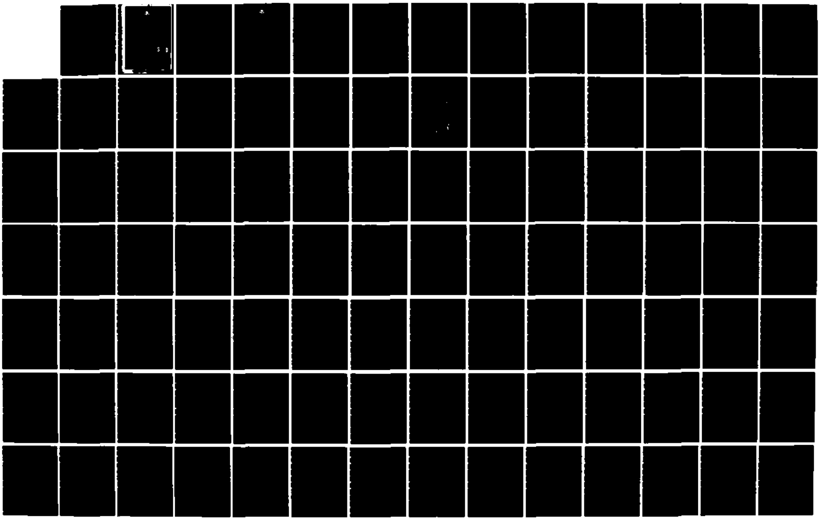
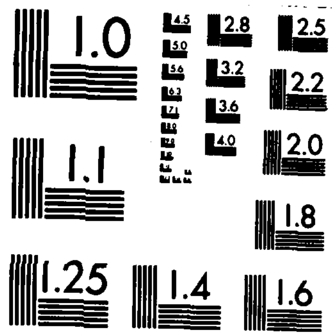
AD-A154 674 MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION(U) HOUSTON UNIV TX B OSTROFSKY ET AL. SEP 81 SBI-AD-F630 659 F04704-80-C-0038 1/2

UNCLASSIFIED F/G 16/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A154 674

//-F6306.59

MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION

Benjamin Ostrofsky
Japhet Law
Ernest A. Kiessling
Mallik Putcha

University of Houston
Houston, Texas 77004

September 1981

This research was supported by the
Department of the Air Force, Ballistic Missile Office
Contract No. F04704-80-C-0038

85 5 28 199

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A154 674	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION		5. TYPE OF REPORT & PERIOD COVERED INTERIM TECHNICAL REPORT 1 Oct 1980 - 30 Sept 1981
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Benjamin Ostrofsky, Japhet Law, Mallik Putcha, E. A. Kiessling		8. CONTRACT OR GRANT NUMBER(s) F04704-80-C-0038
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Houston, 4800 Calhoun, Houston, TX 77004		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Ballistic Missile Office, Norton AFB, CA 92409		12. REPORT DATE September 1981
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) BMO/PMS, Ballistic Missile Office, Norton AFB, CA 92409		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)

18. SUPPLEMENTARY NOTES

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

Design Engineering Methods	Human Engineering	Maintenance Analysis
Planning Methods for Large Systems	Design Morphology	Monte Carlo Simulation
System Design	Design Trade Studies	Data Rate Study
Human Resource Requirements	System Analysis	Information Flow Rate
Human Factors	Logistics Analysis	

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

A multiple criterion function developed in FY 80 was updated along with relevant operational scenarios. Eighty-one (81) candidate systems each with 94 variables were evaluated and ranked showing the current baseline system to rank 48th out of 81. Additional early results indicate low levels of automatic test equipment to be most effective. Parameter values for the most effective, theoretic candidate system was defined.

A preliminary information traffic flow study was made for the MX in addition to developing SIMMX, a Monte Carlo simulation program for estimating maintenance effects on multi-cluste · ·vailability.

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

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION

Benjamin Ostrofsky
Japhet Law
Ernest A. Kiessling
Mallik Putcha

University of Houston
Houston, Texas 77004

September 1981

This research was supported by the
Department of the Air Force, Ballistic Missile Office
Contract No. F04704-80-C-0038

MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION

ABSTRACT

This activity exercised a structured decision process to examine various scenarios for Fault Detection and Dispatch of MX maintenance teams. The effort was the implementation of the design methodology begun earlier. The multiple criterion function structured during FY 80 was updated along with the scenarios. These actions were taken to adjust the analysis from the vertical protective structure basing to the Horizontal Shelter Site (HSS) concept. The study evaluated and ranked 81 candidate systems using 94 variables for each candidate. The results indicated the currently planned system to rank 48th out of 81. Additional results, although preliminary, indicate relatively low levels (25 to 50%) of automatic test equipment to be most effective for the six criteria defined by BMO for this study. (See Section 5.0). Values of the input variables for maximum system effectiveness were defined.

A computerized maintenance simulation program (SIMMX) was developed and installed on the computer system used by BMO. This program allows the study of various MX maintenance problems and the examination of these problem effects on multiple cluster system readiness.

In addition, initial estimates of maintenance information traffic flow were provided (See Appendix B) as a result of a preliminary study based on estimated operational requirements and using available data provided by GTE, TRW, MM, and BMO.

ACKNOWLEDGMENT

Grateful acknowledgment is offered to BMO and to the participants of this study for their support and cooperation in making these results possible. Major Gary Smith, PMS, and Mr. John Gifford of TRW, Inc., provided the technical monitoring and coordination of this activity. Dr. Japhet Law aided in the development of the criterion models and their programming, assisted by Anthony Loh, Kumar Sivaraman, and Kenneth Zingrebe. Dr. C. Donaghey accomplished SIMMX with the help of Mr. B. Truong. Mr. Mallik Putcha provided the assistance necessary to accomplish the C^3 data-rate study of Appendix B. Col. E. A. Kiessling, USAF (Ret.) provided the guidance and expertise to make the maintenance study effective while helping to administer the research activity. Mrs. Jan Baker edited and typed the manuscript.

To these individuals, and to the many others with whom the projected interacted, grateful thanks is extended.

Benjamin Ostrofsky
Principal Investigator

MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION

UNIVERSITY OF HOUSTON

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AFHRL	Air Force Human Resources Laboratory
AFOSR	Air Force Office of Scientific Research
ASC	Area Support Center
AVE	Airborne Vehicle Equipment
BMO	Ballistic Missile Office
C^3	Command, Control and Communications
CAMMS	Computer-Aided Maintenance Management System
CDN	Cable Data Network
CF	Criterion Function
CMF	Cluster Maintenance Facility
C/M	Canisterized Missile
COMM	Communications
CS	Candidate System
CREV	Closure Removal, Emplacement Vehicle
DAA	Designated Assembly Area
DDA	Designated Deployment Area
DREV	Debris Removal Emplacement Vehicle
DTN	Designated Transportation Network
ECS	Environmental Control System
EMT	Electrical Mechnical Team
EPU	Emergency Power Unit
FDD	Fault Detection & Dispatch
GTE	GTE Corp.
HSS	Horizontal Shelter Site
LAF	Launcher Assembly Facility

LRU	Line Replacement Unit
M/M	Martin Marietta Company
MAB	Missile Assembly Building
MGCS	Missile Guidance and Control System
MMT	Missile Maintenance Team
MOSE	Mobile Operational Support Equipment
MX	Missile X
N-L	No-Launch
NTM	National Technical Means
OB	Operational Base
OBTS	Operational Base Test Site
OCC	Operations Control Center
OSE	Operational Support Equipment
PLU	Preservation of Location Uncertainty
PM	*Periodic Maintenance*
PMS	Logistics Organization at BMO
PS	Protective Structure
R/S	Reentry System
ROSE	Resident Operational Support Equipment
SAC	Strategic Air Command
SALVER	Salt Verification
SAMSO	Space and Missile Systems Organization (now BMO)
SEC	Security
SIMMX	MX Maintenance Simulation
STV	Special Transport Vehicle
SUMT	Sequential Unconstrained Minimization Technique

2.3 Candidate Systems

A candidate system by definition[5] includes each of the activities in Figure 2-3. Hence by identifying alternative methods for accomplishing each activity, any combination of one method from each respective activity would constitute a candidate system.

CONTROL	DETECT	DISPATCH	TEAMS
OB	.25 Remote .75 Local	OB	Standard
ASC	.5 Remote .5 Local	ASC	Std. w/specialist Augmentation
OB/ASC	.75 Remote .25 Local	ASC/OB	Multi-skill/Std

3 x 3 x 3 x 3 = 81 Possible Candidate Systems

Figure 2-3: CANDIDATE SYSTEMS & SUBSYSTEMS

Since there are three alternatives for Detect, three for Dispatch, and three for Team Type with three different options for location of Control functions, there is a total of 3 x 3 x 3 x 3 or 81 candidate systems in the set (See Figure 2-4).

CONTROL	A DETECT	B DISPATCH	C TEAM
1	1	1	1
2	2	2	2
3	3	3	3

81 Total Candidate Systems to be Analyzed

Figure 2-4: THE SET OF CANDIDATE SYSTEMS

2.2.3 Advantages of Control at ASC

1. Reduced Span of Control over all maintenance activities
2. Easier transition from Minuteman organizational structure
3. Reduces OCC staff requirement
4. Simpler Personnel Scheduling Problem

2.2.4 Disadvantages of Control at ASC

1. Coordination of Wing Requirements is difficult
2. Increased test equipment costs
3. Variable Supply Costs
4. Increased manning for maintenance control
5. Decreased control over maintenance by maintenance commander
6. Increased pipeline complexity
7. More command positions
8. Increased C^3 complexity

2.2.5 Advantages of Control at OB/ASC combination

1. Span of Control adaptable
2. Inventory, personnel, equipment, and vehicle basing flexible
3. Response to maintenance requirements faster

2.2.6 Disadvantages of Control at OB/ASC combination

1. Increased inventory and equipment cost
2. Personnel support and control requires enhanced coordination

The original scenarios[7] addressed by the project were changed during a meeting at which BMO, M/M and UH were represented. Instead of looking at the location of the Fault Detection and Dispatch, the level or location of control of the operational maintenance activities is of interest. These levels of control now are considered as: Control at the OB only, Control at the ASC only, and Control jointly at OB/ASC combination.

The definition of control in this case would be to exercise restraining or directing influence or to regulate. This would include control of personnel, jobs, scheduling, vehicles, inventory, equipment, and any other resources used in operational maintenance.

The scenarios' advantages and disadvantages are summarized below:

2.2.1 Advantages of Control at OB Only

1. All levels of maintenance management at one location
2. Economies of expertise and skill levels
3. Centralized Scheduling and Control
4. Centralized Maintenance Decision Making
5. Reduced Test Equipment and Inventory Requirements
6. Limited location knowledge
7. Reduced span of control

2.2.2 Disadvantages of Control at OB Only

1. Parallel information processing requirement at the OB and OCC for fault detection
2. Increased management problems
3. PLU compliance problem in limiting location knowledge

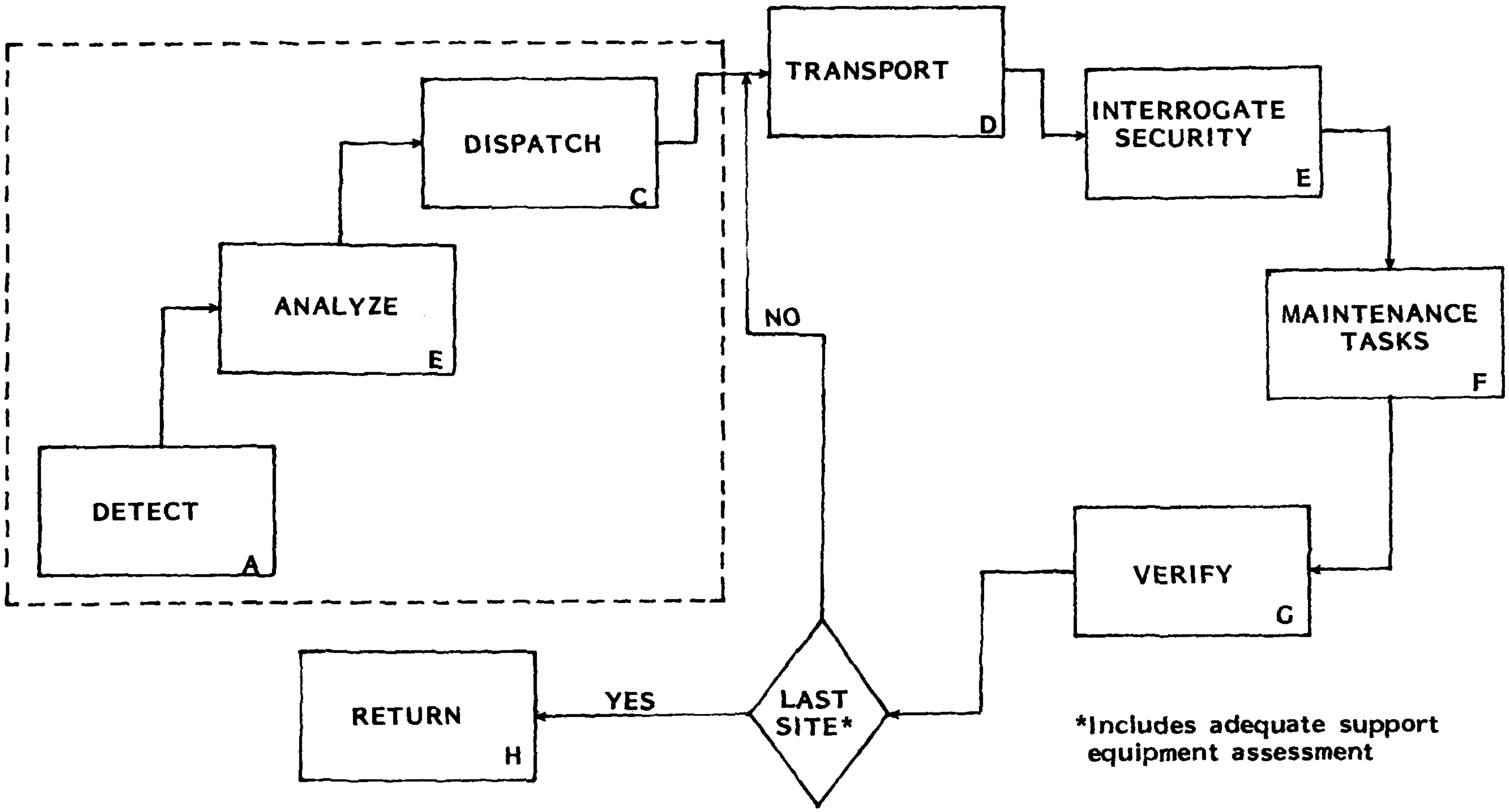


Figure 2-2: FDD OPERATIONS FLOW

1. Automated Monitoring Equipment
2. Software and Procedures for FDD
3. C^3
4. Flexible Dispatch Rules
5. The Maintenance Concept
6. Monitoring Equipment to be easy to operate and to maintain
7. Efficient Personnel Training Program
8. Effective Pipeline for personnel and spares

2.2 Operational Scenarios

Figure 2-2 identifies the basic FDD activity sequence from which assumptions can be made on the nature and location of these activities. Basically, the detect function is the recognition of a fault or discrepancy in the missile force (including OSE). The preciseness of location (PS, LRU, etc.) is left to the subsequent development of candidate systems. Once a fault is detected, the analysis function consists of the process of defining the nature of the fault, its location to the desired level of equipment, the requirements for resolving the fault and the appropriate scheduling of personnel. Dispatch includes the coordination of schedule implementation for command post, job control, transportation, and security. When the maintenance personnel arrive at the PS they clear security requirements ("Interrogate Security") for access to the missile or the associated equipment which may contain the fault. The maintenance tasks are accomplished and verification obtained by clearing with Maintenance Control. The maintenance crew then proceeds to the next PS or returns to their point of dispatch as a function of the prevailing conditions.

on any FDD system that a detail awareness of the accomplishment of these activities must be considered in its development.

Initial consideration for FDD was identified by Boeing[10,11] and for the most part still pertains:

1. In series site coverage
2. Individual trips to PS in sequence
3. Incorporation of PLU tactics
4. Computer directed Randomized Dispatch Schemes

Major FDD system outputs for MX Maintenance Control have been defined[7] as follows:

1. Each PS monitored at least once every 60 seconds
2. 95% of potential faults are to be isolated to one LRU; the remaining 5% of potential faults are to be isolated to 4 LRU
3. There is to be a high level of automation to ease fault definition
4. Complete TO to be readily available (and highly automated)
5. TO Data easy to use
6. Efficient notification and dispatch
7. Maximum utilization of maintenance teams and equipment
8. Effective skill level mix for team composition
9. Minimum spares for planned system availability

Broad conditions prevailing as "inputs" for FDD are as follows:

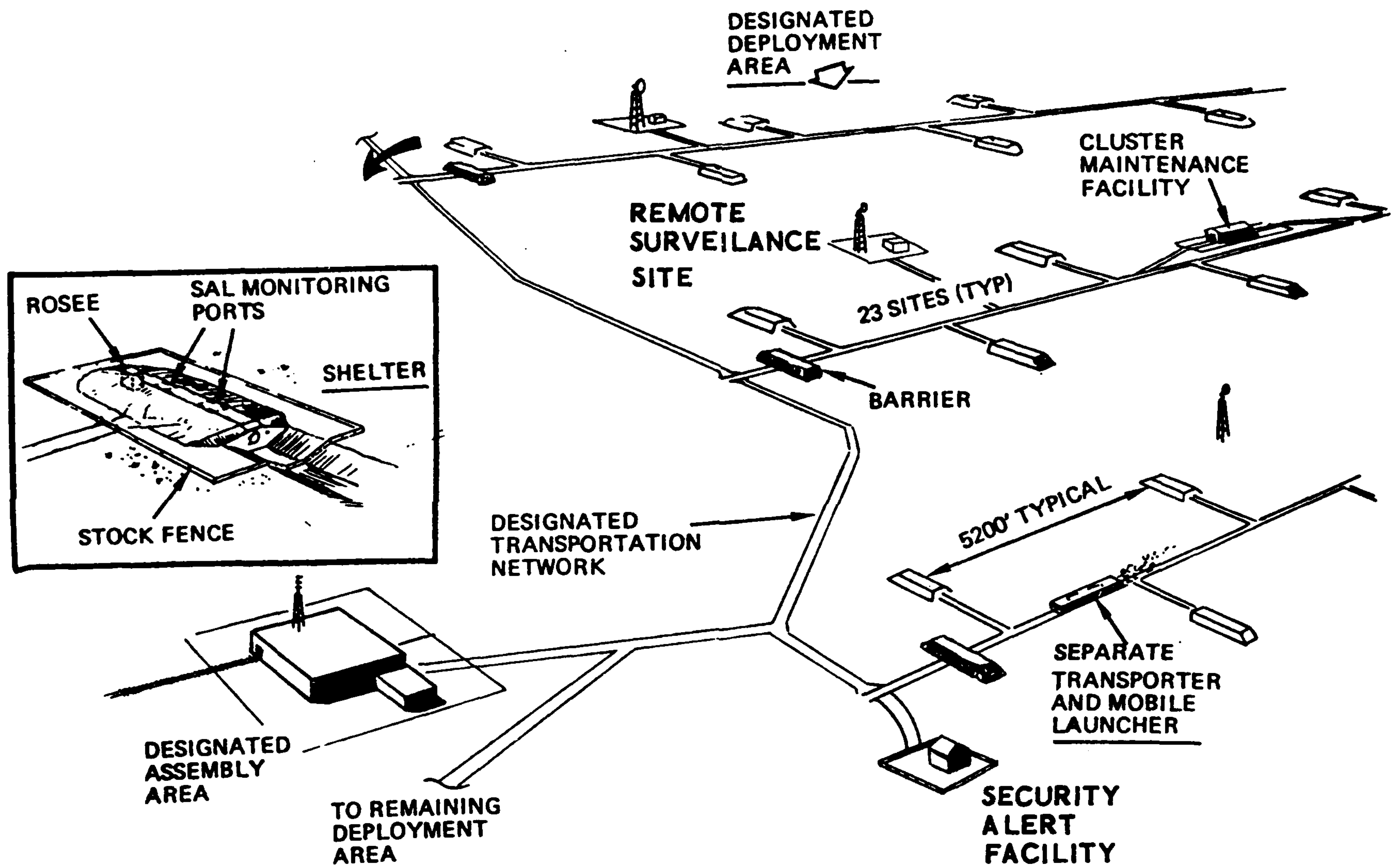


Figure 2-1: HORIZONTAL SHELTER WEAPONS SYSTEM GENERIC CONCEPT

2.0 SUPPORTING RESEARCH AND DEVELOPMENT

2.1 Requirements

The requirements for this activity are similar to those described in FY 80 (See pages 16-19, Reference #7). The Horizontal Shelter Site (HSS) concept was used as the basic system deployment scenario. (See Figure 2-1).

Fundamentally, the requirement for this research was to identify the "best" approach to fault detection, analysis, dispatch, and maintenance of the multi-cluster, MX wing. Hence identification of the optimal Fault Detection and Dispatch System (FDD) will include the activities of Maintenance Control and those of the remaining controls that are necessary to the efficient accomplishment of Maintenace Control responsibilities.

Maintenace Control inclues:

1. Job scheduling, and material control for missile maintenance, communication, Civil Engineering, and transportation.
2. Direct line communications capability from each composite area to all interfacing agencies.
3. Monitor Force Status, dispatch and coordinate maintenance activities and missile decoy movement.

While the primary objective of FDD is to respond to item #3, it is recognized that the interaction of 1 and 2 have such a direct effect

The Maintenance Simulation Interpreter (SIMMX) was completed for multiple cluster, MX deployment and demonstrated for BMO and TRW. (See Appendix A and reference #8).

1.4 Program Constraints

1.4.1 Some problems were encountered coordinating the parameter estimates with BMO. After some scheduling difficulties, an eight-day meeting was accomplished at The Martin Marietta Company where inputs to the UH model were estimated with their help.

1.4.2 The criteria remained unchanged from FY 80 and should be reexamined in light of basing mode changes.

1.4.3 C^3 data was extremely difficult to obtain prior to a meeting with GTE, Martin Marietta, TRW, and UH at BMO. This resulted in the basic data rate estimates that enabled the UH study to continue[9].

1.4.4 A large number of computer processor hours (about 50) was used to identify the design space optimum criterion function value (CF). Toward the end of the year a new algorithm was developed for searching a large dimensioned hyperspace and this gives evidence of being effective in reducing processor time dramatically for large dimensioned spaces.

local estimates were used at the University of Houston to make the models operational and to debug the software.

Second, the MX System Maintenance study was developed as a computerized simulation (SIMMX) of an MX Cluster of the Horizontal Shelter Sites deployment concept. This study uses a simulation language developed at the University of Houston to facilitate synthesis of simulation problems, and was written in Fortran for ease of transfer and use. Development of this model was continued in FY 81.

Finally, an initial study of Maintenance Control Information Flow was made. This provided a preliminary examination of the operational communications requirements in support of BMO/PMS.

1.3 Overview of FY 81 Activities

FY 81 was essentially a continuation of the FY 80 effort. The multiple criterion function developed in FY 80 was modified to accommodate parameter estimates provided by BMO and The Martin Marietta Company. An optimal candidate system was identified and its parameters compared with those resulting from a computerized search of the design space for a maximum criterion function value, thus indicating the potential growth in criterion performance possible from the optimal candidate. Of considerable interest are the methods developed to handle the large number of parametric inputs and the optimization (See Section 5.0).

The Maintenance Information Flow Study was further developed and preliminary estimates of the data flow volumes were made at the major "node" level of the information network (See Appendix B).

presented; knowledgeable trade-offs among the traditionally "hard" criteria were made with "soft" criteria that related more directly to the human resource environment; a clear delineation was achieved of the "best" candidate system of those considered; and finally, an explicit level of "growth" for each input variable ("parameter") was identified from a computerized search of the design space. The latter provided management guidance on where to allocate resources for performance improvement.

In view of the successful application to a small, hardware system, the decision was made to apply the decision structure to a larger, more sophisticated USAF system. After some review, the problem of processing maintenance status change through dispatch, completion of corrective action, and post dispatch debriefing for the MX Weapon System was approved by SAMSO (now BMO), AFHRL, and AFOSR[1].

In FY 79 the Feasibility Study requirements were completed up to and including the definition of Fault Detection and Dispatch Criteria, their relative importance, and the set of parameters from which models of the criteria could be synthesized[1]. This study provided the opportunity for researchers at the University of Houston to become proficient in MX terminology and knowledgeable in the MX support situation.

In FY 80, three separate problems were investigated on the MX System[7]. First, the work on clarification of the Maintenance Mangement System was continued. A six-criterion function was developed using 94 parameters to rank 81 candidate systems in their order of value. Time precluded collection of data from the field to exercise these models, hence maintenance expenditures. Hence the need for the equipment designer to understand the impact of human factors implies the need to assure adequate recognition by all planning approval agencies of these factors in the design decision structure.

An earlier publication[5] provided a decision structure for the development of a technological system which appears to be highly effective when used to design USAF equipment. The relationship between the semantics of the design morphology and those of the USAF were clarified[2] and related to the existing literature in both the human factors and the engineering design areas.

The major thrust of the FY 78 research, funded by the Air Force Office of Scientific Research (AFOSR), was the application of the design decision structure to a current, relatively small design problem, the service stand for the Emergency Power Unit (EPU) of the F1-16 Aircraft[6]. The principal Investigator took on the role of advisor to the design engineers at General Dynamics, Fort Worth plant and, by coordinating with these engineers in regular and frequent sessions, proceeded to apply the morphology successfully. Acceptance of the human factors requirements was dramatically demonstrated by defining a multiple criterion function which included criteria that required human resource considerations in combination with hard, engineering data. The ease with which the designer reviews were satisfactorily accomplished helped to convince General Dynamics management that this methodology was effective when properly applied.

Specifically, accurate design requirements were quickly defined; a detailed record of design decisions was readily available and very clearly

1.0 INTRODUCTION

1.1 Statement of Objectives

1.1.1 The major purpose of this research was to demonstrate the applicability of a design morpholgy to the definition of optimal methods for MX System maintenance management.

1.1.2 A secondary objective was to identify the potential areas of maintenance support improvement and/or growth potential from the optimal maintenance management system for fault detection, analysis, and maintenance.

1.1.3 Additional objectives of this activity were:

a. Extend the investigation of analytical methods for integrating qualitative and quantitative information into a multivariate criterion function.

b. Augment the current definition of human factors and metrics which influence the design decision structure.

c. Clarification of the decision structure for development and implementation of a high technology, large scale system.

1.2 Background

This activity is part of a continuing[1,2,3] Air Force effort to improve the techniques for designing aerospace hardware and systems. Specifically, the difficulties of properly including human factors[4] in the development of Air Force Systems have often created both operational problems in the field and less than desired efficiency in training and

T/L	Transporter Launcher
TO	Technical Order (Document)
TRW	TRW, Inc.
UH	University of Houston
USAF	United States Air Force
V & E	Vehicle and Equipment
x_i	$i^{\underline{th}}$ Design & Development Criterion
y_k	$k^{\underline{th}}$ parameter
z_j	$j^{\underline{th}}$ submodel

Figure 2-5 shows the candidate system which is closest to the baseline system being implemented by BMO for the HSS basing mode.

CONTROL	DETECT	DISPATCH	TEAMS
OB/ASC	.75 Remote .25 Local	ASC/OB	Standard

Figure 2-5: EXAMPLE CANDIDATE SYSTEM (BASELINE)

Figure 2-6 indicates a subjective evaluation of each scenario's ranking in terms of its respective ability to accomplish the areas of Integrated Logistics Support. Overall, this indicates that control centralized at the OB presents maximum benefits to Integrated Logistics Support.

		Scenarios	
	I	II	III
Primary Control:	ASC	ASC/OB	OB
1. Maintenance Planning	2	3	1
2. Support and Test Equipment	2	3	1
3. Supply Support	1	2	3
4. Transportation and Handling	2	3	1
5. Technical Data	2	3	1
6. Facilities (OCC, OB, DAA, CMF)	2	3	1
7. Personnel and Training	2	3	1
8. Relative Costs	2	3	1
9. Management Data	2	3	1
(1 is most desirable)			

Figure 2-6: RELATIVE EFFECTIVENESS OF EACH SCENARIO FOR EACH INTEGRATED LOGISTICS SUPPORT AREA

2.3.1 Detect Function

Level of detect is defined in this case as the degree to which faults are automatically reported to maintenance control without the interface of personnel or large time delays.

Even with a low level of detect the critical LRU would be the items with concentrated automatic or remote detect. As the level of remote detect is increased then the less critical items will have increasingly more automatic detection hardware dedicated to them.

Local detect is detection of faults which occur in the course of daily activities carried on by personnel. This could be activities for the main purpose of fault detection or in which fault detection is coincidental.

It was recognized that the scale of Remote/Local detect is continuous but for ease of handling it was deemed best to operate with the three levels of .25R/.75L, .5R/.5L, and .75R/.25L detection (R = remote detection; L = local or manual detection).

2.3.2 Dispatch Location

Dispatch location is defined as the facility or immediate area from which a team is mobilized and moved to reach the faulty location. The dispatch location may or may not be the same area at or near which they are billetted or reside.

The three options for dispatch were taken to be dispatch from the OB, ASC, or ASC/OB combination.

Dispatch from OB or ASC meant that those were the sites from which the dispatch had to occur. The OB/ASC combination meant that dispatch may occur from either of the sites depending upon which site was deemed most appropriate for the scheduled job or the teams and equipment involved.

2.3.3 Team Type

Team type is defined to be the team personnel composition. The standard team is the maintenance team similar to the present SAC maintenance team.

The standard team with specialist augmentation is conceived to be the SAC meaintenance-team type with certain specialists to handle specific maintenance actions. These specialists will not necessarily accompany the maintenance team on all of their actions but will be utilized when their need is foreseen or encountered. Examples of these specialist types would be hydraulic, micro computer, and environmental technicians to name a few.

Multi-skill type teams would consist of personnel who are cross trained in several skills, thus making personnel assignments easier as well as making optimal use of a limited number of personnel.

