       COMMON PEN(18,18,30),J1,J2,L
      COMMON N(50),IS
       COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
       COMMON NX(40),IP
        IND=IS
        KT=IND-1
        IF(NX(1).GT.0)GO TO 7
        IF(IS-2)17,17,19
    19  IS=1
        IP=1
        I=1
    21  IF(N(IND).EQ.N(IS))GO TO 3
        IF(IS.EQ.KT)GO TO 1
        IS=IS+2
        GO TO 21
     1  CONTINUE
        IS=2
    22  IF(N(KT).EQ.N(IS))GO TO 4
        IF(IS.EQ.IND)GO TO 2
        IS=IS+2
        GO TO 22
     2  CONTINUE
        GO TO 17
     3  NX(1)=N(KT)
        NX(2)=N(IND)
        NX(3)=N(IS+1)
        I=3
        GO TO 7
     4  NX(1)=N(IS-1)
        NX(2)=N(IS)
```

```
      NX(3)=N(IND)
      I=3
    7 IS=1
   23 IF(N(IS).EQ.NX(I))GO TO 12
      IF(IS.EQ.KT)GO TO 6
      IS=IS+2
      GO TO 23
    6 CONTINUE
      GO TO 13
   12 I=I+1
      NX(I)=N(IS+1)
      IF(NX(I).EQ.NX(1))GO TO 17
      GO TO 7
   13 IS=2
   24 IF(N(IS).EQ.NX(1))GO TO 14
      IF(IS.EQ.IND)GO TO 8
      IS=IS+2
      GO TO 24
    8 CONTINUE
      IF(IP.EQ.I)GO TO 17
      GO TO 15
   14 IK=I
      I=I+1
   25 NX(I)=NX(I-1)
      I=I-1
      IF(I.EQ.1)GO TO 9
      GO TO 25
    9 CONTINUE
      NX(1)=N(IS-1)
      I=IK+1
      GO TO 7
   15 IK=I
      K5=NX(IK)
      I=I-1
   16 K4=NX(I)
      IF(I.EQ.1.AND.KEND.LE.2)GO TO 18
      T(K5,K4,M)=1000000000.
      IF(I.EQ.1)GO TO 18
      I=I-1
      GO TO 16
    18 KS=I
      I=IK
   17 IS=IND
      IP=I
      K5=N(IS)
      K4=N(IS-1)
      IF(KEND.EQ.1)GO TO 20
      T(K5,K4,M)=1000000000.
   20 RETURN
      END
     SUBROUTINE RTSUM
```

```
      COMMON TEMP2(20),TEMP(20),T(18,18,30),SUM(50),K1,L1,M
      COMMON PEN(18,18,30),J1,J2,L
     COMMON N(50),IS
      COMMON KEND,LEND,MS,IM,INDX,ID1,ID,DFDR
      COMMON NX(40),IP
       PRINT 1
 1     FORMAT(////,30X,"ROUTE SEQUENCE")
       PRINT 2
 2     FORMAT(///)
       PRINT 3,(NX(LP),LP=1,IP)
 3     FORMAT(18(I2,2X))
       DO 4 LX=1,IP
       NX(LX)=0
 4     CONTINUE
       RETURN
       END
```

APPENDIX B

91ST SMW TRANSPORT-ERECTOR ROUTE MAP

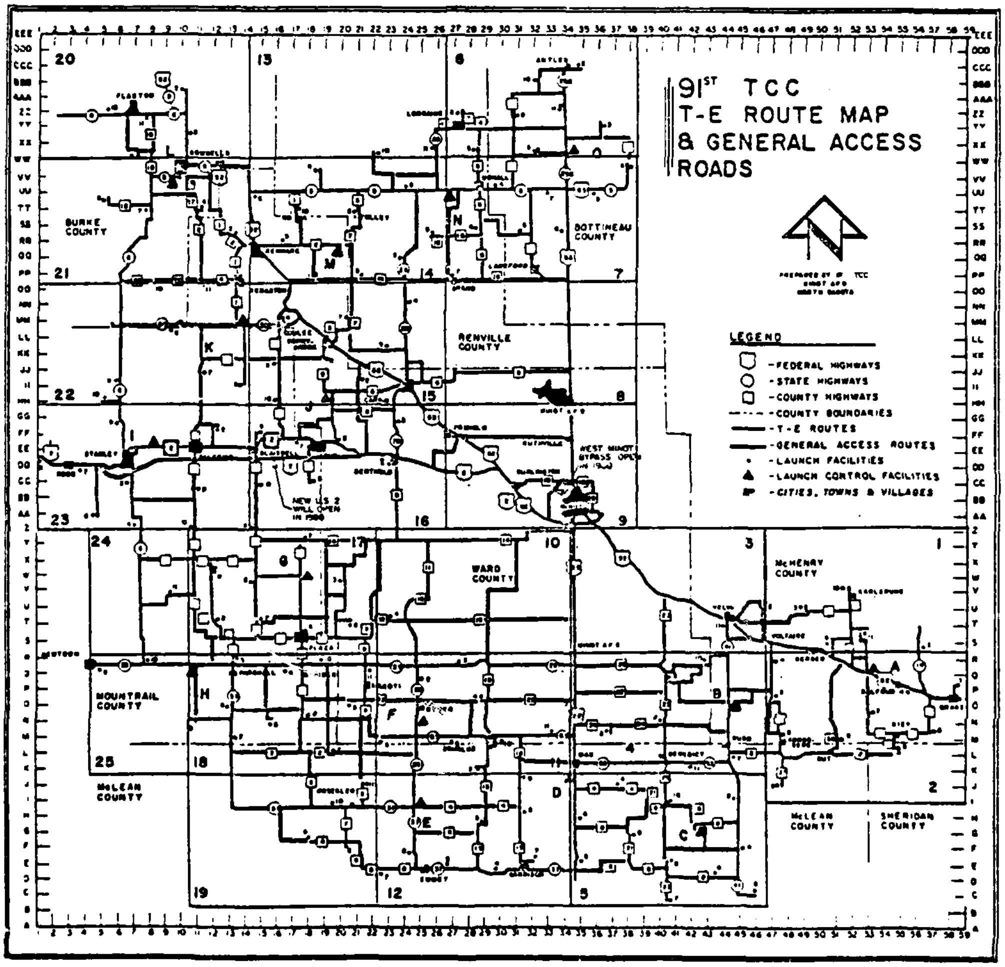

91ST TCC
T-E ROUTE MAP
& GENERAL ACCESS
ROADS
LEGEND
-FEDERAL HIGHWAYS
-STATE HIGHWAYS
-COUNTY HIGHWAYS
-COUNTY BOUNDARIES
-T-E ROUTES
-GENERAL ACCESS ROUTES
-LAUNCH FACILITIES
-LAUNCH CONTROL FACILITIES
-CITIES, TOWNS & VILLAGES
BURKE COUNTY
BOTTINEAU COUNTY
RENVILLE COUNTY
WARD COUNTY
McHENRY COUNTY
MOUNTRAIL COUNTY
McLEAN COUNTY
SHERIDAN COUNTY
WEST MINOT BYPASS OPEN
NEW U.S. 2 WILL OPEN IN 1986

Figure B-1

APPENDIX C

SHORTEST AUTHORIZED ROUTES

TABLE C-1

SHORTEST AUTHORIZED ROUTES FROM THE SMSB

Destination	Route of Travel							Mileage
SMSB								00.00
AØ1	83	52						58.00
BØ1	83	52	41					50.50
CØ1	83	52	23	6				60.25
DØ1	83							46.50
EØ1	83	23	28					67.25
FØ1	83	23	28					57.25
GØ1	83	14	3					51.50
HØ1	83	14	3	23				73.75
IØ1	83	8	2 to Palermo			Old 2		55.50
JØ1	83	6	8					32.00
KØ1	83	6	52	50	1			44.25
LØ1	83	6	52	2	1	17	8	63.75
MØ1	83	6	28	16	7	2		46.50
NØ1	83	5						36.50
OØ1	83	256						28.00

TABLE C-2

SHORTEST AUTHORIZED ROUTES FROM AØ1

Destination	Route of Travel	Mileage
SMSB	52 83	58.00
AØ1		00.00
BØ1	52 27 Road to BØ5 41	25.25
CØ1	52 33 2 41 6	40.25
DØ1	52 33 2 41 53 83	46.00
EØ1	52 33 2 41 53 15 4 28	67.50
FØ1	52 27 Road by BØ5 41 Road by BØ9 22 83 22 28	63.50
GØ1	52 Cut-off by Electric plant 41 20 23 3	73.25
HØ1	52 Cut-off by Electric plant 41 20 23	75.75
IØ1	52 2 to Palermo Old 2	91.50
JØ1	52 2 Old 2 8	70.00
KØ1	52 50	86.50
LØ1	52 2 1 17 8	106.25
MØ1	52 7 2	90.00
NØ1	52 28 5	92.00
OØ1	52 83 256	86.00

TABLE C-3

SHORTEST AUTHORIZED ROUTES FROM BØ1

Destination	Route of Travel	Mileage
SMSB	41 52 83	50.50
AØ1	41 Road to BØ5 27 52	25.25
BØ1		00.00
CØ1	41 6	19.00
