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SEATIDE ANALYSIS PROCESS. VOLUME IIB. NAVAL ENGAGEMENT MODEL (N--ETC(U)

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UNCLASSIFIED VSD-00.1636-VOL-2B-REV-A NL

1 of 2

ADA048 341

SEATIDE ANALYSIS PROCESS

VOLUME IIB

NAVAL ENGAGEMENT MODEL (NE[illegible]

APPENDICES A - I

REPORT NO. [illegible]
JANUARY 1974
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VOUGHT SYSTEMS DIVISION
LTV AEROSPACE CORPORATION
P.O. BOX 5907 · DALLAS, TEXAS 75222

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REPORT NO. 00.1636

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INSTRUCTIONS:

Pages to be removed:	Pages to be inserted:
Title page through ii ✓	Title page through ii ✓
iii through iv ✓	iii through iv ✓
C-1 through C-2 ✓	C-1 through C-2 ✓
C-29 through C-30 ✓	C-29 through C-30 ✓
I-1 through I-11 ✓	I-1 through I-13 ✓

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SEATIDE ANALYSIS PROCESS.

VOLUME IIB.

NAVAL ENGAGEMENT MODEL (NEM).

APPENDICES A - I.

Revision A.

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FOREWORD

(U) This report was prepared by the Vought Systems Division, LTV Aerospace Corporation, P.O. Box 6267, Dallas, Texas 75222 under U. S. Army Electronics Command Contract DAAB09-72-C-0062. The work was initiated under the direction of Captain R. A. Dowd, USN and completed under Captain W. A. Greene, USN, Chief, Long Range Forecast Division, Directorate of Estimates, Defense Intelligence Agency (DIA-DE-1).

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Mr. G. H. Harris	Operations Research
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(U) This report has been prepared in the following volumes:

Volume	Classification	Title
I	S	Summary
IIA	U	Naval Engagement Model (NEM) - Users Manual
IIB	U	NEM - Appendices A - I
IIC	S	NEM - Appendices J - M
IID	U	NEM - Appendix N
IIIA	U	Cruise Missile - Concept Generation and Screening Model (CM-CGSM) - Users Manual
IIIB	U	CM-CGSM Appendices A-B
IIIC	S	CM-CGSM Appendix C
IIID	U	CM-CGSM Appendices D-G
IIIE	U	CM-CGSM Appendix H
IV	S	Relative Worth Model (RWM)
V	U	Relative Cost Model (RCM)

ABSTRACT

(U) The SEATIDE Analysis Process is a semi-automated procedure for the generation of time-phased, high value cruise missile weapon systems concepts, together with the supporting technology and intelligence indicators which would reflect that these technological goals are being achieved. The SEATIDE process can also be used to evaluate the effectiveness of fixed force levels, existing forces in SAL environments, or Naval defenses.

(U) The Defense Intelligence Agency, through its Directorate of Estimates, and The Advanced Research Projects Agency (ARPA) have sponsored the development of this computer based analysis at the weapon system and Naval force structure level. A previous process, RIPTIDE, was developed for DIA for use in analysis of strategic missile systems.

(U) Generic to the SEATIDE Analysis Process are three major computer models: The Naval Engagement Model (NEM), Cruise Missile Concept Generation and Screening Model (CM-CGSM) and Relative Worth Model (RWM). The NEM evaluates force effectiveness, tactics, and task force configurations; the CM-CGSM enables definition and selection of candidate, advanced cruise missile system concepts; and the RWM permits assessment of worth in accordance with a variety of objective and subjective criteria. Each of these models has been checked out by DIA.

(U) In addition to exercising the computer models, there are several other analytical and engineering tasks to be performed, e.g., the identification of areas of current interest and the associated criteria and potential concepts, the creation of a foreign technology data bank in a format needed by the computer models, the engineering of concepts to the required detail, and the use of a verification analysis loop.

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G. Surface-to-air Intercept Model
H. Midcourse Navigation Model
I. Engagement Simulation

Volume IIC (Secret)

J. Target Value Estimation
K. Ship Kill Functions
L. Target Hit and Kill Functions
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APPENDIX A

DATA STRUCTURE - ENGAGEMENT

TITLE	
DATA STRUCTURE - ENGAGEMENT	Appendix A
	NO.
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PREPARED BY L. D. Gregory

APPROVED BY Clob

APPENDIX A

DATA STRUCTURE - ENGAGEMENT

1.0 INTRODUCTION

The purpose of this appendix is to present the Engagement Structure of the Naval Engagement Model (NEM). Description of the present engagement is given, as well as instructions on how to vary and/or develop new engagements to be studied. In keeping with the purpose of the NEM and its role in the SEATIDE Analysis Process (to aid in long range forecast of cruise missile systems), the NEM was developed with a specific scenario in mind. Since the engagement structure (presented here) and the naval systems (in Appendix B) are subject to change by User input, it is anticipated that a great variety of naval situations can be studied. Format details and instructions for making inputs to the computer are given in Volume IIA - Users Manual. A point to be noted is that both the engagement structure and the systems catalog can be placed permanently on magnetic disk, and that many variations in engagements and systems can be studied with relatively few card inputs.

2.0 BASIC SCENARIO

A BLU Task Force is in transit in the open sea. It consists of three Task Groups, two of which contain aircraft carriers and escorts, and the third group contains a guided missile cruiser (with SAMs) and escorts. The Task Force has been under observation for several days, and RED plans a coordinated attack at T = 0 hours. RED will attack with surface ships, submarines, and land based aircraft, all armed with cruise missiles. BLU will defend with carrier based aircraft, surface-to-air missiles, and guns. Both sides will employ submarines armed with torpedoes, and BLU will conduct ASW operations. Both sides have noise jamming capability against search and track radars. No other countermeasures have been modeled at this time.

3.0 FORCE COMPOSITION AND UNIT DEPLOYMENT

Both sides move along pre-planned routes until engagement interactions produce a change. Pre-planned routes are User input. Routes are input for each group, and the Units in each group are given a formation relative to the group center. The User should develop these by beginning with the "planned" positions he desires at time of coordinated attack, T = 0. This also determines the groups and units he desires.

3.1 Deployment at T = 0

The BLU and RED Task Groups and their planned positions at the time of coordinated attack, T = 0, are shown in Figure 1. For modeling convenience, a group may contain many units, or as few as one unit.

First, an arbitrary rectangular coordinate system is chosen. In Figure 1 the BLU Task Force center is placed at X = 1000 NM, Y = 400 NM, moving west at 20 knots. The fifteen BLU groups in this example are placed within a 150 NM circle.

3.1.1 BLU Deployment

BLU group 1 is a carrier task group located at X = 1000 NM, Y = 440 NM. The deployment of the escorts within this group is shown in Figure 2. The escort consists of two DD's, one DDG, two SSN's, and two DLG's. The numbering scheme shown in these figures is an informal one with respect to the entire Task Force and is for labeling purposes only. It does not influence computer action in any way.

BLU group 2 is also a carrier task group, located at X = 1000 NM, Y = 360 NM. This is shown in Figure 3. It contains one AOE, two DD's, one DDG, two DEG's, two DLG's, and two SSN's.

BLU group 3 is a guided missile cruiser group with two DD's for escorts. This is shown in Figure 4 at X = 970 NM, Y = 400 NM.

The remainder of the 15 BLU groups are AEW, ASW, and CAP stations. The details of the contents of these groups is not shown graphically. In most cases it is a single aircraft, but could contain any number.

The above details for BLU Units are coded in Table numbers 0100 through 0115 and are discussed further in Section 4.

3.1.2 RED Deployment

The eighteen RED groups shown in Figure 1 are all deployed outside the 150 NM circle, except for two Charlie Class submarines shown as RED groups 1 and 13 with the acronyms CGRP 1 and CGRP 2.

RED groups 2 and 12 each have two BADGER aircraft carrying cruise missiles and a third used as a jammer.

RED groups 3 and 11 each have two Echo Class submarines carrying cruise missiles.

RED groups 4 and 10 each have one BEAR aircraft used as a stand off jammer.

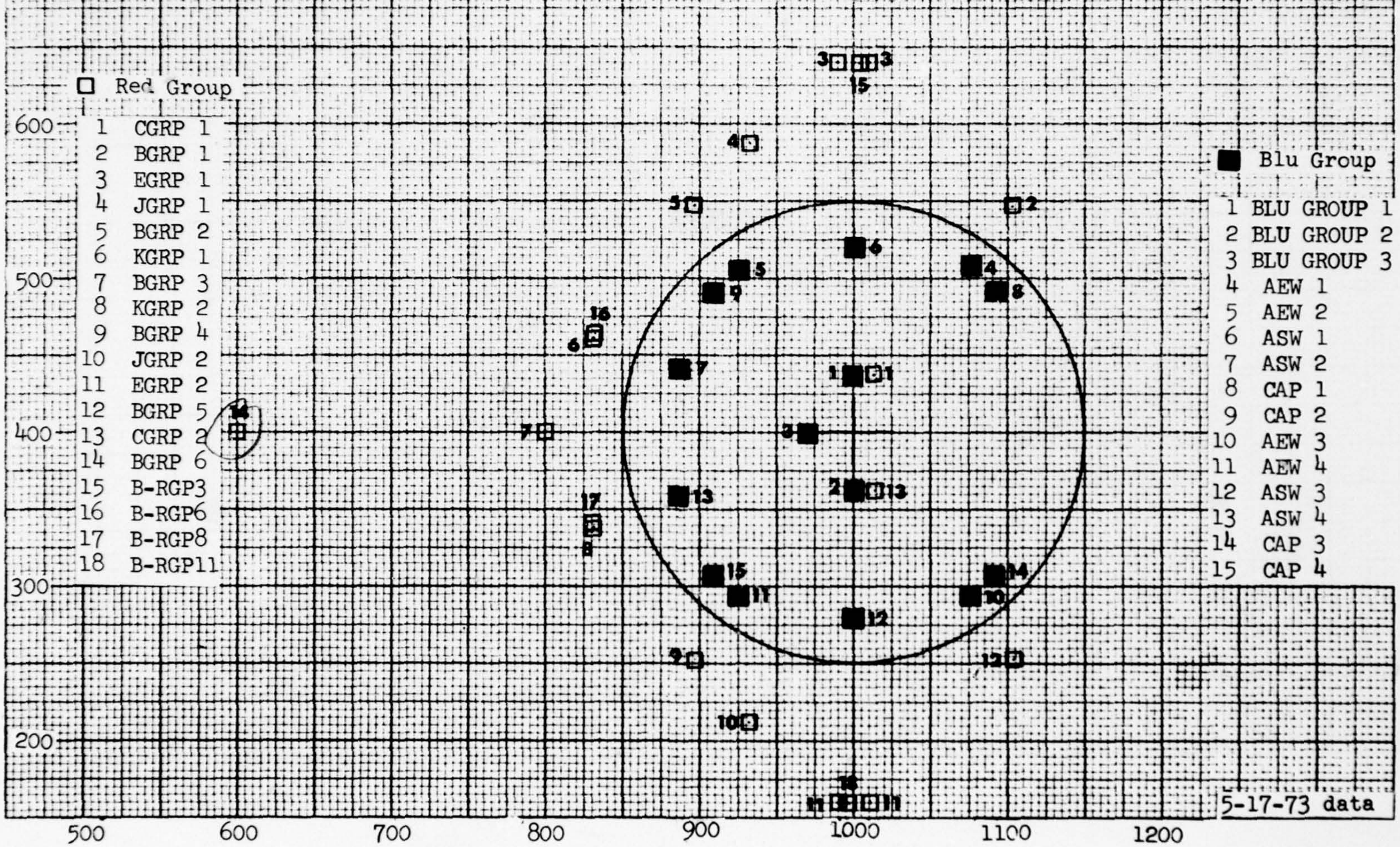
RED groups 5 and 9 each have two BADGER aircraft carrying cruise missiles and a third used as a jammer.