2.4 Criteria

In order to evaluate the potential performance of the candidate systems, criteria must be explicitly identified[5]. Since the FDD is only one of many "sub-systems" in the MX program, within this constraint more explicit measures must be identified. Hence a questionnaire was developed[1] and opportunity was provided for the respondants to add, delete, or change criteria. Ten key individuals identified by BMO/PMS were given the questionnaire, and the following criteria resulted:

1. Availability - the MX force operational availability
2. Comparative Costs - the cost of a given candidate system relative to a standard cost
3. Team Utilization - the level of activity of the maintenance teams measured as a fraction of their available time or other suitable metric.
4. Vehicle and Equipment (V & E) Utilization - the level of activity of all vehicles and equipment necessary for MX force readiness measured as a fraction of their available time or other suitable metric.
5. Preservation of Location Uncertainty - the ability of the candidate system to preserve location uncertainty.
6. Strategic Arms Limitation Verification (SAL VER) - the ability of a candidate system to support SAL VER as identified by an acceptable metric.

These criteria will be used to explicitly evaluate the performance of the 81 candidate systems.

2.4.1 Definition of Relative Importance

The questionnaire[1] provided the opportunity for respondants to identify their opinion regarding the relative importance of each criterion.

Discussion of the response to the questionnaire is presented in references 1 and 7.

Figure 2-7 then represents the criteria and their respective relative importance. Each criterion will be modeled in terms of measurable (or estimable) variables of the candidate systems, all described below.

i	x_i	MEAN RANKING	a_i
1.	PLU	9.650	0.231
2.	Availability	9.150	0.219
3.	Comparative Costs	7.895	0.189
4.	Team Utilization	7.554	0.181
5.	V & E Utilization	6.938	0.166
6.	SAL VER	0.600	0.014
		41.787	1.000

Figure 2-7: DESIGN CRITERIA, $\{x_i\}$, AND THEIR RESPECTIVE RELATIVE WEIGHTS, $\{a_i\}$

2.5 Parameters and Submodels

In order to approach the quantitative estimates of the criteria a set of "elements" is synthesized for each. The various models have been significantly refined and updated to reflect the current baseline concepts in the MX maintenance operations. Both the parameter set and the submodel set have been adjusted to reflect the current modelling results and Figures 2-8 to 2-13 show the respective constituent submodels (z_j) and parameters (y_k) for the given criterion (x_i). The computerized version is shown in the program printout of Appendix C.

---

*"parameter" is defined to be a directly measurable or estimable characteristic of the candidate system.

"submodel" is defined to be a characteristic requiring synthesis of one or more parameters to estimate the value of the characteristic.

x_1, PRESERVATION OF LOCATION UNCERTAINTY, (PLU)

Submodel
z_1 - Number of personnel for FDD
z_3 - Task Time (minute)
z_4 - Dispatch Time (minute)
z_8 - Number of actions per month

Element of y_k:

k	Description
2	Number of OB
3	Number of multiple skill teams
4	Number of MMT
5	Number of shuffle teams
6	Number of MOSE teams
7	Number of COMM/security repair teams
8	Number in multiple skill team
9	Number of PM teams
10	Number in shuffle team
11	Number in MOSE team
12	Number in COMM/security repair team
13	Number in PM team
18	Distance between PS (feet)
19	Missile emplacement time (minute)
21	Number in CREV/DREV team
23	MGCS repair time (minute)
24	MOSE repair time (minute)
25	Number of maint. personnel knowing any missile loc.
29	Number of C/M no launch failures/mon. per missile
30	Number of R/S no launch failures/mon. per missile
31	Number of MOSE no launch failures/mon. per missile
35	Speed of helicopter (feet/minute)
36	Speed of T/L (feet/minute)
37	Speed of van (feet/minute)
38	Number of ROSE repair teams
39	Number in MMT

k	Description
47	Number of MGCS N-L failure per mon. per missile
50	Missile removal time (minute)
51	R/S repair time (minute)
52	Delay (minute)
55	Number of ASC
56	Distance between dispatch Location and CMB (feet)
57	C/M repair time (minute)
58	Distance between CMF and PS (feet)
59	Number in helicopter team
60	PS ROSE repair time (minute)
61	Number in van team
62	Number of PS ROSE failures per mon. per missile
63	Number of FDD personnel per OB
64	Number of FDD personnel per ASC
65	Fraction of no-launch failures req. helicopter
66	Number of persons at CAMMS need to know missile loc.
67	Time to enter/exit site (minute)
68	Time spent at each PS for PLU (minute)
81	SAL verifications (at least once per year)
82	Number of CREV/DREV teams
86	Number of helicopter teams
87	Number of van teams
88	Number of FDD security team
89	Number of FDD security team
92	Number in ROSE reapir team

Figure 2-8: CRITERION x_1, PRESERVATION OF LOCATION UNCERTAINTY (PLU)

x_2, AVAILABILITY

Submodel z_3 - Task time (minutes)
z_4 - Dispatch time (minutes)
z_8 - Number of actions per month

Element of y_k:

k	Description
18	Distance between PS (feet)
19	Missile emplacement time (miniute)
23	MGCS repair time (minut
24	MOSE repair time (minute)
29	Number of C/M no launch failures/mon. per missile
30	Number of R/S no launch fialures/mon. per missile
31	Number of MOSE no launch failures/mon. per missile
35	Speed of helicopter (feet/minute)
36	Speed of T/L (feet/minute)
37	Speed of van (feet/minute)
47	Number of MGCS N-L failure per mon. per missile
50	Missile removal time (minute)
51	R/S repair time (minute)
52	Delay (minute)
56	Distance between dispatch location and CMF (feet)
57	C/M repair time (minute)
58	Distance between CMF and PS (feet)
60	PS ROSE repair time (minute)
62	Number in van team
65	Fraction of no-launch failures req. helicopter
67	Time to enter/exit site (minute)
68	Time spent at each PS for PLU (minute)
81	SAL verifications (at least once per year)

Figure 2-9: CRITERION x_2, AVAILABILITY

x_3, COST

Submodel	z_2	FDD equipment and facilities cost ($)
	z_5	FDD personnel cost ($)
	z_6	FDD vehicle cost ($)
	z_7	FDD operating and spare cost ($)

Element of y_k:

k	Description	k	Description
1	Number of CMF	49	Personnel cost per ROSE repair team ($)
2	Number of OB	53	Number of STV
3	Number of multiple skill teams	55	Number of ASC
4	Number of MMT	63	Number of FDD personnel per OB
5	Number of shuffle teams	64	Number of FDD personnel per OB
6	Number of MOSE teams	69	Average pay for OB personnel ($)
7	Number of COMM/security repair teams	70	Average pay for ASC personnel ($)
9	Number of PM teams	71	Cost per STV ($)
14	Number of helicopters assigned to FDD	72	Cost per CMF ($)
15	Number of vans assigned to FDD	73	Cost per OB ($)
16	Number of T/L	74	Cost per ASC ($)
20	Personnel cost per PM team ($)	75	Equipment cost per CMF ($)
26	Base operating support cost ($)	76	Equipment cost per OB ($)
27	Personnel cost per helicopter team ($)	77	Equipment cost per ASC ($)
28	Personnel cost per van team ($)	78	Spares/supplies cost per CMF ($)
33	Total gross CREV/DREV in dispatch area	79	Spares/supplies cost per OB ($)
38	Number of ROSE repair teams	80	Spares/supplies cost per ASC ($)
40	Cost/van ($)	82	Number of CREV/DREV teams
41	Cost per T/L ($)	85	Cost per CREV/DREV ($)
42	Cost/helicopter ($)	86	Number of helicopter teams
43	Personnel cost per MOSE team ($)	87	Number of van teams
44	Personnel cost per MMT ($)	88	Number of FDD security teams
45	Personnel cost/multiple skill team (4)	90	Personnel cost/FDD security team ($)
46	Personnel cost per shuffle team ($)	91	Personnel cost per CREV/DREV team ($)
48	Personnel cost per COMM/security repair team ($)		

Figure 2-10: x_3 - COMPARATIVE COST

x_4, TEAM UTILIZATION

Submodel z_8 Number of actions per month

Element of y_k:

k	Description
2	Number of OB
3	Number of multiple skill teams
4	Number of MMT
5	Number of shuffle teams
6	Number of MOSE teams
7	Number of COMM/security repair teams
8	Number in multiple skill team
9	Number of PM teams
10	Number of shuffle team
11	Number in MOSE team
12	Number in COMM/security repair team
13	Number in PM team
18	Distance between PS (feet)
21	Number in CREV/DREV team
22	Number of ROSE failures per mon. per missile
23	MGCS repair time (minute)
24	MOSE repair time (minute)
29	Number of C/M no launch failures/mon. per missile
30	Number of R/S no launch failures/mon. per missile
31	Number of MOSE no launch failures/mon. per missile
34	Number of COMM/security failures/mon. per missile
35	Speed of helicopter (feet/minute)
36	Speed of T/L (feet/minute)
37	Speed of van (feet/minute)

k	Description
38	Number of ROSE repair teams
39	Number in MMT
47	Number of MGCS N-L failure per mon. per missile
51	R/S repair time (minute)
55	Number of ASC
56	Distance between dispatch location and CMF (feet)
57	C/M repair time (minute)
58	Distance between CMF and PS (feet)
59	Number in helicopter team
60	PS ROSE repair time (minute)
62	Number of PS ROSE failures per mon. per missile
63	Number of FDD personnel per OB
64	Number of FDD personnel per ASC
65	Fraction of no-launch failures req. helicopter
68	Time spent at each PS for PLU (minute)
81	SAL verifications (at least once per year)
82	Number of CREV/DREV teams
84	Number of CREV/DREV dispatched to CMF
86	Number of helicopter teams
89	Number in FDD security team
92	Number in ROSE repair team
93	ROSE repair time (minute)
94	COMM/security repair time (minute)

Figure 2-11: CRITERION x_4, TEAM UTILIZATION

x_5, VEHICLE AND EQUIPMENT UTILIZATION

Submodel z_8 - Number of actions per month

Element of y_k:

k	Description
14	Number of helicopters assigned to FDD
15	Number of vans assigned to FDD
16	Number of T/L
18	Distance between PS (feet)
22	Number of ROSE failues per month per missile
23	MGCS repair time (minute)
24	MOSE repair time (minute)
29	Number of C/M no launch failures/mon. per missile
30	Number of R/S no launch failures/mon. per missile
31	Number of MOSE no launch failures/mon. per missile
33	Total gross CREV/DREV in dispatch area
34	Number of COMM/security failures/mon. per missile
35	Speed of helicopter (feet/minute)
36	Speed of T/L (feet/minute)
37	Speed of van (feet/minute)
47	Number of MGCS N-L failure per month per missile
51	R/S repair time (minute)
56	Distance between dispatch location and CMF (feet)
57	C/M repair time (minute)
58	Distance between CMF and PS (feet)
60	PS ROSE repair time (minute)
62	Number of PS ROSE failures per month per missile
65	Fraction of no-launch failures req. helicopter
68	Time spent at each PS for PLU (minute)
81	SAL verifications (at least once per year)
84	Number of CREV/DREV dispatched to CMF
93	ROSE repair time (minute)
94	COMM/security repair time (minute)

Figure 2-12: CRITERION x_5, VEHICLE AND EQUIPMENT UTILIZATION

x_6, SALT VERIFICATION

Element of y_k:

k	Description
32	Availability of CREV/DREV force
33	Total gross CREV/DREV in dispatch area
83	One day CREV/DREV reliability
84	Number of CREV/DREV dispatched to CMF

Figure 2-13: CRITERION x_6, SALT VERIFICATION

3.0 SUBMODEL DEVELOPMENT

These submodels are developed using the parameters defined and identified in Section 2.5, Figures 2-8 through 2-13. The submodels developed for the set of criteria are:

<u>Section</u>

3.1 - z_1 - Number of personnel for FDD

3.2 - z_2 - FDD equipment and facility cost ($)

3.3 - z_3 - Task time, (minutes)

3.4 - z_4 - Dispatch time (minutes)

3.5 - z_5 - FDD personnel cost ($)

3.6 - z_6 - FDD vehicle cost ($)

3.7 - z_7 - FDD operating and spares cost ($)

3.8 - z_8 - Number of actions per month

3.1 Number of Personnel for FDD, z_1

This submodel is a compilation of the total number of personnel required for FDD, and is synthesized by summing the products of the type of team and the number required of that respective type:

$$z_1 = y_3y_8 + y_4y_{39} + y_5y_{10} + y_6y_{11} + y_7y_{12} + y_2 y_{63} + y_{55}y_{64} + y_{59}y_{86} + y_{61} y_{87} + y_{88}y_{89} + y_{13}y_9 + y_{82}y_{21} + y_{38}y_{92} \qquad \text{(Eq. 3.1)}$$

Figure 3-1 shows the printout of the constituent parameters, y_k and the model of equation 3.1.

By multiplying the above costs by the number of OB and ASC (i.e., y_2, y_{55}) the FDD personnel cost not associated with a team is obtained. Adding yields z_5:

$$z_5 = (1.33)(6.7101)\Big[y_{46}y_{57} + y_3y_{45} + y_4y_{47} + y_6y_{43} + y_7y_{48} + y_{13}y_{44} + y_{38}y_{49} + y_{86}y_{27} + y_{28}y_{87} + y_1y_{62}y_{68} + y_2y_{63}y_{69} + y_{55}y_{64}y_{70} + y_{88}y_{90} + y_{82}y_{91} + y_{26}\Big] \qquad \text{(Eq. 3.5)}$$

z_5 is adjusted by the manning factor of 1.33 and further assumes an MX life span of 10 years. Therefore, an equal payment series present worth factor is 6.7101. The parameter y_{26} is defined as the base operating support cost that incorporates general costs not directly associated with FDD but required to support FDD activities.

Figure 3.5 shows the computer listing for z_5 including the Fortran version of equation 3.5.

3.5 FDD Personnel Cost, z_5

FDD activities are performed by specialty teams which vary in size and composition according to the task to be performed. They type of teams, their numbers and costs have been defined as:

	Parameter	Cost Per Team
- Multiple skill team	y_3	y_{45}
- MMT team	y_4	y_{44}
- MOSE team	y_6	y_{43}
- COMM/SEC team	y_7	y_{48}
- ROSE repair team	y_{38}	y_{49}
- Shuffle team	y_5	y_{46}
- CREV/DREV team	y_{82}	y_{91}
- Helicopter team	y_{86}	y_{27}
- FDD/Security team	y_{88}	y_{90}
- Van teams	y_{87}	y_{28}
- PMT team	y_9	y_{20}

By multiplying these number of teams by their respective cost per team, the total cost of teams for a candidate system is evaluated.

To the team cost is added the cost for FDD personnel stationed in each OB and ASC. They are identified as follows:

	Parameter	Average Pay
- FDD personnel per OB	y_{63}	y_{69}
- FDD personnel per ASC	y_{64}	y_{70}

```
C********** Z(4) -- DISPATCH TIME **********
C
      SUBROUTINE DISPCH
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C  Z(4)   -- Dispatch time (minute)
C  Z(8)   -- Number of actions per month
C  Y(18) -- Distance between PS (feet)
C  Y(29) -- Number of C/M no-launch failures per
C           month per missile
C  Y(35) -- Speed of helicopter (feet/minute)
C  Y(36) -- Speed of T/L (feet/minute)
C  Y(37) -- Speed of van (feet/minute)
C  Y(52) -- Delay (minute)
C  Y(56) -- Distance between dispatch location and
C           CMF
C  Y(58) -- Distance between CMF and PS (feet)
C  Y(65) -- Fraction of no-launch failures requiring
C           helicopter
C  Y(68) -- Time spent at each PS for PLU (minute)
C  Y(81) -- SAL verifications (at least once per year)
C
C  Assumption :
C
C  1.  P.S.ROSE failures are considered N/L failures.
C  2.  The missile is taken to CMF during all N/L failure
C      repairs and is removed and implaced with the
C      shell game shuffling.
C  3.  If a failure occurs at night,repairs will not begin
C      until daylight.
C  4.  T/L spends certain amount of dwell time at each PS
C      during the shuffle for PLU.
C  5.  There is one C/M per cluster which implies that
C      if the C/M fails then the barrier has to be
C      opened and SALVER is performed.
C  6.  LRU R/R is not allowed at the PS.
C  7.  Y(81) = 1,if Y(29) is greater than 1./12.;
C      0 otherwise.
C  8.  Helicopter services a small portion of N/L failures.
C
C  Constants used :
C
C  4 days of waiting time for salver & closure of portholes
C  -- 4.*24.*60. minutes
C  Number of CMF-PS trips -- 3.
C  Average number of trips between PS, for shell game, in
C  retrieving and installing a missile -- 33.
C  Briefing and preparation time -- 90. minutes
C
      Z(4) = Y(56)*( Y(65)/Y(35) + (1.0D0-Y(65))/Y(37) )
     &        + 3.0D0*( Y(58)+1.1D1*(Y(18) ) )/Y(36) +
     &        5.76D03*( Y(29) + Y(81)*( 1.0D0/1.2D1
     &        - Y(29) ) )/Z(8) + Y(52) + 9.0D1 + 3.3D1*Y(68)
      RETURN
      END
```

Figure 3-4: z_4 Printout

or in terms of parameters:

$$y_{81}\left[\frac{1}{12} - y_{29}\right] \frac{(4 \times 24 \times 60)}{z_8} \qquad \text{(Eq. 3.4.9)}$$

The ϕor y_{81} being 1 if y_{29} is less than $\frac{1}{12}$ and 0 if y_{29} is equal to or greater than $\frac{1}{12}$. The factor 4 x 24 x 60 is the 4-day SALVER in minutes.

The remaining item contributing to waiting time is any other delay which is not handled elsewhere. An example would be delay to start operations until the next shift or daylight. If there is a probability distribution associated with these delays, it is assumed that the expected value is used. The element representing delay is y_{52}. Another item of delay which has its own element designation is delay on each of the 33 trips for PLU purposes when each PS is visited to check up or leave a missile. This element is y_{68}. Note that the delay for PLU purposes is included for only 22 out of the 23 PS in each cluster since it is covered by missile removal and emplacement time in submodel z_3. The resulting expression for total SALVER, waiting time, and delays is:

$$\begin{pmatrix}\text{Waiting}\\ \text{Time}\end{pmatrix} = (4 \times 24 \times 60) \left[y_{29} + y_{81}\left[\frac{1}{12} - y_{29}\right]\right] / z_8 + y_{52} + 33y_{68} \qquad \text{(Eq. 3.4.10)}$$

The complete submodel for dispatch time, including travel, briefing, SAL VER, waiting and delay times is:

$$z_4 = y_{56}\left[\frac{y_{65}}{y_{35}} + \frac{1 - y_{65}}{y_{37}}\right] + \frac{3}{y_{36}}\left[y_{58} + 11y_{18}\right]$$

$$+ \frac{5760}{z_8}\left[y_{29} + y_{81}\left[\frac{1}{12} - y_{29}\right]\right] + y_{52} + 33y_{68} + 90 \qquad \text{(Eq. 3.4.11)}$$

Figure 3-4 shows the printout for z_4, listing the parameter major assumptions, constants, and a Fortran listing of Eq. 3.4.11.

The wait for SALVER occurs at least once per year for each missile or whenever the cluster barrier is removed. This removal is necessary when the C/M fails, because the down missile has to be replaced by a good missile. Such removal is no longer necessary in the case of RS failures as in the previous model since RS is considered as an LRU that can be changed out at CMF. Since the modeling is for one missile, the proportion of the booster failures out of the total failures that occur for one missile is needed. This proportion is:

$$\frac{\begin{pmatrix}\text{No. C/M N-L} \\ \text{failures/mon.}\end{pmatrix}}{\begin{pmatrix}\text{Total \# N-L} \\ \text{failures/mon.}\end{pmatrix}} = \frac{y_{29}}{z_8} \qquad \text{(Eq. 3.4.6)}$$

Where z_8 is the submodel of the total number of no-launch failures per month for one missile.

When the barrier is removed, the total time spent for SALVER is four days. Expressed in minutes in this model, this results in the following:

$$\frac{y_{29}}{z_8}(4 \times 24 \times 60) \qquad \text{(Eq. 3.4.7)}$$

Since this modeling is on the basis of one missile a method is to add SALVER if the barrier was removed less than once per year per missile for repair operations.

If the total number of failures that requires barrier removal is less than once per year or in this model 1/12 per month, the total has to be increased to the needed 1/12 per month. This is done by the following factor:

$$\phi\left[\frac{1}{12} - \begin{pmatrix}\text{\# C/M N-L} \\ \text{Failures/Mon.}\end{pmatrix}\right] \frac{(4 \times 24 \times 60)}{z_8} \qquad \text{(Eq. 3.4.8)}$$

The time spent for retrieving and transporting the missile by the T/L is composed of the time to pick up the down missile, the time to transport it back to the CMF, and the time to get it back to the PS. Therefore, there are three trips between the CMF and PS with the MSS:

$$\begin{pmatrix}\text{Time between}\\ \text{CMF \& PS}\end{pmatrix} = \frac{\begin{pmatrix}\text{Three trips until}\\ \text{End of N-L Status}\end{pmatrix}\begin{pmatrix}\text{Distance between}\\ \text{CMF and PS}\end{pmatrix}}{(\text{Speed of T/L})}$$

$$= \frac{3y_{58}}{y_{36}} \qquad \text{(Eq. 3.4.3)}$$

There is time spent travelling between PS for maintaining PLU and emplacing the good missile in a PS on a random basis. All PS are visited on the retrieval trip. With 23 PS there are 22 trips between PS on the retrieval of the down missile. With an equal random chance that the good missile will be placed at a given PS, the average number of trips between PS is 22 divided by 2 or 11. Therefore, the total average number of trips between PS is 33.

$$\begin{pmatrix}\text{Time between}\\ \text{PS for PLU}\end{pmatrix} = \frac{\begin{pmatrix}\text{33 Trips between Ps}\\ \text{until end of N-L status}\end{pmatrix}\begin{pmatrix}\text{Distance}\\ \text{between PS}\end{pmatrix}}{(\text{Speed of MSS})} = \frac{33y_{18}}{y_{36}}$$

$$\text{(Eq. 3.4.4)}$$

Combining all the travel times resulted in:

$$\begin{pmatrix}\text{Travel}\\ \text{Time}\end{pmatrix} = y_{56}\left[\frac{y_{65}}{y_{35}} + \frac{(1 - y_{65})}{y_{37}}\right] + \frac{3}{y_{36}}\left[y_{58} + 11y_{18}\right] \qquad \text{(Eq. 3.4.5)}$$

Waiting time as modeled is composed of time waiting for Strategic Arms Limitation Verification and any delay not covered by SALVER, travel times, or briefing.

3.4 Dispatch Time, z_4

Dispatch time is defined as the time spent on travelling, briefing, and preparation, or waiting, from fault detection to end of no-launch status.

$$\begin{pmatrix}\text{Dispatch}\\ \text{Time}\end{pmatrix} = \begin{pmatrix}\text{Travel}\\ \text{Time}\end{pmatrix} + \begin{pmatrix}\text{Waiting}\\ \text{Time}\end{pmatrix} + \begin{pmatrix}\text{Briefing and}\\ \text{Preparation Time}\end{pmatrix} \qquad \text{(Eq. 3.4.1)}$$

Briefing and preparation time is assumed to be constant at 90 minutes. Travel time is composed of any time spent on travelling between the dispatch location and CMF, between CMF and PS, and among PS for the shell game.

The original modelling on helicopter usage between dispatch location and CMF was for situations where an extra part, equipment, or personnel were needed because of unforeseen occurrences at the cluster. This has been changed to reflect helicopter dispatches mainly for critical faults on emergencies, instead of as an after thought. The fraction of no-launch failures requiring the use of helicopters is designated as y_{65}. Thus, the time for a crew to travel from the dispatch location to CMF is a weighted average of the travel times when van is used versus the case when helicopter is used.

$$\begin{pmatrix}\text{Time from Dispatch}\\ \text{Location to CMF}\end{pmatrix} = \begin{pmatrix}\text{Fraction of Action}\\ \text{Helicopter is Used}\end{pmatrix} \times \frac{\begin{pmatrix}\text{Distance between Dispatch}\\ \text{Location and CMF}\end{pmatrix}}{(\text{Speed of Helicopter})}$$

$$+ \begin{pmatrix}1 - \begin{matrix}\text{Fraction of Action}\\ \text{Helicopter is Used}\end{matrix}\end{pmatrix} \times \frac{\begin{pmatrix}\text{Distance between Dispatch}\\ \text{Location and CMF}\end{pmatrix}}{(\text{Speed of Van})}$$

$$= y_{65}\,\frac{y_{56}}{y_{35}} + (1 - y_{65})\,\frac{y_{56}}{y_{37}} \qquad \text{(Eq. 3.4.2)}$$

```
C********** Z(3) -- TASK TIME **********
C
      SUBROUTINE TASK
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   Z(3)   -- Task time (minute)
C   Z(8)   -- Number of actions per month
C   Y(19) -- Missile emplacement time (minute)
C   Y(23) -- MGCS repair time (minute)
C   Y(24) -- MOSE repair time (minute)
C   Y(29) -- Number of C/M no launch failures/month
C            per missile
C   Y(30) -- Number of R/S no launch failures/month per
C            missile
C   Y(31) -- Number of MOSE no launch failures/month per
C            missile
C   Y(47) -- Number of MGCS no launch failures per
C            month per missile
C   Y(50) -- Missile removal time (minute)
C   Y(51) -- R/S repair time (minute)
C   Y(57) -- C/M repair time (minute)
C   Y(60) -- PS ROSE repair time (minute)
C   Y(62) -- Number of PS ROSE failures per month
C            per missile
C   Y(67) -- Time to enter/exit site (minute)
C
C   Assumption :
C
C   1.  Launchable faults are handled whenever a no
C       launch failure is acted on.
C   2.  Any maintenance action occuring on site or at
C       the CMF is part of task time.
C   3.  Inspection of both AVE and OSE occurs during
C       each action.
C   4.  MOSE repair team repairs PS ROSE failures.
C   5.  P.S.ROSE failures are considered N/L failures.
C   6.  The missile is taken to CMF during all N/L failure
C       repairs and is removed and implaced with the
C       shell game shuffling.
C
      Z(3) = Y(67) + Y(19) + Y(50) + ( Y(62)*Y(60) +
     &       Y(31)*Y(24) + Y(29)*Y(57) + Y(30)*Y(51) +
     &       Y(47)*Y(23) )/Z(8)
      RETURN
      END
```

Figure 3-3: z_3 **Printout**

Using the element designations and combining with missile removal, emplacement, and enter/exit times, the final form of task time is:

$$z_3 = \underset{\begin{pmatrix}\text{Removal}\\ \text{Time}\end{pmatrix}}{y_{50}} + \underset{\begin{pmatrix}\text{Remove/Replace}\\ \text{Procedures}\end{pmatrix}}{\frac{y_{29}y_{57} + y_{30}y_{51} + y_{31}y_{24} + y_{47}y_{23} + y_{62}y_{60}}{z_8}}$$

$$+ \underset{\begin{pmatrix}\text{Emplacement}\\ \text{Time}\end{pmatrix}}{y_{19}} \quad + \underset{\begin{pmatrix}\text{Enter/Exit}\\ \text{Time}\end{pmatrix}}{y_{67}} \qquad \text{(Eq. 3.3.4)}$$

Figure 3-3 shows the printout of the constituent y_k and Equation 3.3.4.

any of the missiles' subsystems. These inspection times are included in the individual subsystem remove/replace procedure times.

Removal and emplacement time, and the time to enter/exit a PS site are taken to be the same for all types of actions requiring site access and y_{50}, y_{19} and y_{69} are the respective designations for these times.

The time for remove/replace procedures corresponding to failure of the missile is taken to be a weighted average of the individual subsystem repair times, where the weights are the corresponding subsystem failure rates divided by the missile failure rate, z_8. That is:

$$\begin{pmatrix}\text{Remove/Replace Time}\\ \text{from Subsystem } i\end{pmatrix} = \begin{pmatrix}\text{Subsystem } i\\ \text{Repair Time}\end{pmatrix} \times \begin{pmatrix}\text{Subsystem } i\\ \text{Failure rate}\end{pmatrix} \div \begin{pmatrix}\text{Number of Actions}\\ \text{per Month}\end{pmatrix} \qquad \text{(Eq. 3.3.2)}$$

Resulting in:

$$\begin{aligned}\begin{pmatrix}\text{Remove/Replace}\\ \text{Procedures Time}\end{pmatrix} = \Bigg[&\begin{pmatrix}\text{C/M}\\ \text{Failure Rate}\end{pmatrix} \times \begin{pmatrix}\text{C/M}\\ \text{Repair Time}\end{pmatrix}\\ &+ \begin{pmatrix}\text{R/S}\\ \text{Failure Rate}\end{pmatrix} \times \begin{pmatrix}\text{R/S}\\ \text{Repair Time}\end{pmatrix}\\ &+ \begin{pmatrix}\text{MOSE}\\ \text{Failure Rate}\end{pmatrix} \times \begin{pmatrix}\text{MOSE}\\ \text{Repair Time}\end{pmatrix}\\ &+ \begin{pmatrix}\text{MGCS}\\ \text{Failure Rate}\end{pmatrix} \times \begin{pmatrix}\text{MGCS}\\ \text{Repair Time}\end{pmatrix}\\ &+ \begin{pmatrix}\text{PS ROSE}\\ \text{Failure Rate}\end{pmatrix} \times \begin{pmatrix}\text{PS ROSE}\\ \text{Repair Time}\end{pmatrix}\Bigg]\\ &\div \begin{pmatrix}\text{Number of Actions}\\ \text{per Month}\end{pmatrix} \qquad \text{(Eq. 3.3.3)}\end{aligned}$$

3.3 Task Time, z_3

Task time is defined to be the time spent on removal and emplacement of the missile, remove/replace procedures, and entering/exiting site. Task time does not include any time covered by the submodel dispatch time; such as travel, waiting, briefing, and delay times.

$$\begin{pmatrix}\text{Task}\\\text{Time}\end{pmatrix} = \begin{pmatrix}\text{Removal}\\\text{Time}\end{pmatrix} + \begin{pmatrix}\text{Remove/Replace}\\\text{Procedures}\end{pmatrix} + \begin{pmatrix}\text{Emplacement}\\\text{Time}\end{pmatrix} + \begin{pmatrix}\text{Enter/Exit}\\\text{Time}\end{pmatrix} \qquad \text{(Eq. 3.3.1)}$$

The definition of each of the above is:

Removal Time - Time spent in extracting the missile from the PS.

Remove/Replace Procedures - Time spent in removing a faulty LRU from the missile and replacing the LRU with a good unit, plus time taken to inspect, test, calibrate, and adjust any part of the missile. If there are any other repair type activities, their times would be included here.