DØ1	41 53 83	24.50
EØ1	41 24 83 53 28	46.75
FØ1	41 24 83 53 28	41.25
GØ1	41 Road from BØ1 to BØ9 23 20 23 3	63.00
HØ1	41 Road from BØ1 to BØ9 23 20 23	65.50
IØ1	41 52 2 to Palermo Old 2	84.00
JØ1	41 52 2 Old 2 8	62.50
KØ1	41 52 50	79.00
LØ1	41 52 2 1 17 8	98.75
MØ1	41 52 7 2	82.50
NØ1	41 52 28 5	84.50
OØ1	41 52 83 256	78.50

TABLE C-4

SHORTEST AUTHORIZED ROUTES FROM CØ1

Destination	Route of Travel								Mileage
SMSB	6	23	52	83					60.25
AØ1	6	41	2	33	52				40.25
BØ1	6	41							19.00
CØ1									00.00
DØ1	6	21	4	83					18.50
EØ1	6	21	4	83	Max	15	4	28	43.50
FØ1	6	21	4	83	53	28			44.00
GØ1	6	21	4	83	23	3			72.50
HØ1	6	21	4	83	23				75.00
IØ1	6	23	52	2 to	Palermo		Old 2		96.00
JØ1	6	23	52	2	Old 2		8		74.50
KØ1	6	23	52	50					91.00
LØ1	6	23	52	2	1	17	8		110.75
MØ1	6	23	52	7	2				94.50
NØ1	6	23	52	28	5				96.50
OØ1	6	23	52	83	256				90.50

TABLE C-5

SHORTEST AUTHORIZED ROUTES FROM DØ1

Destination	Route of Travel						Mileage
SMSB	83						46.50
AØ1	83	53	41	2	33	52	46.00
BØ1	83	53	41				24.50
CØ1	83	4	21	6			18.50
DØ1							00.00
EØ1	83	Max	15	4	28		25.00
FØ1	83	53	28				25.50
GØ1	83	23	3				54.00
HØ1	83	23					56.50
IØ1	83	52	2 to Palermo		Old 2		81.50
JØ1	83	52	2	Old 2	8		60.00
KØ1	83	52	50				98.00
LØ1	83	52	2	1	17	8	96.25
MØ1	83	52	7	2			80.00
NØ1	83	52	28	5			81.75
OØ1	83	256					74.50

TABLE C-6

SHORTEST AUTHORIZED ROUTES FROM EØ1

Destination	Route of Travel	Mileage
SMSB	28 23 83	67.25
AØ1	28 4 15 53 41 2 33 52	67.50
BØ1	28 53 83 24 41	46.75
CØ1	28 4 15 Max 83 4 21 6	43.50
DØ1	28 4 15 Max 83	25.00
EØ1		00.00
FØ1	28	10.00
GØ1	28 23 3	38.25
HØ1	28 23	40.50
IØ1	28 23 3 GØ1 GØ8 2 to Palermo Old 2	69.50
JØ1	28 16 18 9 14 9 2 Old 2 8	60.25
KØ1	28 23 3 GØ1 GØ8 2 Old 2 Coulee 50	80.00
LØ1	28 23 3 GØ1 GØ8 2 Old 2 50 1 4 2 17 8	103.00
MØ1	28 16 18 9 14 9 28 16 7 2	79.25
NØ1	28 16 18 16 11 14 9 28 5	81.25
OØ1	28 53 83 256	95.50

TABLE C-7

SHORTEST AUTHORIZED ROUTES FROM FØ1

Destination	Route of Travel	Mileage
SMSB	28 23 83	57.25
AØ1	28 22 83 22 Road by BØ9 41 Road by BØ5 27 52	63.50
BØ1	28 53 83 24 41	41.25
CØ1	28 53 83 4 21 6	44.00
DØ1	28 53 83	25.50
EØ1	28	10.00
FØ1		00.00
GØ1	28 23 3	28.25
HØ1	28 23	30.50
IØ1	28 23 3 GØ1 GØ8 2 to Palermo Old 2	59.50
JØ1	28 16 18 9 14 9 2 Old 2 8	50.25
KØ1	28 23 3 GØ1 GØ8 2 Old 2 Coulee 50	70.00
LØ1	28 23 3 GØ1 GØ8 2 Old 2 50 1 4 2 17 8	93.00
MØ1	28 16 18 9 14 9 28 16 7 2	69.25
NØ1	28 16 18 16 11 14 9 28 5	71.25
OØ1	28 23 83 256	85.25

TABLE C-8

SHORTEST AUTHORIZED ROUTES FROM GØ1

Destination	Route of Travel	Mileage
SMSB	3 14 83	51.50
AØ1	3 23 20 41 Cut-off by electric plant 52	73.25
BØ1	3 23 20 23 Road from BØ9 to BØ1 41	63.00
CØ1	3 23 (By BØ9) 83 4 21 6	72.50
DØ1	3 23 83	54.00
EØ1	3 23 28	38.25
FØ1	3 23 28	28.25
GØ1		00.00
HØ1	3 23	22.25
IØ1	GØ8 2 to Palermo Old 2	31.25
JØ1	GØ8 2 Old 2 8	33.00
KØ1	GØ8 2 Old 2 to Coulee 50	41.75
LØ1	GØ8 2 Old 2 50 1 4 2 17 8	64.75
MØ1	GØ8 2 Old 2 to Coulee 52 16 Road by MØ8 2	52.00
NØ1	3 14 9 28 5	60.00
OØ1	3 14 83 256	79.50

TABLE C-9

SHORTEST AUTHORIZED ROUTES FROM HØ1

Destination	Route of Travel	Mileage
SMSB	23 3 14 83	73.75
AØ1	23 20 41 Cut-off by electric plant 52	75.75
BØ1	23 20 (By BØ9) 23 Road from BØ9 to BØ1 41	65.50
CØ1	23 83 4 21 6	75.00
DØ1	23 83	56.50
EØ1	23 28	40.50
FØ1	23 28	30.50
GØ1	23 3	22.25
HØ1		00.00
IØ1	23 Road by G1Ø Old 2	35.75
JØ1	23 Road by HØ3 and GØ8 2 to Tagus Old 2 8	46.75
KØ1	23 Road to Palermo 50	46.50
LØ1	23 8	66.50
MØ1	23 Road by HØ3 & GØ8 Road to Coulee 52 16 Road by MØ8 2	68.75
NØ1	23 3 14 9 28 5	82.25
OØ1	23 83 256	101.00

TABLE C-10

SHORTEST AUTHORIZED ROUTES FROM IØ1

Destination	Route of Travel	Mileage
SMSB	Old 2 to Palermo 2 8 83	55.50
AØ1	Old 2 to Palermo 2 52	91.50
BØ1	Old 2 to Palermo 2 52 41	84.00
CØ1	Old 2 to Palermo 2 52 23 6	96.00