RED groups 6 and 8 each have one KYNDA CLGM, one KRESTA II CLGM, and one KASHIN DLG.

RED groups 7 and 14 each have two BADGER aircraft carrying cruise missiles and a third used as a jammer.

Figure 1

TEST DEPLOYMENT - BLU & RED GROUPS T = 0



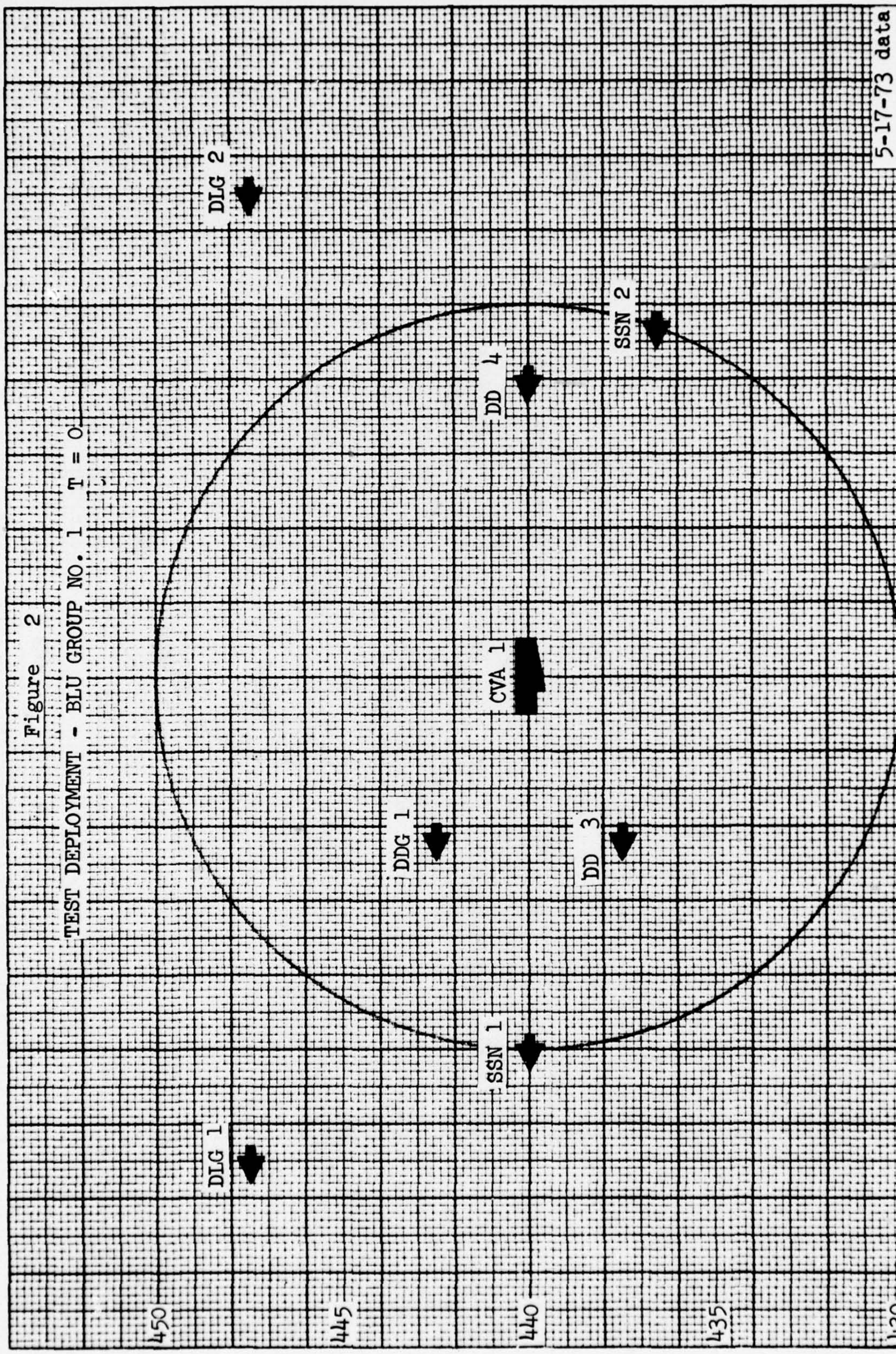


Figure 2

TEST DEPLOYMENT - BLU GROUP NO. 1 T = 0

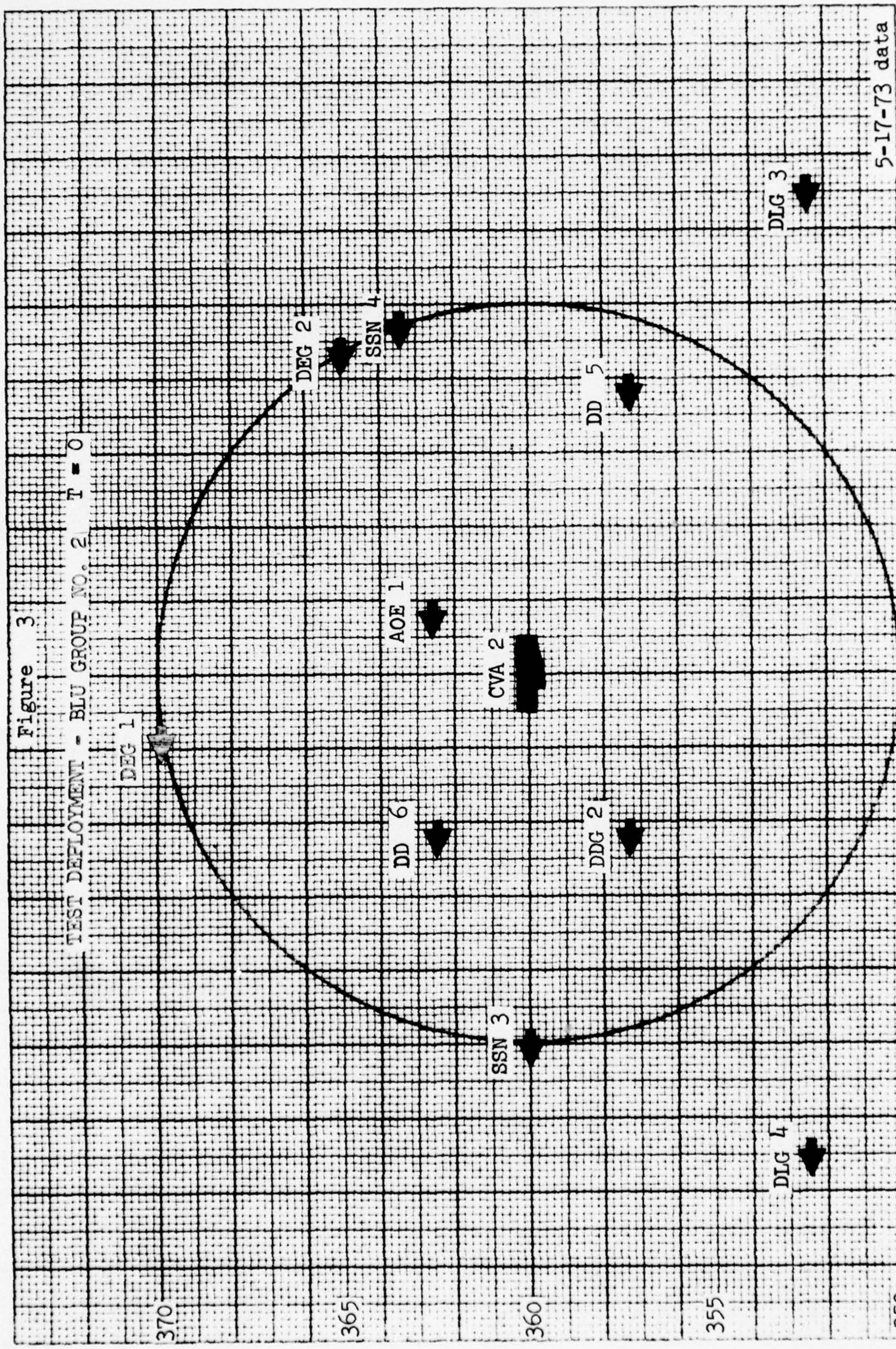


Figure 3
TEST DEPLOYMENT - BLU GROUP NO. 2 T = 0
DEG 1
DEG 2
SSN 4
DD 5
AOE 1
CVA 2
DD 6
DDG 2
SSN 3
DLG 3
DLG 4
5-17-73 data
370
365
360
355
350
990
995
1000
1005
1010