Emplacement Time - Time spent in replacing the missile in the PS.

Enter/Exit Time - Time spent in entering and exiting the PS and its perimeters.

The original modelling for this submodel began with the baseline concept of having AVE and OSE which could be separated from each other at the PS. This baseline was changed to removal and transport of the downed missile to the CMF for remove/replace procedure. Missile inspection is assumed to occur whenever any type of corrective action is taken for

```
C********** Z(2) -- FDD EQUIPMENT AND FACILITIES COST **********
C
      SUBROUTINE EFCOST
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C  Z(2)   -- FDD equipment and facilities cost
C  Y(1)   -- Number of CMF
C  Y(2)   -- Number of OB
C  Y(55)  -- Number of ASC
C  Y(72)  -- Cost of each CMF ($)
C  Y(73)  -- Cost of each OB ($)
C  Y(74)  -- Cost of each ASC ($)
C  Y(75)  -- Equipment cost per CMF ($)
C  Y(76)  -- Equipment cost per OB ($)
C  Y(77)  -- Equipment cost per ASC ($)
C
      Z(2) = Y(1)*(Y(72)+Y(75)) + Y(2)*(Y(76)+Y(73)) +
     &       Y(55)*(Y(74)+Y(77))
      RETURN
      END
```

Figure 3-2: z_2 Printout

3.2 FDD Equipment and Facility Cost, z_2

z_2 is defined as the sum of the costs of facilities and equipment for the CMF, OB, and ASC and is modelled as follows:

$$z_2 = y_1(y_{72} + y_{75}) + y_2(y_{73} + y_{76}) + y_{55}(y_{74} + y_{77}) \quad \text{(Eq. 3.2)}$$

Figure 3-2 shows the printout of the constituent parameters, y_k and the model of equation 3.2.

```
C********** Z(1) -- NUMBER OF PERSONNEL FOR FDD **********
C
      SUBROUTINE PERSON
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   Z(1)   -- Number of personnel for FDD
C   Y(2)   -- Number of OB
C   Y(3)   -- Number of multiple skill teams
C   Y(4)   -- Number of MMT
C   Y(5)   -- Number of shuffle teams
C   Y(6)   -- Number of MOSE teams
C   Y(7)   -- Number of COMM/security repair teams
C   Y(8)   -- Number in multiple skill team
C   Y(9)   -- Number of PM teams
C   Y(10)  -- Number in shuffle team
C   Y(11)  -- Number in MOSE team
C   Y(12)  -- Number in COMM/security repair team
C   Y(13)  -- Number in PM team
C   Y(21)  -- Number in CREV/DREV team
C   Y(38)  -- Number of ROSE repair teams
C   Y(39)  -- Number in MMT
C   Y(55)  -- Number of ASC
C   Y(59)  -- Number in helicopter team
C   Y(61)  -- Number in van team
C   Y(63)  -- Number of FDD personnel per OB
C   Y(64)  -- Number of FDD personnel per ASC
C   Y(82)  -- Number of CREV/DREV teams
C   Y(86)  -- Number of helicopter teams
C   Y(87)  -- Number of van teams
C   Y(88)  -- Number of FDD security teams
C   Y(89)  -- Number in FDD security team
C   Y(92)  -- Number in ROSE repair team
C
      Z(1) = Y(3)*Y(8) + Y(4)*Y(39) + Y(5)*Y(10) + Y(6)*Y(11)
     $        + Y(7)*Y(12) + Y(2)*Y(63) + Y(55)*Y(64)
     $        + Y(59)*Y(86) + Y(61)*Y(87) + Y(88)*Y(89)
     $        + Y(13)*Y(9) + Y(82)*Y(21) + Y(38)*Y(92)
      RETURN
      END
```

Figure 3-1: z_1 Printout

```
C*********** Z(5) -- FDD PERSONNEL COST **********
C
      SUBROUTINE PCOST
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C  Z(5)   -- FDD personnel cost
C  Y(2)   -- Number of OB
C  Y(3)   -- Number of multiple skill teams
C  Y(4)   -- Number of MMT
C  Y(5)   -- Number of shuffle teams
C  Y(6)   -- Number of MOSE teams
C  Y(7)   -- Number of COMM/security repair teams
C  Y(9)   -- Number of PM teams
C  Y(20) -- Personnel cost per PM team ($)
C  Y(26) -- Base operating support cost ($)
C  Y(27) -- Personnel cost per helicopter team ($)
C  Y(28) -- Personnel cost per van team ($)
C  Y(38) -- Number of ROSE repair teams
C  Y(43) -- Personnel cost per MOSE team
C  Y(44) -- Personnel cost per MMT
C  Y(45) -- Personnel cost/multiple skill team
C  Y(46) -- Personnel cost per shuffle team
C  Y(48) -- Personnel cost/COMM - security repair team
C  Y(49) -- Personnel cost/ROSE repair team
C  Y(55) -- Number of ASC
C  Y(63) -- Number of FDD personnel per OB
C  Y(64) -- Number of FDD personnel per ASC
C  Y(69) -- Average pay for OB personnel ($)
C  Y(70) -- Average pay for ASC personnel ($)
C  Y(82) -- Number of CREV/DREV teams
C  Y(86) -- Number of helicopter teams
C  Y(87) -- Number of van teams
C  Y(88) -- Number of FDD security teams
C  Y(90) -- Personnel cost/FDD security team
C  Y(91) -- Personnel cost per CREV/DREV team
C
C  CONSTANT USED :
C
C  10 Years -- Life span of MX program once developed.
C  1.33     -- Manning factor for 75% use of personnel.
C  6.7101   -- Present value of an annual expense for 10
C              years at 8 % per year compounded annually.
C
       Z(5) = (1.33D0*(Y(46)*Y(5) + Y(3)*Y(45) + Y(9)*Y(20)
     &        + Y(6)*Y(43) + Y(7)*Y(48) + Y(4)*Y(44)
     &        + Y(26) + Y(38)*Y(49) + Y(86)*Y(27)
     &        + Y(28)*Y(87) + Y(2)*Y(63)*Y(69)
     &        + Y(55)*Y(64)*Y(70) + Y(88)*Y(90)
     &        + Y(82)*Y(91))*1.0D0)*6.7101D0
       RETURN
       END
```

Figure 3-5: z_5 Printout

3.6 FDD Vehicle Cost, z_6

This submodel computes the cost of vehicles assigned to FDD at each CMF, OB, and ASC. The type of vehicles, their numbers and costs are represented as follows:

Type	Numbers	Costs
Helicopters	y_{14}	y_{42}
Vans	y_{15}	y_{40}
T/L	y_{16}	y_{41}
STV	y_{53}	y_{71}
CREV/DREV	$5y_{33}$	y_{85}

This vehicle cost for a given candidate system is:

$$z_6 = y_{14}y_{42} + y_{15}y_{40} + y_{16}y_{41} + y_{53}y_{71} + 5y_{85}y_{33} \qquad \text{(Eq. 3.6)}$$

Figure 3-6 shows the computer listing for z_6 and equation 3.6.

```
C********** Z(6) -- FDD VEHICLE COST **********
C
      SUBROUTINE VCOST
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C  Z(6)   -- FDD vehicle cost
C  Y(14) -- Number of helicopters assigned to FDD
C  Y(15) -- Number of vans assigned to FDD
C  Y(16) -- Number of T/L
C  Y(33) -- Total gross CREV/DREV in dispatch area
C  Y(40) -- Cost per van ($)
C  Y(41) -- Cost per T/L ($)
C  Y(42) -- Cost per helicopter ($)
C  Y(53) -- Number of STV
C  Y(71) -- Cost per STV ($)
C  Y(85) -- Cost per CREV/DREV ($)
C
C  ASSUMPTION:
C
C  1.  CREV/DREV'S are dispatched from ASC'S.
C
      Z(6) = Y(14)*Y(42) + Y(15)*Y(40) + Y(16)*Y(41)
     &        + Y(53)*Y(71) + 5.0D0*Y(85)*Y(33)
      RETURN
      END
C
```

Figure 3-6: z_6 Printout

3.7 FDD Operating and Spares Costs, z_7

This submodel computes the spares inventory cost associated with each CMF, OB, and DAA. Their symbols are:

y_{78} - Spares/Supplies cost per CMF

y_{79} - Spares/Supplies cost per OB

y_{80} - Spares/Supplies cost per ASC

The FDD operating and spares costs for a given candidate system is obtained by multiplying these costs by the respective number of CMF, OB, or ASC:

$$z_7 = y_1 y_{78} + y_2 y_{79} + y_{55} y_{80} \qquad \text{(Eq. 3.7)}$$

Figure 3-7 shows the computer listing for z_7.

```
C********** Z(7) -- FDD OPERATING AND SPARE COST **********
C
      SUBROUTINE OSCOST
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   Z(7)   -- FDD operating and spare cost
C   Y(1)   -- Number of CMF
C   Y(2)   -- Number of OB
C   Y(55)  -- Number of ASC
C   Y(78)  -- Spares/supplies cost per CMF ($)
C   Y(79)  -- Spares/supplies cost per OB ($)
C   Y(80)  -- Spares/supplies cost per ASC ($)
C
      Z(7) = Y(1)*Y(78) + Y(2)*Y(79) + Y(55)*Y(80)
      RETURN
      END
C
C
C
C
C
C
C
C
C
C
```

Figure 3-7: z_7 Printout

3.8 Number of Actions per Month, z_8

This submodel is defined as the total number of no-launch failures per month for one missile. The missile subsystems are divided into booster, reentry system, and MOSE, and MGSC subsystems. PS ROSE failures are treated as no-launch failures. Hence:

Number of Actions/Month = Number of no-launch C/M failures/month
+ Number of no-launch RS failures/month
+ Number of no-launch MOSE failures/month
+ Number of no-launch MGCS failures/month
+ Number of no-launch PS ROSE failures/month

or

$$z_8 = y_{29} + y_{30} + y_{31} + y_{47} + y_{62} \qquad \text{(Eq. 3.8)}$$

Figure 3-8 shows the computer listing for z_8.

```
C********** Z(8) -- NUMBER OF ACTIONS PER MONTH **********
C
      SUBROUTINE ACTION
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   Z(8)   -- Number of actions per month
C   Y(29) -- Number of C/M no launch failures per
C               month per missile
C   Y(30) -- Number of R/S no launch failures per
C               month per missile
C   Y(31) -- Number of MOSE no launch failures per
C               month per missile
C   Y(47) -- Number of MGCS no launch failures per
C               month per missile
C   Y(62) -- Number of PS ROSE failures per month
C               per missile
C
C   Assumption :
C
C   1. Launchable faults are handled only when
C      no launch failures are acted upon.
C   2. P.S.ROSE failures are considered N/L failures.
C
      Z(8) = Y(29) + Y(30) + Y(31) + Y(47) + Y(62)
      RETURN
      END
```

Figure 3-8: z_8 Printout

4.0 CRITERION MODELS

Section 2.4 identified the criteria to be used for evaluation of candidate system performance as well as the relative importance of each criterion. The sections below develop each criterion model.

4.1 Preservation of Location Uncertainty (PLU), x_1

PLU is defined to be the indicator of location uncertainty retention or non-degredation. It was decided that PLU was related to the number of FDD personnel, other personnel who had to know missile locations, the time of maintenance actions (task time and dispatch time), and time of deceptive actions.

As the number of FDD personnel increases, the number of ways that personnel can be used to reduce the fraction who are aware of missile location increases, hence achieving better levels of PLU. However, the increase in the number of personnel knowing missile locations decreases PLU because of the increase in interaction among the personnel. The longer and more frequent maintenance activity requires increased exposure time so that detection of anomalies becomes easier by unfriendly forces.

To handle the personnel factors:

$$\frac{(\text{Number of personnel for FDD})}{\begin{pmatrix}\text{Number of maintenance}\\ \text{personnel knowing}\\ \text{missile locations}\end{pmatrix} + \begin{pmatrix}\text{Number of CAMMS}\\ \text{personnel who need}\\ \text{to know missile location}\end{pmatrix}} = \frac{z_1}{y_{25} + y_{66}}$$

(Eq. 4.1.1)

Maintenance times are:

$$\frac{\text{Total Time}}{\begin{pmatrix}\text{Number of}\\ \text{Actions/Month}\end{pmatrix}\begin{pmatrix}\text{Task}\\ \text{Time} + \text{Dispatch}\\ \text{Time}\end{pmatrix}} = \frac{43200}{z_8(z_3 + z_4)} \qquad \text{(Eq. 4.1.2)}$$

(Note that these factors are dimensionless).

Summing the personnel factor and the maintenance factor provides a PLU index which is x_1:

$$x_1 = \frac{z_1}{y_{25} + y_{26}} + \frac{43200}{z_8(z_3 + z_4)} \; ; \qquad \text{(Eq. 4.1.3)}$$

Figure 4-1 shows the computer listing, x_1.

```
C********** X(1) -- PRESERVATION OF LOCATION UNCERTAINTY **********
C
      SUBROUTINE PLU
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   X(1)   -- Preservation of location uncertainty
C   Z(1)   -- Number of personnel for FDD
C   Z(3)   -- Task time (minute)
C   Z(4)   -- Dispatch time (minute)
C   Z(8)   -- Number of actions per month
C   Y(25) -- Number of maintenance personnel knowing missile(s)
C            location(s)
C   Y(66) -- Number of personnel at CAMMS need to know missile(s)
C            location(s)
C
C   CONSTANT USED:
C
C   TOTAL -- Total number of minutes in 30 days = 43200
C
      TOTAL = 4.32D4
      X(1) = Z(1)/(Y(25)+Y(66)) + TOTAL/(Z(8)
     &         *(Z(3)+Z(4)))
      RETURN
      END
C
```

Figure 4-1: x_1 Printout

4.2 Availability, x_2

Availability is defined as the fraction of up time divided by the total time and was modeled as the total time minus the down time divided by the total time (the fraction of downtime).

$$\text{Availability} = \frac{(\text{Total Time}) - (\text{Down Time})}{(\text{Total Time})}$$

This availability model is based upon one month's time in minutes and for one missile. "Up time" is defined as time that the missile is launchable to a hard or soft target.

Down time is seen as being composed of time spent on any maintenance task or time spent by crews on other duties not directly involved in tasks, called "dispatch time". The number of actions in one month time for one missile is also needed.

The definition and structuring of task time z_3, dispatch time z_4, and number of actions/month, z_8, submodels are given in the submodel development sections (3.3, 3.4, 3.8).

Using the above items and their designations, availability is:

$$x_2 = \frac{\left(\text{Total Time}\right) - \left(\frac{\text{Number of Actions}}{\text{Month}}\right)\left(\begin{matrix}\text{Dispatch}\\ \text{Time}\end{matrix}\right) + \left(\begin{matrix}\text{Task}\\ \text{Time}\end{matrix}\right)}{(\text{Total Time})}$$

$$= \frac{\text{Total} - z_8(z_4 + z_3)}{\text{Total}}\text{; Total} = 43{,}200 \text{ minutes} \qquad \text{(Eq. 4.2)}$$

Figure 4-2 shows the computer listing for x_2.

```
C********** X(2) -- AVAILABILITY **********
C
      SUBROUTINE AVAIL
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   X(2) -- Availability
C   Z(3) -- Task time (minute)
C   Z(4) -- Dispatch time (minute)
C   Z(8) -- Number of actions per month
C
C   Assumptions :
C
C   1. A missile is launchable (available) if it can be
C      targeted and launched to either a hard or soft target.
C   2. This availability is modeled for one missile.
C   3. Total time is figured on a 30-day month.
C
C   CONSTANT USED:
C
C   TOTAL -- Total number of minutes in 30 days = 43200
C
      TOTAL = 4.32D4
      X(2) = (TOTAL - Z(8)*(Z(4)+Z(3)))/TOTAL
      RETURN
      END
```

Figure 4-2: x_2 Printout

4.3 Comparative Costs, x_3

This criterion estimates the effect of candidate system cost and is measured in dollars and defined in terms of four submodels:

z_2 = FDD equipment and facility costs

z_5 = FDD personnel cost

z_6 = FDD vehicle cost

z_7 = FDD operating and spare cost

Comparative cost, x_3, is defined as the inverse of the sum of these submodels, hence:

$$x_3 = (z_2 + z_5 + z_6 + z_7)^{-1} \quad ; \qquad \text{(Eq. 4.3)}$$

Figure 4-3 shows the computer listing for this criterion.

```
C********** X(3) -- COST **********
C
      SUBROUTINE COST
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C  X(3) -- Cost
C  Z(2) -- FDD equipment and facilities cost ($)
C  Z(5) -- FDD personnel cost ($)
C  Z(6) -- FDD vehicle cost ($)
C  Z(7) -- FDD operating and spare cost ($)
C
      X(3) = 1.0D0/( Z(2)+Z(5)+Z(6)+Z(7) )
      RETURN
      END
```

Figure 4-3: x_3 Printout

4.4.6 CREV/DREV Team C/D

CREV/DREV teams are used whenever there is a SALVER. There is a FDD/SEC team dispatched to accompny the C/D, and the utilization time is obtained as follows:

$$\begin{pmatrix}\text{C/D}\\\text{UTILIZATION}\\\text{TIME}\end{pmatrix} = \begin{pmatrix}\text{NO. OF PERSONNEL}\\\text{FOR C/D AND}\\\text{FDD/SEC PER SALVER}\end{pmatrix} \times \begin{pmatrix}\text{TIME SPENT}\\\text{FOR EACH SALVER}\end{pmatrix} \times \begin{pmatrix}\text{EXPECTED NO. OF SALVER}\\\text{PER MO. PER MISSILE}\end{pmatrix} \qquad \text{(Eq. 4.4.15)}$$

For each SALVER, one FDD/SEC team plus a to-be-determined number of C/D teams are dispatched. Therefore:

$$\begin{aligned}\begin{pmatrix}\text{NO. OF PERSONNEL}\\\text{FOR C/D AND}\\\text{FDD/SEC PER SALVER}\end{pmatrix} &= \begin{pmatrix}\text{NO. OF C/D}\\\text{DISPATCHED TO}\\\text{CMF PER SALVER}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\\text{C/D}\end{pmatrix} + \begin{pmatrix}\text{NO. IN}\\\text{FDD/SEC}\end{pmatrix}\\ &= y_{84}\, y_{21} + y_{89} \qquad \text{(Eq. 4.4.16)}\end{aligned}$$

Substituting back into Eq. 4.4.11 yields the following:

$$\begin{pmatrix} \text{HELICOPTER TEAM} \\ \text{UTILIZATION TIME} \\ \text{PER MONTH PER MISSILE} \end{pmatrix} =$$

$$\frac{2y_{65}\, y_{59}}{y_{35}} \left[z_8\, y_{56} + \left[y_{22} + y_{34} \right] \times \left[y_{56} + y_{58} \right] \right] \qquad \text{(Eq. 4.4.14)}$$

$$\begin{pmatrix}\text{HELICOPTER}\\ \text{USE IN}\\ \text{N/L FAILURES}\\ \text{PER MO. PER MISSILE}\end{pmatrix} = \frac{2\ z(8)\ y(65)\ y(59)\ y(56)}{y(35)} \quad \text{(Eq. 4.4.12)}$$

and

$$\begin{pmatrix}\text{HELICOPTER}\\ \text{USE IN}\\ \text{ROSE AND COMM/SEC}\\ \text{PER MISSILE}\end{pmatrix} = \begin{pmatrix}\text{NO. OF TRIPS}\\ \text{PER ROSE OR}\\ \text{COMM/SEC FAILURE}\end{pmatrix} \times$$

$$\left[\begin{pmatrix}\text{NO. OF ROSE}\\ \text{FAILURES PER}\\ \text{MO. PER MISSILE}\end{pmatrix} + \begin{pmatrix}\text{NO. OF COMM/SEC}\\ \text{FAILURES PER}\\ \text{MO. PER MISSILE}\end{pmatrix}\right]$$

$$\times \begin{pmatrix}\text{PERCENTAGE}\\ \text{HELICOPTER}\\ \text{USED}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{HELICOPTER}\end{pmatrix}$$

$$\times \left[\begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND DISPATCH}\\ \text{LOCATION}\end{pmatrix} + \begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND PS}\end{pmatrix}\right] \Big/$$

$$\begin{pmatrix}\text{SPEED OF}\\ \text{HELICOPTER}\end{pmatrix}$$

$$= \frac{2\ [y(22) + y(34)]\ \ y(65)\ y(59)\ [y(56) + y(58)]}{y(35)}$$

(Eq. 4.4.13)

4.4.5 Helicopter Team

Helicopters are used in a portion of N/L failures, ROSE failures and COMM/SEC failures. In the case of N/L failures, the helicopters take the shuffle crew from the dispatch area to the CMF and returns to the dispatch area immediately. In the case of ROSE and COMM/SEC failures, the helicopters take the repair crew from the dispatch area to the PS and return. No FDD/SEC team is used to accompany the helicopter team, although there is a FDD/SEC team on the helicopter which is traveling with either the shuffle crew or the repair crew.

Helicopter team utilization time is considered to be:

$$\begin{pmatrix}\text{HELICOPTER}\\ \text{USE IN}\\ \text{N/L FAILURES}\\ \text{PER MO. PER MISSILE}\end{pmatrix} + \begin{pmatrix}\text{HELICOPTER}\\ \text{USE IN}\\ \text{ROSE AND COMM/SEC}\\ \text{FAILURES PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \qquad \text{(Eq. 4.4.11)}$$

$$\begin{pmatrix}\text{HELICOPTER}\\ \text{USE IN}\\ \text{N/L FAILURES}\\ \text{PER MO. PER MISSILE}\end{pmatrix} = \begin{pmatrix}\text{NO. OF TRIPS}\\ \text{PER N/L ACTION}\end{pmatrix} \times \begin{pmatrix}\text{NO. OF N/L}\\ \text{ACTION PER}\\ \text{MO. PER MISSILE}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{PERCENTAGE}\\ \text{HELICOPTER}\\ \text{USED}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{HELICOPTER}\\ \text{TEAM}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND DISPATCH}\\ \text{LOCATION}\end{pmatrix} \Big/ \begin{pmatrix}\text{SPEED}\\ \text{OF}\\ \text{HELICOPTER}\end{pmatrix}$$

Since there are 23 PS per cluster, for each shuffle, the T/L makes 22 trips between the PS and 23 stops at the PS for PLU purposes.

$$\begin{pmatrix}\text{TRAVEL TIME}\\ \text{BETWEEN PS}\\ \text{PER SHUFFLE}\end{pmatrix} = \frac{22\begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{PS}\end{pmatrix}}{\begin{pmatrix}\text{SPEED OF}\\ \text{T/L}\end{pmatrix}}$$

$$= \frac{22y_{18}}{y_{36}} \qquad \text{(Eq. 4.4.8)}$$

$$\begin{pmatrix}\text{TIME SPENT}\\ \text{AT PS FOR}\\ \text{PLU PER}\\ \text{SHUFFLE}\end{pmatrix} = 23y_{68} \qquad \text{(Eq. 4.4.9)}$$

Substituting the above into Eq. 4.4.3 and simplifying results in:

$$(z_8 + \frac{1}{12})\ (y_{10} + y_{89}) \left[y_{56}\left(\frac{y_{65}}{y_{35}} + \frac{4-y_{65}}{y_{37}}\right) + \frac{4}{y_{36}}\left(y_{58} + 11y_{18}\right) + 46y_{68} + 270 \right]$$

$$+ \ y_{62}\ (y_{10} + y_{89})\ \left(y_{60} - \frac{2y_{56}}{y_{37}} - 135\right) \qquad \text{(Eq. 4.4.10)}$$

$$\left(\begin{array}{c}\text{AVG. TRAVEL TIME}\\ \text{FROM DISPATCH LOCATION}\\ \text{TO CMF}\end{array}\right) =$$

$$\left[\left(\begin{array}{c}\text{PERCENTAGE}\\ \text{HELICOPTER}\\ \text{USED}\end{array}\right) \times \left(\begin{array}{c}\text{DISTANCE}\\ \text{BETWEEN CMF}\\ \text{AND DISPATCH}\\ \text{LOCATION}\end{array}\right) \Big/ \left(\begin{array}{c}\text{SPEED OF}\\ \text{HELICOPTER}\end{array}\right)\right]$$

$$+ \left[\left(1- \begin{array}{c}\text{PERCENTAGE}\\ \text{HELICOPTER}\\ \text{USED}\end{array}\right) \times \left(\begin{array}{c}\text{DISTANCE}\\ \text{BETWEEN CMF}\\ \text{AND DISPATCH}\\ \text{LOCATION}\end{array}\right) \Big/ \left(\begin{array}{c}\text{SPEED OF}\\ \text{VAN}\end{array}\right)\right]$$

$$= y_{65} \times \frac{y_{56}}{y_{35}} + (1-y_{65}) \times \frac{y_{56}}{y_{37}}$$

(Eq. 4.4.5)

$$\left(\begin{array}{c}\text{TRAVEL TIME}\\ \text{BETWEEN CMF}\\ \text{AND DISPATCH}\\ \text{LOCATION}\\ \text{BY VAN}\end{array}\right) = \frac{\left(\begin{array}{c}\text{DISTANCE BETWEEN CMF AND}\\ \text{DISPATCH LOCATION}\end{array}\right)}{\left(\begin{array}{c}\text{SPEED OF}\\ \text{VAN}\end{array}\right)}$$

$$= \frac{y_{56}}{y_{37}}$$

(Eq. 4.4.6)

$$\left(\begin{array}{c}\text{TRAVEL TIME}\\ \text{BETWEEN CMF}\\ \text{AND PS}\\ \text{PER SHUFFLE}\end{array}\right) = \frac{2\left(\begin{array}{c}\text{DISTANCE BETWEEN CMF}\\ \text{AND PS}\end{array}\right)}{\left(\begin{array}{c}\text{SPEED OF}\\ \text{T/L}\end{array}\right)}$$

$$= \frac{2y_{58}}{y_{36}}$$

(Eq. 4.4.7)

$$\begin{pmatrix}\text{EXPECTED NO. OF} \\ \text{SALVER PER MONTH} \\ \text{PER MISSILE}\end{pmatrix} = 1/12$$

In the consideration of the travel times, the trip from the dispatch location to the CMF for the first shuffle can be made in either a helicopter or a van, with y_{65} as the percentage of helicopter usage. The second shuffle involves only travel by van. Therefore:

$$\begin{pmatrix}\text{AVG. TWO ROUND TRIPS} \\ \text{TRAVEL TIME BETWEEN} \\ \text{DISPATCH LOCATION} \\ \text{AND PS}\end{pmatrix}$$

$$= \begin{pmatrix}\text{AVG. TRAVEL TIME} \\ \text{FROM DISPATCH LOCATION} \\ \text{TO CMF}\end{pmatrix} + 3\begin{pmatrix}\text{TRAVEL TIME} \\ \text{BETWEEN CMF} \\ \text{AND DISPATCH} \\ \text{LOCATION BY} \\ \text{VAN}\end{pmatrix}$$

$$+ 2\left[\begin{pmatrix}\text{TRAVEL TIME} \\ \text{BETWEEN CMF} \\ \text{AND PS} \\ \text{PER SHUFFLE}\end{pmatrix} + \begin{pmatrix}\text{TRAVEL} \\ \text{TIME} \\ \text{BETWEEN} \\ \text{PS PER} \\ \text{SHUFFLE}\end{pmatrix} \times \begin{pmatrix}\text{TIME SPENT} \\ \text{AT PS FOR} \\ \text{PLU PER} \\ \text{SHUFFLE}\end{pmatrix}\right]$$

(Eq. 4.4.4)

with correction for the case of PS ROSE failures, as follows:

$$\begin{pmatrix}\text{NO. OF ACTIONS}\\ \text{PER MO. PER MISSILE}\end{pmatrix} + \begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{SALVER PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \left[\begin{pmatrix}\text{NO. IN}\\ \text{SHUFFLE}\end{pmatrix} + \begin{pmatrix}\text{NO. IN}\\ \text{FDD/SEC.}\end{pmatrix}\right]$$

$$\times \left[\begin{pmatrix}\text{AVG. TWO ROUND TRIPS}\\ \text{TRAVEL TIME BETWEEN}\\ \text{DISPATCH LOCATION}\\ \text{AND PS}\end{pmatrix} + 2\begin{pmatrix}\text{BRIEFING,}\\ \text{PREPARATION,}\\ \text{AND DEBRIEFING}\\ \text{TIME}\end{pmatrix}\right]$$

$$+ \begin{pmatrix}\text{NO. OF PS}\\ \text{ROSE FAILURES}\\ \text{PER MONTH PER}\\ \text{MISSILE}\end{pmatrix} \times \left[\left[\begin{pmatrix}\text{NO. IN}\\ \text{SHUFFLE}\end{pmatrix} + \begin{pmatrix}\text{NO. IN}\\ \text{FDD/SEC}\end{pmatrix}\right]\right.$$

$$\times \left[\begin{pmatrix}\text{PS ROSE}\\ \text{REPAIR TIME}\end{pmatrix} - \begin{pmatrix}\text{ROUND TRIP}\\ \text{TRAVEL TIME BETWEEN}\\ \text{CMF AND DISPATCH}\\ \text{LOCATION BY VAN}\end{pmatrix}\right.$$

$$\left.\left. - \begin{pmatrix}\text{BRIEFING,}\\ \text{PREPARATION,}\\ \text{AND DEBRIEFING}\\ \text{TIME}\end{pmatrix}\right]\right] \qquad \text{(Eq. 4.4.3)}$$

where:

z_8 = No. of actions per month per missile

y_{10} = No. in shuffle

y_{89} = No. in FDD/SEC

y_{62} = No. of PS ROSE failures per mo. per missile

y_{60} = PS ROSE repair time

$$\begin{pmatrix}\text{BRIEFING,}\\ \text{PREPARATION,}\\ \text{AND DEBRIEFING}\\ \text{TIME}\end{pmatrix} = 90 \text{ min.} + 45 \text{ min.} = 135 \text{ min.}$$

$$\begin{pmatrix}\text{On-Duty Time}\\ \text{Per Month}\\ \text{Per Missile}\end{pmatrix} \times$$

$$\left[\begin{pmatrix}\text{No. of FDD}\\ \text{Personnel in OB}\end{pmatrix} + \begin{pmatrix}\text{No. of FDD Personnel}\\ \text{in ASC}\end{pmatrix} + \begin{pmatrix}\text{No. of PMT}\\ \text{Personnel}\end{pmatrix} + \begin{pmatrix}\text{No. of FDD/SEC}\\ \text{Personnel for PMT}\end{pmatrix}\right]$$

$$= \quad 52.8\left[y_2 y_{63} + y_{55} y_{64} + y_9 y_{13} + y_9 y_{89}\right]$$

$$\text{where } 52.8 = \frac{22 \text{ days/mo.} \times 8 \text{ hrs./day} \times 60 \text{ min./hr}}{200 \text{ missiles}}$$

(Eq. 4.4.2)

4.4.4 Shuffle Team, (MHT)

Shuffles are performed whenever there is a N/L failure or Salt Verification. The first shuffle takes the missile to the CMF after visiting all 23 PS's in the cluster, and the second shuffle replaces the missile back into one of the PS's in the same manner after the completion of the required maintenance or SALVER. A FDD/SEC team accompanies the shuffle team on all maintenance assignments. The teams generally return to their dispatch location upon completion of the first shuffle, except in the case when repair time is less than 3 hours (as for PS ROSE repairs), where the teams will wait at the CMF during such repairs. Therefore, the shuffle team utilization time is the number of N/L failures plus the number of SALVER per month per missile, times the total number of personnel involved in each shuffle, times the time for travelling, preparation, briefing and debriefing of two shuffles;

The contribution to x_4 from each of these teams are discussed in the following sections.