DØ1	Old 2 to Palermo 2 52 83	81.50
EØ1	Old 2 to Palermo 2 GØ8 GØ1 3 23 28	69.50
FØ1	Old 2 to Palermo 2 GØ8 GØ1 3 23 28	59.50
GØ1	Old 2 to Palermo 2 GØ8	31.25
HØ1	Old 2 Road by G1Ø 23	35.75
IØ1		00.00
JØ1	Old 2 8	23.00
KØ1	Old 2 Road by KØ7 50	22.75
LØ1	Old 2 8	40.25
MØ1	Old 2 Road to Coulee 52 16 Road by MØ8 2	41.75
NØ1	Old 2 Road to Coulee 52 16 28 5	61.00
OØ1	Old 2 Road to Coulee 52 16 28 5 256	79.00

TABLE C-11

SHORTEST AUTHORIZED ROUTES FROM JØ1

Destination	Route of Travel	Mileage
SMSB	8 6 83	32.00
AØ1	8 Old 2 2 52	70.00
BØ1	8 Old 2 2 52 41	62.50
CØ1	8 Old 2 2 52 23 6	74.50
DØ1	8 Old 2 2 52 83	60.00
EØ1	8 Old 2 9 14 9 18 16 28	60.25
FØ1	8 Old 2 9 14 9 18 16 28	50.25
GØ1	8 Old 2 2 GØ8	33.00
HØ1	8 Old 2 to Tagus 2 Road by GØ8 & HØ3 23	46.75
IØ1	8 Old 2	23.00
JØ1		00.00
KØ1	8 6 5 50	21.00
LØ1	8 6 5 52 2 1 17 8	40.00
MØ1	8 6 5 7 2	23.50
NØ1	8 6 28 5	36.50
OØ1	8 6 28 5 256	54.50

AD-A087 498 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 16/1
THE FUEL EFFICIENT MISSILE COMBAT CREW ROUTING NETWORK.(U)
JUN 80 E O JACQUES, M G WOOLLEY
UNCLASSIFIED AFIT-LSSR-19-80 NL

2 OF 2
AD A
087498

END
DATE
FILMED
9-80
DTIC

TABLE C-11

SHORTEST AUTHORIZED ROUTES FROM JØ1

Destination	Route of Travel	Mileage
SMSB	8 6 83	32.00
AØ1	8 Old 2 2 52	70.00
BØ1	8 Old 2 2 52 41	62.50
CØ1	8 Old 2 2 52 23 6	74.50
DØ1	8 Old 2 2 52 83	60.00
EØ1	8 Old 2 9 14 9 18 16 28	60.25
FØ1	8 Old 2 9 14 9 18 16 28	50.25
GØ1	8 Old 2 2 GØ8	33.00
HØ1	8 Old 2 to Tagus 2 Road by GØ8 & HØ3 23	46.75
IØ1	8 Old 2	23.00
JØ1		00.00
KØ1	8 6 5 50	21.00
LØ1	8 6 5 52 2 1 17 8	40.00
MØ1	8 6 5 7 2	23.50
NØ1	8 6 28 5	36.50
OØ1	8 6 28 5 256	54.50

TABLE C-12

SHORTEST AUTHORIZED ROUTES FROM KØ1

Destination	Route of Travel	Mileage
SMSB	1 50 52 6 83	44.25
AØ1	50 52	86.50
BØ1	50 52 41	79.00
CØ1	50 52 23 6	91.00
DØ1	50 52 83	98.00
EØ1	50 Coulee Old 2 2 GØ8 GØ1 3 23 28	80.00
FØ1	50 Coulee Old 2 2 GØ8 GØ1 3 23 28	70.00
GØ1	50 Coulee Old 2 2 GØ8	41.75
HØ1	50 Road to Palermo 23	46.50
IØ1	50 Road by KØ7 Old 2	22.75
JØ1	50 5 6 8	21.00
KØ1	.	00.00
LØ1	1 4 2 17 8	23.25
MØ1	1 2	19.00
NØ1	1 2 3 5	38.00
OØ1	1 52 5 256	56.00

TABLE C-13

SHORTEST AUTHORIZED ROUTES FROM LØ1

Destination	Route of Travel	Mileage
SMSB	8 17 1 2 52 6 83	63.75
AØ1	8 17 1 2 52	106.25
BØ1	8 17 1 2 52 41	98.75
CØ1	8 17 1 2 52 23 6	110.75
DØ1	8 17 1 2 52 83	96.25
EØ1	8 17 2 4 1 50 Old 2 2 GØ8 GØ1 3 23 28	103.00
FØ1	8 17 2 4 1 50 Old 2 2 GØ8 GØ1 3 23 28	93.00
GØ1	8 17 2 4 1 50 Old 2 2 GØ8	64.75
HØ1	8 23	66.50
IØ1	8 Old 2	40.25
JØ1	8 17 1 2 52 5 6 8	40.00
KØ1	8 17 2 4 1	23.25
LØ1		00.00
MØ1	8 17 1 2	25.00
NØ1	8 5 52 5	34.50
OØ1	8 5 52 5 256	52.50

TABLE C-14

SHORTEST AUTHORIZED ROUTES FROM MØ1

Destination	Route of Travel	Mileage
SMSB	2 7 16 28 6 83	46.50
AØ1	2 7 52	90.00
BØ1	2 7 52 41	82.50
CØ1	2 7 52 23 6	96.50
DØ1	2 7 52 83	80.00
EØ1	2 7 16 28 9 14 9 18 16 28	79.25
FØ1	2 7 16 28 9 14 9 18 16 28	69.25
GØ1	2 Road by MØ8 16 52 Coulee Old 2 2 GØ8	52.00
HØ1	2 Road by MØ8 16 52 Road to Coulee 2 Road by GØ8 & HØ3 23	68.75
IØ1	2 Road by MØ8 16 52 Road to Coulee	41.75
JØ1	2 7 5 6 8	23.50
KØ1	2 1	19.00
LØ1	2 1 17 8	25.00
MØ1		00.00
NØ1	2 3 5	19.00
OØ1	2 3 5 256	37.00

TABLE C-15

SHORTEST AUTHORIZED ROUTES FROM NØ1

Destination	Route of Travel	Mileage
SMSB	5 83	36.50
AØ1	5 28 52	92.00
BØ1	5 28 52 41	84.50
CØ1	5 28 52 23 6	96.50
DØ1	5 28 52 83	81.75
EØ1	5 28 9 14 11 16 18 16 28	81.25
FØ1	5 28 9 14 11 16 18 16 28	71.25
GØ1	5 28 9 14 3	60.00
HØ1	5 28 9 14 3 23	82.25
IØ1	5 28 16 52 Road to Coulee Old 2	61.00
JØ1	5 28 6 8	36.50
KØ1	5 3 2 1	38.00
LØ1	5 52 5 8	34.50
MØ1	5 3 2	19.00
NØ1		00.00
OØ1	5 256	18.00

TABLE C-16

SHORTEST AUTHORIZED ROUTES FROM OØ1

Destination	Route of Travel	Mileage
SMSB	256 83	28.00
AØ1	256 83 52	86.00