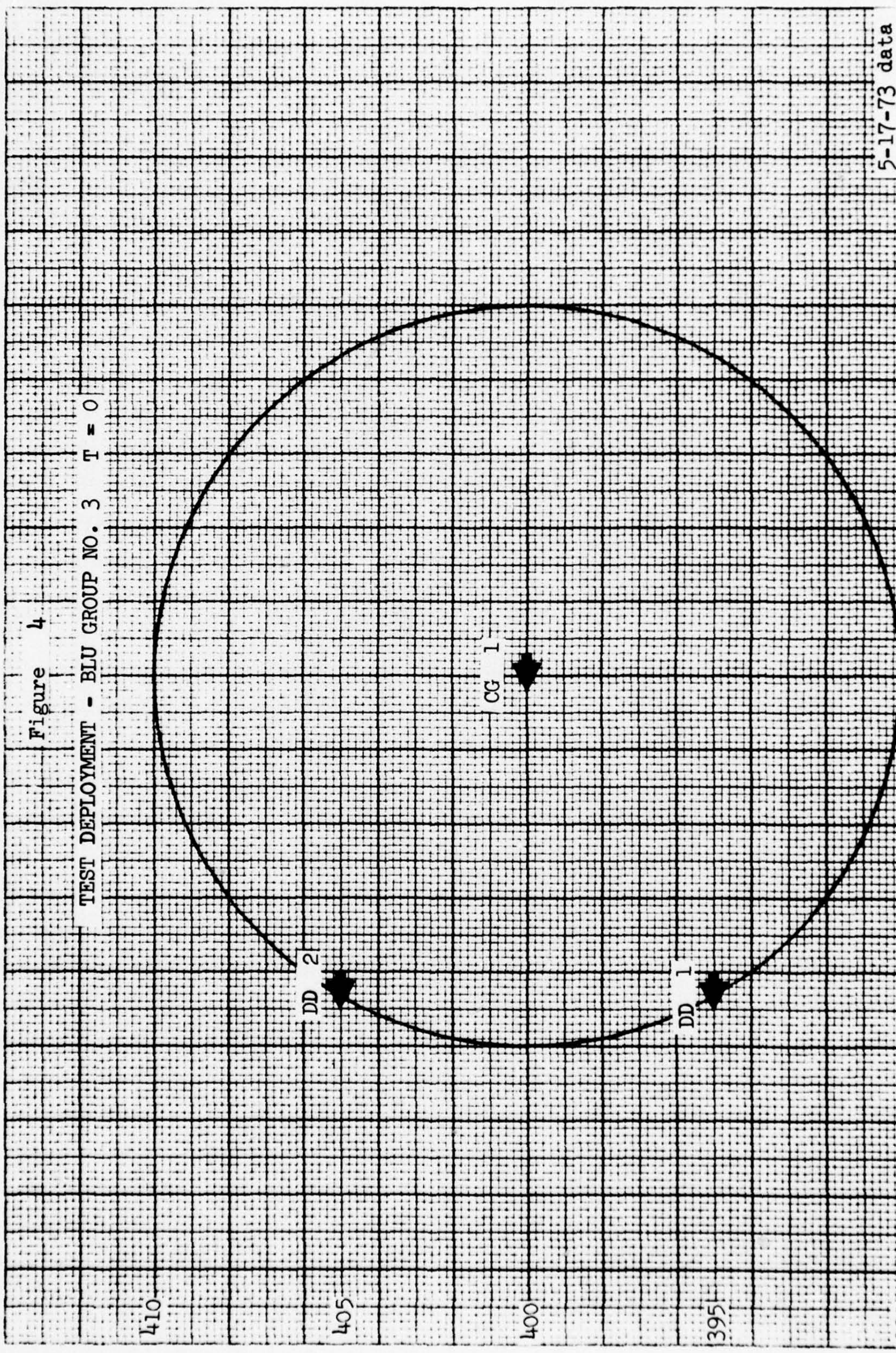


Figure 4
TEST DEPLOYMENT - BLU GROUP NO. 3 T = 0

RED groups 15 and 18 each have one BEAR aircraft to support the Echo Class submarines in groups 3 and 11, respectively.

RED groups 16 and 17 each have one BEAR aircraft to support the surface ships in groups 6 and 8, respectively.

The above details for RED Units are coded in Table numbers 0200 through 0218 and are discussed further in Section 4.

3.2 Planned Routes

Planned routes are User inputs in Tables 0100 for BLU groups and 0200 for RED groups. The routes for RED from T = -2 hours into the attack position at T = 0 hours is shown in Figure 5. In this example it is assumed that the RED aircraft and surface ships approach initially from the west, then at some four or more hours prior to T = 0 begin to deploy so as to approach the BLU Force from three sides, north, west, and south. The two Charlie Class submarines continue to trail the BLU Force, closing in from the fourth side.

The planned routes for RED from T = 0 hours to T = +1 hours is shown in Figure 6. It is assumed that whenever each RED group has launched its cruise missiles that it will break off its attack and rendezvous at a designated point some distance to the northwest. If, due to the random effects in the model, RED groups are delayed in making their attack, they will continue for a limited period of time to close on the designated objective, then if unable to engage will head for the rendezvous point. These latter are the routes shown in Figure 6.

The planned routes for BLU are not shown graphically, but are zig zag in a general westerly direction with a rendezvous point some distance to the southwest.

4.0 DATA PREPARATION AND TABLE STRUCTURE

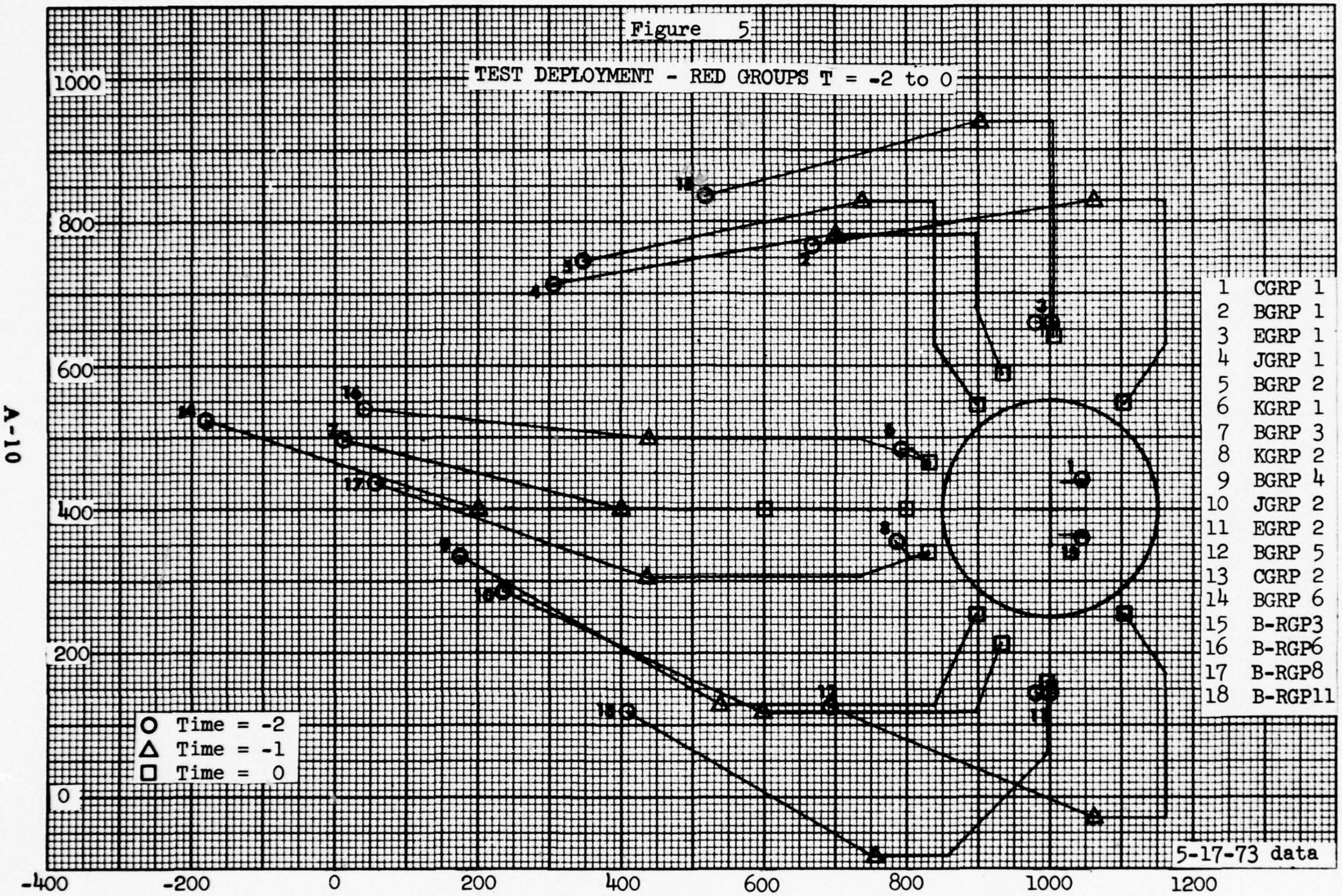
Detailed input format for all Basic Tables is given in Section III.2 of the Users manual. However, preparation of data for the engagement tables is given here.

4.1 Table Number 0001 - BLU and RED Groups

Table number 0001 shown in Figure 7 is essentially a list of BLU and RED group tables which are to be used, i.e., designates whether or not a group is in or out of the engagement. For example, the numbers 100., 101., ···, 115., appearing in the body of the table are treated as four digit table numbers with the leading zero omitted, and call for all 15 tables for the 15 BLU groups, plus the BLU routes in Table 0100. Similarly, the numbers 200., 201., ···, 218., call for the RED routes in Table 0200 and the 18 tables for the 18 RED groups.