4.4.1 FDD Security Team (FDD/SEC)

One FDD/SEC team is assigned to each maintenance assignment with all teams except FDD/OB, FDD/ASC, and HELICOPTER, for security purposes. The total time spent on maintenance assignments is derived with the respective teams in the sections to follow.

4.4.2 Multiple Skill Team, MULTI-SKILL

Multiple skill team has the capability to perform maintenance on both AVE and OSE equipment, including ROSE and COMMUNICATIONS. When MULTI-SKILL teams are considered under any candidate system, their use factor is directly proportional to the number of MULTI-SKILL teams and the number of teams capable of servicing the fault under consideration. The utilization of MULTI-SKILL is considered with the other teams in later sections.

4.4.3 FDD Personnel at OB and ASC, and Periodic Maintenance Team, (FDD/OB, FDD/ASC, PMT)

FDD/OB, FDD/ASC, and PMT are assumed to be on maintenance assignments during all on-duty hours. Each PMT is accompanied by a FDD/SEC team at all on-duty hours. The contributions to both the numerator and the denominator terms in Eq. 4.4.1 are identical and is equal to:

```
C   ASSUMPTIONS:
C
C   1.   P.S.ROSE failures are N/L failures.
C   2.   Shuffle is performed whenever there is a N/L
C        failure or SALVER.
C   3.   Helicopter service a portion of N/L,ROSE, and
C        COMM/SEC failures.
C   4.   Repairs for P.S.ROSE,ROSE,and COMM/SEC failures
C        are performed at the PS.
C   5.   All AVE and OSE changeouts are performed at the CMF.
C   6.   CREV/DREV'S dispatched from ASC'S.
C   7.   There are dwell times involved at PS during shuffle
C        for PLU.
C   8.   Y(31) = 1, if Y(29) is greater than 1/12, and 0 otherwise.
C   9.   Speed of CREV/DREV is the same as van.
C  10.   Helicopters are used only to transport personnel and
C        equipment from the dispatch area to the maintenance
C        area. All return trips are made in vans.
C  11.   Shuffle team waits at the CMF during repairs of
C        3 hours or less.
C  12.   In the cases where helicopters are used and a shuffle
C        is required prior to the repair operation(as in all
C        N/L failures), only the shuffle crew is transported
C        by the helicopter. The repair crew is always dispatched
C        in vans.
C  13.   PMT, FDD/OB, FDD/ASC teams are considered utilized 8
C        hours a day, 22 days a month.
C  14.   All teams are available 8 hours a day, 22 days a month.
C  15.   One FDD/SEC team is assigned to each maintenance assig-
C        nment with all teams except: FDD/OB, FDD/ASC, Helicopter.
C  16.   If Multi-Skill teams are considered under any candidate,
C        their use factor is directly proportional to the number
C        of Multi-Skill team and the total number of teams capable
C        of servicing the fault under consideration.
C  17.   MMT services C/M, R/S and MGCS failures.
C  18.   MOSE team services P.S.ROSE failures also.
```

```
C   Y(64) -- Number of FDD personnel per ASC
C   Y(65) -- Fraction of no launch failures requiring
C            helicopter
C   Y(68) -- Time spent at each PS for PLU (minute)
C   Y(81) -- SAL verifications (at least once per year)
C   Y(82) -- Number of CREV/DREV teams
C   Y(84) -- Number of CREV/DREV dispatched to CMF
C   Y(86) -- Number of helicopter teams
C   Y(88) -- Number of FDD security teams
C   Y(89) -- Number in FDD security team
C   Y(92) -- Number in ROSE repair team
C   Y(93) -- ROSE repair time (minute)
C   Y(94) -- COMM/Security repair time (minute)
C
C   CONSTANTS USED:
C
C   Time available per month per missile  =  22x8x60/200=52.8 mins.
C   Briefing and preparation time = 90 minutes.
C   Debriefing time = 45 minutes.
C   Distance between ASC and CMF = 364,320 feet.
C
      OFTEN = Y(65)/Y(35) + (2.0D0-Y(65))/Y(37)
      OFTEN1=Y(65)/Y(35)+(4.0D0-Y(65)-2.0D0*Y(62)/(Z(8)+1.0D0/1.2D1))/
     &        Y(37)
      OFTEN2 = 2.0D0/Y(37)
      TOP1 = 5.28D1*( Y(2)*Y(63) + Y(55)*Y(64) + Y(9)*(Y(13)+Y(89)) )
      TOP2=(Z(8)+1.0D0/1.2D1)*(Y(10)+Y(89))*(Y(56)*OFTEN1+(4.0D0*Y(58)+
     &        4.4D1*Y(13))/Y(36) + 4.6D1*Y(68) + 2.7D2) + (Y(10)+
     &        Y(89))*(Y(60)-1.35D2)*Y(62)
      TOP3 = 2.0D0*Y(65)*Y(59)*(Z(8)*Y(56)+(Y(22)+Y(34))*(Y(56)+
     &        Y(58)))/Y(35)
      TOP4 = (Y(84)*Y(21)+Y(89)) * (1.45728D6/Y(37) + 1.71D3) *
     &        (Y(29) + Y(31)*( 1.0D0/1.2D1-Y(29) ))
      TOP5 = Y(22)*( Y(89)+(Y(38)*Y(92)+Y(3)*Y(8))/(Y(3)+Y(38)) )
     &        * ( (Y(56)+Y(58))*OFTEN+Y(93)+1.35D2 )
      TOP6 = ( Y(89)+(Y(4)*Y(39)+Y(3)*Y(8))/(Y(3)+Y(4)) ) * ( (Y(29)
     &        +Y(30)+Y(47))*( Y(56)*OFTEN2+1.35D2 ) + Y(29)*Y(57) +
     &        Y(30)*Y(51) + Y(23)*Y(47) )
      TOP7 = (Y(89)+(Y(6)*Y(11)+Y(3)*Y(8))/(Y(3)+Y(6))) * ( (Y(31)
     &        +Y(62))*(Y(56)*OFTEN2+1.35D2) + Y(31)*Y(24) + Y(60)
     &        *Y(62) + Y(58)*OFTEN2*Y(62) )
      TOP8 = Y(34)*( Y(89)+(Y(7)*Y(12)+Y(3)*Y(8))/(Y(3)+Y(7)) ) *
     &        ( (Y(56)+Y(58))*OFTEN + Y(94) + 1.35D2 )
      TOP = TOP1 + TOP2 + TOP3 + TOP4 + TOP5 + TOP6 + TOP7 +
     &      TOP8
      BOTTOM = 5.28D1 * ( Y(55)*Y(64) + Y(2)*Y(63) +
     &           Y(9)*Y(13) + Y(38)*Y(92) + Y(4)*Y(39) +
     &           Y(5)*Y(10) + Y(6)*Y(11) + Y(59)*Y(86) +
     &           Y(21)*Y(82) + Y(7)*Y(12) + Y(3)*Y(8) +
     &           Y(88)*Y(89) )
      X(4) = TOP/BOTTOM
      RETURN
      END
C
```

```
C********** X(4) -- TEAM UTILIZATION **********
C
      SUBROUTINE TUTIL
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   X(4)   -- Team utilization
C   Z(3)   -- Number of actions per month
C   Y(2)   -- Number of OB
C   Y(3)   -- Number of multiple skill teams
C   Y(4)   -- Number of MMT
C   Y(5)   -- Number of shuffle teams
C   Y(6)   -- Number of MOSE teams
C   Y(7)   -- Number of COMM/security repair teams
C   Y(8)   -- Number in multiple skill team
C   Y(9)   -- Number of PM teams
C   Y(10)  -- Number in shuffle team
C   Y(11)  -- Number in MOSE team
C   Y(12)  -- Number in COMM/security repair team
C   Y(13)  -- Number in PM team
C   Y(18)  -- Distance between PS (feet)
C   Y(21)  -- Number in CREV/DREV team
C   Y(22)  -- Number of ROSE failures per month
C             per missile
C   Y(23)  -- MGCS R/R time (minute)
C   Y(24)  -- MOSE R/R time (minute)
C   Y(29)  -- Number of C/M no launch failures per
C             month per missile
C   Y(30)  -- Number of R/S no launch failures per
C             month per missile
C   Y(31)  -- Number of MOSE N/L failures per month
C             per missile.
C   Y(34)  -- Number of COMM/security failures
C             per month per missile
C   Y(35)  -- Speed of helicopter (feet/minute)
C   Y(36)  -- Speed of T/L (feet/minute)
C   Y(37)  -- Speed of van (feet/minute)
C   Y(38)  -- Number of ROSE repair teams
C   Y(39)  -- Number in RMT
C   Y(47)  -- Number of MGCS no launch failures per
C             month per missile
C   Y(51)  -- R/S repair time (minute)
C   Y(55)  -- Number of ASC
C   Y(56)  -- Distance between dispatch location and
C             CMF (feet)
C   Y(57)  -- C/M repair time (minute)
C   Y(58)  -- Distance between CMF and PS (feet)
C   Y(59)  -- Number in helicopter team
C   Y(60)  -- PS ROSE repair time (minute)
C   Y(62)  -- Number of PS ROSE failures per month
C             per missile
C   Y(63)  -- Number of FDD personnel per OB
```

Figure 4-4: x_4 Printout

4.4 Team Utilization, x_4

Team utilization is defined as the ratio of total man-minutes spent on maintenance to total man-minutes available for maintenance activities.

$$X_4 = \begin{array}{c}\text{Team}\\ \text{Utilization}\end{array} = \frac{\displaystyle\sum_{\text{Teams}} \begin{array}{c}\text{Man-minutes spent on maintenance}\\ \text{assignment per month per missile}\end{array}}{\displaystyle\sum_{\text{Teams}} \begin{array}{c}\text{Total Man-minutes available for}\\ \text{maintenance activities per}\\ \text{month per missile}\end{array}} \qquad \text{(Eq. 4.4.1)}$$

All AVE and OSE changeouts are performed at the CMF, with repairs for PS ROSE, ROSE, and COMM/SEC failures performed at the PS. There are altogether twelve teams under consideration in the modeling of X_4:

FDD/SEC	-	FDD security team
MULTI/SKILL	-	Multiple skill team
FDD/OB	-	FDD personnel at OB
FDD/ASC	-	FDD personnel at ASC
PMT	-	Periodic maintenance team
SHUFFLE	-	Shuffle team (MHT - missile handling team)
HELICOPTER	-	Helicopter team
C/D	-	CREV/DREV team
ROSE	-	Rose team (FMT - facility maintenance team)
MMT	-	Missile maintenance team
MOSE	-	MOSE team (EMT - Electric mechanical team)
COMM/SEC	-	Communications security team

The time spent for each SALVER includes travel time, SALVER task time for opening and closing of the cluster and SALVER ports, and briefing, preparation and debriefing.

$$\begin{pmatrix}\text{TIME SPENT FOR}\\ \text{EACH SALVER}\end{pmatrix} = \begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} + \begin{pmatrix}\text{TASK}\\ \text{TIME}\end{pmatrix} + \begin{pmatrix}\text{NO. OF BRIEFING}\\ \text{PREPARATION, AND}\\ \text{DEBRIEFING}\end{pmatrix} \times \begin{pmatrix}\text{BRIEFING,}\\ \text{PREPARATION AND}\\ \text{DEBRIEFING TIME}\end{pmatrix} \quad \text{(Eq. 4.4.17)}$$

C/D's are dispatched from ASC and are assumed to travel at the speed of vans. The time to open or close a cluster from SALVER is 12 hours. Thus,

$$\begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} = \frac{\begin{pmatrix}\text{NO. OF TRIPS}\\ \text{BETWEEN CMF AND}\\ \text{DISPATCH LOCATION}\end{pmatrix} \times \begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND ASC}\end{pmatrix}}{\begin{pmatrix}\text{SPEED OF}\\ \text{VAN}\end{pmatrix}}$$

$$= \frac{4 \times 364{,}320 \text{ ft.}}{y_{37}} \quad \text{(Eq. 4.4.18)}$$

$$\begin{pmatrix}\text{TASK}\\ \text{TIME}\end{pmatrix} = \begin{pmatrix}\text{TIME TO OPEN}\\ \text{CLUSTER FOR SALVER}\end{pmatrix} + \begin{pmatrix}\text{TIME TO CLOSE}\\ \text{CLUSTER AFTER SALVER}\end{pmatrix}$$

$$= 720 + 720 = 1440 \text{ minutes} \quad \text{(Eq. 4.4.19)}$$

Substituting into Eq. 4.4.17 gives:

$$\begin{pmatrix}\text{TIME SPENT FOR}\\ \text{EACH SALVER}\end{pmatrix} = \frac{1,457,280}{y_{37}} + 1440 + 2 \times 135$$

$$= \left[\frac{1,457,280}{y_{37}} + 1710\right] \text{ minutes} \qquad \text{(Eq. 4.4.20)}$$

The derivation of the expected number of SALVER is similar to that of section 3.4 for z_4:

$$\begin{pmatrix}\text{EXPECTED NO. OF SALVER}\\ \text{PER MO. PER MISSILE}\end{pmatrix} = \begin{pmatrix}\text{NO. OF C/M N/L}\\ \text{FAIL. PER MO. PER}\\ \text{MISSILE}\end{pmatrix}$$

$$+ \begin{pmatrix}\text{NO. OF ANNUAL}\\ \text{SALVER PER MO.}\\ \text{PER MISSILE}\end{pmatrix}$$

$$= y_{29} + y_{81}\left[\frac{1}{12} - y_{29}\right]$$

$$\begin{aligned} y_{81} &= 1 \qquad \text{If } y_{29} < \frac{1}{12} \\ &= 0 \qquad \text{OTHERWISE} \end{aligned} \qquad \text{(Eq. 4.4.21)}$$

Combining Eqs. 4.4.16, 4.4.20, and 4.4.21 gives the following expression for C/D utilization time:

$$\left(y_{84}\, y_{21} + y_{89}\right) \times \left(\frac{1,457,280}{y_{37}} + 1710\right) \times \left[y_{29} + y_{81}\left(\frac{1}{12} - y_{29}\right)\right]$$

(Eq. 4.4.22)

4.4.7 ROSE Team, (FMT)

ROSE team utilization time is defined to be:

$$\begin{pmatrix}\text{NO. OF ROSE}\\\text{FAILURES PER}\\\text{MO. PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{EXPECTED NO.}\\\text{OF PERSONNEL}\\\text{DISPATCHED TO}\\\text{EACH ROSE FAILURE}\end{pmatrix}$$

$$\times \left[\begin{pmatrix}\text{TRAVEL}\\\text{TIME}\end{pmatrix} + \begin{pmatrix}\text{REPAIR}\\\text{TIME}\end{pmatrix} + \begin{pmatrix}\text{BRIEFING,}\\\text{PREPARATION, AND}\\\text{DEBRIEFING TIME}\end{pmatrix}\right]$$

Where, y_{22} = no. of ROSE failures per mo. per missile,

and y_{93} = ROSE repair time (Eq. 4.4.23)

Since multiple-skill teams are considered, a weighted average between them and the ROSE teams is used to compute the expected number of personnel dispatched. One FDD/SEC team is dispatched with *each ROSE repair assignment.*

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\\text{PERSONNEL DISPATCHED}\\\text{TO EACH ROSE FAILURE}\end{pmatrix} = \begin{pmatrix}\text{NO. IN}\\\text{FDD/SEC}\\\text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\\text{ROSE TEAM}\\\text{DIAPATCHED}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{NO. IN}\\\text{ROSE}\\\text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\\text{MULTI-SKILL TEAM}\\\text{DISPATCHED}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{NO. IN}\\\text{MULTI-SKILL}\\\text{TEAM}\end{pmatrix} \qquad \text{(Eq. 4.4.24)}$$

Where,

$$\begin{pmatrix}\text{PERCENTAGE}\\\text{ROSE TEAM}\\\text{DISPATCHED}\end{pmatrix} = \begin{pmatrix}\text{NO. OF}\\\text{ROSE}\\\text{TEAM}\end{pmatrix} \Bigg/ \left[\begin{pmatrix}\text{NO. OF}\\\text{ROSE}\\\text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{NO. OF}\\\text{MULTI-SKILL}\\\text{TEAM}\end{pmatrix}\right]$$

$$= \frac{y_{38}}{y_{38} + y_3} \; ; \qquad \text{(Eq. 4.4.25)}$$

and,

$$\begin{pmatrix}\text{PERCENTAGE}\\ \text{MULTI-SKILL TEAM}\\ \text{DISPATCHED}\end{pmatrix} = \begin{pmatrix}\text{NO. OF}\\ \text{MULTI-SKILL}\\ \text{TEAM}\end{pmatrix} \Bigg/ \left[\begin{pmatrix}\text{NO. OF}\\ \text{ROSE}\\ \text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{NO. OF}\\ \text{MULTI-SKILL}\\ \text{TEAM}\end{pmatrix}\right]$$

$$= \frac{y_3}{y_{38} + y_3} \qquad \text{(Eq. 4.4.26)}$$

Which gives the following expression for the exptected number of personnel dispatched:

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH ROSE FAILURE}\end{pmatrix} = y_{89} + \frac{y_{38}\, y_{92} + y_3\, y_8}{y_{38} + y_3} \qquad \text{(Eq. 4.4.27)}$$

Travel time is obtained by considering the fact that a portion of the dispatches are made by helicopters to the PS while the return trips are always made in vans.

$$\begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} = \begin{pmatrix}\text{AVG. TRAVEL TIME}\\ \text{FROM DISPATCH}\\ \text{LOCATION TO PS}\end{pmatrix} + \begin{pmatrix}\text{TRAVEL TIME FROM}\\ \text{PS TO DISPATCH}\\ \text{LOCATION}\end{pmatrix}$$

(Eq. 4.4.28)

where,

$$\begin{pmatrix}\text{AVG. TRAVEL TIME}\\ \text{FROM DISPATCH}\\ \text{LOCATION TO PS}\end{pmatrix} = \left[\begin{pmatrix}\text{PERCENTAGE}\\ \text{HELICOPTER}\\ \text{USED}\end{pmatrix} \times \left[\begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{DISPATCH}\\ \text{LOCATION}\\ \text{AND CMF}\end{pmatrix} + \begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{CMF}\\ \text{AND PS}\end{pmatrix}\right] \Big/ \begin{pmatrix}\text{SPEED OF}\\ \text{HELICOPTER}\end{pmatrix}\right]$$

$$+ \left[\begin{pmatrix}\text{PERCENTAGE}\\ 1 - \text{HELICOPTER}\\ \text{USED}\end{pmatrix} \times \left[\begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{DISPATCH}\\ \text{LOCATION}\\ \text{AND CMF}\end{pmatrix} + \begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{CMF}\\ \text{AND PS}\end{pmatrix}\right] \Big/ \begin{pmatrix}\text{SPEED OF}\\ \text{VAN}\end{pmatrix}\right]$$

$$= y_{65} \frac{[y_{56} + y_{58}]}{y_{35}} + [1 - y_{65}] \frac{[y_{56} + y_{58}]}{y_{37}} \; ; \quad \text{(Eq. 4.4.29)}$$

and,

$$\begin{pmatrix}\text{TRAVEL TIME FROM}\\ \text{PS TO DISPATCH}\\ \text{LOCATION}\end{pmatrix} = \frac{\left[\begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{DISPATCH}\\ \text{LOCATION}\\ \text{AND CMF}\end{pmatrix} + \begin{pmatrix}\text{DISTANCE}\\ \text{BETWEEN}\\ \text{CMF}\\ \text{AND PS}\end{pmatrix}\right]}{\begin{pmatrix}\text{SPEED}\\ \text{OF}\\ \text{VAN}\end{pmatrix}}$$

$$= \frac{y_{56} + y_{58}}{y_{37}} \quad \text{(Eq. 4.4.30)}$$

Resulting in the following:

$$\begin{pmatrix} \text{TRAVEL} \\ \text{TIME} \end{pmatrix} = \left[y_{56} + y_{58} \right] \left[\frac{y_{65}}{y_{35}} + \frac{2-y_{65}}{y_{37}} \right] \qquad \text{(Eq. 4.4.31)}$$

Combining Eqs. 4.4.27 and 4.4.31, together with a briefing, preparation and debriefing time of 135 minutes gives the following expression for ROSE team utilization time:

$$\begin{pmatrix} \text{ROSE} \\ \text{UTILIZATION} \\ \text{TIME} \end{pmatrix} = y_{22} \left[y_{89} + \frac{y_{38}\, y_{92} + y_3\, y_8}{y_{38} + y_3} \right]$$

$$\times \left[\left[y_{56} + y_{58} \right] \times \left[\frac{y_{65}}{y_{35}} + \frac{2-y_{65}}{y_{37}} \right] + y_{93} + 135 \right] \qquad \text{(Eq. 4.4.32)}$$

4.4.8 Missile Maintenance Team (MMT)

MMT handles all C/M, R/S, and MGCS repairs. Multiple-skill teams are again capable of performaing these repairs, thus requiring the weighted average expression for the number of personnel dispatched to the failures under consideration. All travel are strictly by van since any helicopter dispatched would involve only the shuffle team. The MMT utilization time is defined to be:

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH MMT TYPE FAILURE}\end{pmatrix} \times \left[\begin{pmatrix}\text{NO. OF C/M, R/S,}\\ \text{AND MGCS}\\ \text{FAILURES PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \left[\begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} + \begin{pmatrix}\text{BRIEFING}\\ \text{PREPARATION, AND}\\ \text{DEBRIEFING TIME}\end{pmatrix}\right] + \begin{pmatrix}\text{REPAIR TIME}\\ \text{PER MO.}\\ \text{PER MISSILE}\end{pmatrix}\right]$$

(Eq. 4.4.33)

where,

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH MMT}\\ \text{FAILURE}\end{pmatrix} = \begin{pmatrix}\text{NO. IN}\\ \text{FDD/SEC}\\ \text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{MMT}\\ \text{DISPATCHED}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{MMT}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{MULTI-SKILL TEAM}\\ \text{DISPATCHED}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{MULTI-SKILL}\\ \text{TEAM}\end{pmatrix}$$

$$= y_{89} + \frac{y_4\, y_{39} + y_3\, y_8}{y_4 + y_3} \quad ; \qquad \text{(Eq. 4.4.34)}$$

$$\begin{pmatrix}\text{NO. OF C/M,}\\ \text{R/S, AND MGCS}\\ \text{FAILURES PER}\\ \text{MO. PER MISSILE}\end{pmatrix} = y_{29} + y_{30} + y_{47}; \qquad \text{(Eq. 4.4.35)}$$

$$\begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} = \frac{2 \times \begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND}\\ \text{DISPATCH LOCATION}\end{pmatrix}}{\begin{pmatrix}\text{SPEED OF}\\ \text{VAN}\end{pmatrix}} = \frac{2y_{56}}{y_{37}}; \qquad \text{(Eq. 4.4.36)}$$

and,

$$\begin{aligned}\begin{pmatrix}\text{REPAIR}\\ \text{TIME}\\ \text{PER MO.}\\ \text{PER MISSILE}\end{pmatrix} &= \begin{pmatrix}\text{NO. OF C/M}\\ \text{FAIL. PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{C/M}\\ \text{REPAIR}\\ \text{TIME}\end{pmatrix}\\ &+ \begin{pmatrix}\text{NO. OF R/S}\\ \text{FAIL. PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{R/S}\\ \text{REPAIR}\\ \text{TIME}\end{pmatrix}\\ &+ \begin{pmatrix}\text{NO. OF MGCS}\\ \text{FAIL. PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{MGCS}\\ \text{REPAIR}\\ \text{TIME}\end{pmatrix}\\ &= y_{29}\, y_{57} + y_{30}\, y_{51} + y_{47}\, y_{23} \qquad \text{(Eq. 4.4.37)}\end{aligned}$$

Combining these four equations into Equation 4.4.33 gives the following expression for MMT utilization time:

$$\left[y_{89} + \frac{y_4\, y_{39} + y_3\, y_8}{y_4 + y_3}\right]$$

$$\times \left[\begin{array}{l} \left[y_{29} + y_{30} + y_{47}\right] \times \left[\dfrac{2y_{56}}{y_{37}} + 135\right] \\ \\ + y_{29}\, y_{57} + y_{30}\, y_{51} + y_{47}\, y_{23} \end{array}\right] \qquad \text{(Eq. 4.4.38)}$$

4.4.9 MOSE TEAM, (EMT)

Besides MOSE repairs, MOSE team is also responsible for PS ROSE repairs. Thus, the derivation of its utilization time is similar to that of the MMT in section 4.4.8, except that for PS ROSE failures, it is necessary to travel to the PS in order to perform repairs on PS ROSE. Both FDD/SEC and MULTI-SKILL teams are considered with MOSE team modeling. Therefore, the expression for MOSE team utilization time is as follows:

$$\left(\begin{array}{c}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH MOSE OR}\\ \text{PS ROSE FAILURE}\end{array}\right) \times \left[\left(\begin{array}{c}\text{NO. OF MOSE AND}\\ \text{PS ROSE FAILURES}\\ \text{PER MO. PER MISSILE}\end{array}\right)\right.$$

$$\times \left[\left(\begin{array}{c}\text{TRAVEL}\\ \text{TIME BETWEEN}\\ \text{CMF AND}\\ \text{DISPATCH LOCATION}\end{array}\right) + \left(\begin{array}{c}\text{BRIEFING,}\\ \text{PREPARATION, AND}\\ \text{DEBRIEFING TIME}\end{array}\right)\right] + \left(\begin{array}{c}\text{REPAIR}\\ \text{TIME}\\ \text{PER MO.}\\ \text{PER MISSILE}\end{array}\right)$$

$$\left. + \left(\begin{array}{c}\text{TRAVEL TIME BETWEEN}\\ \text{CMF AND PS FOR}\\ \text{PS ROSE FAILURES}\end{array}\right) \times \left(\begin{array}{c}\text{NO. OF PS ROSE}\\ \text{FAILURES PER}\\ \text{MO. PER MISSILE}\end{array}\right)\right] \quad \text{(Eq. 4.4.39)}$$

where,

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH MOSE OR}\\ \text{PS ROSE FAILURE}\end{pmatrix} = \begin{pmatrix}\text{NO. IN}\\ \text{FDD/SEC}\\ \text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{MOSE TEAM}\\ \text{DISPATCHED}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{NO. IN}\\ \text{MOSE TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{MULTI SKILL TEAM}\\ \text{DISPATCHED}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{NO. IN}\\ \text{MULTI-SKILL}\\ \text{TEAM}\end{pmatrix}$$

$$= y_{89} + \frac{y_6 y_{11} + y_3 y_8}{y_6 + y_3} \; ; \qquad \text{(Eq. 4.4.40)}$$

$$\begin{pmatrix}\text{NO. OF MOSE AND}\\ \text{PS ROSE FAILURES}\\ \text{PER MO. PER MISSILE}\end{pmatrix} = y_{31} + y_{62} \; ; \qquad \text{(Eq. 4.4.41)}$$

$$\begin{pmatrix}\text{REPAIR}\\ \text{TIME}\\ \text{PER MO.}\\ \text{PER MISSILE}\end{pmatrix} = \begin{pmatrix}\text{NO. OF MOSE}\\ \text{FAILURE PER}\\ \text{MO. PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{MOSE}\\ \text{REPAIR}\\ \text{TIME}\end{pmatrix}$$

$$+ \begin{pmatrix}\text{NO. OF PS ROSE}\\ \text{FAILURES PER}\\ \text{MO. PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{PS ROSE}\\ \text{REPAIR}\\ \text{TIME}\end{pmatrix}$$

$$= y_{31} y_{24} + y_{62} y_{60} ; \qquad \text{(Eq. 4.4.42)}$$

and,

$$\begin{pmatrix}\text{TRAVEL TIME BETWEEN}\\ \text{CMF AND PS FOR}\\ \text{PS ROSE FAILURES}\end{pmatrix} = \frac{2x\begin{pmatrix}\text{DISTANCE BETWEEN}\\ \text{CMF AND PS}\end{pmatrix}}{\begin{pmatrix}\text{SPEED OF}\\ \text{VAN}\end{pmatrix}}$$

$$= \frac{2y_{58}}{y_{37}} \qquad \text{(Eq. 4.4.43)}$$

Using the above four equations and Eq. 4.4.36 yields the resulting expression for MOSE team utilization time as:

$$\begin{pmatrix}\text{MOSE}\\ \text{TEAM}\\ \text{UTILIZATION}\\ \text{TIME}\end{pmatrix} = \left[y_{89} + \frac{y_6 y_{11} + y_3 y_8}{y_6 + y_3}\right]$$

$$\times \left[\begin{array}{l}\left[y_{31} + y_{62}\right] \times \left[\dfrac{2y_{56}}{y_{37}} + 135\right] \\ \\ + y_{31} y_{24} + y_{62} y_{60} + \dfrac{2y_{58}}{y_{37}} y_{62}\end{array}\right] \qquad \text{(Eq. 4.4.44)}$$

$$\begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH COMM/SEC}\\ \text{FAILURE}\end{pmatrix} = \begin{pmatrix}\text{NO. IN}\\ \text{FDD/SEC}\\ \text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{COMM/SEC TEAM}\\ \text{DISPATCHED}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{NO. IN}\\ \text{COMM/SEC}\\ \text{TEAM}\end{pmatrix} + \begin{pmatrix}\text{PERCENTAGE}\\ \text{MULTI-SKILL TEAM}\\ \text{DISPATCHED}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{MULTI-SKILL}\\ \text{TEAM}\end{pmatrix}$$

$$= y_{89} + \frac{y_7 y_{12} + y_3 y_8}{y_7 + y_3} \quad ; \qquad \text{(Eq. 4.4.46)}$$

Travel time is the same as in Eq. 4.4.31 in section 4.4.7.