BØ1	256 83 52 41	78.50
CØ1	256 83 52 23 6	90.50
DØ1	256 83	74.50
EØ1	256 83 53 28	95.50
FØ1	256 83 23 28	85.25
GØ1	256 83 14 3	79.50
HØ1	256 83 23	101.00
IØ1	256 5 28 16 52 Road to Coulee Old 2	79.00
JØ1	256 5 28 6 8	54.50
KØ1	256 5 52 1	56.00
LØ1	256 5 52 5 8	52.50
MØ1	256 5 3 2	37.00
NØ1	256 5	18.00
OØ1		00.00

APPENDIX D

SHORTEST AUTHORIZED ROUTE DISTANCES

TABLE D-1

SUMMARY OF SHORTEST AUTHORIZED ROUTE DISTANCES IN MILES

	SMSB	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
SMSB	00.00	58.00	50.50	60.25	46.50	67.25	57.25	51.50	73.75	55.50	32.00	44.25	63.75	46.50	36.50	28.00
A	58.00	00.00	25.25	40.25	46.00	67.50	63.50	73.25	75.75	91.50	70.00	86.50	106.25	90.00	92.00	86.00
B	50.50	25.25	00.00	19.00	24.50	46.75	41.25	63.00	65.50	84.00	62.50	79.00	98.75	82.50	84.50	78.50
C	60.25	40.25	19.00	00.00	18.50	43.50	44.00	72.50	75.00	96.00	74.50	91.00	110.75	94.50	96.50	90.50
D	46.50	46.00	24.50	18.50	00.00	25.00	25.50	54.00	56.50	81.50	60.00	98.00	96.25	80.00	81.75	74.50
E	67.25	67.50	46.75	43.50	25.00	00.00	10.00	38.25	40.50	69.50	60.25	80.00	103.00	79.25	81.25	95.50
F	57.25	63.50	41.25	44.00	25.50	10.00	00.00	28.25	30.50	59.50	50.25	70.00	93.00	69.25	71.25	85.25
G	51.50	73.25	63.00	72.50	54.00	38.25	28.25	00.00	22.25	31.25	33.00	41.75	64.75	52.00	60.00	79.50
H	73.75	75.75	65.50	75.00	56.50	40.50	30.50	22.25	00.00	35.75	46.75	46.50	66.50	68.75	82.25	101.00
I	55.50	91.50	84.00	96.00	81.50	69.50	59.50	31.25	35.75	00.00	23.00	22.75	40.25	41.75	61.00	79.00
J	32.00	70.00	62.50	74.50	60.00	60.25	50.25	33.00	46.75	23.00	00.00	21.00	40.00	23.50	36.50	54.50
K	44.25	86.50	79.00	91.00	98.00	80.00	70.00	41.75	46.50	22.75	21.00	00.00	23.25	19.00	38.00	56.00
L	63.75	106.25	98.75	110.75	96.25	103.00	93.00	64.75	66.50	40.25	40.00	23.25	00.00	25.00	34.50	52.50
M	46.50	90.00	82.50	94.50	80.00	79.25	69.25	52.00	68.75	41.75	23.50	19.00	25.00	00.00	19.00	37.00
N	36.50	92.00	84.50	96.50	81.75	81.25	71.25	60.00	82.25	61.00	36.50	38.00	34.50	19.00	00.00	18.00
O	28.00	86.00	78.50	90.50	74.50	95.50	85.25	79.50	101.00	79.00	54.50	56.00	52.50	37.00	18.00	00.00

APPENDIX E

VEHICLE/DEPLOYMENT STRATEGY COMBINATIONS

TABLE E-1

CARRYALL - DEPLOYMENT STRATEGY I

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	116.00	4
SMSB - B - SMSB	101.00	4
SMSB - C - SMSB	120.50	4
SMSB - D - SMSB	93.00	4
SMSB-F-E-F-SMSB	134.50	6
SMSB-G-H-I-H-G-SMSB	219.00	6
SMSB-J-L-K-L-J-SMSB	190.50	6
SMSB-O-N-M-N-O-SMSB	130.00	6
	1104.50	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-B-A-B-SMSB	151.50	4
SMSB-D-C-D-SMSB	130.00	4
SMSB-F-E-F-SMSB	134.50	6
SMSB - G - SMSB	103.00	4
SMSB - H - SMSB	147.50	4
SMSB - I - SMSB	111.00	4
SMSB-J-K-J-SMSB	106.00	6
SMSB-M-L-M-SMSB	143.00	4
SMSB-O-N-O-SMSB	92.00	4
	1118.50	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-B-A-SMSB	204.50	6
SMSB-D-E-F-E-D-SMSB	163.00	6
SMSB-G-H-I-H-G-SMSB	219.00	6
SMSB-J-K-J-SMSB	106.00	6
SMSB - L - SMSB	127.50	4
SMSB - M - SMSB	93.00	4
SMSB - N - SMSB	73.00	4
SMSB - O - SMSB	56.00	4
	1042.00	40
TOTALS	3265.00	120

TABLE E-2

CARRYALL - DEPLOYMENT STRATEGY II

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	116.00	4
SMSB - B - SMSB	101.00	4
SMSB - C - SMSB	120.50	4
SMSB - D - SMSB	93.00	4
SMSB -F-E- SMSB	134.50	6
SMSB-G-H-I-SMSB	165.00	6
SMSB-J-L-K-SMSB	139.50	6
SMSB-O-N-M-SMSB	111.50	6
	981.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-SMSB	162.50	6
SMSB - D - SMSB	93.00	2
SMSB -F-E- SMSB	134.50	6
SMSB - G - SMSB	103.50	4
SMSB - H - SMSB	147.50	4
SMSB - I - SMSB	111.00	4
SMSB -J-K- SMSB	97.25	6
SMSB -M-L- SMSB	135.25	4
SMSB -O-N- SMSB	82.50	4
	1067.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-SMSB	162.50	6
SMSB-D-E-F-SMSB	138.75	6
SMSB-G-H-I-SMSB	165.00	6
SMSB -J-K- SMSB	97.25	6
SMSB - L - SMSB	127.50	4