Figure 5

TEST DEPLOYMENT - RED GROUPS T = -2 to 0



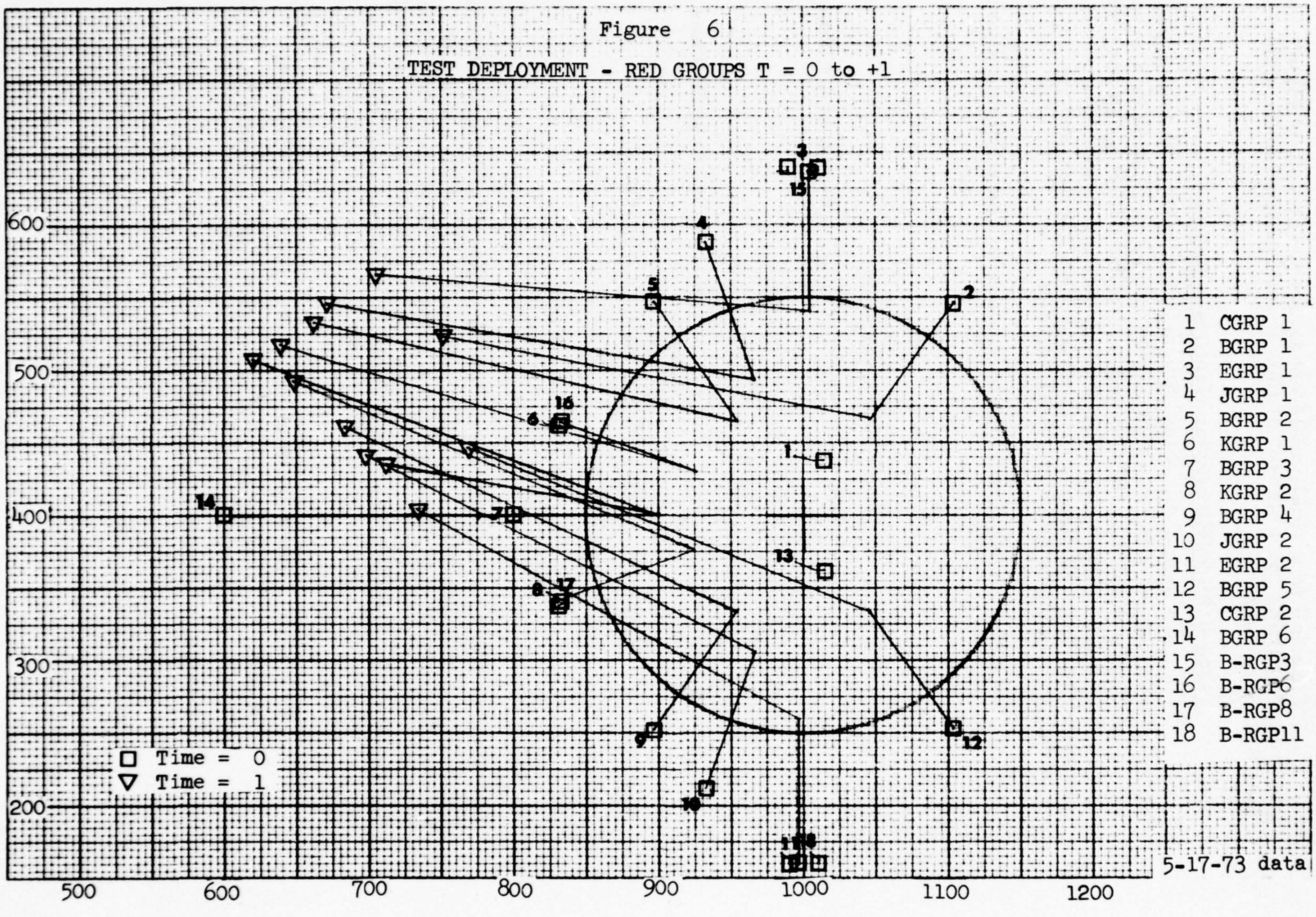


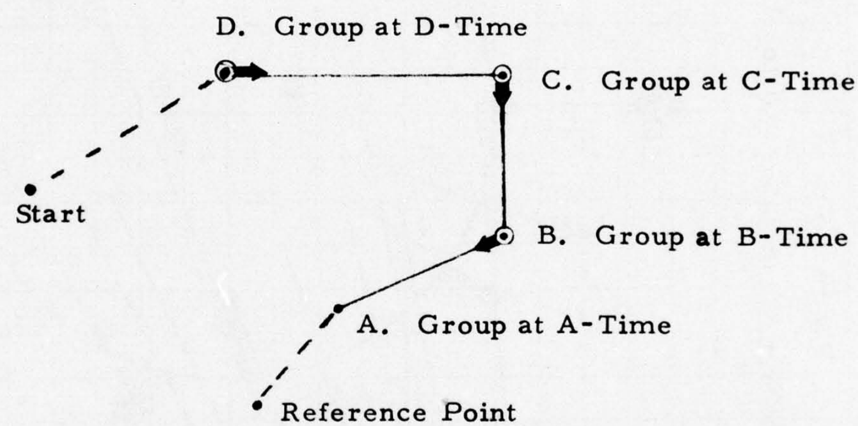
Figure 6
TEST DEPLOYMENT - RED GROUPS T = 0 to +1
1 CGRP 1
2 BGRP 1
3 EGRP 1
4 JGRP 1
5 BGRP 2
6 KGRP 1
7 BGRP 3
8 KGRP 2
9 BGRP 4
10 JGRP 2
11 EGRP 2
12 BGRP 5
13 CGRP 2
14 BGRP 6
15 B-RGP3
16 B-RGP6
17 B-RGP8
18 B-RGP11
Time = 0
Time = 1
5-17-73 data
600
500
400
300
200
500
600
700
800
900
1000
1100
1200

Figure 8 is a small scale engagement version of Figure 7, obtained by calling for a subset of the 15 BLU groups and a subset of the 18 RED groups.

4.2 Table 0100 - BLU Group Centers - Routes

Figure 9 shows the planned routes for the 15 BLU groups. There are 12 columns in the table and 15 rows, two cards to a row. Row 1 gives the details on BLU group 1, called BLGP 1, on through row 15 which gives the details for BLU group 15, called CAP 4. As mentioned earlier, BLU group 1 is an aircraft carrier and its escorts, and BLU group 15 is a CAP station.

To better understand Figure 9 consider the adjoining sketch.



The planned route is developed by locating Point A with respect to a reference (e.g., the BLU Force Center at T = 0). Point A is the planned position of a group at A-TIME, when A-TIME is usually the time of attack, T = 0 hours. The User then works backward in time to establish the previous route into Point A. This is done by specifying for each of the points B, C, and D the following data, e.g., for B:

- B-TIME. Hours decimal minutes, the time at Point B.
- B-VECT. Heading (degrees) decimal speed (knots) leaving point B.
- B-ALT. Altitude in KFT at Point B.

In Figure 9 the reference point in the BLU Force center is given at the bottom of the table as X-CENT = 1000, Y-CENT = 400, with HEADING 270, KNOTS = 20. Thus, Row 1, column 1 says that Point A is on a bearing of 0 degrees and a range of 40 NM from the reference point, and is at an altitude of 0. KFT. Column 3 is blank (read as a zero) and denotes that A-TIME = 0. B-TIME = -.30 denotes a time 30 minutes earlier, B-VECT = 270.020 denotes that the Heading and velocity leaving Point B is 270 degrees at 20 knots. Similarly, for Points C and D.

Also at the bottom of the table, STARTX = 1500 NM, STARTY = 400 NM denotes that the BLU group came generally from the east of its T = 0 position. RENDVX = 700 NM, RENDVY = 200 NM denotes that it will rendezvous to the southwest of its position at T = 0.

Note in card columns 17-20 the table column headed CODE. These are two level indentured codes. In Row 4 for example, CODE = 104 denotes BLU group 4 works with (belongs to) BLU group 1, i.e., that this AEW station is from Task group 1.

4.3 Tables 0101 through 0115 - BLU Units

Each group in BLU Table 0100 needs a table with a related table number to specify details on the units in the group. Figure 10 shows Table 0101 for the units in BLU group 1. There are 11 units, one per row. The unit type is a four digit indentured level code which is discussed in Appendix B. Unit 1 is called CVA 1 corresponding to the informal label shown for the aircraft carrier in Figure 2 above. The type code of 6113 shows the following: The first two digits "61" show it is a BLU ship. The third digit shows it is an aircraft carrier, and the fourth digit "3" shows which aircraft carrier. Table column 1 QTY shows the number of like units at this spot (e.g., aircraft in formation would show a quantity greater than 1). Table columns 2 and 3 show the range (NM) and relative bearing (degrees clockwise from the group velocity vector) of the unit(s) with respect to the group center. Column 4 VALUE shows the unit values established by the analysis in Volume IIC Appendix J. Columns 5 and 6 show the cruise velocity and maximum velocity, respectively.

Figure 10 also shows similar details on Tables 0104, 0105, and 0106 which are groups having single aircraft.

4.4 Table 0200 - RED Group Centers - Routes

Figure 11 shows the planned routes for the 18 RED groups. There are 12 columns in the table and 18 rows, two cards to a row. Row 1 gives the details on RED group 1 called CGRP 1, on through row 18 which gives the details for RED group 18, which is a BEAR aircraft working with the submarines in RED group 11.

The comments in Section 4.2 above apply here. Additional comments are:

(a) Altitudes for submarines are negative when submarines are submerged.

(b) The bearing and range for each group center (column 1) is from the reference point shown at the bottom of the table as X-CENT = 1000 NM, Y-CENT = 400 NM. Note that this is the same as the BLU Force center in Table 0100 but could be different.

(c) The starting point at STARTX = 400 NM and STARTY = 600 NM and the rendezvous point at RENDVX = 400 NM RENDVY = 600 NM shows the RED approach from and departure to the west.

4.5 Tables 0201 through 0218 - RED Units

Each group in RED Table 0200 needs a table with a related table number to specify details on the units in the group. Figure 12 shows Tables 0201, 0202, and 0203 as examples for RED groups 1, 2, and 3.

The comments in Section 4.3 above apply here. Additional comments are:

(a) Table 0201 shows 1 Charlie Class submarine, type 8341 in RED group 1.

(b) Table 0202 shows 2 BADGER aircraft with cruise missiles and 1 BADGER aircraft used as a jammer in RED group 2.

(c) Table 0203 shows 2 ECHO Class submarines type 8343 in RED group 3. One is at a range of 10 NM from the group center at a bearing of 90 degrees clockwise from the group velocity vector. The other is at a range of 10 NM and a bearing of 270 degrees.

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PROGRAM

ROUTINE

NAME

UNIT

EXT.

DATE

PAGE OF

Figure 7
ENGAGEMENT STRUCTURE - FULL SIZE

FORTRAN

IDENTIFICATION 5-17

LOCATION (1-7)	OPERATION A (8-10)	B (11-15)	ADDRESS, TAG, DECREMENT (16-20)	21-30	31-40	41-50	51-60	61-72	73-80
ZIP 7	1.1					READ BASIC TABLE			
TABLE	N∅.	0001	1		10010 10	ENGAGEMENT STRUCTURE			9-1-73
SEQ. ITEM			C∅DE	1. TAB	2. TAB	3. TAB	4. TAB	5. TAB	6. TAB
				7. TAB	8. TAB	9. TAB	0. TAB		
1. BLU	F∅RCE		100	100.	101.	102.	103.	104.	105.
1.				106.	107.	108.	109.		
2. BLU	F∅RCE		110	110.	111.	112.	113.	114.	115.
2.									
3. RED	F∅RCE		200	200.	201.	202.	203.	204.	205.
3.				206.	207.	208.	209.		
4. RED	F∅RCE		210	210.	211.	212.	213.	214.	215.
4.				216.	217.	218.			
-1									
T∅T.	BLU		16	T∅T. RED	19				
C∅NSTANT									

PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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PROGRAM | NAME
ROUTINE | UNIT | DATE
EXT. | PAGE OF

Figure 8
ENGAGEMENT STRUCTURE - SMALL

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Location (1-6)	7	Operation (8-15)	Address, Tag, Decrement (16-20)	21-30	31-40	41-50	51-60	61-72	Identification (73-80)
ZIP	7	1.1				READ BASIC	TABLE		
TABLE	NO.	0001			70011 1.2	ENGAGEMENT	STRUCTURE	(SMALL)	8-20-[illegible]
SEQ. ITEM			CODE	1.TAB	2.TAB	3.TAB	4.TAB	5.TAB	6.TAB
				7.TAB	8.TAB	9.TAB			
1.PLU		FORCE	100	100.	101.	104.	105.	108.	109.
1.			110						
2.RED		FORCE	200	200.	201.	202.	203.	204.	206.
2.			210	214.	215.	216.			
-1.									
TOT		PLU	6	TOT RED	9				
CONSTANT			0		0				

PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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PROGRAM

ROUTINE

Figure 9
PLANNED ROUTES - BLU

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NAME | UNIT | EXT. | DATE | PAGE OF

IDENTIFICATION 7-7

LOCATION	OPERATION	ADDRESS, TAG, DECREMENT (16–20)	21–30	31–40	41–50	51–60	61–72	IDENTIFICATION 73–80
ZIP 7	1.1				READ BASIC	TABLE		
TABLE NO.	0100			70010. 12	BLU GROUP	CENTERS		9-1-73
SEQ. ITEM		CODE	1. B & R.	2. ALT	3. A-TIME	4. B-TIME	5. B-VECT	6. B-ALT
			7. C-TIME	8. C-VECT	9. C-ALT	10. D-TIM	11. D-VEC	12. D-ALT
1. BLGP	1	1	0.040	0.0		-.30	270.020	0.0
1.		1	-1.0	300.020	0.0	-2.0	270.020	0.0
2. BLGP	2	2	180.040	0.0		-.30	270.020	0.0
2.		2	-1.0	300.020	0.0	-2.0	270.020	0.0
3. BLGP	3	3	270.030	0.0		-.30	270.020	0.0
3.		3	-1.0	300.020	0.0	-2.0	270.020	0.0
4. AEW	1	104	35.130	20.		-.30	270.020	20.
4.		104	-1.0	300.020	20.	-2.0	270.020	20.
5. AEW	2	105	325.130	20.		-.30	270.020	20.
5.		105	-1.0	300.020	20.	-2.0	270.020	20.
6. ASW	1	106	0.120	1.0		-.30	270.020	1.0
6.		106	-1.0	300.020	1.0	-2.0	270.020	1.0
7. ASW	2	107	290.120	1.0		-.30	270.020	1.0
7.		107	-1.0	300.020	1.0	-2.0	270.020	1.0
8. CAP	1	108	45.130	20.		-.30	270.020	20.
8.		108	-1.0	300.020	20.	-2.0	270.020	20.
9. CAP	2	109	315.130	20.		-.30	270.020	20.
9.		109	-1.0	300.020	20.	-2.0	270.020	20.