Therefore, combining the above results in:

$$\begin{pmatrix}\text{COMM/SEC}\\ \text{TEAM}\\ \text{UTILIZATION}\\ \text{TIME}\end{pmatrix} = y_{34} \left[y_{89} + \frac{y_7 y_{12} + y_3 y_8}{y_7 + y_3} \right]$$

$$\times \left[\left[y_{56} + y_{58} \right] \left[\frac{y_{65}}{y_{35}} + \frac{2 - y_{65}}{y_{37}} \right] + y_{94} + 135 \right]$$

(Eq. 4.4.47)

4.4.10 COMM/SEC Team

The modeling of the COMM/SEC team utilization time is similar to that of the ROSE team in section 4.4.47. Both FDD/SEC and MULTI-SKILL teams are considered. A portion of the dispatches are made in helicopters, thus requiring a weighted average time for the trip from the dispatch location to the PS.

$$\begin{pmatrix}\text{COMM/SEC}\\ \text{UTILIZATION}\\ \text{TIME}\end{pmatrix} = \begin{pmatrix}\text{NO. OF COMM/SEC}\\ \text{FAILURES PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \begin{pmatrix}\text{EXPECTED NO. OF}\\ \text{PERSONNEL DISPATCHED}\\ \text{TO EACH COMM/SEC}\\ \text{FAILURE}\end{pmatrix}$$

$$\times \left[\begin{pmatrix}\text{TRAVEL}\\ \text{TIME}\end{pmatrix} + \begin{pmatrix}\text{REPAIR}\\ \text{TIME}\end{pmatrix} + \begin{pmatrix}\text{BRIEFING,}\\ \text{PREPARATION, AND}\\ \text{DEBRIEFING TIME}\end{pmatrix}\right] \quad ;$$

where,

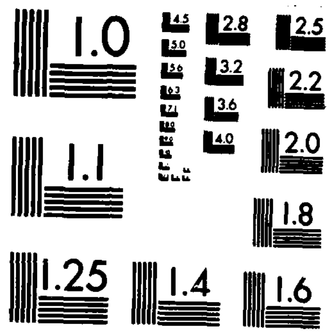
y_{34} = NO. OF COMM/SEC. FAILURES PER MO. PER MISSILE

y_{94} = COMM/SEC REPAIR TIME. (Eq. 4.4.45)

AD-A154 674 MX MAINTENANCE MANAGEMENT SYSTEM DEFINITION(U) HOUSTON UNIV TX B OSTROFSKY ET AL. SEP 81 SBI-AD-F630 659 F04704-80-C-0038 2/2

UNCLASSIFIED F/G 16/1 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4.4.11 TOTAL MAN-MINUTES AVAILABLE FOR MAINTENANCE ACTIVITIES

The denominator term in Eq. 4.4.1 is obtained by the same reasoning used in Eq. 4.4.2, except that all twelve teams given in section 4.4 are included. This results in the following expression:

$$\begin{pmatrix}\text{TOTAL ON-DUTY}\\ \text{TIME PER MO.}\\ \text{PER MISSILE}\end{pmatrix} \times \left[\sum_{\substack{\text{Teams}\\ \text{Under}\\ \text{Consideration}}} \begin{pmatrix}\text{NO. OF}\\ \text{TEAMS}\end{pmatrix} \times \begin{pmatrix}\text{NO. IN}\\ \text{TEAM}\end{pmatrix} \right].$$

$$= 52.8 \times \begin{bmatrix} y_2y_{63} + y_{55}y_{64} + y_9y_{13} \\ + y_5y_{10} + y_{86}y_{59} + y_{82}y_{21} \\ + y_{38}y_{92} + y_4y_{39} + y_6y_{11} \\ + y_7y_{12} + y_{88}y_{89} + y_3y_8 \end{bmatrix} \qquad \text{(Eq. 4.4.48)}$$

Summing Eq. 4.4.2, 4.4.10, 4.4.14, 4.4.22, 4.4.32, 4.4.38, 4.4.44, and 4.4.47 into the numerator term and divide the resulting expression by Eq. 4.4.48 will provide the measurement for team utilization as defined in section 4.4. Fig. 4-4 shows the computer print-out of this model.

4.5 Vehicle and Equipment (V & E) Utilization, x_5

Vehicle and Equipment utilization is defined as the following ratio:

$$\frac{\text{(Total V \& E time utilized per month per missile)}}{\text{(Total V \& E time available per month per missile)}}$$

V & E are considered utilized when used for the maintenance of equipment failures in the HSS, or for SALT verification purposes. This includes any transportation and waiting times in connection to the above activities. The numerator term can be expressed as:

$$\text{(V \& E time utilized)} = \begin{pmatrix}\text{T/L utilization}\\ \text{time}\end{pmatrix} + \begin{pmatrix}\text{Van \& Helicopter}\\ \text{utilization time for}\\ \text{N/L failures}\end{pmatrix}$$

$$+ \begin{pmatrix}\text{Van and Helicopter}\\ \text{utilization time for}\\ \text{ROSE and COMM/SEC}\\ \text{failures}\end{pmatrix}$$

$$+ \begin{pmatrix}\text{CREV/DREV utilization}\\ \text{time for SALVER}\end{pmatrix} \qquad \text{(Eq. 4.5.1)}$$

where all quantities are in terms of time per month per missile.

4.5.1 T/L Utilization Time

T/L's are used to perform shuffle for PLU in cases of N/L failures and SALVER. The expected number of N/L failures per month per missile is simply z_8, and the expected number of SALVER per month per missile is developed as follows:

$$\begin{pmatrix}\text{Expected No. of}\\ \text{SALVER per mon.}\\ \text{per missile}\end{pmatrix} = \frac{\begin{pmatrix}\text{Expected No. of}\\ \text{SALVER per year}\end{pmatrix} - \frac{1}{2}\begin{pmatrix}\text{Expected No. of}\\ \text{SALVER performed}\\ \text{due to C/M failure}\end{pmatrix}}{(12 \text{ months})\ (200 \text{ missile})}$$

$$+ \frac{(\text{Other SALVER})}{(12 \text{ months})\ (200 \text{ missiles})} \qquad \text{(Eq. 4.5.2)}$$

Expected No. of SALVER performed due to C/M failures is approximately 20 per year, and other SALVER's due to TE & O, etc., is estimated to be 10. Therefore, expected number of N/L failures and SALVER is:

$$z_8 + \frac{200 - \frac{1}{2}(20) + 10}{(12)\ (200)} = z_8 + 1/12$$

For each of these actions, two shuffles are necessary. Each shuffle in turn requires one round-trip between the CMF and PS, 22 trips in between the 23 PS's, plus waiting time at each of the 23 PS's for PLU purposes, or for removal & emplacement of the missile. Therefore, the time spent on each shuffle is:

$$\frac{2\begin{pmatrix}\text{distance between}\\ \text{CMF and PS}\end{pmatrix}}{\text{Speed of T/L}} + \frac{22\begin{pmatrix}\text{distance between}\\ \text{PS}\end{pmatrix}}{\text{Speed of T/L}} + 23\begin{pmatrix}\text{Time Spent at}\\ \text{Each PS for PLU}\end{pmatrix}$$

$$= \frac{2\ y_{58}}{y_{36}} + \frac{22\ y_{18}}{y_{36}} + 23\ y_{68} \qquad \text{(Eq. 4.5.3)}$$

Therefore,

$$\begin{pmatrix}\text{T/L utilization}\\ \text{Time}\end{pmatrix} = \left(z_8 + \frac{1}{12}\right) \left[\frac{4y_{58} + 44y_{18}}{y_{36}} + 46y_{68}\right] \qquad \text{(Eq. 4.5.4)}$$

4.5.2 Van and Helicopter Utilization Time for N/L Failures

Van and Helicopter utilization time for N/L failures is developed by considering the travel and waiting times for four mutually exclusive cases. These four cases are constructed by considering whether helicopter was used to transport the shuffle crew out to the CMF or not and whether it was PS ROSE or other N/L failures. It is assumed that if helicopter was used to transport the shuffle crew from the dispatch location to CMF, a van will be used to pick the crew up upon completion of their task. It is further assumed that the shuffle team will wait at the CMF during PS ROSE repair since its repair time is less than 3 hours. The general model for the contribution of the individual cases to the van and helicopter utilization time for N/L failures is:

$$\begin{pmatrix}\text{Percentage of}\\ \text{Helicopters used}\\ \text{or not used}\end{pmatrix} \times \begin{pmatrix}\text{No. of actions}\\ \text{per month per missile}\end{pmatrix} \times \begin{pmatrix}\text{Travel and}\\ \text{waiting time}\\ \text{per action}\end{pmatrix}$$

(Eq. 4.5.5)

Case I: Helicopter used, P.S. ROSE failure.

The shuffle crew is transported to the CMF by helicopter upon which the helicopter returns to its dispatch area. A van is then used to transport the repair crew out to the PS, wait through the repair time, and return the repair crew back to the dispatch location. Another van is dispatched to the CMF to retrieve the shuffle crew upon completion of the second shuffle. Therefore, one helicopter round trip, two van round trips between the dispatch location and CMF, one van round trip between the CMF and PS, and one van waiting through PS ROSE repair are required for each action. These multiplied by the percentage of helicopters used and number of actions give:

$$y_{65}y_{62}\left[\frac{2y_{56}}{y_{35}} + \frac{4y_{56} + 2y_{58}}{y_{37}} + y_{60}\right] \qquad \text{(Eq. 4.5.6)}$$

Case II: Helicopter used, other N/L failures

The shuffle crew is again transported by a helicopter, with no waiting time on the part of the helicopter. A van is then dispatched to take the repair crew out to the CMF, and the same van retrieves the shuffle crew. The second shuffle crew is then dispatched to the CMF by van at the completion of the repair, and again the van picks up the repair crew. Finally, a round trip by van is dispatched to retrieve the second shuffle crew. There is no waiting time involved in this case, and a total of 3 van and 1 helicopter round trips between the dispatch location and CMF. These travel times multiplied by the percentage of helicopters used and number of actions give:

$$y_{65}(z_8 - y_{62})\left[\frac{2y_{56}}{y_{35}} + \frac{6y_{56}}{y_{37}}\right] \qquad \text{(Eq. 4.5.7)}$$

Case III: No helicopters used, PS ROSE failure

The shuffle crew is dispatched to the CMF by van. Since the crew will wait at the CMF during PS ROSE repair and perform the second shuffle, the van will also wait through 2 shuffles and the PS ROSE repair time. Another van is used to dispatch the repair crew to the PS and then wait through the repair before returning the repair crew back to the dispatch location. Therefore, 2 round trips between the dispatch location and CMF, plus one round trip between the CMF and PS are required for this case, in addition to 2 vans waiting through the repair time and one van waiting through the 2 shuffles. Waiting time through the 2 shuffles is given by Eq. 4.5.3. The resulting contribution to van and helicopter utilization time is:

$$(1-y_{65})\ (y_{62})\left[\frac{4y_{56}}{y_{37}} + \frac{2y_{58}}{y_{37}} + 2y_{60} + \frac{4y_{58}}{y_{36}} + \frac{44y_{18}}{y_{36}} + 46y_{68}\right]$$

(Eq. 4.5.8)

Case IV: No helicopters used, other N/L failures.

In this case, each of the repair crews and the two shuffle crews are dispatched to the CMF by their own van, and the vans will stay through the operational time of the crew they were carrying. Therefore, there are 3 van round trips between the dispatch location and CMF, plus waiting time through 2 shuffles and 1 average repair time period. The average repair time is obtained by a simple weighted average among the 4 types of N/L failures under consideration. These travel and waiting times are multiplied by the percentage of time where helicopters are not used, and the number of other N/L actions per month per missile.

$$(1-y_{65})\ (z_8-y_{62})\left[\frac{6y_{56}}{y_{37}} + \left(\frac{4y_{58}}{y_{36}} + \frac{44y_{18}}{y_{36}} + 46y_{68}\right) + \left(\frac{y_{47}y_{23} + y_{31}y_{24} + y_{29}y_{57} + y_{30}y_{51}}{(z_8 - y_{62})}\right)\right]$$

(Eq. 4.5.9)

Since these four cases are mutually exclusive, van and helicopter utilization time for N/L failures is then simply the sum of Eq. 4.5.6 through Eq. 4.5.9.

4.5.3 Van and Helicopter Utilization Time for ROSE and COMM/SEC Failures

In the case of ROSE and COMM/SEC failures, the utilization time for van and helicopter is derived in a similar fashion as in Eq. 4.5.5. No shuffle crews are considered. In the case when helicopters are used, there is 1 round trip for the helicopter and 1 round trip for the van between the dispatch location and PS. No waiting time will incur. If helicopters are not used, then a van will be used for the transportation of the repair crew, and the van will wait through the repair time. The resulting expression is:

$$y_{65}(y_{22}+y_{34})\left[\frac{2(y_{56}+y_{58})}{y_{35}} + \frac{2(y_{56}+y_{58})}{y_{37}}\right]$$

$$+ (1-y_{65})\ (y_{22}+y_{34})\ \left[\frac{2(y_{56}+y_{58})}{y_{37}} + \frac{y_{22}y_{93}+y_{34}y_{94}}{(y_{22}+y_{34})}\right] \qquad \text{(Eq. 4.5.10)}$$

4.5.4 CREV/DREV Utilization Time for SALVER

The total CREV/DREV utlization time for SALVER is obtained as follows:

$$\begin{pmatrix}\text{No. of CREV/DREV's} \\ \text{dispatched to each} \\ \text{SALVER}\end{pmatrix} \times \begin{pmatrix}\text{Travel times between} \\ \text{ASC \& CMF, and time} \\ \text{to open and close cluster}\end{pmatrix}$$

$$\times \begin{pmatrix}\text{Expected no. of} \\ \text{SALVER per month} \\ \text{per missile}\end{pmatrix} \qquad \text{(Eq. 4.5.11)}$$

The number of CREV/DREV's dispatched to each SALVER is simply y_{84}. CREV/DREV's are assumed to travel at the speed of van, and 2 round trips between the ASC and CMF is required. The approximate time to perform the opening and closing of the cluster is 12 hours each. Expected number of SALVER is derived in Eq. 3.4.8. Combining the above results in the following:

$$y_{84}\left[\frac{(4 \times 364,320)}{y_{37}} \times (2 \times 720)\right] \times \left[y_{29} + y_{81}(\tfrac{1}{12} - y_{29})\right] \qquad \text{(Eq. 4.5.12)}$$

4.5.5 Substituting equations 4.5.4, 4.5.6 through 4.5.9, 4.5.10, and 4.5.12 into Eq. 4.5.1 and simplifying the algebraic terms resulted in:

$$\begin{pmatrix}\text{V \& E Time}\\ \text{Utilized}\end{pmatrix} = \left[y_{62}y_{60} + z_8\left(\frac{4y_{58} + 44y_{18}}{y_{36}} + 46y_{68}\right)\right] (2-y_{65})$$

$$+ \frac{y_{56}}{y_{37}} (6z_8 - 2y_{62}) + \frac{2y_{58}}{y_{37}} + \frac{1}{12}\left(\frac{4y_{58} + 44y_{18}}{y_{36}} + 46y_{68}\right)$$

$$+ (1 - y_{65}) \left[y_{47}y_{23} + y_{31}y_{24} + y_{29}y_{57} + y_{30}y_{51} + y_{22}y_{93} + y_{34}y_{94}\right]$$

$$+ 2(y_{56} + y_{58}) (y_{22} + y_{34}) \left[\frac{y_{65}}{y_{35}} + \frac{1}{y_{37}}\right]$$

$$+ y_{84} \left[\frac{(4)(364,320)}{y_{37}} + 1440\right]\left[y_{29} + y_{81} \left(\frac{1}{12} - y_{29}\right)\right] \qquad \text{(Eq. 4.5.13)}$$

Total V & E time available per month per missile is simply the total number of V & E under consideration times the total time in a month and divided by the total number of missiles in the force, i.e.:

$$\frac{(y_{14} + y_{15} + y_{16} + 5y_{33})(30 \times 24 \times 60)}{200}$$

$$= 216 \; (y_{14} + y_{15} + y_{16} + 5y_{33}) \qquad \text{(Eq. 4.5.14)}$$

Therefore, x_5 as defined becomes:

$$x_5 = \frac{\text{Eq. 4.5.13}}{\text{Eq. 4.5.14}} \qquad \text{(Eq. 4.5.15)}$$

Figure 4-5 shows the computer listing for this criterion.

```
C********** X(5) -- VEHICLE AND EQUIPMENT UTILIZATION **********
C
      SUBROUTINE VEUTIL
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   X(5)   -- Vehicle and equipment utilization
C   Z(5)   -- Number of actions per month
C   Y(14)  -- Number of helicopters assigned to FDD
C   Y(15)  -- Number of vans assigned to FDD
C   Y(16)  -- Number of T/L
C   Y(18)  -- Distance between PS (feet)
C   Y(22)  -- Number of ROSE failures per month
C             per missile
C   Y(23)  -- MGCS R/R time (minute)
C   Y(24)  -- MOSE R/R time (minute)
C   Y(29)  -- Number of C/M no launch failures per
C             month per missile
C   Y(30)  -- Number of R/S no launch failures per
C             month per missile
C   Y(31)  -- Number of MOSE no launch failures per
C             month per missile
C   Y(33)  -- Total gross CREV/DREV in dispatch area
C   Y(34)  -- Number of COMM/security failures per
C             month per missile
C   Y(35)  -- Speed of helicopter (feet/minute)
C   Y(36)  -- Speed of T/L (feet/minute)
C   Y(37)  -- Speed of van (feet/minute)
C   Y(47)  -- Number of MGCS no launch failures per
C             month per missile
C   Y(51)  -- R/S repair time (minute)
C   Y(56)  -- Distance between dispatch location and CMF
C   Y(57)  -- C/M repair time (minute)
C   Y(58)  -- Distance between CMF and PS (feet)
C   Y(60)  -- PS ROSE repair time (minute)
C   Y(62)  -- Number of PS ROSE failures per month
C             per missile
C   Y(65)  -- Fraction of no launch failures requiring
C             helicopter
C   Y(68)  -- Time spent at each PS for PLU (minute)
C   Y(81)  -- SAL verifications (at least once per year)
C   Y(84)  -- Number of CREV/DREV dispatched to CMF
C   Y(93)  -- ROSE repair time (minute)
C   Y(94)  -- COMM/Security repair time (minute)
```

Figure 4-5: x_5 Printout

```
C
C   Assumptions :
C
C    1. Speed of CREV/DREV is the same as van.
C    2. In the cases where helicopters are used and a shuffle is
C       required prior to the repair operation(as in all N/L
C       failures), only the shuffle crew is transported by the
C       helicopter. Repair crew is always dispatched in vans.
C    3. Helicopters are used only to transport personnel and
C       equipment from the dispatch area to the maintenance area.
C       All return trips are made in vans.
C    4. Shuffle team waits at the CMF during repairs of 3 hours or less.
C    5. P.S.ROSE failures are N/L failures.
C    6. Shuffle is performed whenever there is a N/L failure or SALVER.
C    7. Vehicle and equipment are considered utilized when they are
C       parked at the CMF to wait for the crew.
C    8. Helicopter services a portion of N/L, ROSE, and COMM/SEC
C       failures.
C    9. Repair for P.S.ROSE, ROSE, and COMM/SEC failures are performed
C       at the PS.
C   10. All AVE and OSE changeouts are performed at the CMF.
C   11. CREV/DREV'S dispatched from ASC'S.
C   12. There are dwell times involved at PS during shuffle for PLU.
C   13. Y(81) = 1, if Y(29) is greater than 1/12, and 0 otherwise.
C   14. Vans are used in a manner so as to minimize the amount
C       of travel.
C
C   CONSTANTS USED:
C
C   Time available in 30 days per month is 30x24x60/200 = 216 mins.
C   Distance from ASC to CMF is 364,320 feet.
C
C
      S = ((4.0D0*Y(58)+4.4D1*Y(13))/Y(36)+4.6D1*Y(68))
      TOP=(Y(62)*Y(60)+Z(3)*S)*(2.0D0-Y(65))+(6.0D0*Z(8)-2.0D0*
     &     Y(62))*Y(56)/Y(37)+(1.0D0-Y(65))*(Y(47)*Y(23)+Y(31)*Y(24)+
     &     Y(29)*Y(57)+Y(30)*Y(51)+Y(22)*Y(93)+Y(34)*Y(94))+
     &     2.0D0*(Y(56)+Y(58))*(Y(22)+Y(34))*(Y(65)/Y(35)+1.0D0/Y(37))+
     &     Y(84)*(1.45728D6/Y(37)+1.44D3)*(Y(29)+Y(81)*
     &     (1.0D0/1.2D1-Y(29))) + S/1.2D1 + 2.0D0*Y(62)*Y(58)/Y(37)
      BOTTOM = 2.16D2*(Y(14)+Y(15)+Y(16)+5.0D0*Y(33))
        5) = TOP/BOTTOM
      R TURN
      END
C
C
```

75.	73	.2318	DISPATCH FROM OB
76.	47	.2317	
77.	19	.2286	
78.	20	.2237	
79.	48	.2202	
80.	75	.2153	
81.	21	.2121	

Ranking continued

	CS	CF VALUE	CONTROL	(%R/%L)	DISPATCH	[illegible]
49.	81	.6726	ASC/OB	75/25	ASC/OB	Multi-Skill
50.	27	.6721	OB	75/25	ASC/OB	Multi-Skill
51.	25	.6713	OB	75/25	ASC/OB	Std
52.	23	.6713	OB	75/25	ASC	Std/Spec
53.	78	.6699	ASC/OB	75/25	ASC	Multi-Skill
54.	26	.6660	OB	75/25	ASC/OB	Std/Spec
55.	56	.2661				
56.	28	.2661				
57.	55	.2583				
58.	30	.2582				
59.	29	.2578				
60.	1	.2550				
61.	57	.2534				
62.	65	.2531				
63.	2	.2502				
64.	3	.2502	DISPATCH FROM OB			
65.	37	.2496				
66.	38	.2448				
67.	39	.2446				
68.	64	.2438				
69.	10	.2419				
70.	74	.2401				
71.	66	.2397				
72.	11	.2370				
73.	46	.2365				
74.	12	.2365				

Ranking Cont'd.

	CS	CF VALUE	CONTROL	DETECT (%R/%L)	DISPATCH	TEAM
22.	54	.7134	ASC	75/25	ASC/OB	Multi-Skill
23.	7	.7132	OB	25/75	ASC/OB	Std
24.	52	.7122	ASC	75/25	ASC/OB	Std
25.	71	.7119	ASC/OB	5/5	ASC/OB	Std/Spec
26.	15	.7101	OB	5/5	ASC	Multi-Skill
27.	8	.7079	OB	25/75	ASC/OB	Std/Spec
28.	53	.7070	ASC	75/25	ASC/OB	Std/Spec
29.	58	.7069	ASC/OB	25/75	ASC	Std
30.	9	.7041	OB	25/75	ASC/OB	Multi-Skill
31.	4	.7039	OB	25/75	ASC	Std
32.	5	.7007	OB	25/75	ASC	Std/Spec
33.	60	.7002	ASC/OB	25/75	ASC	Multi-Skill
34.	6	.6995	OB	25/75	ASC	Multi-Skill
35.	70	.6955	ASC/OB	5/5	ASC/OB	Std
36.	67	.6936	ASC/OB	5/5	ASC	Std
37.	16	.6925	OB	5/5	ASC/OB	Std
38.	13	.6906	OB	5/5	ASC	Std
39.	80	.6899	ASC/OB	75/25	ASC/OB	Std/Spec
40.	72	.6895	ASC/OB	5/5	ASC/OB	Multi-Skill
41.	14	.6875	OB	5/5	ASC	Std/Spec
42.	17	.6870	OB	5/5	ASC/OB	Std/Spec
43.	69	.6865	ASC/OB	5/5	ASC	Multi-Skill
44.	18	.6779	OB	5/5	ASC/OB	Multi-Skill
45.	24	.6776	OB	75/25	ASC	Multi-Skill
46.	76	.6775	ASC/OB	75/25	ASC	Std
47.	22	.6745	OB	75/25	ASC	Std
48.	79	.6743	ASC/OB	75/25	ASC/OB	Std

Ranking Cont'd.

	CS	CF VALUE	CONTROL	DETECT (%R/%L)	DISPATCH	TEAM
1.	59	.7725	ASC/OB	25/75	ASC	Std/Spec
2.	68	.7602	ASC/OB	5/5	ASC	Std/Spec
3.	36	.7543	ASC	25/75	ASC/OB	Multi-Skill
4.	34	.7522	ASC	25/75	ASC/OB	Std
5.	33	.7508	ASC	25/75	ASC	Multi-Skill
6.	32	.7491	ASC	25/75	ASC	Std/Spec
7.	31	.7491	ASC	25/75	ASC	Std
8.	35	.7471	ASC	25/75	ASC/OB	Std/Spec
9.	77	.7452	ASC/OB	75/25	ASC	Std/Spec
10.	42	.7380	ASC	5/5	ASC	Multi-Skill
11.	41	.7366	ASC	5/5	ASC	Std/Spec
12.	40	.7366	ASC	5/5	ASC	Std
13.	43	.7324	ASC	5/5	ASC/OB	Std
14.	62	.7309	ASC/OB	25/75	ASC/OB	Std/Spec
15.	45	.7286	ASC	5/5	ASC/OB	Multi-Skill
16.	44	.7270	ASC	5/5	ASC/OB	Std/Spec
17.	51	.7225	ASC	75/25	ASC	Multi-Skill
18.	50	.7215	ASC	75/25	ASC	Std/Spec
19.	49	.7215	ASC	75/25	ASC	Std/Spec
20.	61	.7162	ASC/OB	25/75	ASC/OB	Std
21.	63	.7157	ASC/OB	25/75	ASC/OB	Multi-Skill

Figure 5-3: RANKING OF CANDIDATE SYSTEMS

given set of estimates of the 94 parameters for a candidate system and each criterion computed for that candidate by computing the appropriate z_j and then the x_i. The minimum and maximum values of the respective x_i for the entire set of candidates were used to estimate the X_i of Equation 5.2.2 and from this the CF_α was computed for each of the 81 candidate systems and then ranked. Figure 5-3 shows the 81 ranked candidate systems in descending order of values. From this ranking the subsequent analyses are made and indicates the highest ranked candidate system to be #59. Figure 5-4 lists the parameter values for this system. It is of interest to note that the baseline system being considered by BMO is ranked 48th in order of desireability. This result is considered to be highly important to the improvement of fault detection and repair efficiency for the HSS deployment concept.

Candidate system #59, the top ranked candidate, would have control jointly at ASC and the OB, 75% of the faults detected locally (manually) and about a 25% level of automatic fault detection with dispatch of maintenance teams from the ASC. Each team would be constituted with the same standard skills and use specialists as required for augmentation of duties.

Note that the second ranked candidate system, #68, has the same characteristics with a higher level of automatic fault detection. Since CF_{59} = 0.7725 and CF_{68} = .7602, it appears that the optimal level of automatic fault detection could be somewhere between 25% and 50% with relatively small effect on maintenance efficiency. Further evidence that the 25% level is better is given and:

$$X_i = \frac{x_i - x_{i\,min}}{x_{i\,max} - x_{i\,min}} \qquad \text{(Eq. 5.2.2)}$$

where:

X_i is the value resulting from the i^{th} criterion model of z_j and y_k

$x_{i\,min}$ is the minimum value achieved from the set of candidate systems for the given criterion, x_i

$x_{i\,max}$ is the maximum value achieved from the set of candidate systems for the given criterion, x_i

While this multiple criterion function form has been used before[5,6] it has several limitations[5], the major one being the implicit assumption of independence among the set of criteria, $\{x_i\}$. Methods for estimating the effects of these criterion interactions have been developed at the University of Houston, but will not be used here in order to expedite the current results.

Major advantages of CF are:

1. Unit measures of y_k are relegated to their respective value .
2. Each criterion is limited in importance to the respective a_i defined for it.
3. Explicit evaluation of criterion importance is estimated (and can be reexamined at will).

5.3 Ranking of Candidate Systems

Each of the 94 parameters were estimated for each of the 81 candidate systems. A computer program was then written that used a where:

a is the candidate system number

b is the control location number

c is the detect level option

d is the dispatch location

e is the team composition option

The Figure 5-1 heading, 79[3,3,3,1] refers to candidate system #79 which is synthesized from the third option for control (scenario of ASC/OB combination); the third option for the level of detection (75% of the faults will be remotely located through automatic detection and 25% will be manually identified); the third option for dispatch location (ASC/OB); and the first option for team type (standard skill-level mix).