SMSB - M - SMSB	93.00	4
SMSB - N - SMSB	73.00	4
SMSB - O - SMSB	56.00	4
	913.00	40
TOTALS	2961.00	120

TABLE E-3

CARRYALL - DEPLOYMENT STRATEGY III

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	232.00	4
SMSB - B - SMSB	202.00	4
SMSB - C - SMSB	241.00	4
SMSB - D - SMSB	186.00	4
SMSB -F-E- SMSB	269.00	6
SMSB-G-H-I-SMSB	330.00	6
SMSB-J-K-L-SMSB	279.00	6
SMSB-O-N-M-SMSB	223.00	6
	1962.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB-A-B-C-SMSB	325.00	6
SMSB - D - SMSB	186.00	2
SMSB -F-E- SMSB	269.00	6
SMSB - G - SMSB	207.00	4
SMSB - H - SMSB	295.00	4
SMSB - I - SMSB	222.00	4
SMSB -J-K- SMSB	194.50	6
SMSB -M-L- SMSB	270.50	4
SMSB -O-N- SMSB	165.00	4
	2134.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB-A-B-C-SMSB	325.00	6
SMSB-D-E-F-SMSB	277.50	6
SMSB-G-H-I-SMSB	330.00	6
SMSB -J-K- SMSB	194.50	6
SMSB - L - SMSB	255.00	4
SMSB - M - SMSB	186.00	4
SMSB - N - SMSB	146.00	4
SMSB - O - SMSB	112.00	4
	1826.00	40
TOTALS	5922.00	120

TABLE E-4

STATION WAGON - DEPLOYMENT STRATEGY I

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	116.00	4
SMSB - B - SMSB	101.00	4
SMSB - C - SMSB	120.50	4
SMSB - D - SMSB	93.00	4
SMSB - E - SMSB	134.50	4
SMSB-G-F-G-SMSB	159.50	4
SMSB-I-H-I-SMSB	182.50	4
SMSB-J-K-J-SMSB	106.00	4
SMSB-M-L-M-SMSB	143.00	4
SMSB-O-N-O-SMSB	92.00	4
	1248.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-B-A-B-SMSB	151.50	4
SMSB-D-C-D-SMSB	130.00	4
SMSB - E - SMSB	134.50	2
SMSB - F - SMSB	114.50	4
SMSB - G - SMSB	103.00	4
SMSB - H - SMSB	147.50	4
SMSB - I - SMSB	111.00	4
SMSB - J - SMSB	64.00	4
SMSB-K-L-K-SMSB	135.00	4
SMSB - M - SMSB	93.00	2
SMSB-O-N-O-SMSB	92.00	4
	1276.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-B-A-B-SMSB	151.50	4
SMSB-D-C-D-SMSB	130.00	4
SMSB-F-E-F-SMSB	134.50	4
SMSB-G-H-G-SMSB	147.50	4
SMSB-J-I-J-SMSB	110.00	4
SMSB - K - SMSB	88.50	4
SMSB - L - SMSB	127.50	4
SMSB - M - SMSB	93.00	4
SMSB - N - SMSB	73.00	4
SMSB - O - SMSB	56.00	4
	1111.50	40
TOTALS	3635.50	120

TABLE E-5

STATION WAGON - DEPLOYMENT STRATEGY II

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	116.00	4
SMSB - B - SMSB	101.00	4
SMSB - C - SMSB	120.50	4
SMSB - D - SMSB	93.00	4
SMSB - E - SMSB	134.50	4
SMSB -G-F- SMSB	137.00	4
SMSB -I-H- SMSB	165.00	4
SMSB -J-K- SMSB	97.25	4
SMSB -M-L- SMSB	135.25	4
SMSB -O-N- SMSB	82.50	4
	1182.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB -B-A- SMSB	133.75	4
SMSB -D-C- SMSB	125.25	4
SMSB - E - SMSB	134.50	2
SMSB - F - SMSB	114.50	4
SMSB - G - SMSB	103.00	4
SMSB - H - SMSB	147.50	4
SMSB - I - SMSB	111.00	4
SMSB - J - SMSB	64.00	4
SMSB -K-L- SMSB	131.25	4
SMSB - M - SMSB	93.00	2
SMSB -O-N- SMSB	82.50	4
	1240.25	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB -B-A- SMSB	133.75	4
SMSB -D-C- SMSB	125.25	4
SMSB -F-E- SMSB	134.50	4
SMSB -G-H- SMSB	147.50	4
SMSB -J-I- SMSB	110.50	4
SMSB - K - SMSB	88.50	4
SMSB - L - SMSB	127.50	4
SMSB - M - SMSB	93.00	4
SMSB - N - SMSB	73.00	4
SMSB - O - SMSB	56.00	4
	1089.50	40
TOTALS	3511.75	120

TABLE E-6

STATION WAGON - DEPLOYMENT STRATEGY III

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A - SMSB	232.00	4
SMSB - B - SMSB	202.00	4
SMSB - C - SMSB	241.00	4
SMSB - D - SMSB	186.00	4
SMSB - E - SMSB	269.00	4
SMSB -G-F- SMSB	274.00	4
SMSB -I-H- SMSB	330.00	4
SMSB -J-K- SMSB	194.50	4
SMSB -M-L- SMSB	270.50	4
SMSB -O-N- SMSB	165.00	4
	2364.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB -B-A- SMSB	267.50	4
SMSB -D-C- SMSB	250.50	4
SMSB - E - SMSB	269.00	2
SMSB - F - SMSB	229.00	4
SMSB - G - SMSB	206.00	4
SMSB - H - SMSB	295.00	4
SMSB - I - SMSB	222.00	4
SMSB - J - SMSB	128.00	4
SMSB -K-L- SMSB	262.50	4
SMSB - M - SMSB	186.00	2
SMSB -O-N- SMSB	165.00	4
	2480.50	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB -B-A- SMSB	267.50	4