PAGE LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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Figure 9 (continued)

PROGRAM | ROUTINE | NAME | UNIT | EXT. | DATE | PAGE OF

IDENTIFICATION 7-7

LOCATION (PAGE SERIAL)	OPERATION	ADDRESS, TAG, DECREMENT (16-20)	21-30	31-40	41-50	51-60	61-72	IDENTIFICATION (73-80)
10.AE?	3	210	145.120	20.		-.30	270.020	20.
10.		210	-1.0	300.020	20.	-2.0	270.020	20.
11.AEW	4	211	215.130	20.		-.30	270.020	20.
11.		211	-1.0	300.020	20.	-2.0	270.020	20.
12.ASW	3	212	180.120	1.0		-.30	270.020	1.0
12.		212	-1.0	300.020	1.0	-2.0	270.020	1.0
13.ASW	4	213	250.120	1.0		-.30	270.020	1.0
13.		213	-1.0	300.020	1.0	-2.0	270.020	1.0
14.CAP	3	214	135.130	20.		-.30	270.020	20.
14.		214	-1.0	300.020	20.	-2.0	270.020	20.
15.CAP	4	215	225.130	20.		-.30	270.020	20.
15.		215	-1.0	300.020	20.	-2.0	270.020	20.
-1								
1. Y-CENT		1000	2. Y-CENT	400	3. HEADNG	270	4. KNØTS	20
5. STARTX		1500	6. STARTY	400	7. RENDVX	700	8. RENDVY	200

PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

PROGRAM
ROUTINE

NAME
UNIT
EXT.
DATE
PAGE OF

Figure 10

UNIT DEPLOYMENTS - BLU

LOCATION		OPERATION								IDENTIFICATION
ZIP	7	1 1					READ BASIC TABLE			
TABLE NO.		0101			70010 6	BLU GROUP 1				9-1-73
SEQ-ITEM			TYPE	1.QTY	2.RANGE	3.D-BRNG	4.VALUE	5.VCRUSE		6.VMAX
1.CVA	1		6113	1.0	0.0	0.0	400.	10.		30.
2.DDG	1		6154	1.0	5.0	30.0	40.	10.		30.
3.DD	4		6153	1.0	8.0	180.	20.	10.		30.
4.DD	3		6153	1.0	5.0	330.	20.	10.		30.
5.SSN	1		6321	1.0	10.0	0.0	40.	10.		30.
6.DLG	1		6155	1.0	15.0	390.	40.	10.		30.
7.DLG	2		6155	1.0	15.0	150.	40.	10.		30.
8.SSN	2		6321	1.0	10.0	200.	40.	10.		30.
9.VA	1		6221	1.0	0.0	0.0	2.	300.		460.
10.VG	1		6252	1.0	0.0	0.0	2.	300.		515.
11.VF	1		6212	1.0	0.0	0.0	2.	300.		600.
-1										
CONSTANT										
CONSTANT										

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Figure 10 (continued)

PROGRAM | ROUTINE | NAME | UNIT | EXT. | DATE | PAGE OF

FORTRAN STATEMENT | LOCATION | OPERATION | ADDRESS, TAG, DECREMENT | FORTRAN | MAP | COBOL | IDENTIFICATION

```
ZIP  7  1.1                                     READ BASIC TABLE
TABLE NØ.    01.04              7001D     6     BLU GROUP 4                               9-1-73
SEQ.ITEM          TYPE    1.QTY     2.RANGE     3.D-BRNG    4.VALUE    5.VCRUSE    6.VMAX
 1.AEW  1         6242    1.0       0.0         0.0         2.         200.        300.
-1
 CØNSTANT
 CØNSTANT

ZIP  7  1.1                                     READ BASIC TABLE
TABLE NØ.    01.05              7001D     6     BLU GROUP 5                               9-1-73
SEQ.ITEM          TYPE    1.QTY     2.RANGE     3.D-BRNG    4.VALUE    5.VCRUSE    6.VMAX
 1.AEW  2         6242    1.0       0.0         0.0         2.         200.        300.
-1
 CØNSTANT
 CØNSTANT

ZIP  7  1.1
TABLE NØ.    01.06              7001.0    6     BLU GRØUP 6                               9-1-73
SEQ.ITEM          TYPE    1.QTY     2.RANGE     3.D-BRNG    4.VALUE    5.VCRUSE    6.VMAX
 1.ASW  1         6231    1.0       0.0         0.0         1.         150.        200.
-1
 CØNSTANT
 CØNSTANT
```

PAGE LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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90 COLUMN CODING AND DATA FORM 0-42797

PROGRAM

ROUTINE

NAME

UNIT | DATE

EXT. | PAGE | OF

Figure 11
PLANNED ROUTES - RED

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LOCATION (PAGE SERIAL)	OPERATION	ADDRESS, TAG, DECREMENT (16-20)	21-30	31-40	41-50	51-60	61-70 (FORTRAN / MAP / COBOL)	IDENTIFICATION 7-7
[illegible]P. 7 1.1					READ BASIC	TAPLE		
TABLE NO.	0300			70210 12	RED GROUP	CENTERS		9-1-73
SEQ. IDEN.		CODE	1. R & R.	2. ALT.	3. A-TIME	4. B-TIME	5. B-VECT	6. B-ALT
			7. C-TIME	8. C-VECT	9. C-ALT	10. D-TIM	11. D-VEC	12. D-ALT
1. CGRP. 1		1	20.040	-.06		-.15	270.020	-.06
1.		1	-1.15	270.030	-.3	-1.30	180.010	-.06
2. B[illegible]RP. 1		2	35.180	25.		-.15	215.400	3.
2.		2	-.45	180.400	3.	-1.0	90.400	25.
3. EGRP. 1		3	0.240	-.06		-.15	180.010	-.06
3.		3	-.45	180.030	-.3	-1.0	180.010	-.06
4. JGRP. 1		4	340.200	25.		-.15	160.400	25.
4.		4	-.30	180.400	3.	-1.0	90.400	3.
5. BGRP. 2		5	325.180	25.		-.15	145.100	3.
5.		5	-.45	180.400	3.	-1.0	90.400	25.
6. KGRP. 1		6	290.180	0.0		-.15	110.030	0.0
6.		6	-1.15	135.030	0.0	-3.0	90.030	0.0
7. BGRP. 3		7	270.200	25.		-.15	90.400	25.
7.		7	-.45	90.400	25.	-1.0	90.400	25.
8. KGRP. 2		8	250.180	0.0		-.30	90.030	0.0
8.		8	-1.00	90.030	0.0	-3.0	135.030	0.0
9. BG-P A		9	215.180	25.		-.15	35.400	3.
9.		9	-.45	90.400	3.	-1.0	90.400	25.

PAGE LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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80 COLUMN CODING AND DATA FORM 0-43797

PROGRAM

ROUTINE

Figure 11 (continued)

NAME

UNIT | DATE

EXT. | PAGE OF

FORTRAN STATEMENT — FORTRAN — IDENTIFICATION

MAP — 7-7

COBOL

LOCATION (PAGE, SERIAL)	OPERATION	ADDRESS, TAG, DECREMENT (16-20)	21-30	31-40	41-50	51-60	61-70	IDENTIFICATION (73-80)
10. JGRP. 2		10	200.200	25.		-.15	20.400	3.
10.		10	-.45	90.400	3.	-1.0	90.400	25.
11. EGRP. 2		11	180.240	-.06		-.15	0.010	-.06
11.		11	-.45	0.030	-.3	-1.0	90.010	-.06
12. BGRP. 5		12	145.180	25.		-.15	325.400	3.
12.		12	-.45	0.400	3.	-1.0	90.400	25.
13. CGRP. 2		13	160.040	-.06		-.15	270.020	-.06
13.		13	-1.15	270.030	-.3	-1.30	0.010	-.06
14. BGRP. 6		14	270.200	25.	0.30	-.15	90.400	25.
14.		14	-.45	90.400	25.	-1.0	90.400	25.
15. B-RGP3		315	1.240	25.		-.15	180.400	3.
15.		15	-.45	180.400	3.	-1.0	90.400	25.
16. B-RGP.6		616	291.180	25.		-.15	112.400	3.
16.		16	-.45	90.400	3.	-1.0	90.400	25.
17. E-HGP8		817	251.180	25.		-.15	70.400	3.
17.		17	-.45	90.400	3.	-1.0	90.400	25.
18. B-RGP.11		1118	181.240	25.		-.15	0.400	3.
18.		18	-.45	45.400	3.	-1.0	90.400	25.
1								
1. X-CENT		1000	2. Y-CENT	400	3. HEADNG	270	4. KNOTS	20
5. STARTX		-400	6. STARTY	400	7. ENDVX	400	8. RENDVY	400

PAGE | LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

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80 COLUMN CODING AND DATA FORM 0-63797

PROGRAM

ROUTINE

NAME | UNIT | EXT. | DATE | PAGE | OF

Figure 12
UNIT DEPLOYMENT - RED

LOCATION (PAGE / SERIAL)	OPERATION	ADDRESS, TAG, DECREMENT (16-20)	21-30	31-40	41-50	51-60	61-72	IDENTIFICATION (73-80)
ZIP 7	1.1				READ BASIC TABLE			
TABLE NO.	0201			7001.0 6	RED GROUP 1			9-1-73
SEQ.ITEM		TYPE	1.QTY	2.RANGE	3.D-BRNG	4.VALUE	5.VCRUISE	6.VMAX
1.SSC 1		8241	1.0	0.0	0.0	40.	15.	30.
-1								
CONSTANT								
CONSTANT								
ZIP 7	1.1				READ BASIC TABLE			
TABLE NO.	0202			7001.0 6	RED GROUP 2			9-1-73
SEQ.ITEM		TYPE	1.QTY	2.RANGE	3.D-BRNG	4.VALUE	5.VCRUISE	6.VMAX
1.BGGM 1		8227	2.0	0.0	0.0	4.	400.	400.
2.BGGJ 1		8243	1.0	0.0	0.0	3.	400.	400.
-1								
CONSTANT								
CONSTANT								
ZIP 7	1.1				READ BASIC TABLE			
TABLE NO.	0203			7001.0 6	RED GROUP 3			9-1-73
SEQ.ITEM		TYPE	1.QTY	2.RANGE	3.D-BRNG	4.VALUE	5.VCRUISE	6.VMAX
1.SSE 1		8343	1.0	10.0	90.0	40.	15.	30.
2.SSE 2		8343	1.0	10.0	270.	40.	15.	30.
-1								
CONSTANT								
CONSTANT								

PAGE LINE | LABEL | OPERATION | OPERAND | AUTOCODER | IDENTIFICATION

APPENDIX B

DATA STRUCTURE - SYSTEMS CATALOG

TITLE	Appendix B
DATA STRUCTURE - SYSTEMS CATALOG	NO.
	DATE

Page No.