5.2 Synthesis of Multiple Criterion Function

In order to achieve a performance index for each of the 180 candidate systems a rational procedure for combining the respective criterion models must be used. The format presented in Equation 15 represents an expedient approach toward evaluation of candidate system performance that includes each criterion at its respective relative importance.

$$CF_{\alpha} = \sum_{i=1}^{6} a_i X_i \qquad \text{(Eq. 5.2.1)}$$

Where:

CF_{α} is the figure of merit of the α candidate system

a_i is the relative importance of the i^{th} criterion

CANDIDATE # ____________

Control ____________ ; Dispatch ____________

Detect ____________ ; Teams ____________

P A R A M E T E R S

Name	Value	Name	Value	Name	Value
1. No. of CMF		34. No. COMM/Sec fail./mon/miss.		67. Time to Enter/Exit site	
2. No. of OB		35. Speed of Helicopter		68. Time at each PS for PLU	
3. No. of Multi-skill teams		36. Speed of T/L		69. Ave. pay for OB personnel	
4. No. of MMT		37. Speed of Van		70. Ave. pay for ASC personnel	
5. No. of shuffle teams		38. No. of ROSE repair teams		71. Cost/STV	
6. No. of MOSE teams		39. No. in MMT		72. Cost/CMF	
7. No. COMM/Sec repair teams		40. Cost/Van		73. Cost/OB	
8. No. in Multi-skill team		41. Cost/T/L		74. Cost/ASC	
9. No. of PM teams		42. Cost/Helicopter		75. Equip. cost/CMF	
10. No. in shuffle team		43. Personnel cost/MOSE team		76. Equip. cost/OB	
11. No. in MOSE team		44. Personnel cost/MMT		77. Equip. cost/ASC	
12. No. in COMM/sec repair team		45. Pers. cost/Multi-skill team		78. Spares/Supplies cost/CMF	
13. No. in PM team		46. Personnel cost/shuffle team		79. Spares/Supplies cost/OB	
14. No. of FDD helicopters		47. No. MGCS N-L fail/mon./miss.		80. Spares/supplies cost/ASC	
15. No. of FDD vans		48. Pers. $/COMM-sec repair team		81. SALVER (once per year)	
16. No. of T/L		49. Pers. cost/ROSE repair team		82. No. of CREV/DREV teams	
17. No. of clusters		50. Missile removal time		83. One day CREV/DREV reliability	
18. Distance between PS		51. R/S repair time		84. No. CREV/DREV disp. to CMF	
19. Missile Emplacement time		52. Delay		85. Cost/CREV/DREV	
20. Personnel cost/PM team		53. No. of STV		86. No. of helicopter teams	
21. No. in CREV/DREV team		54. Speed of STV		87. No. of van teams	
22. No. of ROSE fail./mon./miss.		55. No. of ASC		88. No. of FDD security teams	
23. MGCS repair time		56. Dist. betw. Dispatch & CMF		89. No. in FDD security teams	
24. MOSE repair time		57. C/M repair time		90. Pers. cost/FDD security team	
25. Main. pers. know. miss. loc.		58. Dist. betw. CMF and PS		91. Pers. cost/CREV/DREV team	
26. Base operating support cost		59. No. in helicopter team		92. No. in ROSE repair team	
27. Pers. cost/helicopter team		60. PS ROSE repair time		93. ROSE repair time	
28. Pers. cost/van team		61. No. in van team		94. COMM/sec repair time	
29. No. C/M N-L fail./mon/miss.		62. No. PS ROSE fail./mon./miss.		95.	
30. No. R/S N-L fail./mon./miss.		63. No. of FDD personnel/OB		96.	
31. No. MOSE N-L fail./mon./miss.		64. No. of FDD personnel/ASC		97.	
32. Avail. of CREV/DREV force		65. Frac. N-L fail. using heli.		98.	
33. Total CREV/DREV/dispatch area		66. CAMM pers. know. miss. loc.		99.	

Figure 5-2: PARAMETER DEFINITIONS

CANDIDATE # 79 (3,3,3,1)

Control ASC/OB ; Dispatch ASC/OB

Detect .75R/.25L ; Teams STD

PARAMETERS

Name	Value	Name	Value	Name	Value
1.	200	34.	1.25	67.	5
2.	2	35.	13,200	68.	20
3.	0	36.	704	69.	52,000
4.	25	37.	3,520	70.	41,600
5.	260	38.	180	71.	5,200,000
6.	180	39.	4	72.	1,000,000
7.	125	40.	10,000	73.	2,000,000,000
8.	0	41.	8,900,000	74.	3,500,000
9.	10	42.	3,900,000	75.	1,000,000
10.	2	43.	68,432	76.	300,000,000
11.	2	44.	136,864	77.	10,000,000
12.	3	45.	0	78.	0
13.	4	46.	68,432	79.	35,000,000
14.	15	47.	.11	80.	4,000,000
15.	100	48.	102,648	81.	1
16.	202	49.	68,432	82.	60
17.	200	50.	5	83.	.8
18.	5,200	51.	2,340	84.	4
19.	5	52.	1,080	85.	150,000
20.	136,864	53.	5	86.	30
21.	2	54.	1,760	87.	40
22.	2.32	55.	5	88.	400
23.	1,920	56.	447,216	89.	2
24.	300	57.	2,040	90.	49,920
25.	520	58.	5,200	91.	68,432
26.	5,000,000	59.	2	92.	2
27.	120,000	60.	120	93.	120
28.	34,216	61.	1	94.	120
29.	.0075	62.	.0077	95.	
30.	.02	63.	180	96.	
31.	.17	64.	45	97.	
32.	.6	65.	.1	98.	
33.	6	66.	0	99.	

Figure 5-1: SAMPLE CANDIDATE SYSTEM & WORKSHEET

5.0 OPTIMIZATION

5.1 Parameter Estimates

Parameter estimates are the values of y_k that are inputs to the criteria models, and therefore represent the link between a given candidate system and these criteria models, estimating the performance of that candidate system. The best available estimates of each y_k should be used. When these estimates become critical and accuracy of the y_k is questioned, the y_k should be verified from field data, testing, experimentation, or other reliable sources.

The MX logistics contractor supplied UH with values of each of the 94 parameters for all 27 candidates under the ASC/OB combination control. Based upon this collaboration, values were determined for the remaining 54 candidates, or a total of 81 candidate systems.

Hence 7614 parameter values (81 x 94) were programmed to compute the respective CF_{α} value for each candidate system.

A sample candidate system is shown in Figure 5-1 and, although the y_k are defined in Section 2.5, they are shown again in condensed form in Figure 5-2.

The heading format in the data sheet (Fig. 5-1) is:

a[b,c,d,e]

```
C********** X(6) -- SAL VERIFICATION **********
C
      SUBROUTINE SAL
C
      IMPLICIT DOUBLE PRECISION (A-C,E-H,O-Z)
C
      COMMON /DEVICE/ X(6),Y(100),Z(10)
C
C   X(6)  -- SAL verification
C   Y(32) -- Availability of CREV/DREV force
C   Y(33) -- Total gross CREV/DREV in dispatch area
C   Y(83) -- One day CREV/DREV reliability
C   Y(84) -- Number of CREV/DREV dispatched to CMF
C
C   ASSUMPTIONS:
C
C   1.  CREV/DREV'S dispatched from ASC'S.
C   2.  CREV/DREV'S are not shared among ASC'S.
C   3.  SALVER timeline is : day 1 - shuffle
C                            day 2 - open cluster and SAL ports
C                            day 3&4 - NTM inspection
C                            day 5 - close SAL ports and cluster
C                            day 6 - shuffle
C   4.  At least 3 CREV/DREV'S are required to successfully complete
C       the task of opening or closing a cluster for SALVER within
C       the timeline.
C   5.  Expected number of SALVER per year is 223.
C   6.  CREV/DREV'S always available for activities in day 5,
C       once SALVER is started.
C
      SUM1 = 0.0D0
      DO 10 I = 3,IFIX( Y(84) )
      SUM1 = SUM1 + IFACT( IFIX( Y(84) ) )/( IFACT(I) *
     & IFACT(IFIX( Y(84)-I )) ) * Y(83)**I * ( 1.0D0 -
     $ Y(83) )**IFIX( Y(84)-I )
 10   CONTINUE
      SUM2 = 0.0D0
      DO 20 I = IFIX( Y(84) ),IFIX( Y(33) )
      SUM2 = SUM2 + IFACT( IFIX( Y(33) ) )/( IFACT(I) *
     $ IFACT(IFIX( Y(33)-I )) ) * Y(32)**I * ( 1.0D0 -
     $ Y(32) )**IFIX( Y(33)-I )
 20   CONTINUE
      X(6) = SUM1*SUM2
      RETURN
      END
C
```

Figure 4-6: x_6 Printout

$$\begin{pmatrix}\text{Expected No. of} \\ \text{SALVER in Dispatch} \\ \text{Area}\end{pmatrix} = \frac{\begin{pmatrix}\text{Expected No. of} \\ \text{SALVER per year}\end{pmatrix}\begin{pmatrix}\text{SALVER} \\ \text{Duration}\end{pmatrix}}{\begin{pmatrix}\text{No. of Days} \\ \text{per year}\end{pmatrix}\begin{pmatrix}\text{No. of Dispatch} \\ \text{Areas}\end{pmatrix}}$$

$$= \frac{228 \times 4}{365 \times 5} = 0.50 \qquad \text{(Eq. 4.6.4)}$$

Resulting in the following expression for the probability of successfully completing the second and fifth day tasks:

$$\sum_{i=3}^{y_{84}} \binom{y_{84}}{i} y_{83}^{\,i} \; (1-y_{83})^{(y_{84}-i)} \qquad \text{(Eq. 4.6.5)}$$

and, the measure for SALVER is:

$$X_6 = \left[\sum_{i=y_{84}}^{y_{33}} \binom{y_{33}}{i} y_{32}^{\,i} \; (1-y_{32})^{(y_{33}-i)}\right]$$

$$\times \left[\sum_{i=3}^{y_{84}} \binom{y_{84}}{i} y_{83}^{\,i} \; (1-y_{83})^{(y_{84}-i)}\right]$$

(Eq. 4.6.6)

Figure 4-6 shows the computer listing of this model.

are available for the first day tasks, where m is the required number of CREV/DREV's to be dispatched, a is the availability of the CREV/DREV force, and t is the total number of CREV/DREV's in dispatch area, is:

$$\sum_{i=m}^{t} \binom{t}{i} a^{i} (1-a)^{t-i} \qquad \text{(Eq. 4.6.1)}$$

Substituting m, a, and t by their corresponding parameters yielded:

$$\sum_{i=y_{84}}^{y_{33}} \binom{y_{33}}{i} y_{32}{}^{i} (1-y_{32})^{(y_{33}-i)} \qquad \text{(Eq. 4.6.2)}$$

The corresponding expression for the probability that at least 3 CREV/DREV's survive the second and fifth day tasks, given that n is the number of CREV/DREV's dispatched to the CMF, and r is the 1 day reliability of a CREV/DREV, is as follows:

$$\left[\sum_{i=3}^{n} \binom{n}{i} r^{i} (1-r)^{n-i} \right]^{2s} \qquad \text{(Eq. 4.6.3)}$$

where s is the expected number of SALVER at any one time in dispatch area.

Using 228 as the expected number of SALVER per year for the force, and assuming 4 day SALVER timeline where CREV/DREV's are involved from day 2 through day 5, then:

4.6 SAL Verification (SALVER), X_6

The quantified measurement developed for purposes of evaluating SALVER tasks among the candidate systems is defined to be the probability that SALVER activities are accomplished within the specified period of time. The timeline established for SALVER is as follows:

Day 1	Remove missile
Day 2	Remove SAL parts
Day 3-4	NTM inspection
Day 5	SAL parts replacement
Day 6	Replace missile

In order to successfully accomplish the above tasks as scheduled, the required number of CREV/DREV's must be available to be dispatched to the CMF under consideration. Then at least three CREV/DREV's must survive the second day tasks. Upon completion of the NTM inspection it is assumed that CREV/DREV's will be available for the SAL part and barrier replacement tasks. Again at least three CREV/DREV's must survive the fifth day tasks.

The binomial distribution is used to obtain the desired probability expressions based on the availability of the CREV/DREV force, the reliability of the CREV/DREV, the number of CREV/DREV's dispatched to the CMF for each SALVER, and the total number of CREV/DREV's in each dispatch area. All CREV/DREV's are assumed to be dispatched from the ASC's, and the model can be generalized to include alternate dispatch locations for our modeling purpose. It is also assumed that the dispatch locations do not share their CREV/DREV's. The binomial expression for the probability that at least m CREV/DREV's

CANDIDATE #59 (3, 1, 2, 1)

Control: ASC/OB   Dispatch: ASC

Detect: 25/75   Team: Std/Spec

PARAMETERS

	Value		Value		Value
1.	200	32.	.6	63.	180
2.	2	33.	6	64.	82
3.	0	34.	1.25	65.	.1
4.	17	35.	13,200	66.	0
5.	260	36.	704	67.	5
6.	180	37.	3,520	68.	20
7.	125	38.	180	69.	52,000
8.	0	39.	4	70.	43,680
9.	18	40.	10,000	71.	5,200,000
10.	2	41.	8,900,000	72.	1,000,000
11.	2	42.	3,900,000	73.	2,000,000,000
12.	3	43.	68,432	74.	4,100,000
13.	4	44.	136,864	75.	1,000,000
14.	15	45.	0	76.	290,000,000
15.	100	46.	68,432	77.	140
16.	202	47.	.11	78.	0
17.	200	48.	102,648	79.	15,000,000
18.	5,200	49.	68,432	80	8,000,000
19.	5	50.	5	81.	1
20.	136,864	51.	2,340	82.	60
21.	2	52.	1,080	83.	.8
22.	2.32	53.	5	84.	4
23.	1920	54.	1,760	85.	150,000
24.	300	55.	5	86.	30
25.	520	56.	36,432	87.	40
26.	5,000,000	57.	2,040	88.	400
27.	120,000	58.	5,200	89.	2
28.	34,216	59.	2	90.	49,420
29.	.0075	60.	120	91.	68,432
30.	.02	61.	1	92.	2
31.	.17	62.	.0077	93.	120
				94.	120

Figure 5-4: PARAMETER LISTING FOR TOP RANKING CANDIDATE

in Figure 5-3 from noting that the ranked candidate systems from number 3 through 8 all indicate the 25% automatic detect level.

Further, it appears that team type has less influence upon the final ranking of the top candidates than the other characteristics.

Another major observation is that dispatch from OB results in very low CF values in all cases, thus indicating this dispatch source to be unfavorable for efficient maintenance.

5.4 Design Space Search

The design space is defined as the hyperspace resulting from the range of each parameter, y_k, and that of the *criterion* function, CF_α. The ranges of the parameters are obtained from the parameter estimates of the 81 candidate systems as discussed in section 5.2. A candidate system can then be defined as the vector of parameters and the resultant value of CF_α. Further, a candidate system is feasible only when every value of y_k in its vector exists in the design space. It can easily be shown that CF_α as defined in section 5.3 satisfies the following inequality:

$$0.0 \leq CF_\alpha \leq 1.0 \qquad \text{(Eq. 5.4.1)}$$

where $CF_\alpha = 1.0$ represents the theoretical best criteria function value any candidate system can obtain. However, for complex systems, the CF_α value of 1.0 seldom exists so that the search for the maximum CF in the design space must be accomplished.

The purpose of the design space search is to obtain the maximum value of CF from the design space along with the attendant set y_k which yields the theoretic maximum CF. It is important to note that the existence of this set does not necessarily imply the existence of a real candidate system. However, knowledge of the optimal combination of parameters which indicates a maximum "performance" measure can point to possible directions of improvement and provide insight into the design of the system.

The formulation of the criteria function as given in sections 3 and 4 results in a highly nonlinear surface in the design space. This coupled with the large number of parameters resulted in a fairly complex nonlinear optimization problem. The Sequential Unconstrained Minimization Technique (SUMT)[12,13,14,15,16] is used to solve the resulting problem, combining the criteria function and the range constraints into a penalty function. (See Figure 5-5.)

The problem under consideration can be stated as follows: Find a 94 dimensional vector V which consists of the parameters in the design space that maximizes the criteria function value, subject to the range constraints in the design space.

$$\begin{aligned} &\text{Maximize} && CF(V) && \\ &\text{Subject to} && g_i(V) = 0 && i = 1, \ldots, m; \\ & && h_j(V) = 0 && j = 1, \ldots, n. \end{aligned} \qquad \text{(Eq. 5.4.2)}$$

SUMT *transforms the above program* into the minimization of a nonlinear penalty function as follows:

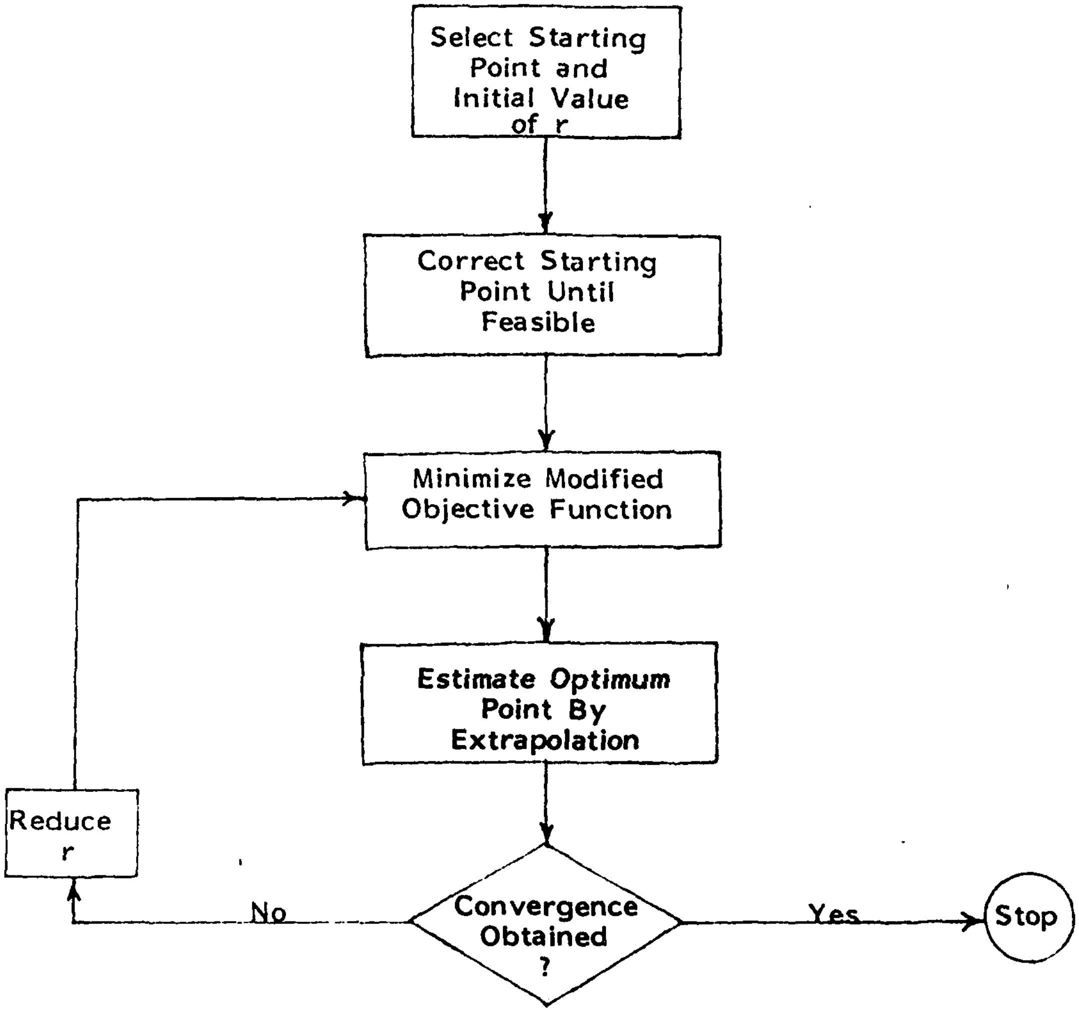


Figure 5-5: FIACCO AND McCORMICK (SUMT ALGORITHM) LOGIC DIAGRAM

$$\text{Minimize } P(V,r) = -CF(V) - r \sum_{i=1}^{m} \ln g_i(V) + \sum_{j=1}^{n} \frac{[h_j(V)]^2}{r} \qquad \text{(Eq. 5.4.3)}$$

where r is positive and decreases monotonically. As r becomes small, P(V,r) approaches CF(V) under suitable conditions. An overview flowchart of the solution procedure is given in figure 5-5. As in most nonlinear programming problems, there are various options and adjustments one can make to "fine-tune" the algorithm to improve its effectiveness for a given program. One such option worth mentioning is the choice of the unconstrained minimization approach for the penalty function. It appears that out of the various choices of algorithms tested such as the steepest descent, Fletcher-Powell, and Generalized Newton-Ralphson methods, the Generalized Newton-Ralphson method with modifications to the orthogonal move vector seems to be most effective for the criteria function under consideration. The results of the optimization are presented in figures 5-6 and 5-7 for both the 27 candidate systems and 81 candidate systems. The CF values obtained were 0.965 and 0.994 respectively. Analysis of these optimal results is presented in section 5.5.

5.5 Design Space Search Results

Figures 5-6 and 5-7 indicate the design space search results for all three scenarios (81 candidate systems) and scenario III (27 candidate systems) separately. When scenario III was run separately (the 27 CS) it appeared that control was at ASC/OB, dispatch from ASC, and a standard maintenance team augmented with specialists were most effective with lower levels of automatic fault detection. However (See Figure 5-8), when all three scenarios were evaluated, entire control at the ASC (monitored at OCC) appeared

Parameters y_i	Optimal	Parameters y_i	Optimal	Parameters y_i	Optimal
1	200.0	32	.6	64	147.3
2	2.0	33	6	65	0.16
3	98.6	34	1.25	66	0
4	15.5	35	13,200	67	5
5	292.5	36	704	68	20
6	127.1	37	3,520	69	52,268.0
7	91.1	38	128.1	70	43,126.5
8	2.0	39	4	71	5.2M
9	24.6	40	10,000	72	1.0M
10	2.0	41	8.9M	73	2,000.0M
11	2.0	42	3.9M	74	4.1M
12	3.0	43	68,432	75	1.0M
13	4.0	44	136,864	76	280.8M
14	16.0	45	5,635.8	77	14.0M
15	102.1	46	68,432	78	0
16	202	47	.11	79	15.0M
17	200	48	102,648	80	8.0M
18	5,200	49	68,432	81	1
19	5	50	5	82	61.8
20	136,864	51	2,340	83	.8
21	2	52	1,080	84	4
22	2.32	53	5	85	150,000
23	1,920	54	1,760	86	32.3
24	300	55	5	87	62.3
25	522.1	56	365,023.5	88	351.9
26	5.0M	57	2,040	89	2
27	120,000	58	5,200	90	49,920
28	34,216	59	2	91	68,432
29	.0075	60	120	92	2
30	.02	61	1	93	120
31	.17	62	.0077	94	
		63	320.9		

CF = 0.994
M = Millions

Figure 5-6: OPTIMAL PARAMETER VECTOR FOR 81 CANDIDATE SYSTEMS

Parameters Yi	Optimal	Parameters Yi	Optimal	Parameters Yi	Optimal
1	200.0	33	6	65	0.19
2	2.0	34	1.25	66	0
3	0.0	35	13,200	67	5
4	11.0	36	704	68	20
5	260.0	37	3,520	69	52,000.0
6	124.0	38	124.0	70	42,798.24
7	86.0	39	4	71	5.2
8	2.7	40	10,000	72	1.0M
9	26.0	41	8.9M	73	2,000.0M
10	2.0	42	3.9M	74	4.1M
11	2.0	43	68,432	75	1.0M
12	3.0	44	136,864	76	290.0M
13	4.0	45	3,556.2	77	14.0M
14	15.0	46	68,432	78	0
15	100.0	47	.11	79	15.0M
16	202	48	102,648	80	8.0M
17	200	49	68,432	81	1
18	5,200	50	5	82	60.0
19	5	51	2,340	83	.8
20	136,864	52	1,080	84	4
21	2	53	5	85	150,000
22	2.32	54	1,760	86	30.0
23	1,920	55	5	87	63.8
24	300	56	364,461.1	88	350.0
25	520.0	57	2,040	89	2
26	5.0M	58	5,200	90	49,920
27	120,000	59	2	91	68,432
28	34,216	60	120	92	2
29	.0075	61	1	93	120
30	.02	62	.0077	94	120
31	.17	63	285.0		
32	.6	64	82.0		

CF - 0.965

M = Millions

Figure 5-7: OPTIMAL PARAMETER VECTOR
FOR 27 CANDIDATE SYSTEMS

almost as effective, and only the top three candidates of scenario III (27 candidates) ranked in the top 10 of all three scenarios (81 candidates). However, the same two candidate systems topped both lists. Hence CS_{59} and CS_{68} are the leading candidates from this research. (See Figure 5-3).

CANDIDATE SYSTEMS

CS No.	Rank Among 81 CS	Rank Among 27 CS
59	1	1
68	2	2
36	3	-
34	4	-
33	5	-
32	6	-
31	7	-
35	8	-
77	9	3
42	10	-

Figure 5-8: COMPARATIVE RANKINGS OF TOP 10 CANDIDATE SYSTEMS

Figure 5-9 compares the parameters of the optimal candidate system (CS_{59}), those of the baseline system currently being considered by BMO (and ranked 48th) with the parameters indicated from the computer search of the design space yielding a theoretic candidate system (CF=0.994).

It is apparent that improved planning can increase the MX maintenance support effectiveness. Of interest is the exactness of the recommendations emerging from Figure 5-9.

	PARAMETERS	OPTIMAL	TOP	BASELINE
1.	No. of CMF	200.0	200.0	200.0
2.	No. of OB	2.0	2.0	2.0
3.	No. of Multi-skill teams	98.6	0.0	0.0
4.	No. of MMT	15.5	17.0	25.0
5.	No. of shuffle teams	292.5	260.0	260.0
6.	No. of MOSE teams	127.1	180.0	180.0
7.	No. of COMM/Sec repair teams	91.1	125.0	125.0
8.	No. in Multi-skill team	2.0	0.0	0.0
9.	No. of PM teams	24.6	18.0	10.0
10.	No. in shuffle team	2.0	2.0	2.0
11.	No. in MOSE team	2.0	2.0	2.0
12.	No. in COMM/Sec repair team	3.0	3.0	3.0
13.	No. in PM team	4.0	4.0	4.0
14.	No. of FDD helicopters	16.0	15.0	15.0
15.	No. of FDD vans	102.1	100.0	100.0
16.	No. of T/L	202	202	202
17.	No. of clusters	200	200	200
18.	Distance between PS	5,200	5,200	5,200
19.	Missile Emplacement time	5	5	5
20.	Personnel cost/PM team	136,864	136,864	136,864
21.	No. in CREV/DREV team	2	2	2
22.	No. of ROSE fail./mon./miss.	2.32	2.32	2.32
23.	MGCS repair time	1,920	1,920	1,920
24.	MOSE repair time	300	300	300
25.	Main. pers. know. miss. loc.	522.1	520.0	520.0
26.	Base operating support cost	5.0M	5.0M	5.0M
27.	Pers. cost/helicopter team	120,000	120,000	120,000
28.	Pers. cost/van team	34,216	34,216	34,216
29.	No. C/M N-L fail./mon./miss.	.0075	.0075	.0075
30.	No. R/S N-L fail./mon./miss.	.02	.02	.02
31.	No. MOSE N-L fail./mon./miss.	.17	.17	.17
32.	Avail. of CREV/DREV/force	.6	.6	.6
33.	Total CREV/DREV/Dispatch Area	6	6	6
34.	No. COMM/Sec fail./mon./miss.	1.25	1.25	1.25
35.	Speed of Helicopter	13,200	13,200	13,200
36.	Speed of T/L	704	704	704
37.	Speed of Van	3,520	3,520	3,520
38.	No. of ROSE repair teams	128.2	180.0	180.0
39.	No. in MMT	4	4	4
40.	Cost/Van	10,000	10,000	10,000
41.	Cost/T/L	8.9M	8.9M	8.9M
42.	Cost/Helicopter	3.9M	3.9M	3.9M
43.	Personnel cost/MOSE team	68,432	68,432	68,432
44.	Personnel cost?MMT	136,864	136,864	136,864
45.	Pers. cost/Multi-skill team	5635.8	0.0	0.0
46.	Personnel cost/shuffle team	68,432	68,432	68,432
47.	No. MGCS N-L fail./mon./miss.	.11	.11	.11
48.	Pers. $/COMM-Sec repair team	102,648	102,648	102,648
49.	Pers. cost/ROSE repair team	68,432	68,432	68,432
50.	Missile removal time	5	5	5

Figure 5-9: COMPARISON OF OPTIMAL CANDIDATE SYSTEM, BASELINE SYSTEM AND THEORETIC MAXIMUM PERFORMANCE SYSTEM

	PARAMETERS	OPTIMAL	TOP	BASELINE
51.	R/S repair time	2,340	2,340	2,340
52.	Delay	1,080	1,080	1,080
53.	No. of STV	5	5	5
54.	Speed of STV	1,760	1,760	1,760
55.	No. of ASC	5	5	5
56.	Dist. betw. Dispatch & CMF	365,023	364,320	447,216
57.	C/M repair time	2,040	2,040	2,040
58.	Dist. betw. CMF and PS	5,200	5,200	5,200
59.	No. in helicopter team	2	2	2
60.	PS ROSE repair time	120	120	120
61.	No. in van team	1	1	1
62.	No. PS ROSE fail./mon./miss.	.0077	.0077	.0077
63.	No. of FDD personnel/OB	320.9	180.0	180.0
64.	No. of FDD personnel/ASC	147.3	82.0	45.0
65.	Frac. N-L fail. using helicopter	.10	0.1	0.1
66.	CAMM pers. know. miss. loc.	0	0	0
67.	Time to Enter/Exit site	5	5	5
68.	Time at each PS for PLU	20	20	20
69.	Ave. pay for OB personnel	52,268	52,000	52,000
70.	Ave. pay for ASC personnel	43,126	43,680	41,600
71.	Cost/STV	5.2M	5.2M	5.2M
72.	Cost/CMF	1.0M	1.0M	1.0M
73.	Cost/OB	2,000M	2,000M	2,000M
74.	Cost/ASC	4,099,394	4.1M	3.5M
75.	Equip. Cost/CMF	1.0M	1.0M	1.0M
76.	Equip. cost/OB	218M	290M	300M
77.	Equip. cost/ASC	14M	14M	10M
78.	Spares/Supplies cost/CMF	0	0	0
79.	Spares/Supplies cost/OB	15M	15M	35M
80.	Spares/Supplies cost/ASC	7.99M	8M	4M
81.	Salver (once per year)	1	1	1
82.	No. of CREV/DREV teams	61.8	60.0	60.0
83.	One day CREV/DREV reliab.	.8	.8	.8
84.	No. CREV/DREV disp. to CMF	4	4	4
85.	Cost/CREV/DREV	150,000	150,000	150,000
86.	No. of helicopter teams	32.3	30.0	30.0
87.	No. of van teams	62.2	40.0	40.0
88.	No. of FDD security teams	351.9	400.0	400.0
89.	No. in FDD security teams	2	2	2
90.	PERS. Cost/FDD Security	49,920	49,920	49,920
91.	PERS. Cost/CREV/DREV Teams	68,432	68,432	68,432
92.	No. in ROSE repair team	2	2	2
93.	ROSE repair time	120	120	120
94.	COMM/sec repair time	120	120	120

Figure 5-9 (cont.): COMPARISON OF OPTIMAL CANDIDATE SYSTEM, BASELINE SYSTEM AND THEORETIC MAXIMUM PERFORMANCE SYSTEM

6.0 CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

6.1.1 CS_{59} is the optimal candidate system for both scenario III (where control of the fault monitoring system is shared between ASC and OB) and the combination of all three scenarios (where control of fault monitoring could be at any of the ASC, OB, or ASC/OB).

