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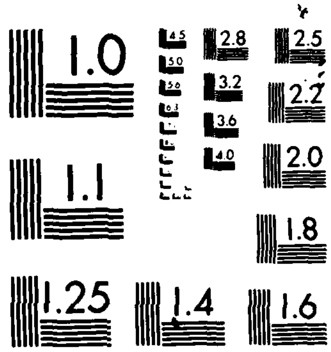

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Report No. CG-D-14-86

AD-A172 685

RMA MODEL FOR EVALUATION OF MARINE VEHICLES IN THE COAST GUARD

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JOSEPH DRAGO III

FINAL REPORT
SEPTEMBER 1984

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16. Abstract

This report defines the structure of the reliability/maintainability/availability model which is being developed to support the evaluation of marine vehicles being considered as cutters in support of U.S. Coast Guard missions. This document represents the current description for the computer model which has been developed using the SLAM II simulation language on a VAX 11/780. Included in this report is a definition of purpose of the model; a description of the approach used in developing the model; a detailed description of the model, including its structure and subroutines; results of model testing; and supporting information such as data element descriptions. Keywords;

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METRIC CONVERSION FACTORS

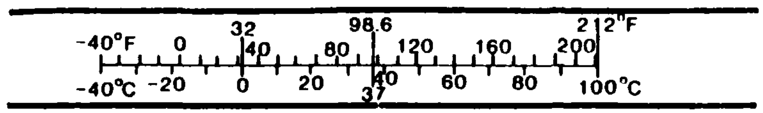
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10.286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ABSTRACT

This report defines the structure of the reliability/maintainability/availability model which is being developed to support the evaluation of marine vehicles being considered as cutters in support of U.S. Coast Guard missions. This document represents the current description for the computer model which has been developed using the SLAM II simulation language on a VAX 11/780. Included in this report is a definition of purpose of the model; a description of the approach used in developing the model; a detailed description of the model, including its structure and subroutines; results of model testing; and supporting information such as data element descriptions.

PREFACE

This document has been prepared for David Taylor Naval Ship Research and Development Center, Carderock, Maryland, and U.S. Coast Guard Research and Development Center, Groton, Connecticut, by Advanced Technology, Inc. under Contract No. N00600-82-D-3166, Subcontract No. 66600B. The principal authors were Louis C. Tedeschi and Joseph Drago III. Brister S. Gray's reliability/maintainability/availability expertise contributed significantly to this effort.

This effort was coordinated for the Coast Guard by Clark Pritchett of the U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut. Coast Guard personnel who contributed significantly included LCDR Mike Sprague, LT Tom Coe, and Joe Smith.

1.0 INTRODUCTION

1.1 Document Overview

This document has been prepared for David Taylor Naval Ship Research and Development Center, Carderock, Maryland, and U.S. Coast Guard Research and Development Center, Groton, Connecticut, as a final report on the development of the RMA computer model which was proposed and outlined in "Development of RMA Model for Evaluation of Advanced Marine Vehicles in the Coast Guard," L.C. Tedeschi and W.R. Hudson, of 3 August 1983. This document is the final report and incorporates all deliverables required under all tasks of Contract N00600-82-D-3166, subcontract 66600B. A brief description of each section follows.

Section 1 provides background on the development of the RMA model, objectives of the model, and its interface with the U.S. Coast Guard Advanced Marine Vehicles Evaluation Program.

Section 2 describes the overall approach which is being used in the development of the RMA model structure, including data flow diagrams; the data elements are defined in Appendix A.

Section 3 describes the details of the model, including its characteristics, structure, inputs, outputs, and operating procedure.

Section 4 describes the inputs and procedures employed to test the model. The input files include reliability diagrams for sample cutters such as the SES-100B and a WPB.

Appendices contain supporting information, including data element descriptions and SLAM Network symbol definitions.

1.2 Background

During the development of craft measures of effectiveness (MOEs) to evaluate advanced marine vehicles (AMVs) in Coast Guard missions, availability was recognized as an important factor but was not developed during the initial effort. Availability was considered to be part of the "force-mix" problem which directly affected the total number of vessels required and their life cycle cost rather than individual craft performance evaluation. Priority was given to developing individual craft measures with "force-mix" problems to be addressed at a later date.

Previously, during development of MOEs, it was assumed that sortie/mission completion was dependent on operational capabilities only. A reliability model is required to address the probability of mission completion based on system/equipment failures. These failures may cause the mission to be aborted, result in degraded operational capability, increase the time to perform a mission, or reduce the time available during the sortie/mission to perform specific tasks. All of these items cause a decrease in mission performance.

Overall craft availability is dependent on two major factors. The first is the inherent availability which is based on the craft's reliability and maintainability. The second is the modified availability which is the effect of the Coast Guard logistic support system in providing adequate and timely support including trained personnel, spare parts, industrial facilities, etc. The impact that any new craft will have on the Coast Guard logistic support system will be reflected in overall craft availability.

Life cycle costs are affected by the combined effect of reliability, maintainability, and availability.

- o Reduced reliability results in increased cost of support parts and maintenance service.

- Increased maintenance affects facilities, personnel, and training costs.

- Reduced availability due to logistic delay time will require additional units to fulfill operational commitments.

1.3 Task Objective

The overall objective of this task is to provide a quantifiable measure of reliability, maintainability, and availability (RMA) of candidate AMVs that may be considered during the acquisition process by the U.S. Coast Guard.

The model will allow the user to evaluate the effects on overall cutter availability due to the reliability of each individual system, subsystem, and equipment; maintenance philosophies; and logistics requirements of AMVs.

Outputs from the model will be useful in future efforts, such as determining the total number of cutters required, mission measures of effectiveness, and life cycle costs of AMVs.

1.4 Interface with AMV Evaluation Program

Figure 1-1 illustrates the interfaces of the RMA model with other tasks within the AMV evaluation program.

The RMA model will be developed such that it can provide the following information to future efforts: availability information to the overall evaluation project, reliability information to the MOE model, and maintainability information to the life cycle cost model.

The RMA model obtains data from the AMV Data Base which is currently under development.

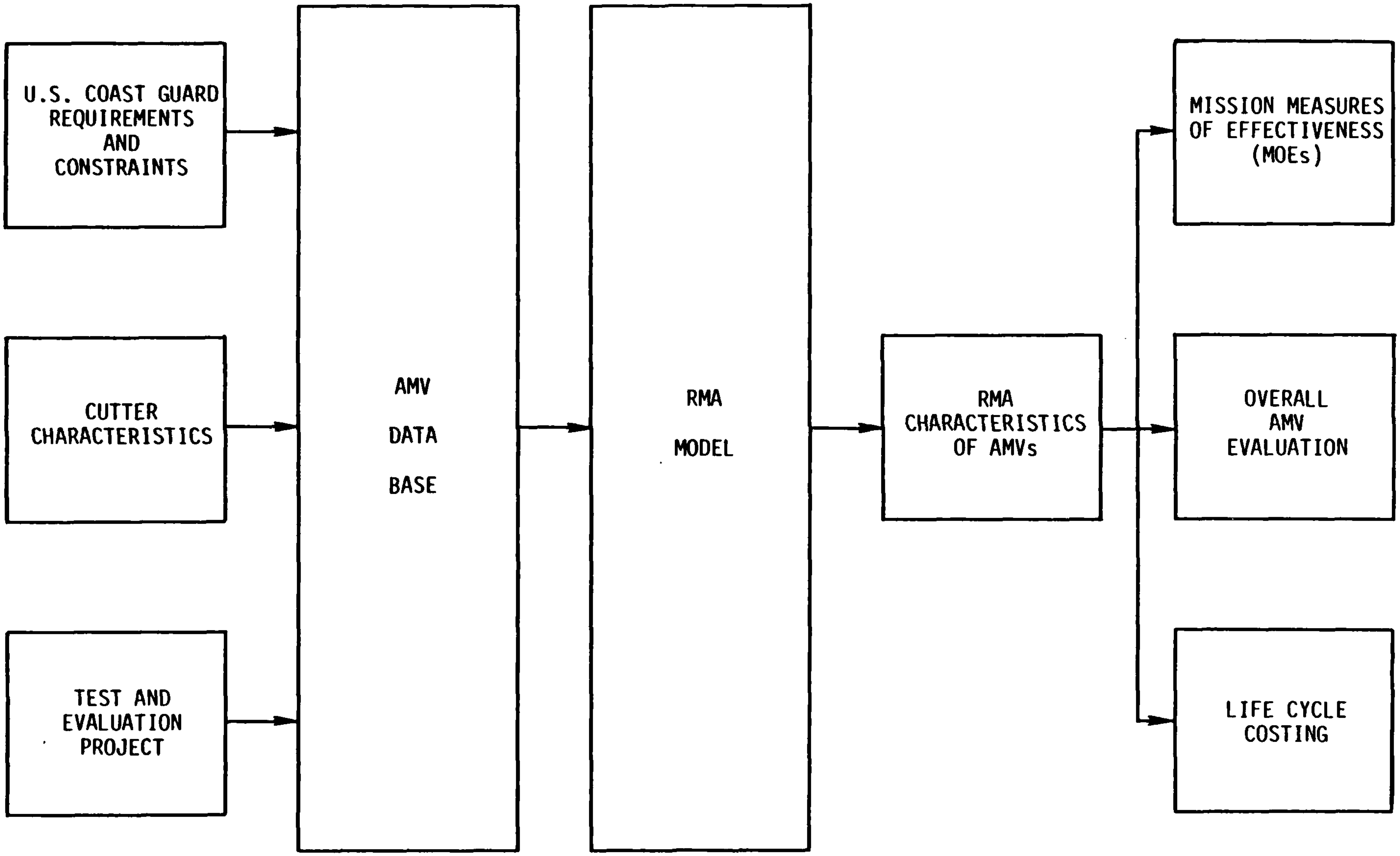


FIGURE 1-1. AMV EVALUATION PROGRAM

2.0 OVERALL APPROACH

2.1 Develop Data Flow Diagrams

A structured approach was used to develop the RMA simulation model. The physical operation of a cutter was analyzed and a logical model developed. As an aid in the development of the computer model, data flow diagrams were structured to represent the flow of data between logical functions related to cutter operations. The resulting functions and data identified through this process helped to structure the simulation and to develop inputs, outputs, and internal files.

The Level 0 diagram, Figure 2-1, is an overview of the complete RMA model. The Level 1 diagrams, Figures 2-2 through 2-5, represent a more detailed description of each of the processes illustrated in the Level 0 diagram. Each function in the Level 1 diagram was modeled by discrete events using the SLAM II simulation language and FORTRAN 77. The definitions of all the data identified in the data flow diagrams is contained in Appendix A, Data Element Dictionary.