1. Introduction B-3
2. Basic Table Codes B-3
3. Description B-3
4. Expansion or Update B-3

PREPARED BY L.D. Gregory

APPROVED BY (LDG)

PAGE B-1 OF B-26

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APPENDIX B

DATA STRUCTURE - SYSTEMS CATALOG

1. INTRODUCTION

The purpose of this appendix is to define the numerical codes used on each of the BLU and RED sides in the Naval Engagement Model (NEM) to identify platforms, systems, and sub-systems by types having common characteristics.

Figure 1 shows the 17 types defined in parallel fashion for each side. Types 61 thru 79 are BLU systems, and types 81 thru 99 are RED systems. None of these types or type numbers can be changed by the User without significant changes to the FORTRAN programming of the NEM. However, the flexibility needed by the User for expansion and/or update of systems data is provided in the next level of the type code as shown in Figure 2. This is discussed more later on.

2. BASIC TABLE CODES

Systems data is input in Basic Table format as shown in section III of Volume IIA Users Manual. The identification codes for these tables are directly related to the type codes in Figure 2. For example, Table 6110 (with its 5 extents) contains the systems data on BLU ships having type codes from 6111 thru 6119. A complete list of basic tables required is in the Users Manual cited above.

3. DESCRIPTION

Figure 2 contains the detail system codes for all categories shown in Figure 1. The format shows in indentured code the particular systems in that category, giving an informal short name and/or numerical designation. For example, type 61.13* is an aircraft carrier, informally designated here as CVA-1 but having hull number 59 in the U.S. Navy. A column is reserved for data date. An entry in this column means that there is a complete set of data for that system now in the system catalog. No entry, means that there is no data or that the data is incomplete or unverified. These entries are shown here to help make clear what kind of system belongs in each category.

4. EXPANSION OR UPDATE

Updating and maintaining basic tables on the computer files is discussed in the Users Manual. However, the content of those files and the rules they must follow are discussed below:

a. Except where obvious by present usage, there is a maximum of 9 system types in any one category. For example, in category 61.10 CARRIERS there are already entries for 7 of the 9 slots available. Two of these 7 slots have complete data in the catalog as of 9-1-73. The others are available for new systems. An exception is category 65.20 which is merely a continuation of 65.10 SHIP SEARCH RADAR (Also 85.20). This allows a maximum of 9+9= 18 types in this category.

* Type codes are shown here as indentured codes with a decimal separating the two levels. In other contexts they appear as 4 digit integers without the decimal.

b. Obsolete systems may be dropped and their type code used for a new system if desired. Care should be taken to replace all old data with the new.

c. All data is subject to update by replacement within the format rules stated in the Users Manual. A place is provided on the table title card to show the date of the update.

d. Certain distinctions are necessary. For example, type 82.22 is a BEAR B aircraft which is a missile carrier while 82.41 is a BEAR B aircraft used as a jammer. Type 72.12 is a ship launched MK44 torpedo and type 72.14 is an air launched MK44 torpedo.

e. If an actual radar is used first as a search radar and then as a track radar, it must be entered as two radars, once under each category.

f. In category 87.50 MIDCOURSE GUIDANCE actual systems must be fitted into one of the five types shown.

g. In category 73.10 and 93.10 helicopters with ASW functions are listed as weapons with characteristics like torpedoes or ASW projectors depending on which they carry.

h. Nuclear warheads are permitted only on anti-ship weapons (e.g., SUBROC, Cruise Missiles).

i. A distinction is made between a large air-to-surface missile such as the RED cruise missiles in category 98.10 and small air-to-surface missiles such as BULL PUP in category 78.40, where the latter is not subject to being intercepted. (Bombs in categories 78.30 and 98.30 are likewise not subject to being intercepted.)

j. Not all categories of systems shown in the catalog are modeled in the NEM at this time. However, space has been reserved for some likely candidates and empty slots remain for yet others.

FIGURE 1

INDEX TO SYSTEMS CATALOG

BLU CATALOG		RED CATALOG	
CODE	ITEM	CODE	ITEM
60.	RESERVED	80.	RESERVED
61.	SHIPS	81.	SHIPS
62.	AIRCRAFT	82.	AIRCRAFT
63.	SUBMARINES	83.	SUBMARINES
64.		84.	
65.	ACT. SENSORS	85.	ACT. SENSORS
66.	PASS. SENSRS	86.	PASS. SENSRS
67.	FIRE CONTROL	87.	FIRE CONTROL
68.	CM/CCM	88.	CM/CCM
69.	CCC,NTDS	89.	CCC,NTDS
70.	RESERVED	90.	RESERVED
71.	S-S GUNS	91.	S-S GUNS
72.	TORPEDOES	92.	TORPEDOES
73.	ASW WEAPONS	93.	ASW WEAPONS
74.	ASW ROCKETS	94.	ASW ROCKETS
75.	ANTI-AIR GUN	95.	ANTI-AIR GUN
76.	S-S MISSILES	96.	S-S MISSILES
77.	S-A MISSILES	97.	S-A MISSILES
78.	A-S MISSILES	98.	A-S MISSILES
79.	AA MISS,GUNS	99.	AA MISS,GUNS

FIGURE 2

DATA STRUCTURE - SYSTEMS CATALOG

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
61.	SHIPS		81.	SHIPS	
61.10	CARRIERS		81.10	CARRIERS	
.11	CV -1		.11	CHG-MOSKVA	
.12	CV -2		.12		
.13	CVA-1 59	9- 1-73	.13		
.14	CVA-2 63	9- 1-73	.14		
.15	CVA-3 67		.15		
.16	CVAN-1 65		.16		
.17	CVAN-2 68		.17		
.18			.18		
.19			.19		
61.20	AUXILIARIES		81.20	AUXILIARIES	
.21	AOE-1 1	9- 1-73	.21		
.22			.22		
.23			.23		
.24			.24		
61.30	CRUISERS		81.30	CRUISERS	
.31	CA -1 139		.31	OCA-1 KIROV	
.32	CG -1 10	9- 1-73	.32		
.33			.33		
.34	CLG-1 4		.34	CLG-1 DZERZ	
.35			.35	CLGM-1 KYNDA	9- 1-73
.36			.36	CLGM-2 KR I	
.37	CGN-1 9		.37	CLGM-3 KR II	9- 1-73
.38			.38		
.39			.39		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
61.	SHIPS(CONT.)		81.	SHIPS(CONT.)	
61.50	DESTROYERS		81.50	DESTROYERS	
.51	DE-1 1052	9- 1-73	.51		
.52	DEG-1 1	9- 1-73	.52		
.53	DD-1 945M	9- 1-73	.53		
.54	DDG-1 2	9- 1-73	.54	DLG-1 KASHIN	9- 1-73
.55	DLG-1 16	9- 1-73	.55		
.56	DLG-2 26	9- 1-73	.56	DDGS KILDIN	
.57	DDGN-1		.57	DDGSP KRIVAK	
.58	DLGN-1 35	9- 1-73	.58		
.59	DLGN-2 36	9- 1-73	.59		
61.60	PATROL		81.60	PATROL	
.61			.61		
.62			.62	PTFG OSA	
.63			.63	PTG KOMAR	
.64			.64		
.65			.65		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG			DATA	RED CATALOG		DATA
CODE	ITEM		DATE	CODE	ITEM	DATE
62.	AIRCRAFT			82.	AIRCRAFT	
62.10	FIGHTERS			82.10	FIGHTERS	
.11	VF-1	F4-B		.11		
.12	VF-2	F8-H	9- 1-73	.12		
.13	VF-3	F14		.13		
.14				.14		
.15				.15		
.16				.16		
.17				.17		
.18				.18		
.19				.19		
62.20	ATTACK			82.20	ANTI-SHIP -M	
.21	VA-1	A6-A	9- 1-73	.21		
.22				.22	BEAR-B 1-AS3	9- 1-73
.23	VA-3	A7-E	9- 1-73	.23		
.24				.24		
.25				.25		
.26				.26	BADG-C 1-AS2	9- 1-73
.27				.27	BADG-G 2-AS5	9- 1-73
.28				.28	BADG-G 2-AS6	9- 1-73
.29				.29		
62.30	ASW			82.30	ASW	
.31	VS-1	S2-D	9- 1-73	.31		
.32	VS-2	S3		.32		
.33				.33		
.34				.34		
.35				.35		
.36				.36		
.37				.37		
.38				.38		
.39				.39		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
62.	AIRCRAFT(CONT)		82.	AIRCRAFT(CONT)	
62.40	AEW & CCC		82.40	AEW & CCC	
.41			.41	BEAR-B JAM	9- 1-73
.42	VW-2 E2-C	9- 1-73	.42	BEAR-D GUID	9- 1-73
.43			.43	BADG-H,J JAM	9- 1-73
.44			.44		
.45			.45		
.46			.46		
.47			.47		
.48			.48		
.49			.49		
62.50	CM & CCM		82.50		
.51			.51		
.52	VQ-2 EA6-A	9- 1-73	.52		
.53			.53		
.54			.54		
.55			.55		
.56			.56		
.57			.57		
.58			.58		
.59			.59		
62.60	HELICOPTERS		82.60	HELICOPTERS	
.61			.61		
.62			.62		
.63			.63		
.64			.64		
.65			.65		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG			DATA
CODE	ITEM	DATE	CODE	ITEM		DATE
63.	SUBMARINES		83.	SUBMARINES		
63.10	ATTACK		83.10	ATTACK		
.11	SS-GUPPY III	9- 1-73	.11	SS-	B	
.12	SS-TANG	9- 1-73	.12	SS-	F	
.13	SS-SAILFISH	9- 1-73	.13	SS-	Q	
.14	SS-BARBEL	9- 1-73	.14	SS-	R	
.15			.15	SS-	W	
.16			.16	SS-	Z	
.17			.17			
.18			.18			
.19			.19			
63.20	ATTACK-NUCL		83.20			
.21	SSN-NAUTILUS	9- 1-73	.21	SSN-1	V	
.22	SSN-SEAWOLF	9- 1-73	.22	SSN-2	N	
.23	SSN-SKATE	9- 1-73	.23			
.24	SSN-SKPJACK	9- 1-73	.24			
.25	SSN-PERMIT	9- 1-73	.25			
.26	SSN-TULUIBEE	9- 1-73	.26			
.27	SSN-STURGEON	9- 1-73	.27			
.28	SSN-NARWHAL	9- 1-73	.28			
.29			.29			