SMSB -D-C- SMSB	250.25	4
SMSB -F-E- SMSB	269.00	4
SMSB -G-H- SMSB	295.00	4
SMSB -J-I- SMSB	221.00	4
SMSB - K - SMSB	177.00	4
SMSB - L - SMSB	255.00	4
SMSB - M - SMSB	186.00	4
SMSB - N - SMSB	146.00	4
SMSB - O - SMSB	112.00	4
	2178.75	40
TOTALS	7023.25	120

TABLE E-7

VAN - DEPLOYMENT STRATEGY I

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - A-B-C-B-A - SMSB	204.50	12
SMSB - D-E-F-E-D - SMSB	163.00	10
SMSB - J-I-H-G-H-I-J - SMSB	226.00	8
SMSB-O-N-M-L-K-L-M-N-O-SMSB	226.50	10
	820.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-D-E-D-C-B-A-SMSB	291.50	10
SMSB - G-H-F-H-G - SMSB	208.50	12
SMSB - J-I-K-I-J - SMSB	155.50	10
SMSB - O-N-L-M-L-N-O - SMSB	211.00	8
	866.50	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB - D-C-B-A-B-C-D - SMSB	218.50	8
SMSB - G-H-F-E-F-H-G - SMSB	228.50	8
SMSB - J-I-L-K-L-I-J - SMSB	237.00	12
SMSB - O-N-M-N-O - SMSB	130.00	12
	814.00	40
TOTALS	2500.50	120

TABLE E-8

VAN - DEPLOYMENT STRATEGY II

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-SMSB	162.50	12
SMSB-D-E-F-SMSB	138.75	10
SMSB - J-I-H-G-SMSB	164.50	8
SMSB-O-N-M-L-K-SMSB	157.50	10
	623.25	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-D-E-SMSB	213.00	10
SMSB-G-H-F-SMSB	161.50	12
SMSB-J-I-K-SMSB	122.00	10
SMSB - O-N-L-M-SMSB	152.00	8
	648.50	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-D-C-B-A-SMSB	167.25	8
SMSB-G-H-F-E-SMSB	181.50	8
SMSB-J-I-L-K-SMSB	162.75	12
SMSB - O-N-M-SMSB	111.50	12
	623.00	40
TOTALS	1894.75	120

TABLE E-9

VAN - DEPLOYMENT STRATEGY III

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-SMSB	325.00	12
SMSB-D-E-F-SMSB	277.50	10
SMSB - J-I-H-G-SMSB	329.00	8
SMSB-O-N-M-L-K-SMSB	315.00	10
	1246.50	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB-A-B-C-D-E-SMSB	426.00	10
SMSB-G-H-F-SMSB	323.00	12
SMSB-J-I-K-SMSB	244.00	10
SMSB - O-N-L-M-SMSB	304.00	8
	1297.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB-D-C-B-A-SMSB	334.50	8
SMSB-G-H-F-E-SMSB	363.00	8
SMSB-J-I-L-K-SMSB	325.50	12
SMSB-O-N-M-SMSB	223.00	12
	1246.00	40

TOTALS	3789.50	120

TABLE E-10

29 PAX BUS - DEPLOYMENT STRATEGY I

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-D-E-D-C-B-A-SMSB	291.50	20
SMSB-O-N-M-L-K-I-H-F-G-J-G-F-H-I-K-L-M-N-O-SMSB	527.00	20
	818.50	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-B-C-D-E-F-H-G-SMSB	404.00	22
SMSB-O-N-M-L-K-I-J-I-K-L-M-N-O-SMSB	318.00	18
	722.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-J-I-H-G-E-F-D-C-B-A-B-C-D-F-E-G-H-I-J-SMSB	499.00	20
SMSB-O-N-M-L-K-L-M-N-O-SMSB	226.50	20
	725.50	40
TOTALS	2266.00	120

TABLE E-11

29 PAX BUS - DEPLOYMENT STRATEGY II

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-D-E-SMSB	213.00	20
SMSB-O-N-M-L-K-I-H-F-G-J-SMSB	295.50	20
	508.50	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-SMSB	260.00	22
SMSB-O-N-M-L-K-I-J-SMSB	191.00	18
	451.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-J-I-H-G-E-F-D-C-B-A-SMSB	307.50	20
SMSB-O-N-M-L-K-SMSB	157.50	20
	465.00	40
TOTALS	1424.50	120

TABLE E-12

29 PAX BUS - DEPLOYMENT STRATEGY III

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-A-B-C-D-E-SMSB	426.00	20
SMSB-O-N-M-L-K-I-H-F-G-J-SMSB	591.00	20
	1017.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB-G-H-F-E-D-C-B-A-SMSB	520.00	22
SMSB-O-N-M-L-K-I-J-SMSB	382.00	18
	902.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB-J-I-H-G-E-F-D-C-B-A-SMSB	615.00	20
SMSB-O-N-M-L-K-SMSB	315.00	20
	930.00	40
TOTALS	2849.00	120

TABLE E-13

45 PAX BUS - DEPLOYMENT STRATEGY I

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-B-C-D-E-F-H-G-SMSB	404.00	26
SMSB-O-N-M-L-K-I-J-I-K-L-M-N-O-SMSB	318.00	14
	722.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-B-C-D-E-F-H-G-SMSB	404.00	22