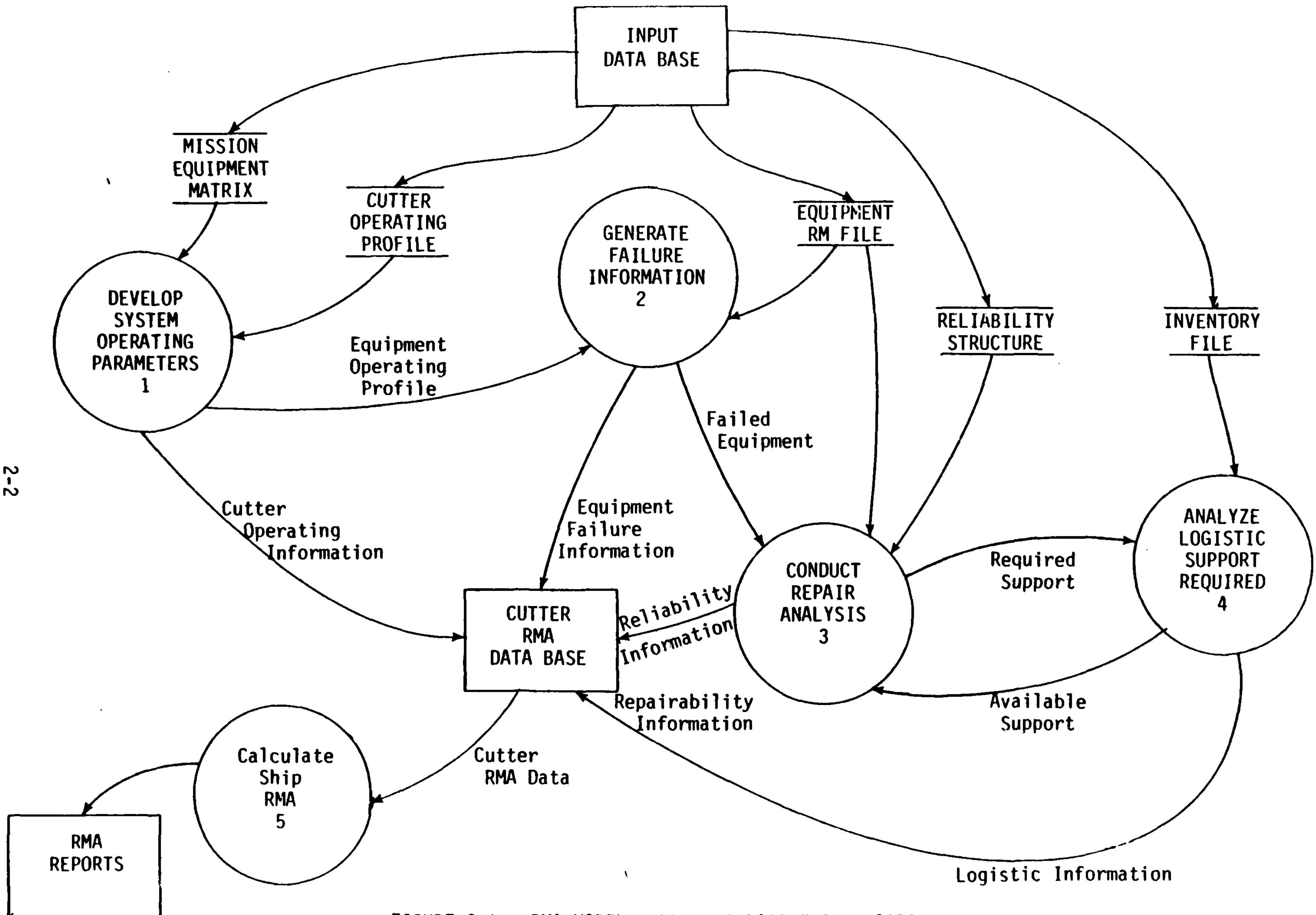


FIGURE 2-1. RMA MODEL - LEVEL 0 DATA FLOW DIAGRAM

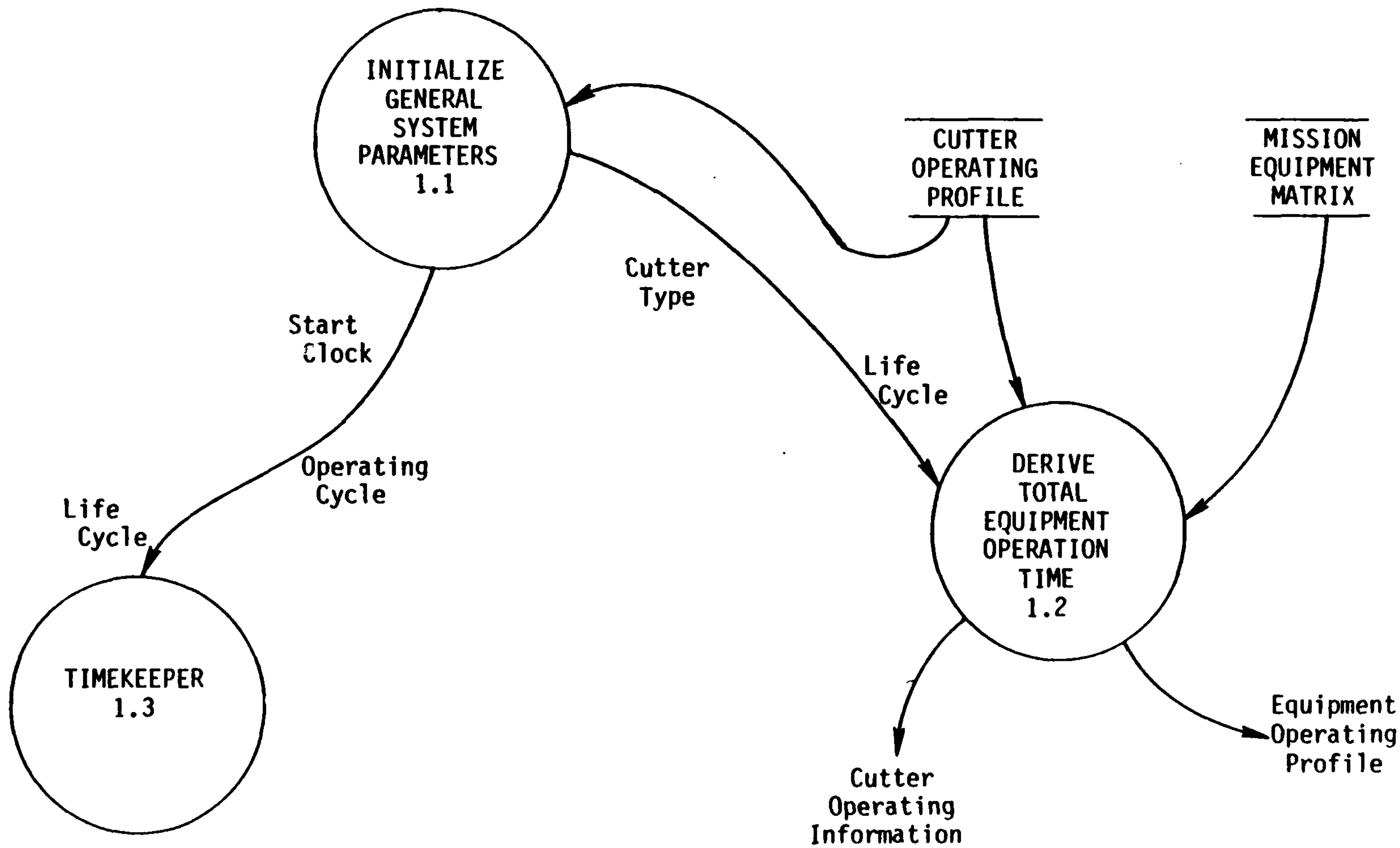


FIGURE 2-2. ACTIVITY 1 - DEVELOP SYSTEM OPERATING PARAMETERS

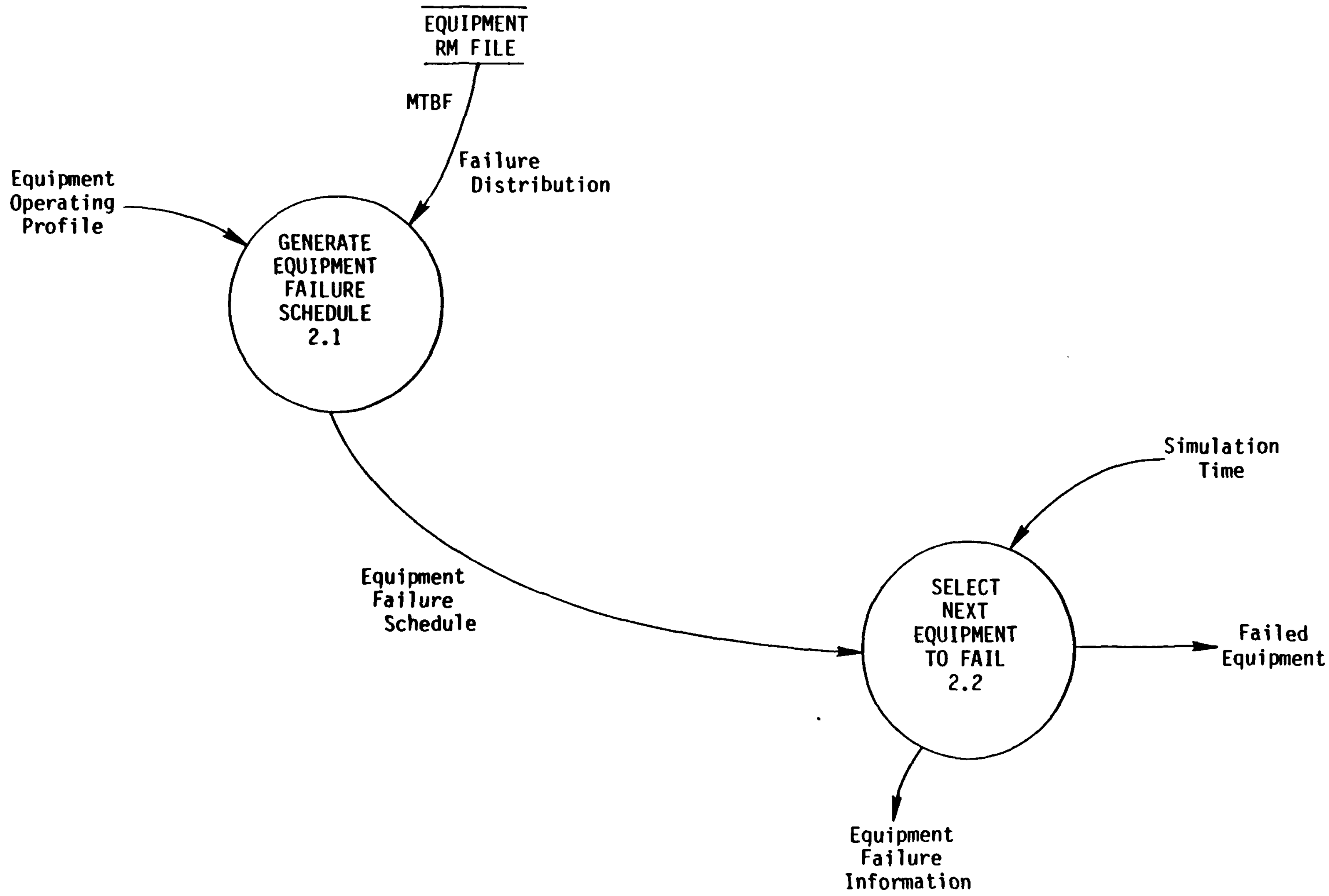


FIGURE 2-3. ACTIVITY 2 - GENERATE FAILURE DATA

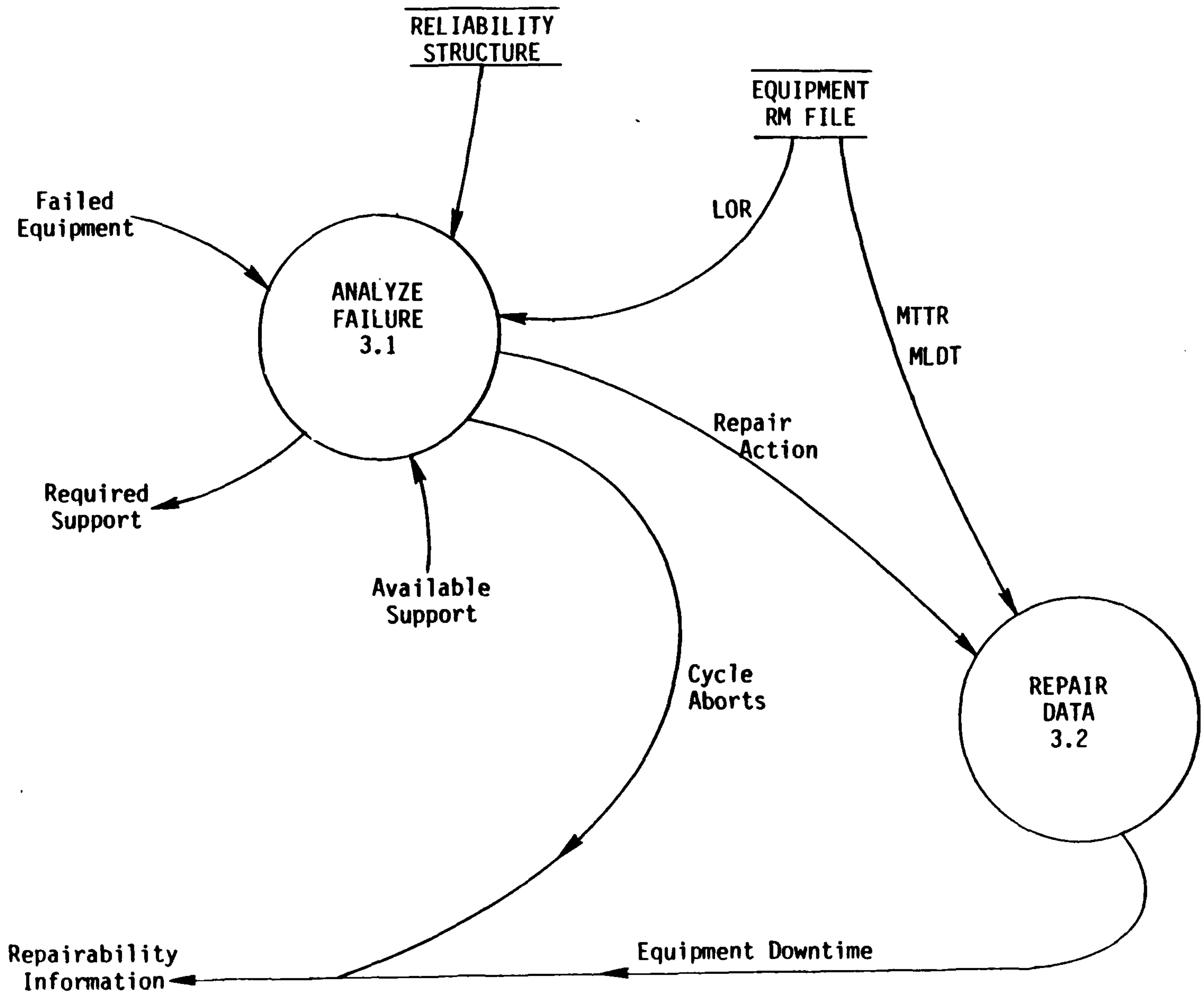


FIGURE 2-4. ACTIVITY 3 - CONDUCT REPAIR ANALYSIS

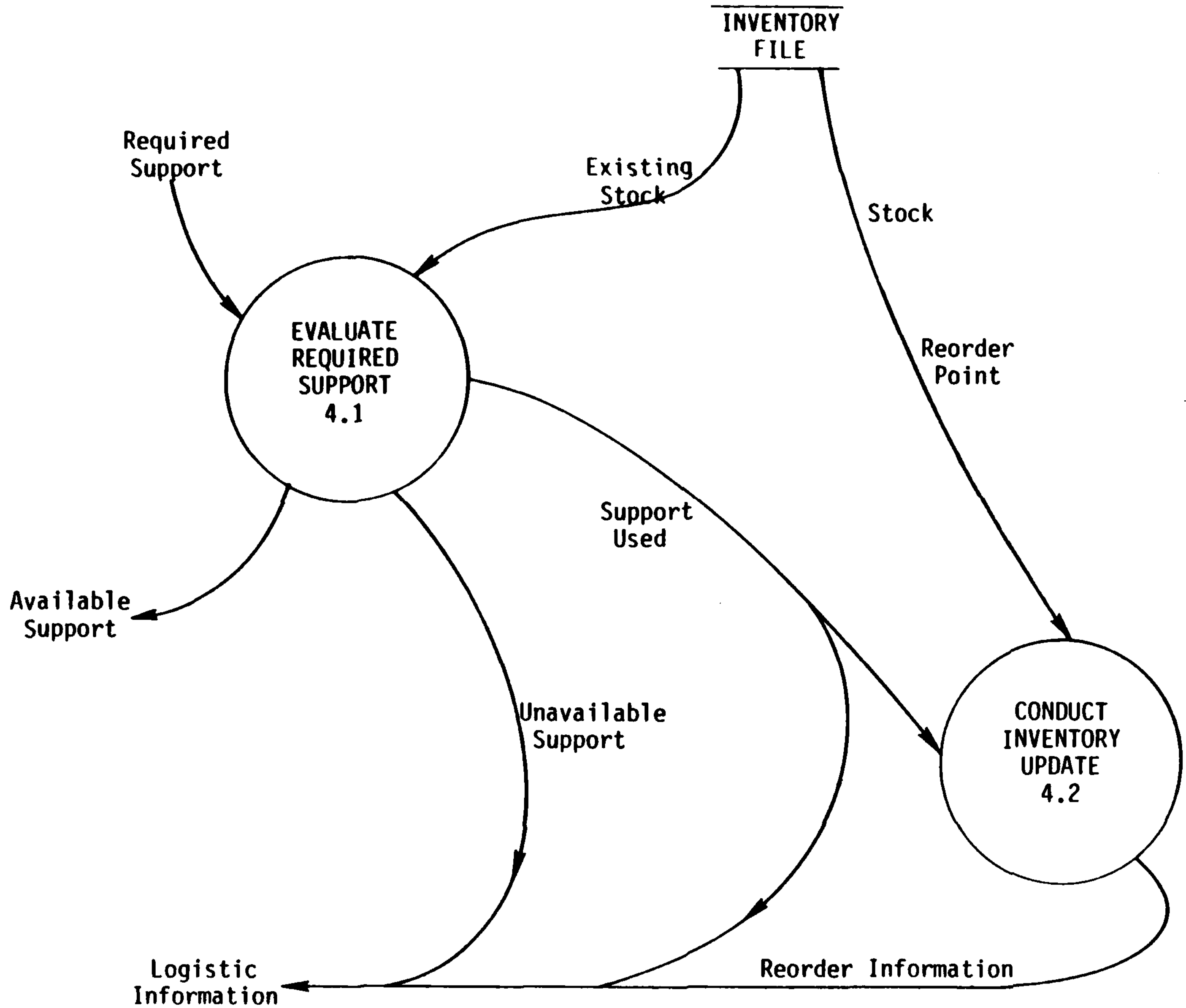


FIGURE 2-5. ACTIVITY 4 - ANALYZE LOGISTIC SUPPORT REQUIREMENTS

2.2 Inputs and Outputs Identified

As the logical model was developed by structuring the data flow diagrams, the required input files and the desired output reports were also identified. The data flow diagrams reflected the data output required from the simulation and subsequent data inputs needed to run SLAM II. The input files and output reports are discussed in more detail in Sections 3.2 and 3.3, respectively.