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
63.	SUBMARINES(CONT)		83.	SUBMARINES(CONT)	
63.30	GUIDED MISSILE		83.30	GUIDED MISSILE	
.31	SSG-1		.31	SSG-1 J	9- 1-73
.32			.32	SSG-2 W-TWIN	
.33			.33	SSG-3 W-LONG	
.34			.34	SSG-4 W-S	
.35			.35		
.36			.36		
.37			.37		
.38			.38		
.39			.39		
63.40	SSGN(NUCLEAR)		83.40	SSGN(NUCLEAR)	
.41	SSGN-1		.41	SSGN-1 C	9- 1-73
.42			.42	SSGN-2 E-I	
.43			.43	SSGN-3 E-II	9- 1-73
.44			.44	SSGN-4 P	
.45			.45		
.46			.46		
.47			.47		
.48			.48		
.49			.49		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
65.	ACTIVE SENSORS		85.	ACTIVE SENSORS	
65.10	SHIP SEARCH RADAR		85.10	SHIP SEARCH RADAR	
.11			.11	TOP SAIL	9- 1-73
.12			.12	HEAD NET C	9- 1-73
.13			.13		
.14	SPS-10F	9- 1-73	.14	BIG NET	9- 1-73
.15			.15		
.16	SPS-29E	9- 1-73	.16		
.17	SPS-30	9- 1-73	.17		
.18			.18		
.19			.19		
65.20	(CONTINUED)		85.20	(CONTINUED)	
.21			.21		
.22	SPS-39A	9- 1-73	.22		
.23	SPS-40	9- 1-73	.23		
.24	SPS-43A	9- 1-73	.24		
.25	SPS-48V	9- 1-73	.25		
.26			.26		
.27	SPS-52		.27		
.28			.28		
.29			.29		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
65.	ACTIVE SENSORS(CONT)		85.	ACTIVE SENSORS(CONT)	
65.30	SHIP SONAR		85.30	SHIP SONAR	
.31			.31		
.32	SQS-23	9- 1-73	.32	15-23 KHZ	9- 1-73
.33			.33	PEGAS 2-M	9- 1-73
.34			.34	TAMIR 5-M	
.35	SQS-26	9- 1-73	.35	HERCULES	9- 1-73
.36			.36	TAMIR 11M	
.37			.37	KEEL 8MHZ	9- 1-73
.38			.38		
.39			.39		
65.40	SUB SEARCH RADAR		85.40	SUB SEARCH RADAR	
.41			.41	SNOOP TRAY	
.42			.42	SNOOP PLATE	
.43	BPS-1	9- 1-73	.43	SNOOP SLAB	
.44			.44	BOAT SAIL	
.45			.45		
.46			.46		
.47			.47		
.48			.48		
.49			.49		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLUE CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
65.	ACTIVE SENSORS(CONT)		85.	ACTIVE SENSORS(cont)	
65.50	SUB SONAR		85.50	SUB SONAR	
.51	SQS-4	9- 1-73	.51	3.25 KHZ	9- 1-73
.52			.52	HERCULES	9- 1-73
.53	BQR-2	9- 1-73	.53	FEZ	9- 1-73
.54	BQR-4	9- 1-73	.54	7.2 KHZ	9- 1-73
.55			.55	FENIKS	
.56			.56	TAMIR 5LS	
.57			.57	MARS	
.58			.58		
.59			.59		
65.60	RESERVED		85.60	RESERVED	
.61			.61		
.62			.62		
.63			.63		
.64			.64		
.65			.65		
.66			.66		
.67			.67		
.68			.68		
.69			.69		
65.70	A/C, RDRSCH		85.70	A/C, RDRSCH	
.71	APS-96 AEW	9- 1-73	.71	CROWN DRUM	9- 1-73
.72			.72		
.73			.73		
.74			.74	PUFF BALL	9- 1-73
.75			.75		
.76			.76	SHORT HORN	9- 1-73
.77			.77	BIG BULGE	9- 1-73
.78			.78		
.79			.79		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
66.	PASSIVE SENSORS		86.	PASSIVE SENSORS	
66.10	WARNING RECEIVERS		86.10	WARNING RECEIVERS	
.11	WLR-1		.11	SIREN A -2	
.12	WLR-1F		.12		
.13	WLR-1E		.13		
.14	WLR-3		.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
66.20	PASSIVE SONAR		86.20	PASSIVE SONAR	
.21			.21		
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
67.	FIRE CONTROL		87.	FIRE CONTROL	
67.10	SHIP-SAM		87.10	SHIP-SAM	
.11	SPG TALOS	9- 1-73	.11	PEEL GROUP	9- 1-73
.12	SPG TARTAR	9- 1-73	.12	FAN SONG E	9- 1-73
.13	SPG- TERRIER	9- 1-73	.13	HEAD LIGHTS	9- 1-73
.14	BPDSMS	9- 1-73	.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
67.20	SHIP-SSM		87.20	SHIP-SSM	
.21			.21	TOP BOW	
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		
67.30	A/C AIR-AIR		87.30	A/C AIR-AIR	
.31			.31		
.32			.32		
.33			.33		
.34			.34		
.35			.35		
.36			.36		
.37			.37		
.38			.38		
.39			.39		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
67.	FIRE CONTROL(CONT)		87.	FIRE CONTROL(CONT)	
67.40	MSL HOMING		87.40	MSL HOMING	
.41			.41	T-1044 AS2,6	9- 1-73
.42			.42	A358Z AS-5	9- 1-73
.43			.43		
.44			.44		
.45			.45	T8839 SS-N-7	9- 1-73
.46			.46	T1030 SSN-3K	9- 1-73
.47			.47		
.48			.48	T5557 SSN-10	9- 1-73
.49			.49		
67.50	MID-COURSE GUID		87.50	MID-COURSE GUID	
.51			.51	AUTOPILOT + TC	
.52			.52	DOPPLER + TC	
.53			.53	INERTIAL + TC	
.54			.54	INERTIAL ONLY	
.55			.55	ANY + VIDEO	
.56			.56		
.57			.57		
.58			.58		
.59			.59		
67.60			87.60		
.61			.61		
.62			.62		
.63			.63		
.64			.64		
.65			.65		
.66			.66		
.67			.67		
.68			.68		
.69			.69		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
68.	CM/CCM		88.	CM/CCM	
68.10	RESERVED		88.10	RESERVED	
.11	SLQ-26	9- 1-73	.11	VSD 1-A	9- 1-73
.12	ULQ-6		.12	VSD 1-B	9- 1-73
.13	ULQ-6C		.13		
.14	ULQ-6B	9- 1-73	.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19	STOP LIGHT	
68.20	RESERVED		88.20	RESERVED	
.21	CHAFF		.21	CHAFF	
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		
68.30	A/C - CM/CCM		88.30	A/C - CM/CCM	
.31			.31	A306Z	
.32			.32		
.33			.33		
.34			.34		
.35			.35		
.36			.36		
.37			.37		
.38			.38		
.39			.39		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
69.	CCC		89.	CCC	
69.10	RESERVED		89.10	RESERVED	
69.11	NTDS/WDS		.11		
.12			.12		
.13	LINK 11		.13		
.14	LINK 14		.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
70.	RESERVED		90.	RESERVED	
71.	S-S GUNS		91.	S-S GUNS	
71.10	RESERVED		91.10	RESERVED	
.11	8 INCH/55		.11		
.12			.12		
.13			.13		
.14			.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
72.	TORPEDOES		92.	TORPEDOES	
72.10	RESERVED		92.10	RESERVED	
.11	MK-37		.11	ET-80A	9- 1-73
.12	MK-44	9- 1-73	.12	E40-63A	
.13	MK-43	9- 1-73	.13		
.14	MK-44 AIR L.		.14	AIR LAUNCHED	
.15	MK-43 AIR L.	9- 1-73	.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
73.	ASW WEAPONS		93.	ASW WEAPONS	
73.10	RESERVED		93.10	RESERVED	
.11	LAMPS		.11	HORMONE	9- 1-73
.12	ASW PROJ.	9- 1-73	.12		
.13			.13		
.14			.14		
.15			.15		
.16			.16	MBU-2500A	9- 1-73
.17			.17	MBU-4500A	9- 1-73

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
74.	ASW ROCKETS		94.	ASW ROCKETS	
74.10	RESERVED		94.10	RESERVED	
.11	ASROC	9- 1-73	.11	FRAS	
.12	SUBROC		.12		
.13			.13		
.14			.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
75.	A-A GUNS		95.	A-A GUNS	
75.10	RESERVED		95.10	RESERVED	
.11	3 INCH/50	9- 1-73	.11	180/57	
.12	5 INCH/38	9- 1-73	.12	152/57	
.13	5 INCH/54	9- 1-73	.13		
.14	6 INCH/47		.14		
.15			.15		
.16			.16		
.17			.17	3.35"/52	9- 1-73
.18			.18		
.19			.19	57/70	9- 1-73
75.20	(CONTINUED)		75.20	(CONTINUED)	
.21			.21	45/85	
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
76.	S-S MISSILES		96.	S-S MISSILES	
76.10	RESERVED		96.10	RESERVED	
.11			.11		
.12			.12		
.13			.13	SS-N-3K	9- 1-73
.14			.14	SS-N-7	9- 1-73
.15			.15		
.16			.16	SS-N-10	9- 1-73
.17			.17		
.18			.18		
.19			.19	SS-N-3S	9- 1-73
77.	S-A MISSILES		97.	S-A MISSILES	
77.10	RESERVED		97.10	RESERVED	
.11	TARTAR	9- 1-73	.11	SAN1	9- 1-73
.12	TERRIER	9- 1-73	.12	SAN2	
.13	TALOS	9- 1-73	.13	SAN3	9- 1-73
.14	BPDMS	9- 1-73	.14	SAN4	
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
78.	A-S MISSILES		98.	A-S MISSILES	
78.10	RESERVED		98.10	RESERVED	
.11			.11		
.12			.12	AS-2	9- 1-73
.13			.13	AS-3	
.14			.14		
.15			.15	AS-5	9- 1-73
.16			.16	AS-6	9- 1-73
.17			.17		
.18			.18		
.19			.19		
78.20	RESERVED		98.20	RESERVED	
.21			.21		
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		
78.30	BOMBS		98.30	BOMBS	
.31			.31		
.32	MK-82 A-7		.32		
.33			.33		
.34			.34		
.35			.35		
.36			.36		
.37			.37		
.38			.38		
.39			.39		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
78.40	SMALL ASM		98.40	SMALL ASM	
.41	BULLPUP A		.41		
.42	BULLPUP B	9- 1-73	.42		
.43			.43		
.44			.44		
.45			.45		
.46			.46		
.47			.47		
.48			.48		
.49			.49		

FIGURE 2 (continued)

DATA STRUCTURE - SYSTEMS CATALOG (cont'd)

BLU CATALOG		DATA	RED CATALOG		DATA
CODE	ITEM	DATE	CODE	ITEM	DATE
79.	A-A MISSILES,GUNS		99.	A-A MISSILES,GUNS	
79.10	A-A MISSILES		99.10	A-A MISSILES	
.11			.11		
.12	SIDEWINDER	9- 1-73	.12		
.13			.13		
.14			.14		
.15			.15		
.16			.16		
.17			.17		
.18			.18		
.19			.19		
79.20	A-A GUNS		99.20	A-A GUNS	
.21	MK-12		.21		
.22			.22		
.23			.23		
.24			.24		
.25			.25		
.26			.26		
.27			.27		
.28			.28		
.29			.29		

APPENDIX C

RADAR COMPUTER PROGRAM METHODOLOGY

UNCLASSIFIED

VOUGHT SYSTEMS DIVISION
LTV AEROSPACE CORPORATION

TITLE	
RADAR COMPUTER PROGRAM METHODOLOGY	Appendix C NO. DATE

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PREPARED BY A. C. Morris

APPROVED BY [signature]

UNCLASSIFIED

I. INTRODUCTION

(U) The radar computer program was developed to provide the radar performance data required in the Naval Engagement Model (NEM) of the SEATIDE process. The program computes the performance of ship based and airborne search and fire control radars against appropriate targets in the presence of clutter and jamming. The effects of attenuation on fan beam radars due to rain and the effects of multipath due to surface reflections are included in the program.