SMSB-O-N-M-L-K-I-J-I-K-L-M-N-O-SMSB	318.00	18
	722.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-B-C-D-E-F-H-G-SMSB	404.00	16
SMSB-O-N-M-L-K-I-J-I-K-L-M-N-O-SMSB	318.00	24
	722.00	40
TOTALS	2166.00	120

TABLE E-14

45 PAX BUS - DEPLOYMENT STRATEGY II

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-SMSB	260.00	26
SMSB-O-N-M-L-K-I-J-SMSB	191.00	14
	451.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-SMSB	260.00	22
SMSB-O-N-M-L-K-I-J-SMSB	191.00	18
	451.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-SMSB	260.00	16
SMSB-O-N-M-L-K-I-J-SMSB	191.00	24
	451.00	40
TOTALS	1353.00	120

TABLE E-15

45 PAX BUS - DEPLOYMENT STRATEGY III

Day 1 of 3-day Changeover Cycle - 740th SMS

ROUTE	MILES	# OF PEOPLE TRANSPORTED
SMSB-G-H-F-E-D-C-B-A-SMSB	520.00	26
SMSB-O-N-M-L-K-I-J-SMSB	382.00	14
	902.00	40

Day 2 of 3-day Changeover Cycle - 741st SMS

SMSB-G-H-F-E-D-C-B-A-SMSB	520.00	22
SMSB-O-N-M-L-K-I-J-SMSB	382.00	18
	902.00	40

Day 3 of 3-day Changeover Cycle - 742nd SMS

SMSB-G-H-F-E-D-C-B-A-SMSB	520.00	16
SMSB-O-N-M-L-K-I-J-SMSB	382.00	24
	902.00	40
TOTALS	2706.00	120

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Bellman, Richard. "Dynamic Programming Treatment of the Traveling Salesman Problem," Journal of the Association for Computing Machinery, January 1962, pp. 61-70.

2. Bellmore, M. and Nemhauser, G. L. "The Traveling Salesman Problem: A Survey," Operations Research, May-June 1968, pp. 538-558.

3. Bradley, Stephen P., Arnoldo C. Hax, and Thomas L. Magnanti. Applied Mathematical Programming. Phillipines: Addison-Wesley Publishing Company, Inc., 1977.

4. Budnick, Frank S., Richard Mojena, and Thomas E. Vollmann. Principles of Operations Research for Management. Homewood IL: Richard D. Irwin, Inc., 1977.

5. ________. Instructor's Manual for Principles of Operations Research for Management. Homewood IL: Richard D. Irwin, Inc., 1977.

6. Christofides, N. "The Vehicle Routing Problem," Revue Francaise d' Automatique, d'Informatique et de Recherche Operationelle, Vol 10, February 1976, pp. 55-70.

7. Cox, Captain Randy, USAF. Action Officer, HQ SAC/LGTV, Telephone interview, subject: SAC Missile Combat Crew Fuel Efficiency Study, 30 August 1979.

8. Dagner, Lyle A. Chief Missile Engineer, 91st Strategic Missile Wing/CES. Telephone interview, subject: Transport-Erector Route Book, 1 November 1979.

9. Dantzig, G. B., D. R. Fulkerson, and S. M. Johnson, "Solution of a Large Scale Traveling Salesman Problem," Operations Research, November 1954, pp. 393-410.

10. Dantzig, B. and Ramser, J. H. "The Truck Dispatching Problem," Management Science, October 1959, pp. 80-91.

11. Davis, Technical Sergeant Glenn A., USAF. Chief Dispatcher, 91st Strategic Missile Wing/LGT. Telephone interview, subject: Limitations on Vehicle Drivers, 15 November 1979.

12. Eastman, W. L. "Linear Programming With Pattern Constraints," PhD. Dissertation, Harvard, 1958.

13. Eilon, S. and Christofides, N. "An Algorithm for the Vehicle Dispatching Problem," Operational Research Quarterly, September 1969, pp. 309-318.

14. Gilmore, P. C. and Gomory, R. E. "Sequencing a One-State Variable Machine: A Solvable Case of the Traveling Salesman Problem," Operations Research, September/October 1964, pp. 655-679.

15. Gomory, R. E. "An Algorithm for Integer Solutions to Linear Programs," Recent Advances in Mathematical Programming. New York: McGraw-Hill, 1963, pp. 269-302.

16. Gonzales, R. H. "Solution to the Traveling Salesman Problem by Dynamic Programming on the Hypercube," Technical Report No. 18, O. R. Center, M.I.T., 1962.

17. Grant, Captain Douglas A., USAF. Former Missile Maintenance Officer at Whiteman AFB MD. Personal interview, 14 November 1979.