2.3 Overall Operational System

The computer model was developed by using the data flow diagrams as an aid in the structuring of the program. The model is coded using FORTRAN 77 and incorporates the SLAM II simulation lanaguage. The model is resident on a Digital Equipment Corporation (DEC) VAX 11/780 computer system. Presently, inputs to and outputs from the model reside in permanent storage on the VAX.

The overall model will eventually also include a DEC Professional 350 personal computer. The Professional 350 will be used to conduct pre-processing of the input data and post-processing of the output data. The Professional 350 will allow the graphical display of the simulation results. Simulation outputs will be stored on permanent storage to allow a user to conduct post-processing of data generated from a previous execution of the simulation. A generalized flow diagram of the overall system is shown in Figure 2-6. Presently, only the VAX simulation portion of the overall system has been developed.

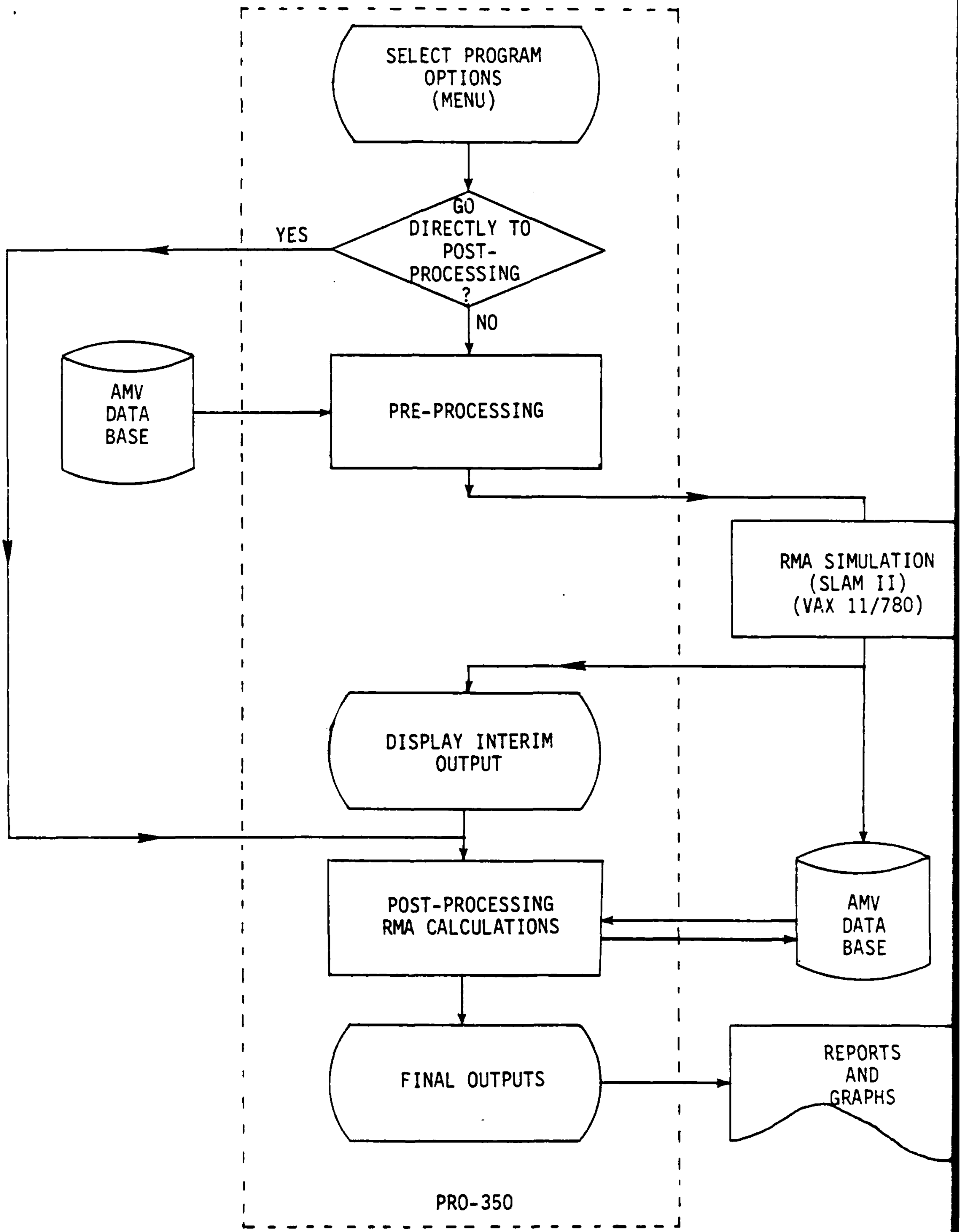


FIGURE 2-6. OVERALL RMA CONTROL DIAGRAM

2.4 Develop Program Structure

The program structure was developed by using the data flow diagrams presented in Section 2.1 to identify the major types of discrete events which take place during the operation of a cutter. The major events identified were:

1. The beginning of an operating cycle (including equipment startups),

2. An equipment shutdown,

3. An equipment failure,

4. A repair completion and equipment startup, and

5. The end of an operating cycle.

Each of these events was programmed as a separate FORTRAN subroutine in the computer model. To control the execution of these routines, a group of SLAM Network routines was developed, using the SLAM II simulation language. Finally, another FORTRAN subroutine was developed to serve as an interface between the SLAM Network routines and the discrete event routines. Also, the following simulation functions were identified and developed into separate subroutines:

1. Initialization of simulation parameters and the reading in of input data,

2. The replenishment and depletion of inventory stock during cutter operation, both at sea and shore based,

3. The evaluation of equipment failures to determine whether or not an abort of an operating cycle would be caused,

4. The processing of simulation results into output reports.

The relationship of all the subroutines identified above is shown in Figure 2-7. The program structure is described in detail in Section 3.1.

2.5 Develop Subroutine Software

The events and functions identified in Section 2.4 were each programmed as separate subroutines. Structured programming techniques were implemented using FORTRAN 77 in the development of each subroutine. Each subroutine was developed independently from the overall model and tested for correct performance before being inserted into the model. The SLAM Network routines were developed by following programming techniques presented in "Introduction to Simulation and SLAM", by A. Alan, B. Pritsker, and Claude Dennis Pegden, 1979. The network routines were also tested and verified independently from the FORTRAN subroutines before being inserted into the overall model.

2.6 Interface With SLAM II

The RMA model has been developed using the SLAM simulation language. SLAM is an advanced FORTRAN-based language that allows simulation models to be built based on three different world views: process/network, discrete event, and continuous operations. It provides network symbols for building graphical models that are easily translated into input statements for direct computer processing. It contains subprograms which support both discrete and continuous model developments, and specifies the organizational structure for building such models. By combining network, discrete event, and continuous modeling capabilities, SLAM allows the systems analyst to develop models from a process-interaction, next-event, or activity-scanning perspective.

The RMA model uses a combination of the network and discrete event modeling capabilities to provide a next-event approach. The SLAM executive controls the occurrences of each of the discrete events identified in Section 2.4, the FORTRAN subroutines developed for the model process the events which correspond to them, and the network routines provide the interaction between the SLAM executive and the discrete event subroutines. A

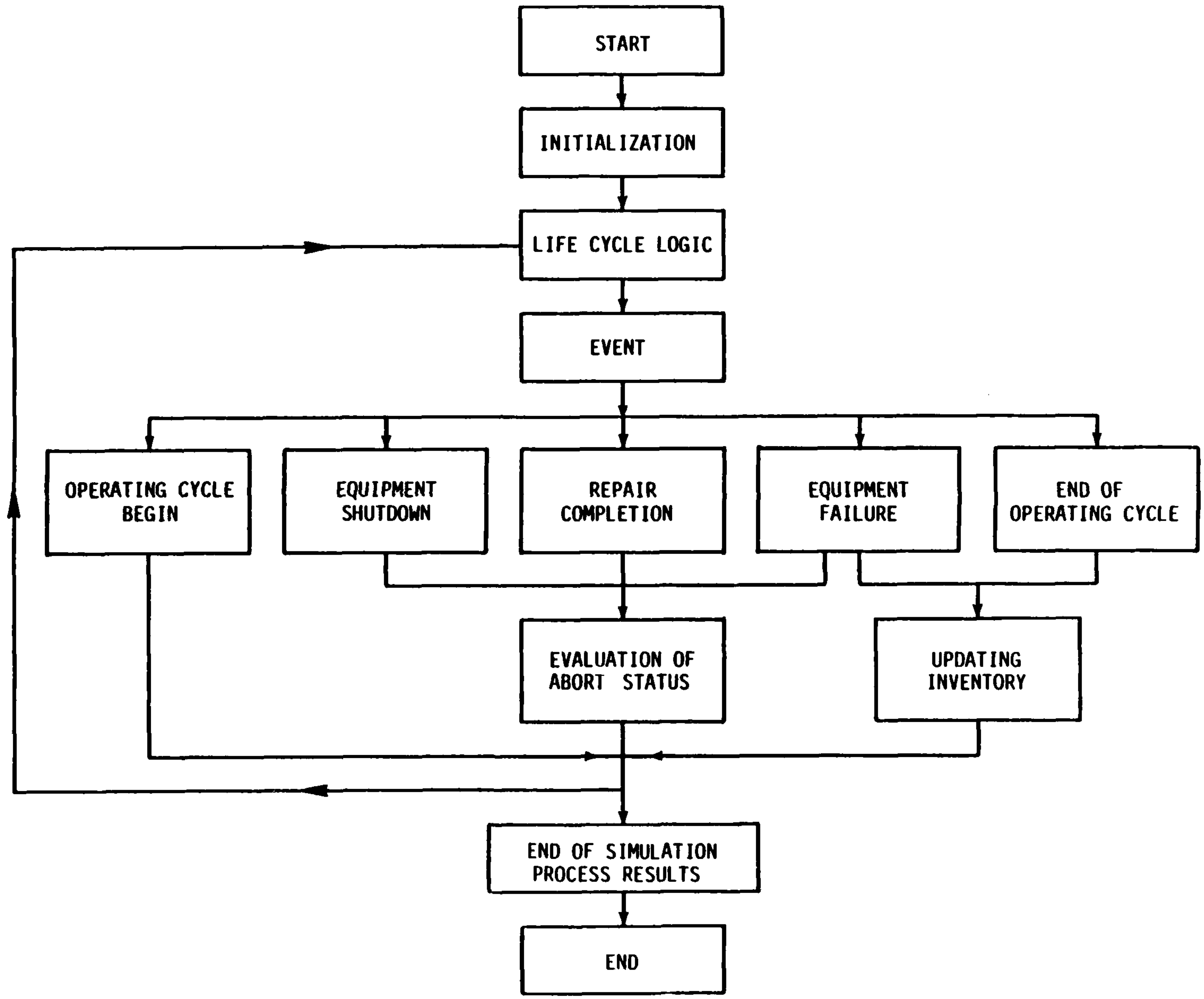


FIGURE 2-7. STRUCTURE OF SIMULATION PROGRAM

graphical representation of the SLAM Network which was developed to model the overall life cycle logic of a cutter is illustrated in Figure 2-8. The symbology used in the graphical representation is defined in Appendix B. The SLAM Network diagram differs from the data flow diagram in that the data flow diagrams provide a time-compressed representation of the simulation, whereas the SLAM Network provides a time-sequenced representation of the simulation.

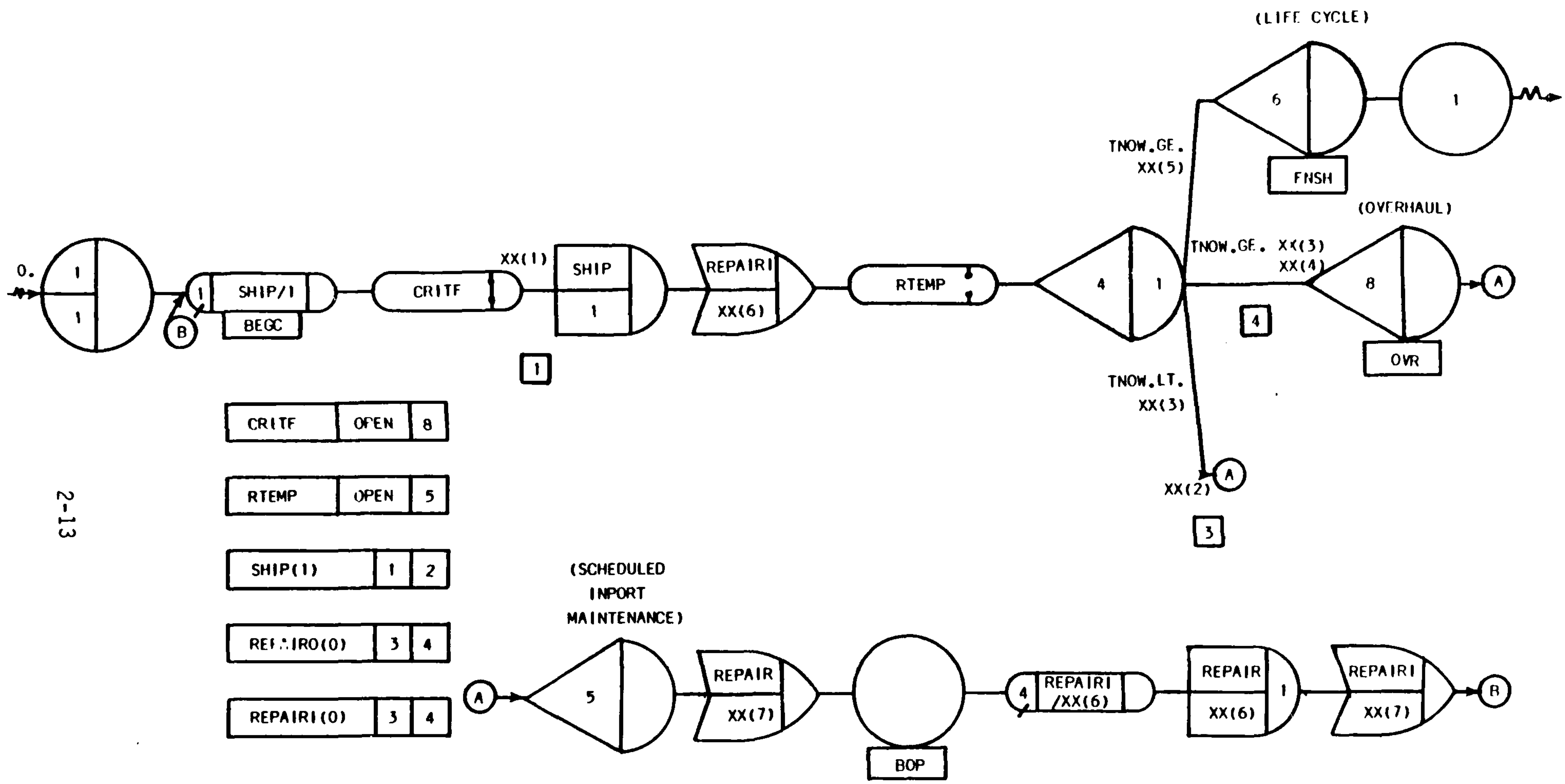


FIGURE 2-8. LIFE CYCLE LOGIC

3.0 DETAILED MODEL DESCRIPTION

3.1 Structure of Model

The RMA simulation model uses a combination of the SLAM network and discrete event modeling capabilities to provide a next-event approach to modeling. The overall structure of the model is presented in Figure 3-1. To support this methodology the major discrete events which occur during cutter operations were identified and developed into separate FORTRAN subroutines. The following event subroutines were developed:

1. OPCBEG.FOR Beginning of Operating Cycle
2. EQPSHUT.FOR Equipment Shutdown
3. EQPFAIL.FOR Equipment Failure
4. RPREND.FOR Repair Completion
5. OPCEND.FOR End of Operating Cycle

These SLAM network routines were developed to control the execution of the event routines and the processes which occur as a result of these events. The three network routines which were developed to model the processes are:

1. Life Cycle Logic
2. Repair Logic
3. Critical Failure Logic

The Life Cycle Logic routine controls the timing of the operating cycles, scheduled input maintenance periods, overhaul cycles, and cutter life. The Repair Logic routine controls the repairing of each equipment, including assigning either onboard or inport repair personnel to each failure and timing of the repair duration. The Critical Failure Logic routine processes all critical failures which occur. This includes aborting the current operating cycle, controlling inport repair personnel, and beginning a new operating cycle once the critical failure has been resolved. The graphical representation of the three network routines are illustrated in Figures 3-2 through 3-4. The symbology used in the graphical representation is defined

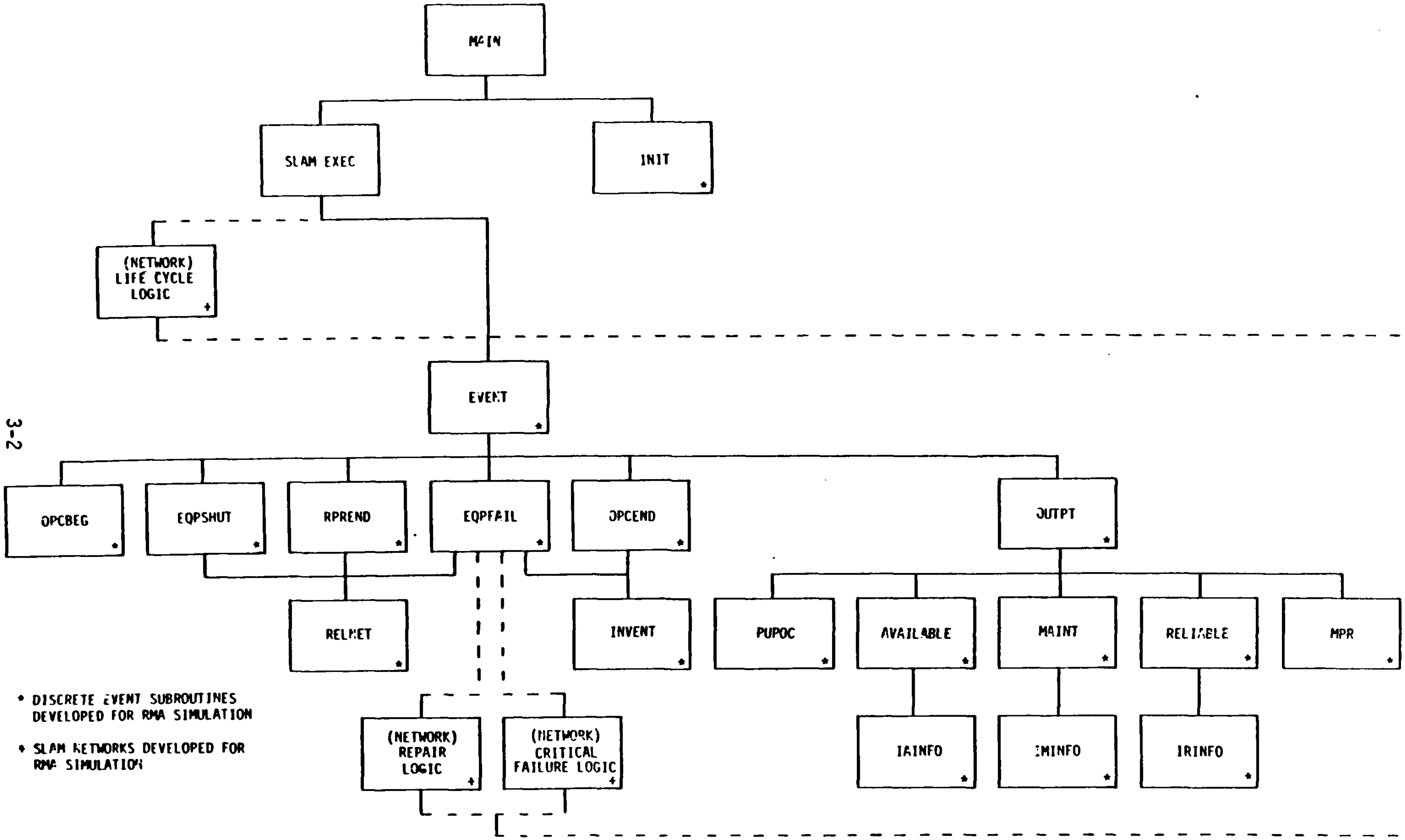


FIGURE 3-1. RMA SIMULATION STRUCTURE

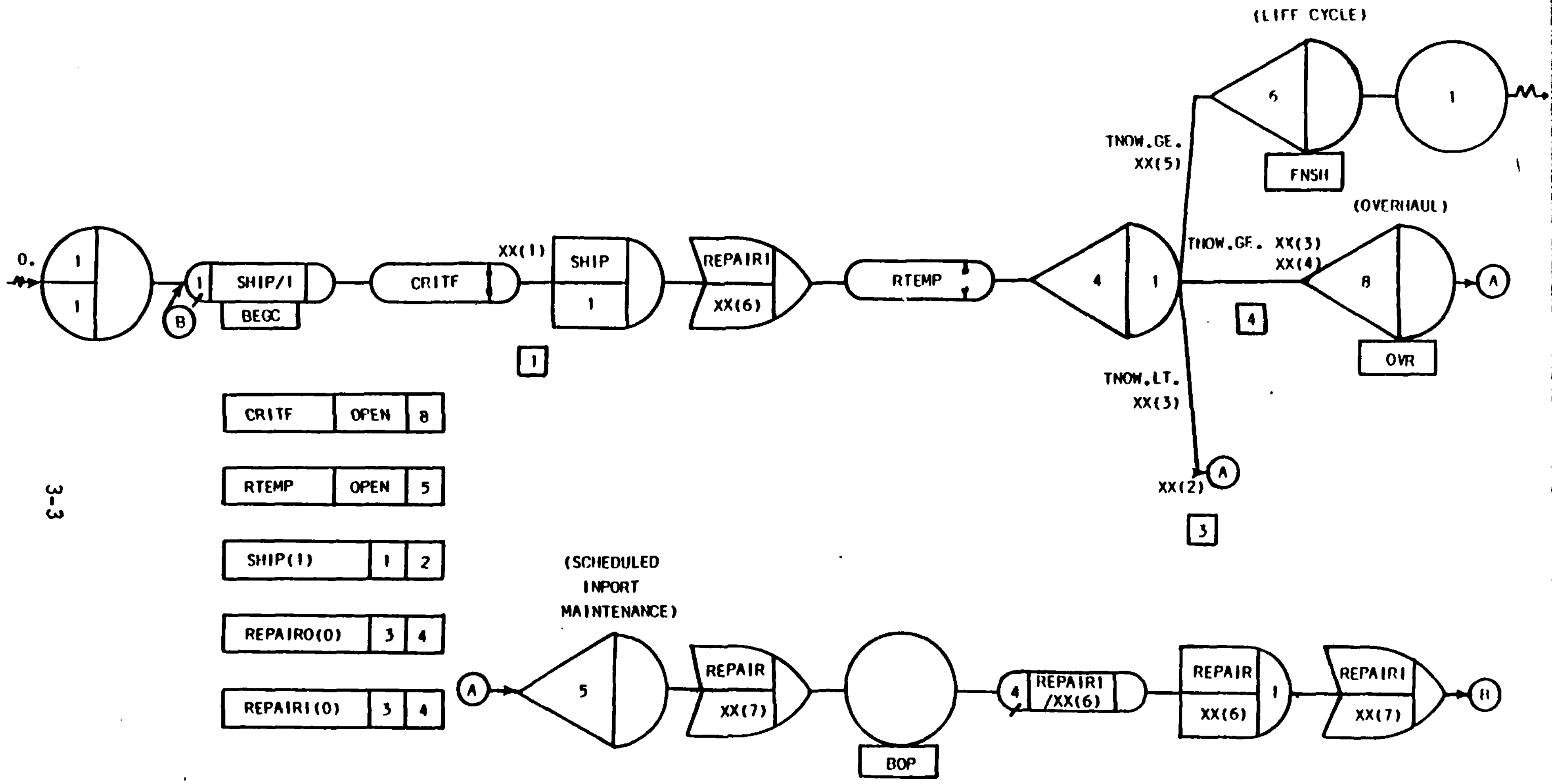


FIGURE 3-2. LIFE CYCLE LOGIC

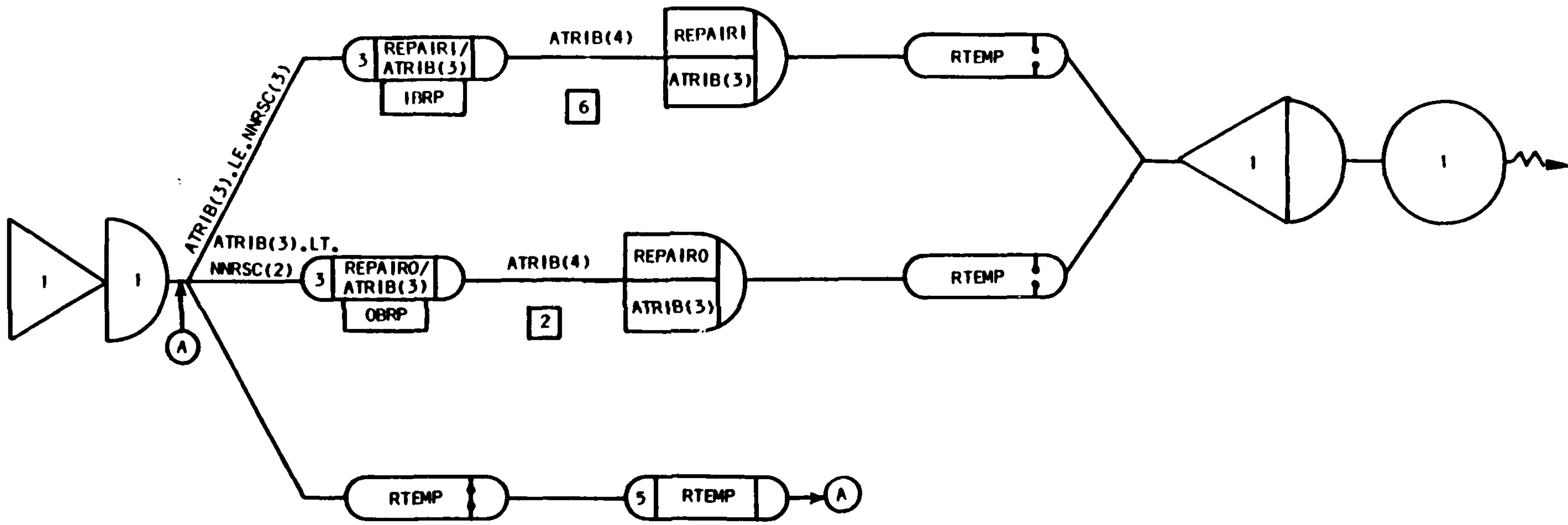


FIGURE 3-3. REPAIR LOGIC

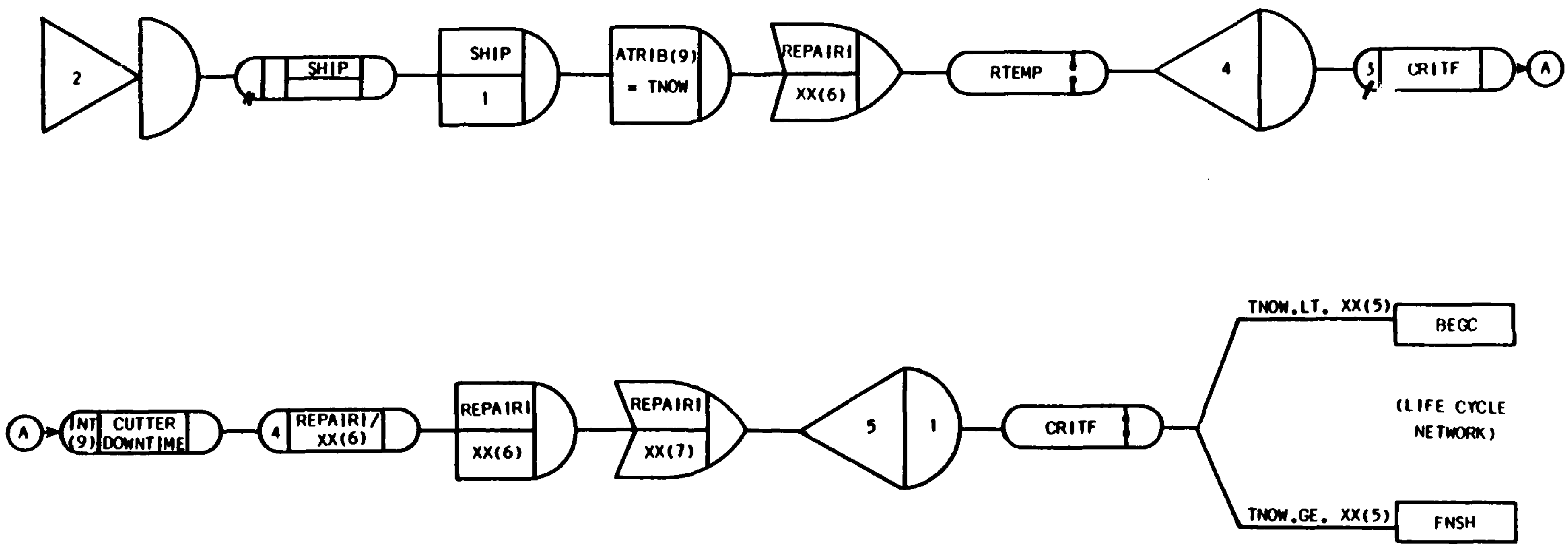


FIGURE 3-4. CRITICAL FAILURE LOGIC

in Appendix B. Interface between these routines is coordinated by the SLAM Executive and a FORTRAN subroutine, EVENT.FOR.