6.1.2 The level of automatic fault detection appears to be optimal at about the 25% level, degrading overall maintenance effectiveness slightly with increased automation up to approximately the 50% level.

6.1.3 Standard MMT composition with specialist augmentation appears to be the most effective personnel policy for the maintenance activity.

6.1.4 The baseline candidate system (CS_{79}) ranked 48th in the list of 81 candidate systems, indicating considerably improved effectiveness to be possible.

6.1.5 Using this design/planning methodology is an effective method for optimization of initial MX maintenance planning.

6.1.6 Dispatching maintenance crews from OB appears to be ineffective under all three scenarios.

6.1.7 Explicit values of support characteristics are identified for performance growth of both the baseline and optimal candidate systems (see sections 5.4 and 5.5).

6.1.8 SIMMX has been installed at TRW and is operational at BMO. This program can materially aid the support planning activity.

6.1.9 Initial study of data rates and traffic volume has been made for C^3 systems.

6.2 Recommendations

6.2.1 All practical steps should be taken to include optimal system characteristics.

6.2.2 Update the maintenance management model (Criterion Function Studies) to include modifications in the basing mode.

6.2.3 Expand the SIMMX to include the next level of support planning detail.

6.2.4 Develop analytical programs to support C^3 studies.

6.2.5 Validate current date rate estimates from the major nodes

6.2.6 Improve accuracy of date rate estimates from the secondary nodes.

7.0 REFERENCES

1. Ostrofsky, Benjamin, "Development of Aerospace Systems With Integration of Human Factors Using a Design Morphology," AFOSR Contract #F49620-77-C-0116, (1 October 1978 - 30 September 1979), University of Houston, Houston, Texas, September 1979.

2. ____________, "Morphology of Design of Aerospace Systems with Inclusion of Human Resource Factors," AFOSR Grant #77-3148, University of Houston, Houston, Texas, August 1977.

3. ____________, Augmentation of Research into Morphology of Design of Aerospace Systems with Inclusion of Human Factors," AFOSR Contract #F49610-77-C-0116 (1 September 1977 - 1 October 1978), University of Houston, Houston, Texas, September 1978.

4. "Manpower Analysis Requirements for System Acquisition," Memorandum for Secretaries of the Military Departments, Office of Assistant Secretary of Defense, Washington, D.C., 17 August 1978.

5. Ostrofsky, Benjamin, Design, Planning and Development Methodology, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1977.

6. ____________, "Application of a Structured Decision Process for Proper Inclusion of Human Resources in the Design of a Power Unit Support Stand," University of Houston, Houston, Texas, 1978.

7. ____________, Charles E. Donaghey, Nelson E. Marquina, E. A. Kiessling, "Application of a Design Morphology to the MX/OCC Definition of a Fault Detection and Dispatch System," University of Houston, Houston, Texas, September 1980.

8. Donaghey, Charles E., Bau Truong, "SIMMX (Simulation of Maintenance MX) Users Manual", Industrial Engineering Department, University of Houston, July 1, 1981.

9. Minutes of MMS Working Group Meeting, Ballistic Missile Office, Norton Air Force Base, California, June 16 to June 19, 1981.

10. "MX Vertical Shelter Ground System: Definition Systems," The Boeing Company Document No. D 295-10134-1, 25 September 1978, pp. 5 - 240 to 243.

TABLE B-2: MX MAINTENANCE DISPATCHES (ESTIMATE)

PRIORITY	DISPATCHES/MONTH	W/O
1-4	37,500	37,500
5-7	37,500	5,360
	75,000	42,860

BASED ON ESTIMATE OF 75,000 DISPATCHES (TOTAL BALL PARK) in priorities 5 thru 7 would be 37,500. Similarly using the number of work orders per dispatch in the priority category, the work orders in priorities 1 thru 4 would be 37,500 (one work order per dispatch) and in priorities 5 thru 7 would be 5,360 (seven work orders per dispatch). These calculations are illustrated in Table B-2. In the following section, it is shown how the 37,500 work orders in priorities 1 thru 4 are contributed by the major nodes identified in Figure B-1.

B.2.2 Estimation of Maintenance Work Orders by Major Nodes

Reference 19 provides a preliminary MX OSE reliability prediction update. It further indicates the failures per month per system (defined as failure rate) for the OSE components. The equipment failure rates have been assigned priority based on priority designators.[18]

As an example, the failure rates specified in reference 19 are illustrated in Table B-3. The failure rates for Horizontal Shelter Site (HSS) equipment (in major node DDA) are taken from reference 19. Based on this reference, priorities are assigned for each of the equipment failures. Then, each assigned priority is given a weight equivalent to the percentages based on Minuteman example in Table B-1. For instance, HSS OSE C^3 (PS) is predicted to a failure rate of 118.21 failures/month/system. The failure is assigned a priority of 2 from reference 18. Table B-1 specified that priority 2 work orders constitute only 7.5% of the total work orders. Thus to make MX work orders generation consistent with Minuteman example, a priority weight of 0.075 is applied to the failure rate. The priority weighted failure rate for HSS OSE C^3 (PS) is calculated as 8.859 or (118.21 x 0.075).

TABLE B-1: WORK ORDER SAMPLE FROM MINUTEMAN

PRIORITY	W/O	DISPATCHES	%
1	4	4	5
2	6	6	7.5
3	10	10	12.5
4	20	20	25.0
5-7	280	40	50.0
SUMMARY			
1-4	40	40	50.0
5-7	280	40	50.0

(BASED ON W/O SAMPLE)

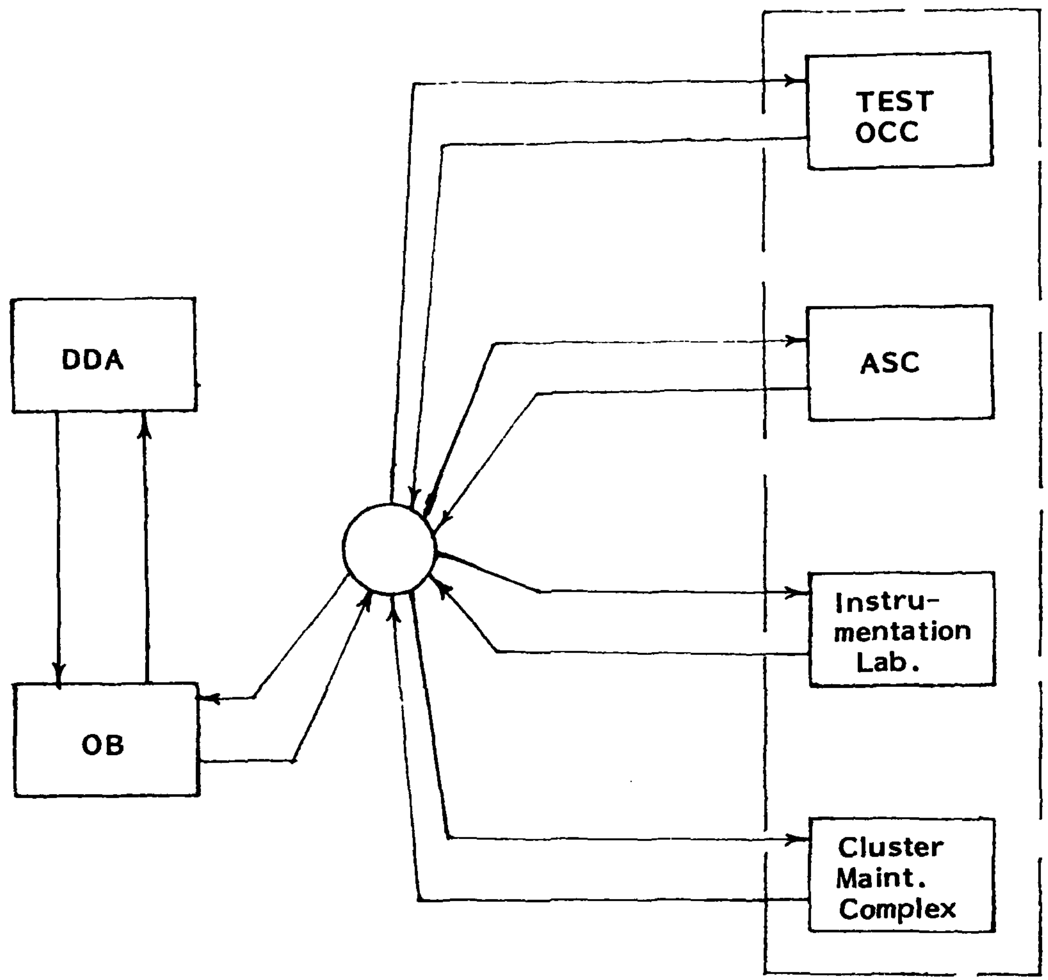


Figure B-5: SECONDARY INFORMATION NODES AT OBTS

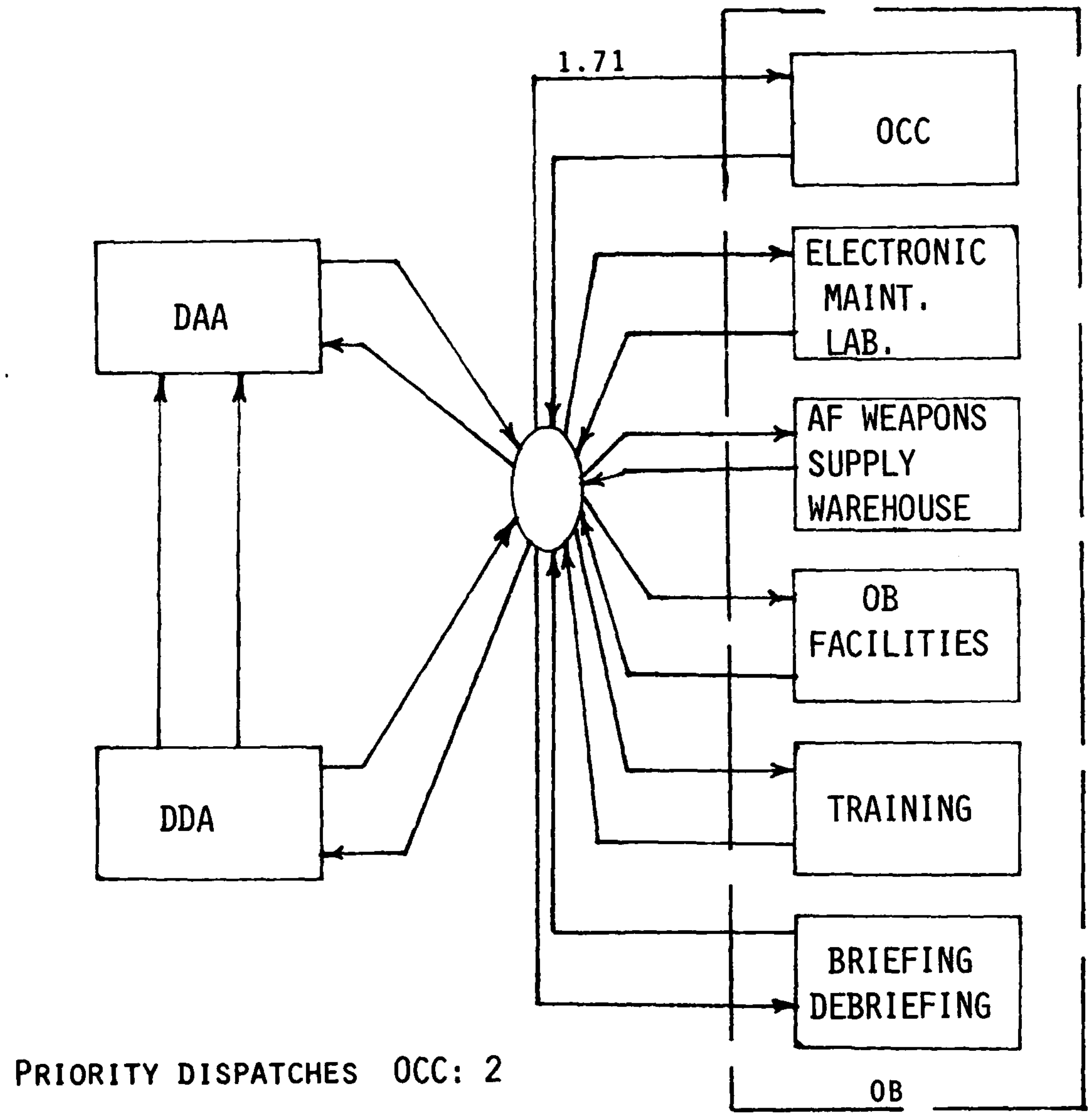


Figure B-4: SECONDARY INFORMATION NODES AT OB

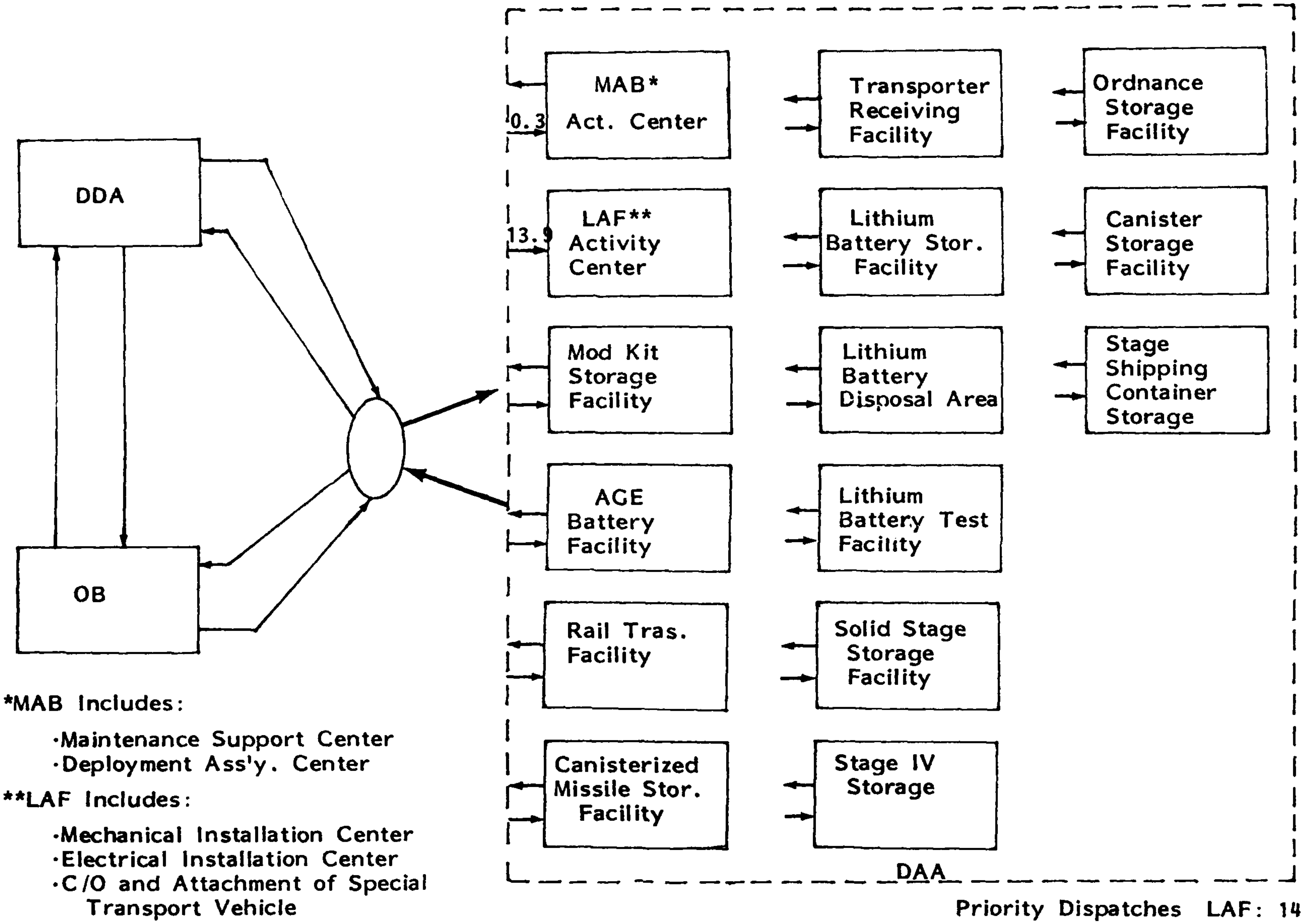
The OB are provided to accommodate personnel and to support administration and operations. The secondary information nodes at OB are shown in Figure B-4.

The OBTS provides central capability for weapon system test and evaluation. The secondary information nodes at OBTS are identified in Figure B-5. The possible information flow path between secondary nodes can be estimated as twice the product of number of secondary nodes per each major node. The actual paths can be determined based on the traffic flow analysis.

B.2.1 Estimation of Maintenance Frequency Requirements

BMO provided a typical daily work order sample from the Minuteman system. This is shown in Table B-1 and illustrates the estimated number of work orders with an assigned priority as well as the number of resulting dispatches. Further, based on the sample, percentages for each priority category are calculated and shown in Table B-1. Only 5% of the dispatches are of priority 1. Note from the table that each work order in priorities 1 thru 4 results in a dispatch, whereas a total of seven work orders in priorities 5 thru 7 result in a dispatch. Further note from Table B-1 that in priorities 1 thru 4, there are 40 work orders (and hence 40 dispatches) and in priorities 5 thru 7 there are 280 work orders (and only 40 dispatches). The percentage of dispatches in priority categories 1 thru 4 and 5 thru 7 is 50.

Using the Minuteman data approximately 75,000 dispatches per month will be experienced. Using these sample percentages, the number of dispatches in priorities 1 thru 4 would be 37,500 (50% of 75,000) and



*MAB Includes:

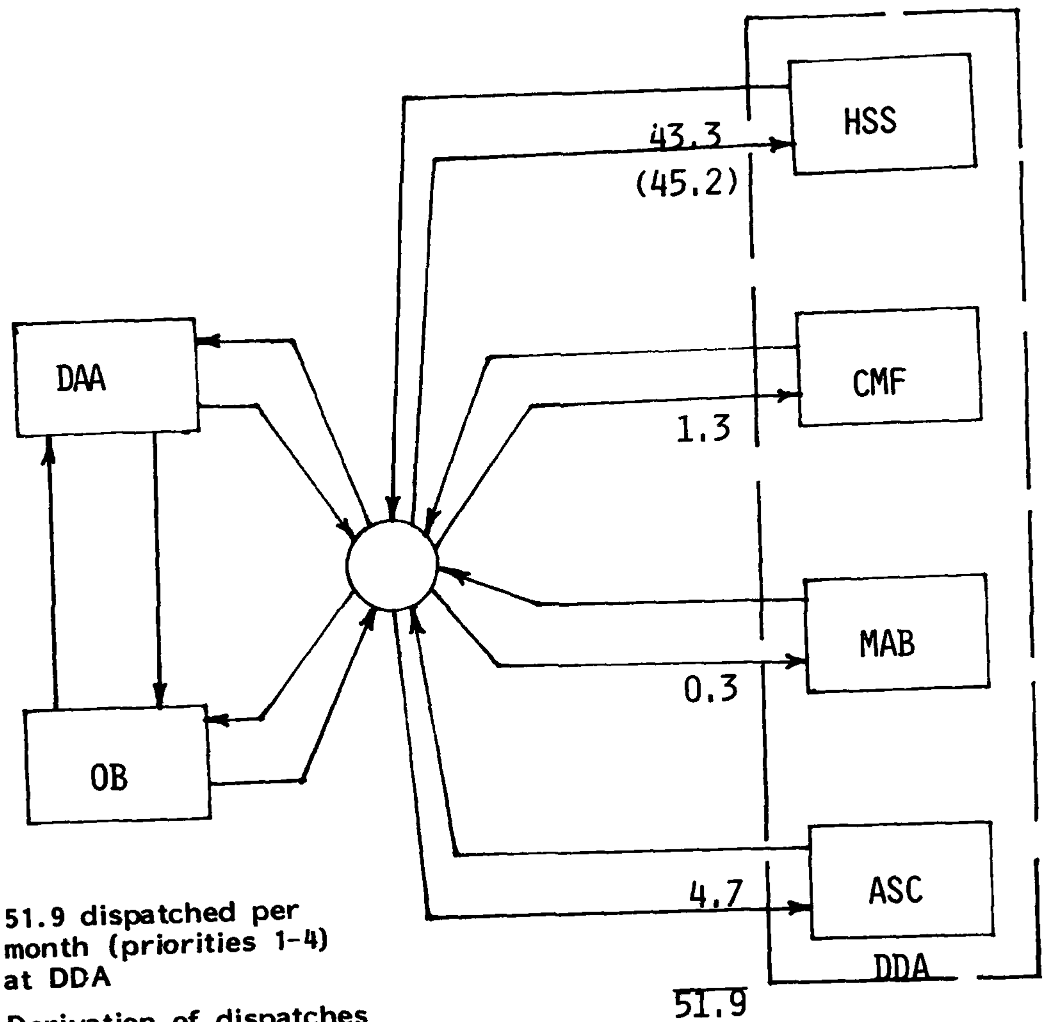
- Maintenance Support Center
- Deployment Ass'y. Center

**LAF Includes:

- Mechanical Installation Center
- Electrical Installation Center
- C/O and Attachment of Special Transport Vehicle

NOTE: All the facilities at DAA are supposed to originate from the node.

Figure B-3: SECONDARY INFORMATION NODES AT DAA



NOTE:
1. 51.9 dispatched per month (priorities 1-4) at DDA
2. Derivation of dispatches per month discussed in B.2.2

Figure B-2: SECONDARY MAINTENANCE INFORMATION NODES AT DDA

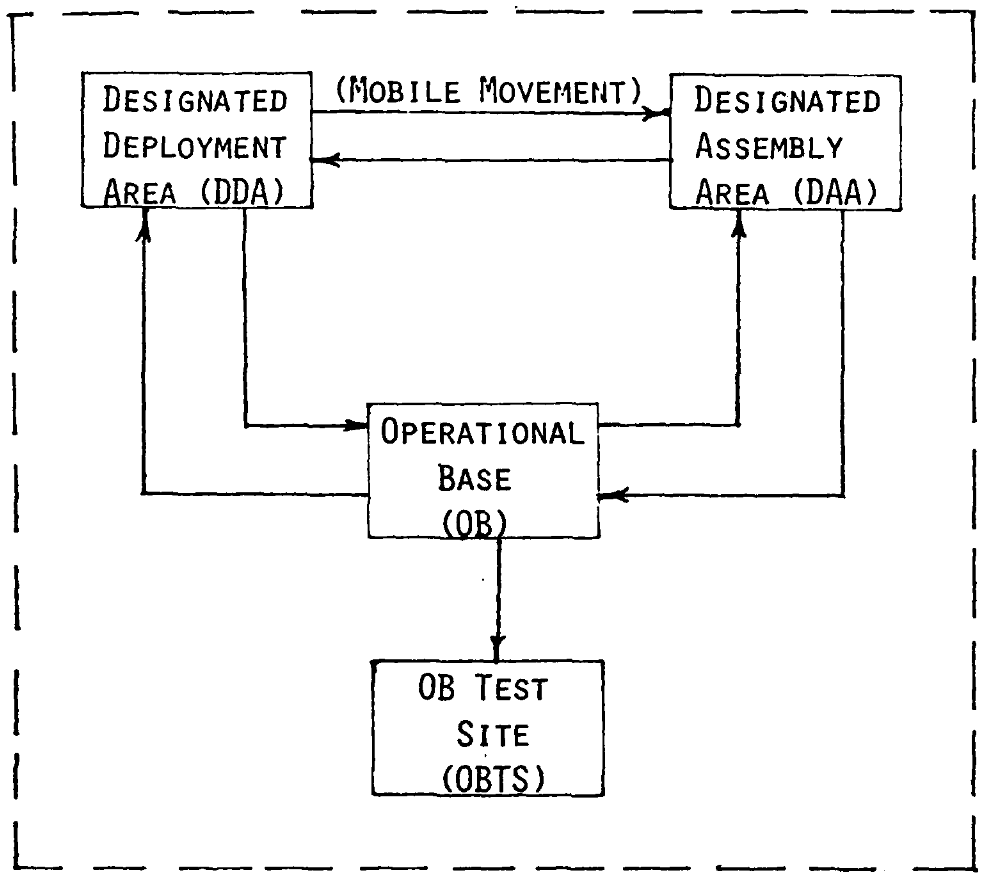


Figure B-1: MAINTENANCE NETWORK TRAFFIC NODES TOP LEVEL

Reference 20 identifies the data rates for a dispatch. Based on the number of dispatches at a major node, an estimate is made of the data rates and transmission times. From these calculattions, probable points of maximum volume in the maintenance network are established.

B.2.0 OVERVIEW OF MAINTENANCE NETWORK

Reference 17 provides a detailed description of the maintenance facilities. These include the Designated Deployment Area (DDA), Designated Assembly Area (DAA). DAA, located near an Operating Base (OB), is adjacent to the DDA but separated from it by a distinct, observable Designated Transportation Network (DTN). An OB Test Site (OBTS), constructed near the DAA, is required to provide facilities to support subsystem and system development tests. DDA, DAA, OB and OBTS are identified in Figure B-1 as the major nodes for maintenance tasks. The direction of information flow between the nodes is indicated with an arrow.

The DDA is an area identified by specific boundaries within which elements of the weapon system are deployed, accounted for, and controlled. The facilities in the DDA are required to allow the missile to perform the operational mission under pre- and post-attack environmental conditions. Facilities required for maintenance are called secondary maintenance information nodes and they are identified in Figure B-2.

The DAA provides areas to support incoming inspection and storage of missile components, launcher and canisterized missile assembly areas and facilities to support intermediate maintenance of failed operational equipment and systems. Figure B-3 explicitly identifies the secondary information nodes at DAA.

APPENDIX B - MAINTENANCE INFORMATION TRAFFIC FLOW ESTIMATES*

B.1.0 APPROACH

The approach consists of identifying the MX maintenance network.[17] This network identifies the major nodes and secondary nodes and further indicates the direction of flow of maintenance traffic and maintenance facilities at the secondary nodes.

BMO provided a typical daily work order sample from the Minuteman system with assigned priorities. From this sample, the percentage of dispatches in priority categories 1 thru 4 and 5 thru 7 was derived and the MX system dispatches have been estimated at 75,000 per month and they have been apportioned to each priority category from the sample.

Reference 19 provides the MX Operational Support Equipment (OSE) reliability and prediction and reference 18 defines the priority assignment for the maintenance actions. The MX failure rates identified in reference 19 are assigned a priority and based on the Minuteman example, an appropriate weight has been applied to the priorities 1 thru 4 and 5 thru 7. Using this procedure, dispatches required at major nodes of MX are estimated.

The total number of dispatches calculated in Section B.2.2 are allocated to the major nodes based on the similar distribution derived in the Section B.2.2.

---

*Grateful acknowledgment is given to Mallik Putcha for his help in accomplishing this study.

SIMMX is not intended for detailed simulation models. Its purpose is to examine broad maintenance scenarios under different levels of resources and failure rates and it will report on resource utilization and availability of the missile system for any length of simulated time. The simulation system is relatively inexpensive to use. Typical models that have been studied usually have from one to four types of failures, and ten to twenty types of resources. This type of model will usually cost less than $10.00 for computer time when it is simulated for one year of operation.

APPENDIX A - SIMULATION OF MX MAINTENANCE (SIMMX)

The SIMMX language interpreter was completed,[8] and delivered to BMO and is now operational. SIMMX (Simulation of Maintenance MX) is a problem-oriented, Monte Carlo simulation language designed specifically for examining maintenance strategies for the MX system. It allows a modeler to quickly and conveniently describe a maintenance strategy, and then observe how this strategy performs under various failure rates and levels of resources. The interpreter for the language was written in Fortran IV, and has been used on a variety of computer systems. The program is entirely self-contained and uses no software or features common only to selected hardware systems.

The modeler first describes, in network form, the maintenance tasks required to repair a failure. Each arc of the network represents a single task, and the network shows the precedence order of the tasks to be performed. Each failure type included in the model must have its associated network of repair tasks. The modeler then describes this network information and the levels of each of the required resources in SIMMX statements. The "SIMMX Users Manual"[8] describes the language and gives examples of its use. The language can be learned and applied very quickly. In briefings to TRW personnel, it was found that two hours of instruction was adequate to allow them to begin utilizing SIMMX. The system can be used in either a batch or time sharing environment, and the language is essentially format free. Instructions can be entered in any column and spaces are ignored.

11. "MX Vertical Shelter Ground System: Definition Systems," The Boeing Company, Document No. D 295-10134-1, 25 September 1978, pp. 5 - 240, 5 - 243.

12. Crockett, J.B., and H. Chernoff, "Gradient Methods of Maximization," Pacific J. Math., 5: 33-50 (1955).

13. Fiacco, A.V., and G.P. McCormick, "Nonlinear Sequential Unconstrained Minimization Techniques," John Wiley and Sons, Inc., New York, N.Y., 1968.

14. Kuester, J.L., and J.H. Mize, "Optimization Techniques with Fortran," McGraw-Hill Book Co., New York, N.Y., 1973.

15. Fiacco, A.V., and G.P. McCormick, "The Sequential Unconstrained Minimization Technique for Convex Programming: A Primal-Dual Method," Man. Sci., Vol. 10, No. 2, 1964.

16. Fiacco, A.V., and G.P. McCormick, "Extension of SUMT for Nonlinear Programming -- Equality Constraints and Extrapolation," Man. Sci., Vol. 12, No. 11, 1966.