18. Hatfield, D. J. and Pierce, J. F. "Production Sequencing by Combinatorial Programming," IBM Cambridge Scientific Center, Cambridge, Massachusetts, 1966.

19. Heidler, Captain Claire D., USAF. "A Review of the Closed Circuit Problem," Unpublished term paper, AFIT/SL, Wright-Patterson AFB OH, May 1975.

20. Held, Michael and Karp, Richard M. "A Dynamic Programming Approach to Sequencing Problems," Journal of the Society for Industrial and Applied Mathematics, March 1962, pp. 196-210.

21. Horne, Major, USAF. Action Officer, Energy Management Branch, HQ USAF/LEYSF. Telephone interview, subject: Presidential Memorandums on the Reduction of Energy Use, 15 October 1979.

22. HQ SAC/LG/DO Message, 132115Z June 1979. Subject: Fuel Efficient Vehicles in High Mileage Operations. OPR: HQ SAC/LGTV.

23. Karg, Robert L. and Thompson, Gerald L. "A Heuristic Approach to Solving Traveling Salesman Problems," Management Science, January 1964, pp. 225-248.

24. Light, Brigadier General James E. Jr., USAF. Deputy Chief of Staff Logistics, HQ SAC/LG. Point paper, subject: Missile Crew Transportation, to HQ SAC/CV, 21 May 1979.

25. ________. Letter, subject: Fuel Efficient Vehicles, to HQ AFLC/LO, 4 June 1979.

26. Lin, Shen. "Computer Solutions of the Traveling Salesman Problem," The Bell System Technical Journal, December 1965, pp. 2245-2269.

27. Little, John D., Katta G. Murty, Dura W. Sweeney, and Caroline Karel. "An Algorithm for the Traveling Salesman Problem," Journal of Operations Research, November-December 1963, pp. 972-989.

28. Longsworth, Colonel T. W., USAF. Acting Assistant Deputy Chief of Staff Logistics, HQ SAC/LG. Point paper, subject: Use of Subcompact Vehicles to Support Missile Crews, to HQ SAC/CV, 27 June 1979.

29. Miller, C. E., A. W. Tucker, and R. A. Zemlin. "Integer Programming Formulation of Traveling Salesman Problems," Journal of the Association for Computing Machinery, 1960, pp. 326-329.

30. Mole, R. H. "A Survey of Local Delivery Vehicle Routing Methodology," Journal of the Operational Research Society, March 1979, pp. 245-252.

31. Pierce, J. F. "Direct Search Algorithms for Truck Dispatching Problems," Transportation Research, Vol 3, pp. 1-42.

32. Reiter, S. and Sherman, G. "Discrete Optimizing," Journal of the Society for Industrial and Applied Mathematics, Vol 13 (1965), pp. 864-889.

33. Shapiro, D. "Algorithms for the Solution of the Optimal Cost Traveling Salesman Problem," ScD. Thesis, Washington University, St. Louis MO, 1966.

34. Stewart, Major Todd I., USAF. Assistant Professor of Management Science, AFIT/SL. Personal interview, subject: Integer Programming, 9 December 1979.

35. Transport-Erector Route Book, Wing III, 91st Strategic Missile Wing, Minot AFB ND.

36. Whiting, P. D. and Hillier, J. A. "A Method for Finding the Shortest Route Through a Road Network," Operational Research Quarterly, March-June 1960, pp. 37-40.

37. Yellow, P. C. "A Computational Modification to the Savings Method of Vehicle Scheduling," Operational Research Quarterly, June 1970, pp. 281-283.

38. 91st Strategic Missile Wing, Deputy Commander for Operations, Operating Instruction 77-2, Subject: Crew Vehicle Dispatch Procedures and Travel Routes To/From LCFs, 30 August 1979.

B. RELATED SOURCES

Leavitt, Lieutenant General Lloyd R. Jr., USAF. Vice Commander In Chief Strategic Air Command, HQ SAC/CV. Memo, subject: Fuel Efficient Vehicles, to HQ SAC/LG, 23 April 1979.

________. Memo, subject: Fuel Efficient Vehicles, to HQ SAC/LG, 1 May 1979.

________. Memo, subject: Fuel Efficient Vehicles, to HQ SAC/LG, 3 May 1979.

Light, Brigadier General James E. Jr., USAF. Deputy Chief of Staff Logistics, HQ SAC/LG. Point paper, subject: Diesel Engines for Vehicles, to HQ SAC/CV, 26 April 1979.

Lin, S. and Kernighan, B. W. "An Effective Heuristic Algorithm for the Traveling Salesman Problem," Operations Research, March-April 1973, pp. 498-516.

Lindsey, Colonel Clarence H., USAF. Director of Transportation, Deputy Chief of Staff Logistics, HQ SAC/LGT. Point paper, subject: Fuel Efficient Vehicle Test, to HQ SAC/LG, 14 September 1979.

Roberts, S. M. and Flores, B. "An Engineering Approach to the Traveling Salesman Problem," Management Science, November 1966, pp. 269-288.

Russell, Robert A. "An Effective Heuristic for the M-tour Traveling Salesman Problem With Some Side Conditions," Operations Research, May-June 1977, pp. 517-524.

Van Denberg, Captain David R., USAF, and Veith, Captain Jon D., USAF. "Optimal Placement of Regional Flight Simulators." Unpublished master's thesis. LSSR 18-78B, AFIT/SL, Wright-Patterson AFB OH, September 1978.

BIOGRAPHICAL SKETCH OF THE AUTHORS

Captain Edward O. Jacques, Jr., was commissioned in 1970 after graduating with a Bachelor of Arts degree in Economics from DePauw University. He has served in Aero-Space Defence Command (ADC) as a supply officer, and in Strategic Air Command (SAC) as a Minuteman Combat Crew Member, Combat Crew Instructor, and Emergency War Order Instructor. He came to AFIT following his Minuteman experience at Minot AFB, North Dakota. His next assignment after graduation is to Whiteman AFB, Missouri, as a Minuteman Missile Maintenance Officer.

Captain Michael G. Woolley was commissioned in 1974 after receiving a Bachelor of Science degree in Computing Science from University of Evansville. He has served in SAC as a Minuteman Combat Crew Member and Combat Crew Instructor. He came to AFIT following an assignment as a Missile Crew Commander at Minot AFB, North Dakota. His next assignment after graduation is to McConnell AFB, Kansas, as a Titan Missile Maintenance Officer.