In addition to the FORTRAN subroutines and the network routines mentioned above, the following subroutines were developed to perform additional functions:

1. INIT.FOR
2. INVENT.FOR
3. RELNET.FOR
4. OUTPT.FOR

The subroutine INIT is executed once at the beginning of the simulation execution to initialize all required variables and constants and read in all of the input files. The depletion and replenishment of inventory stock is controlled by the subroutine INVENT. The subroutine RELNET determines the abort status of the ship and controls sytem and subsystem status. OUTPT consists of a group of subroutines which are executed at the end of the simulation to compile the simulation results into various reports. A brief description of each of the FORTRAN subroutines that were developed is presented in Appendix C.

3.2 Required Inputs

The input data required by the RMA model has been divided into five separate data files:

1. Cutter Operating Profile
2. Mission Equipment Matrix
3. Equipment Reliability/Maintainability (RM) File
4. Reliability Structure
5. Inventory File

The cutter operating profile and mission/equipment matrix are based on a specific cutter type such as WMEC. The reliability structure is oriented to a specific ship design since it includes specific equipment and their operational interdependencies. The equipment RM file is based on equipment data which can generally be considered generic in nature and not applicable to specific ship types. The inventory file allocates spare parts support aboard ship and ashore and is representative of the maintenance philosophy.

The data contained in each of the five above mentioned input data files is required to be in a specific format and column location in the file. A sample data file for each of the input files has been included as a deliverable with the model. The sample data files included are:

1.	OPERATING.DAT	Cutter Operating Profile
2.	EQPMATRIX.DAT	Mission Equipment Matrix
3.	EQPRM.DAT	Equipment Reliability/Maintainability File
4.	RELSTR.DAT	Reliability Structure
5.	IVENTORY.DAT	Inventory File

Each of these data files contains header records which label each data item type and give the required format (i = integer, r = real, a = alphanumeric) and column location of each data item. To vary input data, the user may choose to either modify these sample files or create his own files. If the user creates his own input files, the format of the new files must be in complete coherence with the sample files. All header lines must be included in the new files, though the information on each header line does not have to be the same, and the data items must be in the same format and column location as that presented in the sample files. A brief description of each file follows.

3.2.1 <u>Cutter Operating Profile</u>

This file allocates time during the life of the cutter to its various operational and maintenance modes. The major parameters to be input include:

1. Cutter life (years)
2. Maintenance time
   - o Time between overhauls (years)
   - o Length of overhaul (months)
   - o Scheduled inport maintenance (days)
3. Operational time
   - o Operating cycle (length of deployment) (days)
   - o Time for each mission (percent of time/year)

Algorithms within the preprocessing portion of the program accept this input data and construct a cycle timeline as depicted in Figure 3-5. The cutter operating profile input format is shown in Figure 3-6.

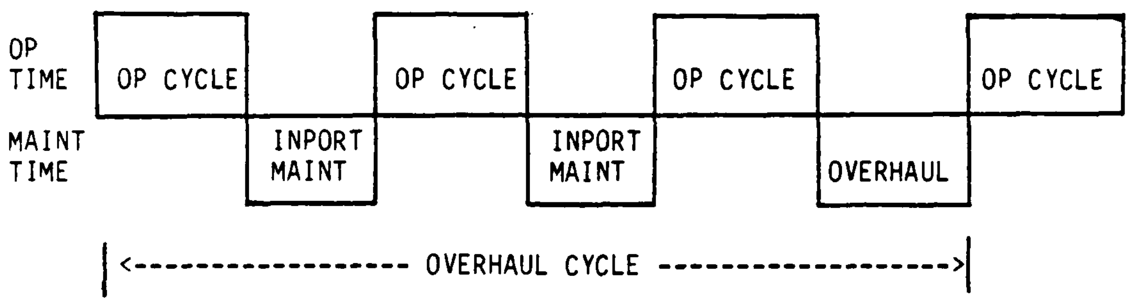


FIGURE 3-5. CUTTER LIFE CYCLE TIME LINE

COLUMN LOCATION

```
1                18               35               52               69         80
|----------------|----------------|----------------|----------------|----------|-

*CUTTER TYPE
SES-100
*CUTTER LIFE    OVERHAUL CYCLE  OVERHAUL TIME    SCHED. INPORT   OPERATING CYCLE
*   YEARS           YEARS          MONTHS        MAINT. DAYS          DAYS
rrr.rr          rrr.rr          rrr.rr           rrr.rr          rrr.rr
 30.             10.             30.              25.             90.
*# OF REPAIR PERSONNEL     # OF REPAIR PERSONNEL
*   ON BOARD                  ON BOARD
III                           III
  8                            20
*%OPERATING TIME FOR EACH MISSION (ALL MUST ADD UP TO 1.)
R.RR
.7
.3
```

FIGURE 3-6. CUTTER OPERATING PROFILE INPUT FORMAT

3.2.2 Mission Equipment Matrix

The mission equipment matrix relates operating time of equipment required to support each mission. Some equipment, such as hydrofoils, may be required 80% for SAR mission whereas they may only be required 30% for marine environmental protection. Equipment numbers must be in the range of 100 to 999 and will correspond to equipment numbers identified in the Equipment Reliability/Maintainability File and the Reliability Structure File. Each column under the percent time operational heading represents a separate mission. The order of the columns should correspond with the order of the mission percent operating time data which is included in the Cutter Operating Profile. The structure of this file is included in Figure 3-7.

COLUMN LOCATION

```
1          12    18    24                                                        80
|----------+-----+-----+---------------------------------------------------------+--

*EQUIP #   PERCENT TIME OPERATIONAL FOR EACH MISSION TYPE
iii        r.rr  r.rr  ...
111        1.    1.
112        1.    1.
113        1.    1.
114        1.    1.
115        1.    1.
116        1.    1.
117         .5    .5
118        1.    1.
119        1.    1.
121        1.    1.
122        1.    1.
123        1.    1.
124        1.    1.
```

FIGURE 3-7. MISSION EQUIPMENT MATRIX FILE

3.2.3 Equipment RM File

The equipment reliability/maintainability file provides basic RM information that is not cutter-oriented. This file will be developed based on similar equipment presently operational in marine vehicles for which an RM data base is being maintained. Equipment number must be in the range of 100 to 999 and will correspond to equipment numbers identified in the Mission Equipment Matrix file and the Reliability Structure File. The structure of this file is included in Figure 3-8. A normal failure distribution has been incorporated for MTBF; the mean value has been listed under MTBF HRS; and the variance has been listed under MTBF VAR. An exponential distribution has been selected for MTTR.

COLUMN LOCATION

```
1   7                   25    31        41      49      58                      80
+---+-------------------+-----+---------+-------+-------+-----------------------+-
```

*EQUIP * #	EQUIP NAME	EQUIP TYPE	MTBF HRS	MTBF VAR	MTTR HRS	REPAIRMEN REQUIRED
iii	aaaaaaaaaaaaaaa	iiii	rrrrr.rr	rrr.rr	rrrr.rr	rrr.rr
111	DIESEL ENGINE	20	10325.	100.	513.	4.
112	REDUCTION GEARS	20	20150.	300.	327.5	3.5
113	SHAFT	26	60920.	900.	108.	4.
114	BEARINGS	23	7500.	50.	24.	3.
116	PROP	20	33215.	900.	132.	9.
117	LIFT FANS	20	16195.	300.	57.5	7.
118	LUBE & OIL	26	3990.	20.	8.	2.
119	FUEL SYSTEM	23	5522.	50.	914.	3.
121	COMPRESSOR	31	8175.	100.	950.	2.
122	LORAN C	20	2730.	50.	3.	2.
123	RADIO	20	4315.	30.	2.5	1.
124	ENGINE CONTROLS	26	11420.	200.	8.	2.
115	ALARM PANEL	31	24750.	800.	2.	2.

FIGURE 3-8. EQUIPMENT RM FILE STRUCTURE

3.2.4 Reliability Structure

The reliability structure file defines the interrelationships and criticality of all the cutter systems, subsystems, and equipments. The file is divided into two distinct sections: a cutter systems configuration matrix and subsystem configuration matrices for each system. The system and subsystem configuration matrices contain a line for each system and subsystem, which includes the system or subsystem ID, name, number of components, number of components required to operate, a criticality index (a value of 1 denotes that failure of that subsystem or system causes an operating cycle abort; a value of 0 denotes a noncritical system or subsystem), and the IDs of each component of the system or subsystem. System IDs must be integer values between 1 and 9, and subsystem IDs must be integer values in the range of 10 through 99. System components may be other systems, subsystems, and/or equipments; subsystem components may be other subsystems and/or equipments. The structure of the subsystem configuration matrices is shown in Figure 3-9.

COLUMN LOCATION

```
1       10                28      36      44   49    55                       80
+-------+-----------------+-------+-------+----+-----+-----------------------+-
```

*SUBSYS * #	SUBSYS NAME	# OF COMP.	# COMP REQ	CRIT 1,0	COMP #	COMP #	...
ii	aaaaaaaaaaaaaaa	ii	ii	i	iii	iii	
10	SUBSYSTEM 10	2	1	0	111	112	
20	SUBSYSTEM 20	2	2	0	10	113	
30	SUBSYSTEM 30	2	1	0	114	115	
40	SUBSYSTEM 40	2	2	0	30	116	
50	SUBSYSTEM 50	2	1	0	20	40	
60	SUBSYSTEM 60	2	2	0	117	118	
70	SUBSYSTEM 70	2	2	0	119	121	
80	SUBSYSTEM 80	2	1	0	60	70	
90	SUBSYSTEM 90	2	1	0	122	123	

*SYS * #	SYS NAME	# OF COMP.	# COMP REQ	CRIT 1,0	COMP #	COMP #	...
i	aaaaaaaaaaaaaaa	ii	ii	i	iii	iii	
1	SYSTEM 1	3	3	0	50	80	90
2	SYSTEM 2	1	1	0	124		
3	SYSTEM 3	2	2	1	1	2	

FIGURE 3-9. RELIABILITY STRUCTURE

3.2.5 Inventory File

The inventory file contains the initial inventory stock and reorder guidelines for each equipment type. The file is divided into two sections, an onboard inventory and an inport inventory, with each having its own separate stock and reorder guidelines. The values for CONTROL LEVEL will represent the desired inventory level for each equipment type at each of the locations. The structure of this file is included in Figure 3-10.

COLUMN LOCATION

```
1        10       19       28       37       46       55       64               80
|--------+--------+--------+--------+--------+--------+--------+---------------+-
```

	ONBOARD			INPORT			
*EQUIP *TYPE	REPAIR STOCK	REORDER POINT	CONTROL LEVEL	REPAIR STOCK	REORDER POINT	CONTROL LEVEL	REORDER TIME (DAYS)
iiii	iiii	iiii	iiii	iiii	iiii	iiii	rrr.rr
20	5	3	6	5	4	6	100.
23	2	0	2	2	1	2	20.
26	3	1	3	1	0	4	600.
31	1	0	1	0	0	2	130.

FIGURE 3-10. INVENTORY FILE

3.3 Output Reports

3.3.1 Introduction

The RMA model will produce reliability, maintainability, and availability information that will aid the decision maker in determing RMA characteristics of proposed cutter designs, including advanced marine vehicles and conventional cutters. This information can be used to compare RMA characteristics of alternative hull types for the same cutter requirements. RMA outputs can be used to conduct sensitivity analysis for each individual cutter such as that required to improve the overall cutter availability. Finally, RMA information can be used to analyze the impact of various maintenance philosophies.

The simulation will automatically generate five analysis reports. These reports will be stored in separate data files. The user may either view these data files on the CRT screen or send them to the printer. To view a report on the screen the user must type TYPE followed by the name of the data file which contains the desired report. The available output reports are:

1. Availability Analysis Report,
2. Maintainability Analysis,
3. Maintenance Personnel Report,
4. Parts Usage Per Operating Cycle Report, and
5. Reliability Analysis Report.

These reports are discussed in greater detail in the following sections.

3.3.2 Availability Report

Availability is an overall measure of a cutter's ability to respond to a mission when it is called upon. It is a fundamental basis for determining the number of cutters that may be required to meet U.S. Coast Guard mission requirements.

Availability of systems/subsystems/equipment in turn affects a cutter's ability to perform specific missions. An example would be inability to attain high speed in a SAR mission due to unavailability of one of two diesel engines in the propulsion subsystem.

Finally, availability is affected by the maintainence and logistic support system. A maintainence philosophy which limits onboard repairs may cause reduction of availability through aborted missions due to lack of onboard repair capability. A logistic support system which causes delays in repairs due to untimely delivery of repair parts can add to loss of operational time.

The Availability Analysis Report, which is created by the simulation, can be used to assist the decision maker in evaluating the above factors for a specific cutter design. This report contains values for the four following data items at the ship, system, subsystem, and equipment levels:

1. Desired Duty Cycle,
2. Observed Duty Cycle,
3. Operational Availability (A_0), and
4. Uptime.

Each of these values is calculated as a percentage of the input cutter operating cycle:

1. The Desired Duty Cycle is calculated based on equipment operating inputs and represents the percentage of time that the system, subsystem, or equipment is required to operate during a cutter operating cycle. This value will always be 100 percent for the ship system.

2. The Observed Duty Cycle is the ratio of the respective ship, system, subsystem, or equipment average uptime per cutter operating cycle.

3. Operational Availability is the ratio of the respective ship, system, subsystem, or equipment uptime over the sum of the respective uptime and downtime due to failure.

4. The Uptime is calculated as the ratio of the system, subsystem, or equipment uptime over the ship uptime. This value will not be displayed at the ship level, as it will always be equivalent to 100 percent.

The format of the Availability Analysis report is presented in Figure 3-11. Changes in system design, maintenance philosophy, and support system can be evaluated by changing inputs described in Section 3.2.