17. MX Weapon System Operational System Maintenance Plan, L05-012001A, February 1981.

18. Intercontinental Ballistic Missile Maintenance Management SACR 66-12, Vol. III, November 1979.

19. Preliminary MX OSE Reliability Prediction Update, TRW Memo 6843.DJ.80-030, 10 October 1980.

20. Cable Data Network (CDN) and Data Transfer Between Maintenance Processors, GTE Memo 0070-I-01032, August 21, 1980.

21. Minutes of MMS Working Group Meeting, BMO/NAFB, 16-19 June 1981.

TABLE B-3: FAILURE RATE CALCULATION FOR SECONDARY NODE HSS (MAJOR NODE DDA)

	Equipment	Failure Rate[1] (Failures/Month/System)	Assigned Priority[2]	Priority Weight[3]	Priority Weighted Failure Rate (Failures/Month/System)
1)	HSS OSE CCC (PS)	118.21	2	0.075	8.859 (118.21 x 0.075)
2)	HSS ECS	67.16	3	0.125	8.395
3)	HSS OSE Power	181.742	2	0.075	13.631
4)	HSS PS Closure	1.259	3	0.125	0.157
5)	HSS PSS/PI & A Equipment	118.224	2	0.075	8.867
6)	HSS Auto Umbilical Receptacle	1.276	1	0.05	0.064
7)	HSS Countermeasures	67.160	1	0.05	3.358
					43.331

Priority weighted HSS failure rate/month/system = 43.3

Since all HSS failures are in priorities 1 thru 4, the number dispatches for HSS: 43

NOTE: 1) Failure rates are taken from reference 19

2) Priority assignment is based on Table B-3

3) Priority weight is based on Minuteman example Table B-1

Similarly, all the HSS equipment failure rates specified in reference 20 are provided with a priority weighted failure rates. As shown in Table B-3 for HSS, the priority weighted failure rate is 43.3 failures/month/system. These failures result in equal number of work orders for HSS. Since all the failures at HSS are of priority 1 thru 4, the dispatch rate for HSS is 43.3 per month or 43 per month.

An assumption is made that a launcher has to be either at an HSS or Launcher Assembly Facility (LAF) center. Hence, launcher's OSE failure rates are to be associated with HSS while its support facilities and equipment failures are to be associated with the LAF center. Then the combined HSS/Lanucher failure rates are 45.2 and the dispatches are 45 per month. This value is also shown in parenthesis in Figure B-2.

Using a similar procedure illustrated in Table B-4, from reference 19, priority weighted failure rates for the secondary nodes in each major node are calculated and the number of dispatches per month are established. In case of DDA, the total number of dispatches are calculated to be 50 (52). In Table B-4, the number of dispatches from the other major nodes are also identified. As shown in Table B-4, the total number of dispatches with priorities 1 thru 4 from the major nodes is 70 (72). Percentages for each major node out of the total is also derived. Thus, the number of dispatches from DDA constitute about 72.2% out of the total dispatches.

From Table B-2 for the MX system, it was estimated that the total number of dispatches with priorities 1 thru 4 are 37,500. This number is allocated to the major nodes based on the derived percentages in

TABLE B-4: DISPATCHES REQUIRED AT MAJOR NODES

NODE	DISPATCH PRIORITY	DISPATCHES PER MONTH	PERCENTAGES OF THE TOTAL DISPATCHES
DDA	1,2,3	50(52)[A]	71.4(72.2)
DAA	4	14	20.0
OB	2	2	2.9
VEHICLES	4	4	5.8
		70(72)	100.1

[A] 52 includes mobile equipment

[B] Priorities 5-7 are estimated at the same number of dispatches, each dispatch to handle 7 work orders.

[C] Maintenance priorities per SACR 66-12

TABLE B-5: DISPATCHES REQUIRED BY MAJOR NODES

	DISPATCHES/MO.
DDA	27,082
DAA	7,292
OB	1,042
VEHICLES	2,084
	37,500

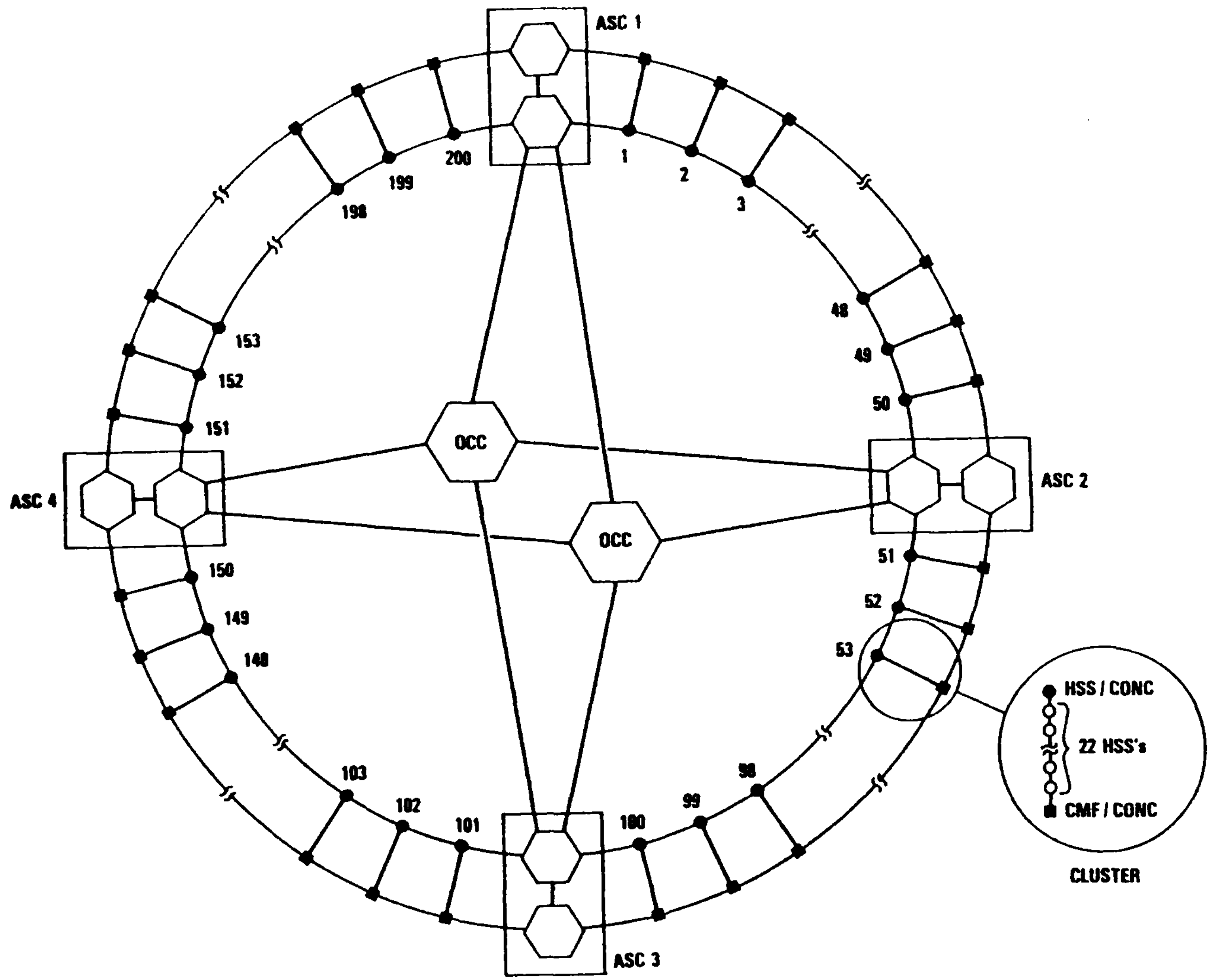


Figure B-6: CABLE DATA NETWORK CLUSTER LOOP CONNECTIVITY

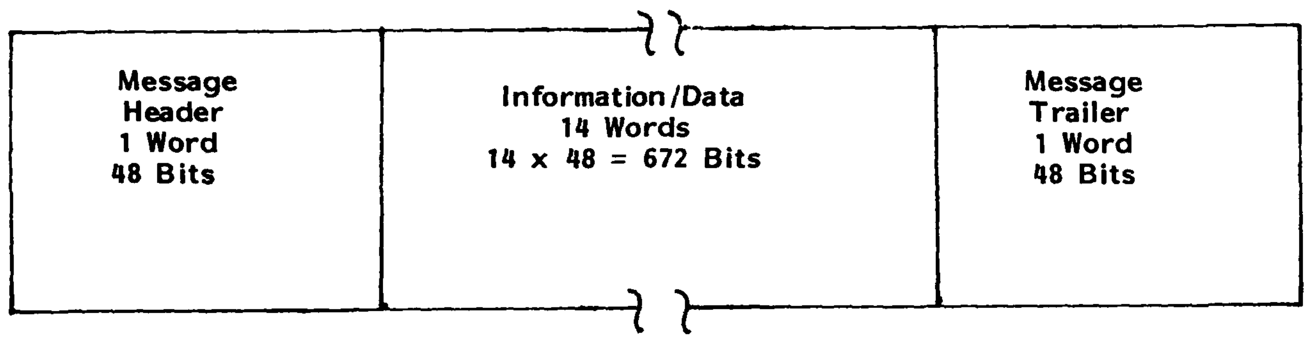


Figure B-7: CDN MESSAGE FORMAT WITH OVERHEAD

Table B-4. Thus, for DDA, the apportioned number of dispatches are 27,082 (0.722 x 37,500) per month. Similarly the dispatches for the remaining nodes in Table B-5 are also calculated.

Once the number of dispatches from the major nodes are established, with an estimation for number of pages and data content per dispatch, it is possible to calculate the data rates. The next section describes the details tc calculate the data rates for the maintenance dispatches.

B.3.0 ESTIMATION OF MAINTENANCE DATA VOLUME PER LOCATION

References 20 and 21 provide a realistic measure of maintenance data transfer. The GTE analysis is based on the Cable Data Network (CDN) architecture shown in Figure B-6. Further as shown in *Figure B-6, the* GTE CDN study provided work order definition for an average and worst case dispatches. The average work order consists of 12 pages of text and 3 pages of graphics. Each page of text results in a total of 34 CDN messages and each graphic page results in a total of 50 CDN messages. Thus, each average work order results in 558 CDN messages, while each worst case work order results in 930 CDN messages. Reference 20 provided a format for a CDN message. The message format is shown in Figure B-7. Thus a CDN message consists of 768 bits (48 + 672 + 48). Hence as shown in Table B-6, an average work order dispatch results in a data rate of 428.5 kbps (558 x 0.768 kbps) while a worst case work order results in 714.2 kbps. Reference 20 specifies a transmission rate of 48 kbps for synchronous serial character-oriented communication. Hence, the transmission time for an average and worst case dispatch takes 8.93 (428.5/48) and 14.88 (714.2/48) seconds respectively. (See Table B-7).

TABLE B-6: WORK ORDER DEFINITION

Page Estimates	Average	Worst Case
Text	12	20
Graphics	3	5
	15	25

Text Page Generation

- 40 lines at 75 characters
- 90 characters per CDN message
- Total of 34 CDN messages (40 x 75/90)

Graphics Page Generation

- 400 commands
  - 200 line vectors
  - 100 arcs and circles
  - 100 six-character captions
- 8 commands per CDN message
- Total of 50 CDN messages (400/8)

Work Order Generation

- Average -- 558 CDN messages (34 x 12 + 50 x 3)
- Worst case -- 930 CDN messages (34 x 20 + 50 x 5)

TABLE B-7: SUMMARY OF DATA PER DISPATCH

	Data Rate in Kilobits Per Second	Transmission Time in Seconds
	With CDN Message Overhead	
Average	428.5	8.93
Worst Case	714.2	14.88

Assumption

- 48 kbps CDN *transmission rate from major* nodes to ASC

Table B-5 established the number of dispatches per month at each major node and Table B-8 consolidates the dispatches per day at the major nodes DDA, DAA and OB. DDA requires 903 dispatches per day. Since each dispatch is a result of a work order (priorities 1 thru 4), the number of work orders per day from DDA is 903. Each average dispatch takes 8.93 seconds, the transmission time for DDA dispatches is 134.4 minutes (8.93 x 903/60) as shown in Table B-9 Similarly, the transmission time for a worst case dispatch is 223.9 minutes. Transmission times for the remaining major nodes are also identified in Table B-9.

B.3.1 Estimation of Major Nodes Input/Output Data Rates

GTE estimated the maintenance control data traffic based 18.4.1 Data Traffic Analysis work sheets.[21] Table B-10 shows the summary of the daily as well as peak traffic rates for the functional users. These rates are allocated to the major nodes based on the percentages of total daily dispatches originating from each of them. For instance, DDA daily rate is obtained as 0.722 x 1317 = 950.9 kilobytes. In Table B-4, 0.722 is the fraction of dispatches originating from DDA. Similarly, the data rates in remaining major nodes can be obtained. Note that Table B-11 identifies the input and output data rates for each major node. Further, analysis is required to estimate the traffic from and to each major node.

B.4.0 CONCLUSIONS

This maintenance information flow analysis identified the major nodes and secondary nodes in the MX Maintenance Network. Further, based on a gross estimate, the data rates in the major nodes have been

TABLE B-8: DISPATCHES REQUIRED BY MAJOR NODES

	DISPATCHES/MONTH	DISPATCHES/DAY	PERCENTAGES OF TOTAL DAILY DISPATCHES
DDA	27082	903	72.2
DAA	9376	313	25.0
OB	1042	35	2.8
		1251	100.0

Assumption: Vehicle maintenance will be done at DAA and hence dispatches by major node vehicles are added to DAA.

TABLE B-9: TRANSMISSION TIMES FOR DISPATCHES BY MAJOR NODES

MAJOR NODE (DISPATCHES/DAY)	TRANSMISSION TIME IN MINUTES AVERAGE	TRANSMISSION TIME IN MINUTES WORST CASE
DDA (903)	134.4 (2.24)*	223.9 (3.73)*
DAA (313)	46.6	77.6 (1.29)*
OB (35)	5.2	8.7

*Time in hours

TABLE B-10: GTE MAINTENANCE CONTROL
DATA TRAFFIC ESTIMATES

	Daily Rate (Kilobytes)		Peak Rate (Kilobytes/Hour)	
	INPUT	OUTPUT	INPUT	OUTPUT
All Functional Users	1317	9553	369	2634

TABLE B-11: ESTIMATION INPUT/OUTPUT TRAFFIC RATES AT MAJOR NODES

	Daily Rate (Kilobytes)		Peak Rate (Kilobytes/Hour)	
	INPUT	OUTPUT	INPUT	OUTPUT
DDA	950.9	6897.3	266.4	1901.8
DAA	263.4	1910.6	73.8	526.8
OB	38.2	277.0	10.7	76.4
Vehicles	76.4	554.1	21.4	152.8
	1328.9	9639.0	372.3	2657.8

NOTE: The totals are about 0.1% in excess of the totals in Table B-10 since percentages in Table B-4 sum to 100.1%

estimated. Future study should validate the results of the current study and update the accuracy of data rates in the major nodes. Another aspect that needs further study is the data flow between seconday nodes.

APPENDIX C - CRITERIA, SUBMODELS AND PARAMETERS ("TABLE III")

		X(1)					X(2)				X(3)					X(4)				X(5)			X(6)
	Z(j)	1	3	4	8	D	3	4	8	D	2	5	6	7	D	3	4	8	D	4	8	D	D
Z(1)	Number of personnel for FDD	X																					
Z(2)	FDD equipment and facilities cost ($)										X												
Z(3)	Task time (minutes)		X				X																
Z(4)	Dispatch time (minutes)			X				X															
Z(5)	FDD personnel cost ($)											X											
Z(6)	FDD vehicle cost ($)												X										
Z(7)	FDD operating and spare cost ($)													X									
Z(8)	Number of actions per month				X				X									X			X		

		X(1)					X(2)				X(3)					X(4)				X(5)			X(6)
																				X			
	Z(j)	1	3	4	8	D	3	4	8	D	2	5	6	7	D	3	4	8	D	4	8	D	D
Y(1)	Number of CMF										X			X									
											X			X									
Y(2)	Number of OB	X									X	X		X					X				
		X									X	X		X					X				
Y(3)	Number of multiple skill	X										X							X				
	teams	X										X							X				
Y(4)	Number of MMT	X										X							X				
		X										X							X				
Y(5)	Number of shuffle teams	X										X							X				
		X										X							X				
Y(6)	Number of MOSE teams	X										X							X				
		X										X							X				
Y(7)	Number of COMM/security	X										X							X				
	repair teams	X										X							X				
Y(8)	Number in multiple skill	X																	X				
	team	X																	X				
Y(9)	Number of PM teams	X										X							X				
		X										X							X				
Y(10)	Number in shuffle team	X																	X				
		X																	X				

		X(1)					X(2)				X(3)					X(4)				X(5)			X(6)
																				X			
	Z(j)	1	3	4	8	D	3	4	8	D	2	5	6	7	D	3	4	8	D	4	8	D	D
Y(11)	Number in MOSE team	X																	X				
		X																	X				
Y(12)	Number in COMM/security repair team	X																	X				
		X																	X				
Y(13)	Number in PM team	X																	X				
		X																	X				
Y(14)	Number of helicopters assigned to FDD												X									X	
													X									X	
Y(15)	Number of vans assigned to FDD												X									X	
													X									X	
Y(16)	Number of T/L												X									X	
													X									X	
Y(17)	Number of clusters																						
Y(18)	Distance between PS (feet)			X				X											X			X	
				X				X											X			X	
Y(19)	Missile emplacement time (minute)		X				X																
			X				X																
Y(20)	Personnel cost per PM team ($)											X											
												X											

```
---------------------------------------------------------------------------------------
|     |                             |    X(1)    |   X(2)   |    X(3)    |   X(4)   |  X(5)  |X(6)|
---------------------------------------------------------------------------------------
|     |                             | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|     |                             | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|     |                             | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|     |                             | : : : : : | : : : : | : : : : : | : : : : |X: : : | : |
|     |                         Z(j)|1:3:4:8:D: |3:4:8:D: |2:5:6:7:D: |3:4:8:D: |4:8:D: |D: |
---------------------------------------------------------------------------------------
|Y(21)|Number in CREV/DREV team     |X: : : : : | : : : : | : : : : : | : : :X: | : : : | : |
|     |                             |X: : : : : | : : : : | : : : : : | : : :X: | : : : | : |
---------------------------------------------------------------------------------------
|Y(22)|Number of ROSE failures      | : : : : : | : : : : | : : : : : | : : :X: | : :X: | : |
|     |per month per missile        | : : : : : | : : : : | : : : : : | : : :X: | : :X: | : |
---------------------------------------------------------------------------------------
|Y(23)|MGCS repair time (minute)    | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | : |
|     |                             | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | : |
---------------------------------------------------------------------------------------
|Y(24)|MOSE repair time (minute)    | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | : |
|     |                             | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | : |
---------------------------------------------------------------------------------------
|Y(25)|Number of maint. personnel   | : : : :X: | : : : : | : : : : : | : : : : | : : : | : |
|     |knowing any missile loc.     | : : : :X: | : : : : | : : : : : | : : : : | : : : | : |
---------------------------------------------------------------------------------------
|Y(26)|Base operating support       | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
|     |cost ($)                     | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
---------------------------------------------------------------------------------------
|Y(27)|Personnel cost per           | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
|     |helicopter team ($)          | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
---------------------------------------------------------------------------------------
|Y(28)|Personnel cost per van       | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
|     |team ($)                     | : : : : : | : : : : | :X: : : : | : : : : | : : : | : |
---------------------------------------------------------------------------------------
|Y(29)|Number of C/M no launch      | :X:X:X: : |X:X:X: : | : : : : : | : :X:X: | :X:X: | : |
|     |failures/mon. per missile    | :X:X:X: : |X:X:X: : | : : : : : | : :X:X: | :X:X: | : |
---------------------------------------------------------------------------------------
|Y(30)|Number of R/S no launch      | :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | : |
|     |failures/mon. per missile    | :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | : |
---------------------------------------------------------------------------------------
```

		X(1)					X(2)				X(3)					X(4)				X(5)			X(6)
	Z(j)	1	3	4	8	D	3	4	8	D	2	5	6	7	D	3	4	8	D	4	8	D	D
Y(31)	Number of MOSE no launch		X		X		X		X									X	X		X	X	
	failures/mon. per missile		X		X		X		X									X	X		X	X	
Y(32)	Availability of CREV/DREV																						X
	force																						X
Y(33)	Total gros CREV/DREV in												X									X	X
	dispatch area												X									X	X
Y(34)	Number of COMM/security																		X			X	
	failures/month per missile																		X			X	
Y(35)	Speed of helicopter			X				X											X			X	
	(feet/minute)			X				X											X			X	
Y(36)	Speed of T/L (feet/minute)			X				X											X			X	
				X				X											X			X	
Y(37)	Speed of van (feet/minute)			X				X											X			X	
				X				X											X			X	
Y(38)	Number of ROSE repair	X										X							X				
	teams	X										X							X				
Y(39)	Number in MMT	X																	X				
		X																	X				
Y(40)	Cost/van ($)												X										
													X										

```
------------------------------------------------------------------------------------
|     |                         |   X(1)    |  X(2)   |   X(3)    |  X(4)   | X(5)  |X(6)|
------------------------------------------------------------------------------------
|     |                         | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | : : : : : | : : : : |X: : : | :  |
|     |                     Z(j)|1:3:4:8:D: |3:4:8:D: |2:5:6:7:D: |3:4:8:D: |4:8:D: |D:  |
------------------------------------------------------------------------------------
|Y(41)|Cost per T/L ($)         | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(42)|Cost/helicopter ($)      | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(43)|Personnel cost per MOSE  | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |team ($)                 | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(44)|Personnel cost per MMT ($)| : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |                         | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(45)|Personnel cost/multiple  | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |skill team ($)           | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(46)|Personnel cost per shuffle| : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |team ($)                 | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(47)|Number of MGCS N-L failure| :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | :  |
|     |per month per missile    | :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | :  |
------------------------------------------------------------------------------------
|Y(48)|Personnel cost per COMM/ | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |security repair team ($) | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(49)|Personnel cost per ROSE  | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |repair team ($)          | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
|Y(50)|Missile removal time     | :X: : : : |X: : : : | : : : : : | : : : : | : : : | :  |
|     |(minute)                 | :X: : : : |X: : : : | : : : : : | : : : : | : : : | :  |
------------------------------------------------------------------------------------
```

```
-------------------------------------------------------------------------------------
|      |                              |   X(1)    |  X(2)   |   X(3)    |  X(4)   | X(5)  |X(6)|
-------------------------------------------------------------------------------------
|      |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|      |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|      |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|      |                              | : : : : : | : : : : | : : : : : | : : : : |X: : : | :  |
|      |                          Z(j)|1:3:4:8:D: |3:4:8:D: |2:5:6:7:D: |3:4:8:D: |4:8:D: |D:  |
-------------------------------------------------------------------------------------
|Y(51)|R/S repair time (minute)       | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
|      |                              | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
-------------------------------------------------------------------------------------
|Y(52)|Delay (minute)                 | : :X: : : | :X: : : | : : : : : | : : : : | : : : | :  |
|      |                              | : :X: : : | :X: : : | : : : : : | : : : : | : : : | :  |
-------------------------------------------------------------------------------------
|Y(53)|Number of STV                  | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
|      |                              | : : : : : | : : : : | : :X: : : | : : : : | : : : | :  |
-------------------------------------------------------------------------------------
|Y(54)|Speed of STV (feet/minute)     | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|      |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
-------------------------------------------------------------------------------------
|Y(55)|Number of ASC                  |X: : : : : | : : : : |X:X: :X: : | : : :X: | : : : | :  |
|      |                              |X: : : : : | : : : : |X:X: :X: : | : : :X: | : : : | :  |
-------------------------------------------------------------------------------------
|Y(56)|Distance between dispatch      | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
|      |location and CMF (feet)        | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
-------------------------------------------------------------------------------------
|Y(57)|C/M repair time (minute)       | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
|      |                              | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
-------------------------------------------------------------------------------------
|Y(58)|Distance between CMF and       | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
|      |PS (feet)                      | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
-------------------------------------------------------------------------------------
|Y(59)|Number in helicopter team      |X: : : : : | : : : : | : : : : : | : : :X: | : : : | :  |
|      |                              |X: : : : : | : : : : | : : : : : | : : :X: | : : : | :  |
-------------------------------------------------------------------------------------
|Y(60)|PS ROSE repair time            | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
|      |(minute)                       | :X: : : : |X: : : : | : : : : : | : : :X: | : :X: | :  |
-------------------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------------------------------------
|     |                              |   X(1)    |  X(2)   |   X(3)    |  X(4)   | X(5)  |X(6)|
-----------------------------------------------------------------------------------------------------
|     |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                              | : : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                              | : : : : : | : : : : | : : : : : | : : : : |X: : : | :  |
|     |                         Z(j) |1:3:4:8:D: |3:4:8:D: |2:5:6:7:D: |3:4:8:D: |4:8:D: |D:  |
-----------------------------------------------------------------------------------------------------
|Y(61)|Number in van team            |X: : : : : | : : : : | : : : : : | : : : : | : : : | :  |
|     |                              |X: : : : : | : : : : | : : : : : | : : : : | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(62)|Number of PS ROSE failures    | :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | :  |
|     |per month per missile         | :X: :X: : |X: :X: : | : : : : : | : :X:X: | :X:X: | :  |
-----------------------------------------------------------------------------------------------------
|Y(63)|Number of FDD personnel       |X: : : : : | : : : : | :X: : : : | : : :X: | : : : | :  |
|     |per OB                        |X: : : : : | : : : : | :X: : : : | : : :X: | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(64)|Number of FDD personnel       |X: : : : : | : : : : | :X: : : : | : : :X: | : : : | :  |
|     |per ASC                       |X: : : : : | : : : : | :X: : : : | : : :X: | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(65)|Fraction of no-launch         | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
|     |failures req. helicopter      | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
-----------------------------------------------------------------------------------------------------
|Y(66)|Number of persons at CAMMS    | : : : :X: | : : : : | : : : : : | : : : : | : : : | :  |
|     |need to know missile loc.     | : : : :X: | : : : : | : : : : : | : : : : | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(67)|Time to enter/exit site       | :X: : : : |X: : : : | : : : : : | : : : : | : : : | :  |
|     |(minute)                      | :X: : : : |X: : : : | : : : : : | : : : : | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(68)|Time spent at each PS for     | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
|     |PLU (minute)                  | : :X: : : | :X: : : | : : : : : | : : :X: | : :X: | :  |
-----------------------------------------------------------------------------------------------------
|Y(69)|Average pay for OB            | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |personnel ($)                 | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
-----------------------------------------------------------------------------------------------------
|Y(70)|Average pay for ASC           | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
|     |personnel ($)                 | : : : : : | : : : : | :X: : : : | : : : : | : : : | :  |
-----------------------------------------------------------------------------------------------------
```

```
-------------------------------------------------------------------------------------------
|      |                           |   X(1)    |  X(2)   |    X(3)     |  X(4)   | X(5)  |X(6)|
-------------------------------------------------------------------------------------------
|      |                           | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : | : : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : | : : : : : | : : : : |X: : : | : |
|      |                       Z(j)|1:3:4:8:D: |3:4:8:D: |2:5:6:7:D: |3:4:8:D: |4:8:D: |D: |
-------------------------------------------------------------------------------------------
|Y(71)|Cost per STV ($)            | : : : : : | : : : : | : :X: : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : | : :X: : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(72)|Cost per CMF ($)            | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(73)|Cost per OB ($)             | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(74)|Cost per ASC ($)            | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(75)|Equipment cost per CMF ($)  | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(76)|Equipment cost per OB ($)   | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(77)|Equipment cost per ASC ($)  | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
|      |                           | : : : : : | : : : : |X: : : : : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(78)|Spares/supplies cost per    | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
|      |CMF ($)                    | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(79)|Spares/supplies cost per    | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
|      |OB ($)                     | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
|Y(80)|Spares/supplies cost per    | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
|      |ASC ($)                    | : : : : : | : : : : | : : :X: : | : : : : | : : : | : |
-------------------------------------------------------------------------------------------
```

		X(1)					X(2)				X(3)					X(4)				X(5)			X(6)
																				X			
	Z(j)	1	3	4	8	D	3	4	8	D	2	5	6	7	D	3	4	8	D	4	8	D	D
Y(81)	SAL verifications (at			X				X											X			X	
	least once per year)			X				X											X			X	
Y(82)	Number of CREV/DREV teams	X										X							X				
		X										X							X				
Y(83)	One day CREV/DREV																						X
	reliability																						X
Y(84)	Number of CREV/DREV																		X			X	X
	dispatched to CMF																		X			X	X
Y(85)	Cost per CREV/DREV ($)												X										
													X										
Y(86)	Number of helicopter teams	X										X							X				
		X										X							X				
Y(87)	Number of van teams	X										X											
		X										X											
Y(88)	Number of FDD security	X										X											
	teams	X										X											
Y(89)	Number in FDD security	X																	X				
	team	X																	X				
Y(90)	Personnel cost/FDD											X											
	security team ($)											X											

```
-------------------------------------------------------------------------------------------
|      |                               |    X(1)    |  X(2)    |    X(3)     |  X(4)    | X(5)   |X(6)|
-------------------------------------------------------------------------------------------
|      |                               | : : : : :  | : : : :  | : : : : :   | : : : :  | : : :  | :  |
|      |                               | : : : : :  | : : : :  | : : : : :   | : : : :  | : : :  | :  |
|      |                               | : : : : :  | : : : :  | : : : : :   | : : : :  | : : :  | :  |
|      |                               | : : : : :  | : : : :  | : : : : :   | : : : :  |X: : :  | :  |
|      |                           Z(j)|1:3:4:8:D:  |3:4:8:D:  |2:5:6:7:D:   |3:4:8:D:  |4:8:D:  |D:  |
-------------------------------------------------------------------------------------------
|Y(91)|Personnel cost per              | : : : : :  | : : : :  | :X: : : :   | : : : :  | : : :  | :  |
|      |CREV/DREV team ($)              | : : : : :  | : : : :  | :X: : : :   | : : : :  | : : :  | :  |
-------------------------------------------------------------------------------------------
|Y(92)|Number in ROSE repair team      |X: : : : :  | : : : :  | : : : : :   | : : :X:  | : : :  | :  |
|      |                                |X: : : : :  | : : : :  | : : : : :   | : : :X:  | : : :  | :  |
-------------------------------------------------------------------------------------------
|Y(93)|ROSE repair time (minute)       | : : : : :  | : : : :  | : : : : :   | : : :X:  | : :X:  | :  |
|      |                                | : : : : :  | : : : :  | : : : : :   | : : :X:  | : :X:  | :  |
-------------------------------------------------------------------------------------------
|Y(94)|COMM/security repair time       | : : : : :  | : : : :  | : : : : :   | : : :X:  | : :X:  | :  |
|      |(minute)                        | : : : : :  | : : : :  | : : : : :   | : : :X:  | : :X:  | :  |
-------------------------------------------------------------------------------------------
```

END

FILMED

7-85

DTIC