AVAILABILITY ANALYSIS

PAGE: 1

CUTTER TYPE: SES-100

OPERATING CYCLE: 90.00 DAYS

OVERHAUL CYCLE: 10.00 YEARS

REPORT DATE: 26-JUL-84

LIFE CYCLE: 30.00 YEARS

ITEM	DESIRED DUTY CYCLE(%)	OBSERVED DUTY CYCLE(%)	Ao(%)	UPTIME(%)
SHIP	100.00	87.56	87.56	
SYSTEM				
SYSTEM 1	100.00	87.56	87.56	100.00
SYSTEM 2	100.00	87.56	87.56	100.00
SYSTEM 3	100.00	87.56	87.56	100.00
SUBSYSTEM				
SUBSYSTEM 10	100.00	87.45	87.45	99.87
SUBSYSTEM 20	100.00	87.45	87.45	99.87
SUBSYSTEM 30	100.00	85.29	85.29	97.40
SUBSYSTEM 40	100.00	85.29	85.29	97.40
SUBSYSTEM 50	100.00	87.56	87.56	100.00
SUBSYSTEM 60	100.00	85.32	85.32	97.43
SUBSYSTEM 70	100.00	71.48	71.48	81.63
SUBSYSTEM 80	100.00	87.56	87.56	100.00
SUBSYSTEM 90	100.00	87.56	87.56	100.00
EQUIPMENT				
DIESEL ENGINE	100.00	83.81	83.81	95.71
REDUCTION GEARS	100.00	86.41	86.41	98.68
SHAFT	100.00	87.45	87.45	99.87
BEARINGS	100.00	84.88	84.88	96.93
ALARM PANEL	100.00	85.28	85.28	97.39
PROP	100.00	85.29	85.29	97.40
LIFT FANS	100.00	50.00	95.14	57.18
LUBE & OIL	100.00	86.88	86.88	99.22
FUEL SYSTEM	100.00	71.03	71.03	81.11
COMPRESSOR	100.00	71.01	71.01	81.09
LORAN C	100.00	87.47	87.47	99.89
RADIO	100.00	87.51	87.51	99.94
ENGINE CONTROLS	100.00	87.56	87.56	100.00

FIGURE 3-11. AVAILABILITY ANALYSIS

3.3.3 Reliability Report

Analysis of the effect of equipment failures on system and cutter performance is a method of evaluating cutter reliability. Equipments are physically and/or functionally connected into subsystems and systems. The failure of subsystems/systems will directly affect the ability of the cutter to perform a mission. Some failures may be cause for mission aborts and, consequently, reduction in availability.

The Reliability Analysis report, which is created by the simulation, can be used to evaluate the reliability of specific cutter designs. It provides a method to obtain an overall measure of reliability, identify the effect of failures on mission aborts, and pinpoint high failure subsystems/equipments to evaluate their effect on overall cutter availability. This report presents failure information at the ship, system, subsystem, and equipment levels. The data items contained in this report are:

1. Average number of equipment failures per operating cycle,
2. Number of ship aborts caused, and
3. Mean time between failures (MTBF) in hours.

At the ship, system, and subsystem levels the failures per operating cycle and MTBF data items represent equipment failures for each of the respective configurations. The format of the Reliability Analysis report is illustrated in Figure 3-12.

Changes to system design can be evaluated by varying inputs to the reliability structure and equipment selected from the Equipment RM File as described in Sections 3.2.3 and 3.2.4.

RELIABILITY ANALYSIS

CUTTER TYPE: SES-100

OPERATING CYCLE: 90.00 DAYS

OVERHAUL CYCLE: 10.00 YEARS

REPORT DATE: 26-JUL-84

LIFE CYCLE: 30.00 YEARS

ITEM	FAILURES PER OPERATING CYCLE	SHIP ABORTS PER CUTTER LIFE	MTBF (HOURS)
SHIP	3.32	22	0.00
SYSTEM			
SYSTEM 1	3.15	6	686.45
SYSTEM 2	0.18	15	11852.68
SYSTEM 3	3.33	22	648.87
SUBSYSTEM			
SUBSYSTEM 10	0.29	0	7398.26
SUBSYSTEM 20	0.32	0	6829.16
SUBSYSTEM 30	0.34	0	6184.67
SUBSYSTEM 40	0.40	0	5247.60
SUBSYSTEM 50	0.72	0	3013.39
SUBSYSTEM 60	0.61	5	3464.49
SUBSYSTEM 70	0.53	6	3298.33
SUBSYSTEM 80	1.14	6	1891.38
SUBSYSTEM 90	1.29	0	1677.27
EQUIPMENT			
DIESEL ENGINE	0.19	0	10635.08
REDUCTION GEARS	0.10	0	21929.83
SHAFT	0.02	0	88779.09
BEARINGS	0.27	0	7833.39
ALARM PANEL	0.07	0	28858.65
PROP	0.06	0	34634.15
LIFT FANS	0.07	0	16943.27
LUBE & OIL	0.53	5	4009.29
FUEL SYSTEM	0.32	4	5546.71
COMPRESSOR	0.21	2	8480.80
LORAN C	0.79	0	2732.20
RADIO	0.50	0	4333.78
ENGINE CONTROLS	0.18	15	11852.68

FIGURE 3-12. RELIABILITY ANALYSIS

3.3.4 Maintainability Reports

The major factors affecting maintainability are equipment design, availability of repair personnel and parts aboard ship, and delay times in replenishing repair parts. These factors all add to potential downtime for equipment and, subsequently, affect system and cutter availability for operation of its assigned mission.

The maintainence philosophy determines the availability of repair personnel and parts aboard ship, while the logistic support system drives the delay in parts support.

There are three separate maintainability reports which are generated by the simulation to provide a measure of a proposed cutter's maintainability. As described above, maintainability is sensitive to equipment selection; to the maintainance philosophy which has been incorporated into the cutter design; and to external influence from the Coast Guard logistic support system. The three reports, which are described in greater detail below, are the Maintainability Analysis report, the Maintenance Personnel report, and the Parts Usage Per Operating Cycle report. By varying inputs which are representive of these factors, as described in Section 3.2, a quantitative effect in maintainability can be evaluated.

3.3.4.1 Maintainability Analysis Report

The Maintainability Analysis Report presents information regarding repair duration and repair personnel hours at the ship, system, subsystem, and equipment levels. The data items contained in tnis report are:

1. Mean time to repair (MTTR),
2. Average repair personnel hours per operating cycle,
3. Average repair personnel hours per overhaul cycle, and
4. Average repair personnel hours per life cycle.

All the data items presented in this report are in hours. The format of the Maintainability Analysis report is illustrated in Figure 3-13.

MAINTAINABILITY ANALYSIS

CUTTER TYPE: SES-100

OPERATING CYCLE: 90.00 DAYS

OVERHAUL CYCLE: 10.00 YEARS

REPORT DATE: 26-JUL-84

LIFE CYCLE: 30.00 YEARS

ITEM	MTTR (HOURS)	AVERAGE REPAIR PERS HOURS PER CYCLE		
		OPERATING	OVERHAUL	LIFE
SHIP	198.50	1951.65	79367.12	160640.81
SYSTEM				
SYSTEM 1	208.74	1948.57	79241.65	160386.86
SYSTEM 2	8.46	3.08	125.45	253.90
SYSTEM 3	197.78	1951.65	79367.09	160640.75
SUBSYSTEM				
SUBSYSTEM 10	451.35	510.45	20758.32	42015.31
SUBSYSTEM 20	425.05	521.09	21191.17	42891.40
SUBSYSTEM 30	19.09	19.28	784.19	1587.22
SUBSYSTEM 40	36.26	91.66	3727.35	7544.24
SUBSYSTEM 50	207.59	612.75	24918.52	50435.64
SUBSYSTEM 60	13.63	37.70	1533.13	3103.09
SUBSYSTEM 70	928.23	1292.19	52548.90	106360.14
SUBSYSTEM 80	441.74	1329.89	54082.02	109463.22
SUBSYSTEM 90	2.77	5.93	241.12	488.03
EQUIPMENT				
DIESEL ENGINE	512.77	398.70	16213.98	32817.45
REDUCTION GEARS	328.49	111.75	4544.35	9197.86
SHAFT	109.51	10.64	432.85	876.09
BEARINGS	213.55	18.88	767.83	1554.10
ALARM PANEL	2.76	0.40	16.37	33.12
PROP	132.38	72.37	2943.16	5957.01
LIFT FANS	58.02	29.60	1203.89	2436.70
LUBE & OIL	7.57	8.10	329.24	666.39
FUEL SYSTEM	949.07	899.37	36574.28	74027.16
COMPRESSOR	950.97	392.82	15974.62	32332.99
LORAN C	2.99	4.73	192.17	388.95
RADIO	2.42	1.20	48.95	99.08
ENGINE CONTROLS	8.46	3.08	125.45	253.90

FIGURE 3-13. MAINTAINABILITY ANALYSIS

3.3.4.2 Maintenance Personnel Report

The Maintenance Personnel Report presents simulation results regarding utilization of repair personnel and repair delays. The report is divided into three sections:

1. Onboard Repair Personnel,
2. Inport Repair Personnel, and
3. Repair Delays Caused by Unavailable Personnel.

The Onboard Repair Personnel section contains the number of repair personnel onboard, the maximum number who were busy during the cutter life cycle, the average number of onboard repair personnel who were busy during the life cycle, the total number of onboard repair personnel hours expended, and the average hours per repair person. The Inport Repair Personnel section contains the number of repair personnel inport, the maximum number which were busy during inport periods, the average number of inport repair personnel which were busy during inport periods, the total number of inport repair personnel hours expended, and the average hours per repair person. The Repair Delays section contains the total number of repair delays incurred by unavailable repair personnel and the average duration, in hours, of the delays. The format of the Maintenance Personnel Report is illustrated in Figure 3-14.

MAINTENANCE PERSONNEL REPORT

CUTTER TYPE: SES-100
REPORT DATE: 26-JUL-84

ONBOARD REPAIR PERSONNEL:

NUMBER ONBOARD:	8
MAXIMUM NUMBER BUSY:	8
AVERAGE NUMBER BUSY:	0.57
TOTAL REPAIRMAN HOURS:	150199.16
AVERAGE HOURS PER REPAIR PERSON:	18774.89

INPORT REPAIR PERSONNEL:

NUMBER INPORT:	20
MAXIMUM NUMBER BUSY:	20
AVERAGE NUMBER BUSY:	0.10
TOTAL REPAIRMAN HOURS:	9143.67
AVERAGE HOURS PER REPAIR PERSON:	457.18

REPAIR DELAYS CAUSED BY UNAVAILABLE PERSONNEL:

NUMBER OF DELAYS:	140
AVERAGE DELAY (in hours):	50.28

FIGURE 3-14. MAINTENANCE PERSONNEL REPORT

3.3.4.3 Parts Usage Per Operating Cycle

The Parts Usage Per Operating Cycle report provides information regarding inventory transactions which occurred both onboard and inport during the simulated life cycle. All inventory transactions are based on equipment type. The data items contained in this report for each equipment type are:

1. Initial Onboard Stock,
2. Average Onboard Stock used during an operating cycle,
3. Minimum and Maximum Onboard Stock used during an operating cycle,
4. Average number of onboard stockouts per operating cycle,
5. Initial inport stock,
6. Average inport stock used during an inport period, and
7. Average number of inport stockouts per inport periods.

The format of the Parts Usage Per Operating Cycle report is illustrated in Figure 3-15.

PARTS USAGE PER OPERATING CYCLE

PAGE: 1

CUTTER TYPE: SES-100 OPERATING CYCLE: 90.00 DAYS

EQUIPMENT TYPE	ONBOARD					INPORT		
	INITIAL STOCK	AVG USED	MIN USED	MAX USED	STOCK OUTS	INITIAL STOCK	AVG USED	STOCK OUTS
20	5	1.71	0	4	0.00	5	1.73	0.49
23	2	0.55	0	2	0.04	2	0.53	0.27
26	3	0.74	0	2	0.00	1	0.74	0.16

FIGURE 3-15. PARTS USAGE PER OPERATING CYCLE

3.4 Model Execution

The RMA model can be executed in either real-time or batch mode. The three major steps involved in executing the model are:

1. Preparation of inputs,
2. Execution of simulation program, and
3. Analysis of Results.

The first step in the process, preparation of inputs, is optional. The user may desire to either create his own data files or use existing data files. The guidelines for creation of new data files and modification of existing data files is presented in Section 3.2.

To execute the simulation program the user must first enter the directory where the program is resident. Presently the program resides on a VAX 11/780 at the Naval Underwater Systems Center (NUSC), New London, Connecticut in the directory [CGRDC.JOED]. Once the user has entered the correct directory he must type the following two commands:

```
ASSIGN RMANETW.DAT FOR005.DAT
RUN SLAMRMA
```

This will begin program execution. The simulation will then print the SLAM copyright information on the screen. The user should ignore this information. Next the program will prompt the user to enter the names of the five data files which are required by the simulation. These data files are described in detail in Section 3.2. After the five data file names have been entered, the program will begin the simulation. Once the simulation has been completed the model will display the following:

```
FORTRAN STOP.
```

The final step in the execution of the model is the analysis of the results. The simulation automatically creates five permanent output files which contain the output reports discussed in Section 3.3. The names of the output data files and the report that each contains are:

1.	AVAIL.DAT	Availability Analysis Report
2.	MAINTAIN.DAT	Maintainability Analysis Report
3.	MANREPORT.DAT	Maintenance Personnel Report
4.	PARTSUSE.DAT	Parts Usage Per Operating Cycle Report
5.	RELI.DAT	Reliability Analysis Report

The user may then either have these reports displayed on the screen or have them printed on the printer.

4.0 RMA MODEL TESTS

4.1 Scope of Testing

The individual user generated modules described in Section 3 were tested in an individually and integrated manner as they were developed. Representative data was used to verify accuracy of algorithms used for outputs. Extensive testing of parameters with live data was beyond the scope of this initial effort.

4.2 Data Requirements

To provide a realistic test of the RMA model, an approach was developed to obtain operational data for evaluating availability and reliability of proposed Coast Guard cutters. The objectives of this approach were to:

1. Evaluate applicability of operational data.

2. Obtain operational inputs on mission abort criteria.

3. Validate approach to development of reliability block diagrams.

The tasks that were undertaken to obtain this data were:

1. Define purpose and describe proposed reliability block diagram.

2. Describe physical system dependency block diagrams and system definitions.

3. Define standard tasks for WSES.

4. Develop equipment/tasks for WSES.

5. Define missions for WSES.

6. Develop mission/tasks for WSES.

7. Record cutter operational data.

These tasks are described in the following sections. Although the WSES was not available to obtain the above information, support from a local WPB was solicited to validate the approach. Results from this effort are included in each section.

4.3 Configuration Diagrams

A configuration diagram such as that of Figure 4-1 for the WSES represents the physical groupings of systems and subsystems according to a work breakdown structure (WBS) used by the U.S. Navy in ship design and maintenance. Figure 4-1 illustrates the physical interdependencies of systems and subsystems for the WSES.

A reliability block diagram of Figure 4-2 illustrates the physical interdependency of systems that are required to support a specific mission or operation. Figure 4-2 identifies the series and parallel dependencies of systems/equipment for the WSES during a high speed transit. This diagram will be used to generate the reliability interdependency input to the RMA model.

4.4 Equipment Operating Profile

The equipment operating profile was established in three steps. The first was to relate equipment/systems to identifiable tasks. Figure 4-3 illustrates this matrix for a WSES. The definitions of the tasks are provided in Table 4-1. A completed table for the USCG PT KNOLL is shown in Figure 4-4. Inherent in this information is the mission abort criteria as defined by the operators. A distinction is made between critical failures that may cause mission degradation (R) and mission abort (C).

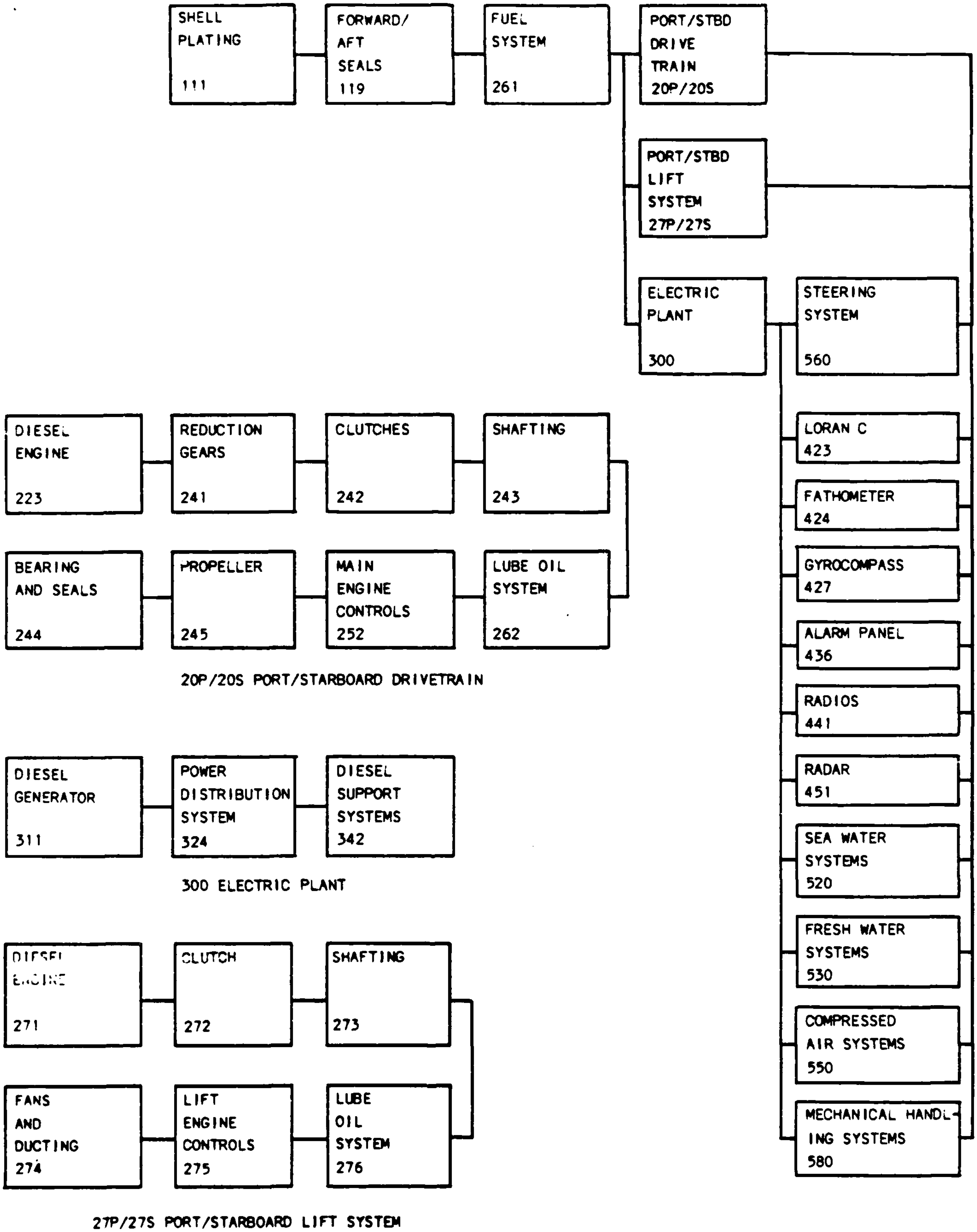


FIGURE 4-1. WSES CONFIGURATION BLOCK DIAGRAM

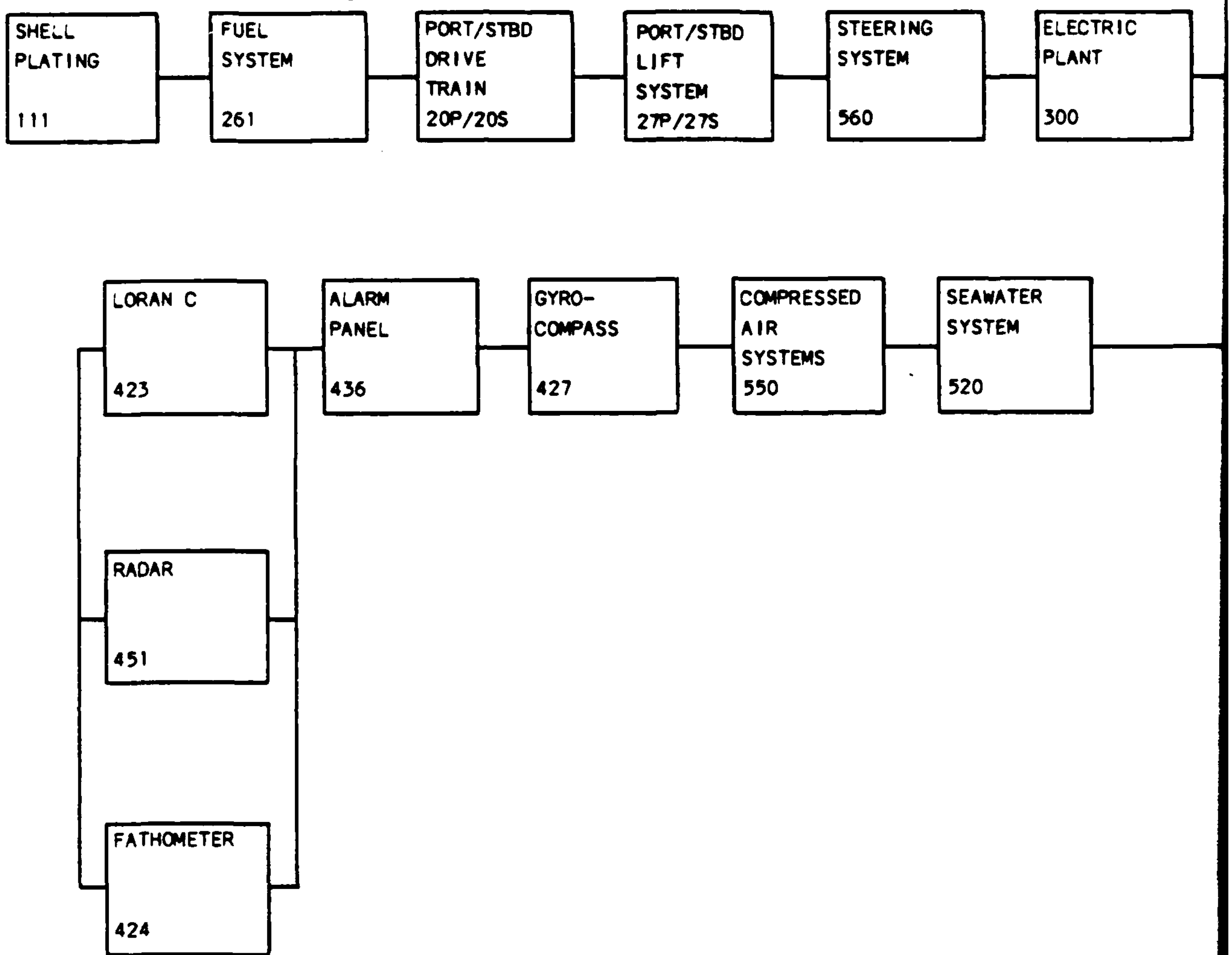


FIGURE 4-2. PROPOSED RELIABILITY BLOCK DIAGRAM FOR WSES HIGH SPEED TRANSIT

SYSTEM/EQUIPMENT		TASKS									
ID	DESCRIPTION	High Speed Transit	Cruise Speed Transit	Visual Search	Sensor Search	Standby On Scene	Transfer by Small Boat	Escort	Tow	Rescue and Assist	
111	Shell Plating										
261	Fuel Systems										
20P	Port Drive Train										
20S	Starboard Drive Train										
560	Steering System										
300	Electric Plant										
423	Loran C										
424	Fathometer										
427	Gyro Compass										
436	Alarm Panel										
441	Radios										
451	Radar										
520	Sea Water Systems										
530	Fresh Water Systems										
550	Compressed Air Systems										
580	Mechanical Handling Systems										
27P	Port Lift Systems										
27S	Starboard Lift Systems										

KEY: N - Not Required
C - Critical (Failure will cause mission abort)
R - Required (Failure will not cause mission abort)

FIGURE 4-3. EQUIPMENT/TASKS FOR WSES

TABLE 4-1. TASK DEFINITIONS

<u>HIGH SPEED TRANSIT</u>. Travel at full speed from one location to the operational area or expected location of a distressed unit or people.

<u>CRUISE SPEED TRANSIT</u>. Travel at economical speeds or on one shaft to designated operational area in order to conserve fuel.

<u>VISUAL SEARCH</u>. Conduct of visual search at reduced speeds for personnel or afloat units without the use of radar or other sensors. Does not apply to transit tasks, sensor search, or during conduct of other tasks

<u>SENSOR SEARCH</u>. Conduct of search with radar or other sensor for personnel or other afloat units. Does not apply during transit, visual search, or when other tasks are being conducted.

<u>STANDBY ON SCENE</u>. Conduct visual or sensor surveillance and maintain communications with shore command while remaining in area by minimal use of engines.

<u>BOARD WITH SMALL BOAT</u>. Launch small boat from cutter, inspect vessel with boarding crew, and retrieve small boat. Handling gear and communications are required. Cutter must maintain speed to remain in visual contact with boat and vessel being boarded.

<u>ESCORT</u>. Accompany a vessel usually at reduced speed and maintain visual contact. Communications are required during this task.

<u>TOW</u>. Pick up and release tow of a disabled or seized vessel. This reduced speed operation usually requires full power capability and handling system. Communications are necessary during this task to maintain contact with shore command and for communication with other vessels in immediate area.

<u>RESCUE AND ASSIST</u>. Provide support to disabled vessel including assisting in fighting fires and controlling flooding.

SYSTEM/EQUIPMENT ID	SYSTEM/EQUIPMENT DESCRIPTION	High Speed Transit	Cruise Speed Transit	Visual Search	Sensor Search	Standby On Scene	Transfer by Small Boat	Escort	Tow	Rescue and Assist
111	Shell Plating	C	C	C	C	C	C	C	C	C
261	Fuel Systems	C	C	C	C	C	C	C	C	C
	Starting System	C	C	C	C	C	C	C	C	C
20P	Port Drive Train	C	C	C	C	C	C	C	C	C
20S	Starboard Drive Train	C	R	R	R	R	R	R	R	R
560	Steering System	C	R	R	R	R	R	R	R	R
300	Electric Plant	C	C	C	C	C	C	C	C	C
423	Loran C	R	R	R	R	R	R	R	R	R
424	Fathometer	R	R	R	R	N	N	R	R	R
436	Alarm Panel	R	R	R	R	R	R	R	R	R
441	Radios	R	R	R	R	R	R	R	R	R
451	Radar	R	R	R	C	R	R	R	R	R
520	Sea Water Systems	R	R	R	R	R	R	R	R	C
530	Fresh Water Systems	N	N	N	N	N	N	N	N	N
550	Compressed Air Systems	N	N	N	N	N	N	N	N	N

KEY: N - Not Required
C - Critical (Failure will cause mission abort)
R - Required (Failure will not cause mission abort)

FIGURE 4-4. EQUIPMENT/TASKS FOR WPB (USCG PT KNOLL)

The second step was to relate missions to tasks as shown in Figure 4-5. this two-step process helps the operators to associate with the operation and avoids ambiguities in defining equipment to missions directly. Table 4-2 defines the missions for a WPB/WSES. Figure 4-6 represents inputs from the USCG PT KNOLL for a typical WPB.

The third step was to obtain cutter operational data which relates the equipment to actual operating hours. Figure 4-7 is an input from USCG PT KNOLL compiled from Cutter Abstract of Operations (CG-3273C). This information is readily available for each cutter.

EMPLOYMENT AREAS	TASK (Percent time performed)										
	High Speed Transit	Cruise Speed Transit	Visual Search	Sensor Search	Standby On Scene	Transfer by Small Boat	Escort	Tow	Rescue and Assist		
SAR											100%
ELT											100%
PSS											100%
MEP											100%
OTHER*											100%

* Includes non-designated standby and other program areas (Aids to navigation, marine science activities, public relations, etc.)

FIGURE 4-5. MISSION/TASKS FOR WSES

TABLE 4-2. MISSION DEFINITIONS

SEARCH AND RESCUE (SAR). Objective is minimizing loss of life, injury, and property damage, on, over, or under the water; includes:

o	RESPOND	to cases of emergency
o	SEARCH	to find the distressed unit
o	RESCUE	people in need from the danger involved
o	ASSIST	people and property in need to prevent emergencies

ENFORCEMENT OF LAWS AND TREATIES (ELT). Objective is protecting and preserving the national resources and national interests within jurisdictional waters; includes:

o	GATHER DATA	by surveillance and inspection
o	DETER	potential violators of the law
o	ENFORCE	violations of the law by seizure, detection, or arrest
o	DETECT	violations of the law
o	RESPOND	to violations of the law
o	INVESTIGATE	to insure compliance with the law

MARINE ENVIRONMENTAL PROTECTION (MEP). Objective is maintaining, improving, and protecting the marine environment from pollution of oil or hazardous substances; includes:

o	DETECT	oil and hazardous substances in the water by surveillance
o	ENFORCE	violations of the law by seizure, detection, arrest
o	PREVENT	damage to marine environment by education and presence
o	RESPOND	to pollution incidents with cleanup equipment
o	INVESTIGATE	to insure compliance with the law or to determine extent of pollution
o	COORDINATE	resources at site of incident and act as on scene commander directing removal of pollution

PORT SAFETY AND SECURITY (PSS). Objective is safeguarding the nation's ports and waterways; includes:

o	INSPECT	waterfront facilities and specified vessels
o	MONITOR	liquid bulk transfer operations and hazardous cargo operations
o	DETECT	violations of the law or unsafe practices in the port areas
o	ENFORCE	violations of the law by seizure, detection, or arrest
o	SURVEY	vessels of interest
o	TRANSPORT	miscellaneous equipment
o	RESPOND	to port disasters

EMPLOYMENT AREAS	High Speed Transit	Cruise Speed Transit	Visual Search	Sensor Search	Standby On Scene	Transfer by Small Boat	Escort	Tow		
SAR	20	0	15	15	10	0	10	30		100
ELT	0	15	40	30	10	5	0	0		100
PSS	0	5	0	0	95	0	0	0		100
MEP	0	10	0	0	30	0	60	0		100
OTHER*	0	15	0	0	45	0	40	0		100

TASK (Percent time performed)

* Includes non-designated standby and other program areas (Aids to navigation, marine science activities, public relations, etc.)

FIGURE 4-6. MISSION/TASKS FOR WPB (USCG PT KNOLL)

UNIT:	USCGC PT KNOLL	BASE:	New London, CT
CO:	LTJG Milburn	PHONE:	203/447-1155

DATES: from 1 APR 83 to 31 MAR 84 (366 days)

Number of days underway:	99
Number of days in maintenance:	128
Number of days in standby:	139
Total:	366

Number of sorties/patrols:	114
Minimum duration of patrol:	1 day
Maximum duration of patrol:	4 days
Most likely duration of patrol:	2 days

DISTRIBUTION OF TIME (%) ON MISSION AREAS

	Underway	Standby*
SAR	9	95
ELT	55	--
PSS	2	--
MEP	6	--
Other**	28	5
	100%	100%

* All standby time is designated SAR standby except during operational training and America's Cup Patrols

** America's Cup Patrol, Operational Training, Engineering Tests, Transit Time

FIGURE 4-7. CUTTER OPERATIONAL DATA

APPENDIX A

DATA DICTIONARY

AVAILABILITY ANALYSIS	Output of simulation Cutter type + operating cycle + overhaul cycle + life cycle + [system name + desired duty cycle + observed duty cycle + operational availability + uptime] + [subsystem name + desired duty cycle + observed duty cycle + operational availability + uptime] + [equipment name + desired duty cycle + observed duty cycle + operational availability + uptime]
AVAILABLE SUPPORT	Spare parts package or replacement item, and repair personnel available to repair a given failure
CUTTER OPERATING PROFILE	Cutter operation schedule during its life cycle. Operating cycle length + scheduled inport time + overhaul cycle + overhaul time + cutter life + number of onboard repair personnel + number of inport repair personnel + [mission type + percent of operational time per year]
CUTTER TYPE	A descriptive code which represents the type of cutter being modeled
CUTTER OPERATING INFORMATION	Data collected during simulation Operating cycle length + overhaul cycle length + cutter life + number of attempted operating cycles + [aborts per overhaul cycle] + [cutter downtime per operating cycle]
CYCLE ABORT	A critical failure has caused the abort of an operating cycle
EQUIPMENT DOWNTIME	The time between the failure of a specific equipment and the time it is returned to operation

EQUIPMENT FAILURE INFORMATION	[System ID + observed MTBF] + [subsystem ID + observed MTBF]
EQUIPMENT FAILURE SCHEDULE	[Equipment ID + time for next failure]
EQUIPMENT OPERATING PROFILE	[Equipment ID + hours of operating per operating cycle]
EQUIPMENT RM FILE	[Equipment ID + equipment name + equipment type + MTBF + MTBF distribution + MTTR + repair personnel required]
FAILED EQUIPMENT	ID of equipment that has just failed
FAILURE DISTRIBUTION	Parameters which describe the distribution of the failure rate of each equipment
INVENTORY FILE	[Equipment type + number of onboard parts packages or replacements + onboard reorder point + onboard control level + number of inport parts packages or replacements + inport reorder point + inport control level + reorder time]
LIFE CYCLE	Length of the cutter's life (in years)
LOGISTIC INFORMATION	Data collected during simulation [Equipment name + initial onboard stock + number of onboard used + maximum used in one operating cycle + minimum used in one operating cycle + number of onbard stock-outs + initial inport stock + number of inport used + number of inport stock-outs] + maximum repair personnel busy + average number busy + total repairman hours + number of delays caused unavailable personnel + total delay time
LOR	Level of repair, whether repair should be conducted onboard or inport

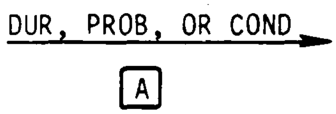
MAINTAINABILITY ANALYSIS	Cutter type + operating cycle + overhaul cycle + life cycle + [system name + MTTR (hours) + average repairman hours per operating cycle + average repairman hours per overhaul cycle + average repairman hours per life] + [subsystem name + MTTR + average repairman hours per operating cycle + average repairman hours per overhaul cycle + average repairman hours per life] + [equipment name + MTTR + average repairman hours per operating cycle + average repairman hours per overhaul cycle + average repairman hours per life]
MAINTENANCE PERSONNEL REPORT	Cutter type + number of repair personnel onboard + maximum number of onboard personnel busy + average number of onboard repair personnel busy + total onboard repairman hours + average hours per onboard repairman + number of inport repair personnel + maximum number of inport repair personnel busy + average number of inport repair personnel busy + total inport repairman hours + average hours per inport repairman + number of repair delays + average delay duration (hours)
MISSION EQUIPMENT MATRIX	[Equipment ID + percent of time of each mission that equipment is operating]
MLDT	Mean logistic delay time for repair of an equipment
MTBF	Mean time between failures of an equipment
MTTR	Mean time to repair an equipment
PARTS USAGE PER OPERATING CYCLE	Cutter type + operating cycle + [equipment type + initial onboard stock + average onboard used + minimum onboard used + maximum onboard used + average number of onboard stockouts + initial inport stock + average inport used + average number of inport stockouts]

RELIABILITY ANALYSIS	Output of simulation Cutter type + operating cycle + overhaul cycle + life cycle + [system name + average number of equipment failures per operating cycle + number of ship aborts caused during cutter life + MTBF (hours)] + [subsystem name + average number of equipment failures per operating cycle + number of ship aborts caused during cutter life + MTBF] + [equipment name + average number of failures per operating cycle + number of ship aborts caused during cutter life + MTBF]
RELIABILITY STRUCTURE	Interrelationships and criticality of all systems, subsystems, and equipments [(Sub)system number + name + number of components + number of components required + criticality + [component IDs]]
REPAIRABILITY INFORMATION	Data collected during simulation [System name + number of system failures + total system downtime + cutter aborts caused by system + cutter downtime caused by system + observed MTTR + total repairman hours] + [subsystem name + number of subsystem failures + total subsystem downtime + cutter aborts caused by subsystem + cutter downtime caused by subsystem + observed MTTR + total repairman hours] + [equipment name + downtime]
REORDER INFORMATION	Onboard and inport reorders of parts packages and replacements
REQUIRED SUPPORT	Spare parts package or replacement item, and repair personnel required to repair a given failure
SIMULATION TIME	Time from running simulation clock
SUPPORT USED	Spare parts package or replacement item, and repair personnel used to repair a given failure
UNAVAILABILE SUPPORT	Delays caused by unavailable repair personnel and inventory stock-outs

APPENDIX B
NETWORK SYMBOLS
USED IN RMA SIMULATION

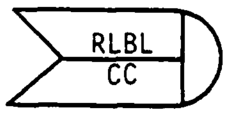
NAME | **SYMBOL** | **DESCRIPTION**

ACTIVITY



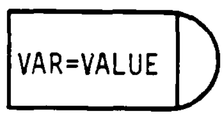
The ACTIVITY node is used to delay entities by a specified duration and perform conditional/probabilistic testing. Utilization statistics are compiled for every activity number (A).

ALTER



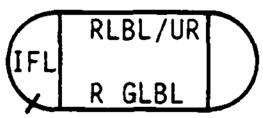
The ALTER node changes the capacity of resource RLBL by CC units.

ASSIGN



The ASSIGN node is used to assign values to SLAM variables (VAR) at each arrival of an entity to the node.

AWAIT

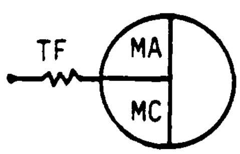


The AWAIT node operates in two modes. In the resource mode, the AWAIT node delays an entity in file IFL until UR units of resource RLBL are available. The entity then seizes the UR units of RLBL. In the gate mode, the AWAIT node releases the entity if the gate status is open and delays the entity in file IFL if the gate is closed.

CLOSE

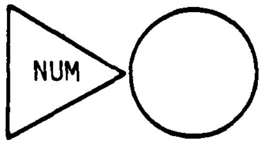
The CLOSE node changes the status of gate GLBL to closed.

CREATE



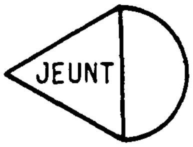
The CREATE node generates MC entities starting at time TF and stores the creating time in ATRIB(MA).

ENTER



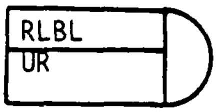
The ENTER node is provided to permit the user to enter an entity into the network from a user-written event routine, via a user call to subroutine ENTER(NUM).

EVENT



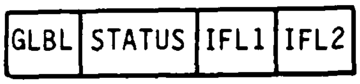
The EVENT node causes subroutine EVENT to be called with event code JEUNT at each entity arrival.

FREE



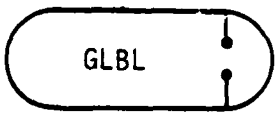
The FREE node releases UF units of resource RLBL.

GATE



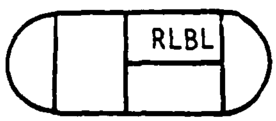
A GATE block defines a gate by its label GLBL. STATUS is the initial status of the gate and the file numbers, IFLs, reference the AWAIT nodes where entities waiting for the gate to open are queued.

OPEN



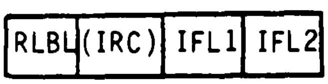
The OPEN mode changes the status of gate GLBL to open.

PREEMPT



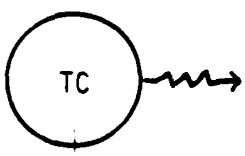
The PREEMPT node is used to preempt the activity holding resource, RLBL, and terminate that entity.

RESOURCE



A RESOURCE block defines a resource by its label, RLBL, and its initial capacity or availability, IRC. The file numbers, ILFs, which are associated with AWAIT and PREEMPT nodes, are where entities requesting units of the resource are queued.

TERMINATE



The TERMINATE node is used to destroy entities and/or terminate the simulation after TC entities have passed through.

APPENDIX C

DISCRETE EVENT SUBROUTINES

SUBROUTINE	FUNCTION
INTLC	o Reads in data files -- Cutter Operating Profile -- Mission Equipment Matrix -- Equipment Information - equipment type, MTBF, MTBF distribution, MTTR, number of repairmen required -- Reliability Structure -- Onboard and Inport Inventory for each equipment
	o Calculates equipment operating times and initial failure time
	o Defines network time variables
	o Determines initial status of all systems and subsystems
	o Initializes all variables, constants, etc.
EVENT	o Called by both the SLAM EXECUTIVE and the SLAM Network routines when an event occurs, in which case the EVENT subroutine will call the appropriate subroutine to process the event
	o Possible events include: 1: End of Repair 2: Equipment Shutdown 3: Equipment Failure 4: End of Operating Cycle 5: Beginning of Operating Cycle 6: End of Simulation 7: Inport Stock Delivery 8: End of Overhaul Cycle
OPCBEG	o Schedule equipment failures or shutdowns
	o Turns appropriate equipments on
EQPSHUT	o Turn equipment off
	o Update operating time and time to fail of equipment
	o Call subroutine RELNET to update reliability structure

SUBROUTINE	FUNCTION
EQPFAIL	o Turn equipment off and update operating time
	o Call subroutine RELNET to update reliability structure
	o Calculate time to repair
	o Call subroutine INVENT to check for inventory availability
	o Enter network logic to repair equipment
	o If failure is critical, enter network logic to abort the operating cycle
INVENT	o Checks for availability of repair stock for a given equipment
	o Updates inventory
RPREND	o Turns repaired equipment on and collects downtime statistics
	o Schedules next failure of equipment
	o Calls subroutine RELNET to update reliability structure
RELNET	o Takes a given equipment turn-on, shutdown, or failure, runs it through the inputted reliability structure, and determines any changes in system and/or subsystem status caused by the given equipment
	o Turns on or off appropriate systems, subsystems, and/or equipments
	o Determines if a critical failure has occurred
	o Collects uptime and failure statistics
OPCEND	o Shuts down all operating equipment
	o Checks both inport and onboard inventories for reorder
	o Collects operating and inventory reorder statistics

SUBROUTINE	FUNCTION
OUTPT	o Calls the following subroutines to prepare and output simulation reports: 1: AVAILABLE — Availability Analysis Report 2: MAINT — Maintainability Analysis Report 3: MPR — Maintenance Personnel Report 4: PUPOC — Parts Usage Per Operating Cycle Report 5: RELIABLE — Reliability Analysis Report
AVAILABLE	o Called by subroutine OUTPT to calculate and output the Availability Analysis report o Prints page format and headings for report o Calls subroutine IAINFO to print ship and system availability information o Prints subsystem and equipment availability information o Report is output to a file named AVAIL.DAT
IAINFO	o Called by subroutine AVAILABLE to print ship and system availability information
MAINT	o Called by subroutine OUTPT to calculate and output the Maintainability Analysis Report o Report is output to a file named MANREPORT.DAT o Prints page format and headings for report o Calls subroutine IMINFO to print ship and system maintainability information o Prints subsystem and equipment maintainability information o Report is output to a file named MAINTAIN.DAT
IMINFO	o Called by subroutine MAINT to print ship and system maintainability information
MPR	o Called by subroutine OUTPT to calculate and output the Maintenance Personnel Report o Calculates and outputs onboard and inport repair personnel utilization statistics and repair delay statistics

SUBROUTINE	FUNCTION
PUPOC	o Called by OUTPT to caculate and output Parts Usage Per Operating Cycle Report o Report is output to a file named PARTSUSE.DAT
RELIABLE	o Called by OUTPT to calculate and output Reliability Analysis Report o Prints page format and headings for report o Calls subroutine IRINFO to print ship and system reliability information o Prints subsystem and equipment reliability information
IRINFO	o Called by subroutine RELIABLE to print ship and system reliability information

END

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