(U) The program uses the multipath and probability of detection methodology described by L. V. Blake in NRL Report No. 6930 (Reference 1) and the basic equations for radar performance described by M. I. Skolnik (Reference 2).

II. PROGRAM INPUT AND OUTPUT

(U) Tables I and II define the required inputs and expected outputs of the radar program. The inputs shown include both the characteristics of the radar and expected jammers. A program flow diagram is shown in Table III.

(U) The inputs and outputs shown here are for the radar program as run in the stand alone version. The inputs and outputs for the radar program as integrated into the Naval Engagement Model are in the NEM Users Manual.

TABLE I
RADAR INPUT PARAMETER DEFINITIONS

Variable	Definition	Sample Data
AK20	Descent constant, sine of descent angle (ratio of altitude/slant range)	0.
ALPHA	Rainfall attenuation at specified rainfall rate and wavelength (XLAMDA), decibels/meter	0.
ALTGT	Projected length of target orthogonal to the line-of-sight, feet	
*AZ	Azimuth component of scan field-of-view, degrees	1.8
BJ	Jammer signal bandwidth, always equal to or greater than BR, Hertz	7.5E7
BR	Radar receiver bandwidth, Hertz	5.E6
BWA	Antenna azimuth beamwidth, degrees	1.8
BWE	Antenna elevation beamwidth, degrees	16.
DR	Range at which the target begins its descent, nautical miles NOTE: If target maintains constant altitude, set DR = 0.	0.
EINSTR	Instrument error affecting angle accuracy, milliradians	.1
*EL	Elevation component of scan field-of-view, degrees	16.
FAN	Frequency agility factor, the number of pulses which change in frequency by the reciprocal of the pulse width	1.
**GJDB	Transmit antenna gain of jammer, decibels	1.
GRDB	Receiver radar antenna gain, decibels	30.
GTDB	Transmit radar antenna gain, decibels	30.
H1K	Altitude of radar, thousand feet	.1
H2K	Altitude of the target, thousand feet	

* Used only for NMODE = 4
** Used only for JAM = 1, and JAM = 2

TABLE I (Continued)

Variable	Definition	Sample Data
ISS	Sea state, numeric	4
ITYPE	Type of normalized antenna gain function = 1, is symmetrical sin X/X pattern = 2, is cosecant squared pattern	2
JAM	Jam control constant = 0, no jamming = 1, jammer colocated with the target = 2, stand-off jammer	
MOD	Type of modulation used = 1, uncompressed pulse = 2, pulse compression	1
NMODE	Operating mode = 1, for radar operating in surveillance or search mode = 2, for radar operating in track mode and using simultaneous lobing (monopulse) = 3, for radar operating in track mode and using conical scan = 4, for radar operating in limited volume search	1
NSW	Swerling case number (an integer indicating the target fluctuation model)	1
*PCRAT	Pulse compression ratio, numeric	1.
PFA	Probability of false alarm	1. E-6
**PHIZER	Minimum angle off antenna boresight at which the pattern function becomes a cosecant squared function, degrees.	5.
PJ	Generated jammer power, watts	500.
PRF	Pulse repetition frequency, pulses/second	610.
PWR	Peak transmitting power, watts	2.85E5
RATE	Rainfall rate, millimeters/hour	0.
***RATE1	Antenna azimuth scan rate, degrees/second	102.

* Used only for MOD = 2
** Used only for NMODE = 4
*** Used only for NMODE = 1

TABLE I (Concluded)

Variable	Definition	Sample Data
SIGMAT	Radar cross section of the target, square meters	
SNRODB	Not used	
*SOR	Stand off range of jammer, nautical miles	150.
STOP	Preset to +1 for continuous group of runs = -1, input in last run to stop after run	
TA	Antenna temperature, degrees K	350.
TAU	Radar pulse width, microseconds	1.17
**TF	Frame time, seconds	1.
***TI	Integration or smoothing time, seconds	.1
TILT	Fixed angle between the local horizontal at the radar and the boresight of the radar. Tilt is positive if above the radar's local horizontal and negative if below it.	2.5
TITLE	28 column title for each page; input: TITLE(1)=4H ..., TITLE(2)=4H ..., ...TITLE(7)=4H ...	
VRELK	Relative closing velocity, knots	
XLAMDA	Radar wavelength, centimeters	5.5
****XLJDB	Losses in the jammer transmitter chain such as antenna and waveguide losses, decibels	1.
****XLRDB	Receiver losses such as efficiency or antenna pattern, decibels	3.
XLSDB	Radar system losses, decibels	7.
XLTDB	Radar system losses ahead of RF amplifier, decibels	1.
XNFDB	Radar receiver noise figure, decibels	14.

* Used only for JAM = 2
** Used only for NMODE = 4
*** Used only for NMODE = 2, 3
**** Used only for JAM = 1, 2

TABLE II
RADAR OUTPUT PARAMETER DEFINITIONS

ANTENNA PROPAGATION FACTOR (FF)	The ratio, at a point in space, of the field strength E that is actually present to that which would have been present, E_o, if free-space propagation had occurred and the point were in the antenna-pattern maximum.
CUMULATIVE PROBABILITY OF DETECTION, PDCUM	Cumulative probability of detection from scan to scan during search
DYNAMIC RANGE (DB)	Ratio of total input signal power to receiver thermal noise
HANDOFF ERROR (MRAD)	RMS error in angular measurement of target location during search
PROB. DET. PER LOOK, PD	Probability of detection during observation time TO. TO may be dwell time during one scan across the target, range resolution cell traversal time or smoothing time in track
PSTA(DB)	Ratio of signal power from the target to one watt expressed in decibels (db)
RANGE NMI	Slant range between the radar and the target in nautical miles
SNRI(DB)	Single pulse signal-to-interference power ratio expressed in decibels (db)
XLOW(DB)	Composite interference power comprised of system noise, clutter, and jamming, expressed in decibels referenced to one watt

TABLE III
RADAR PROGRAM FLOW DIAGRAM

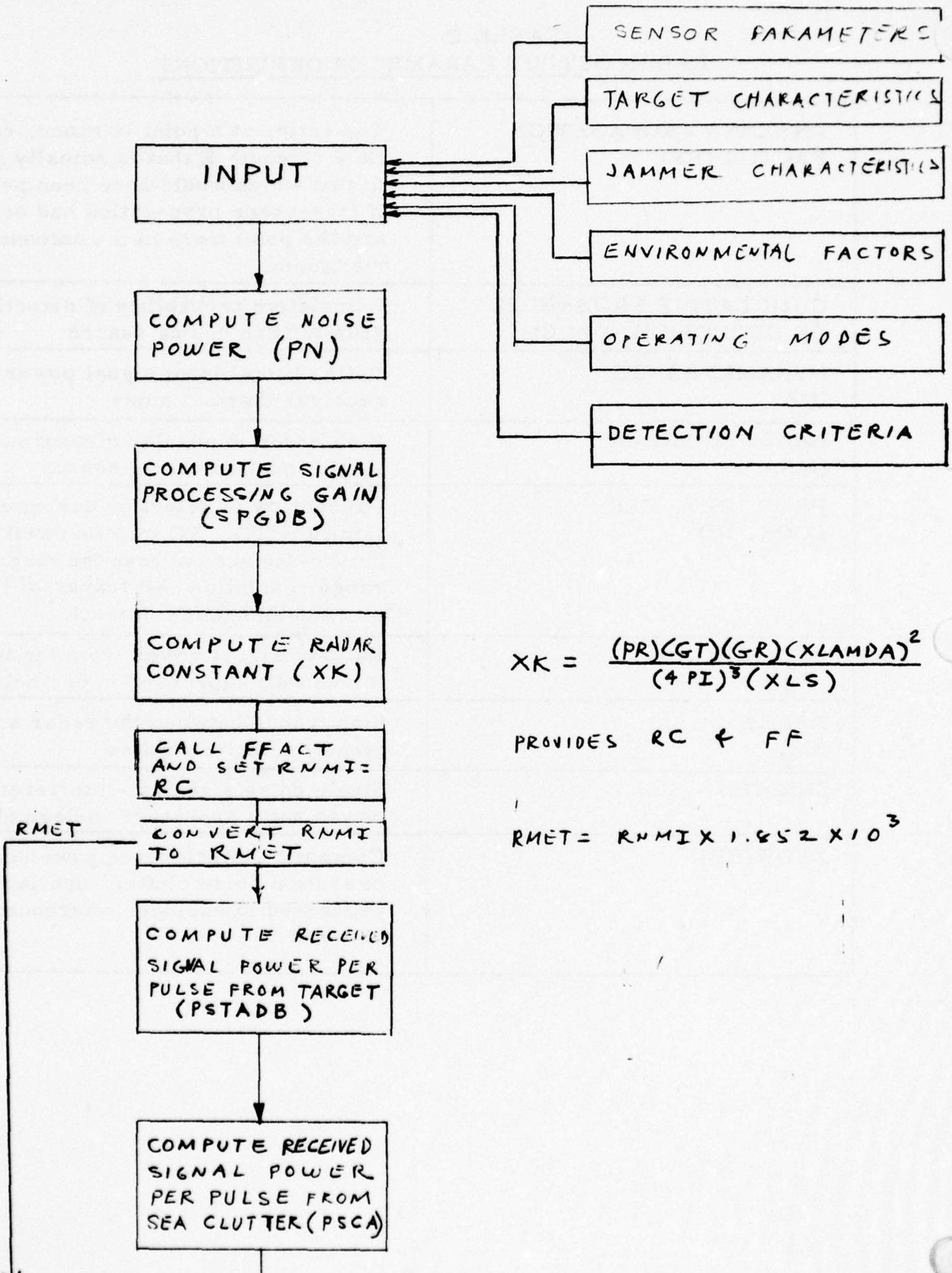


TABLE III (Continued)

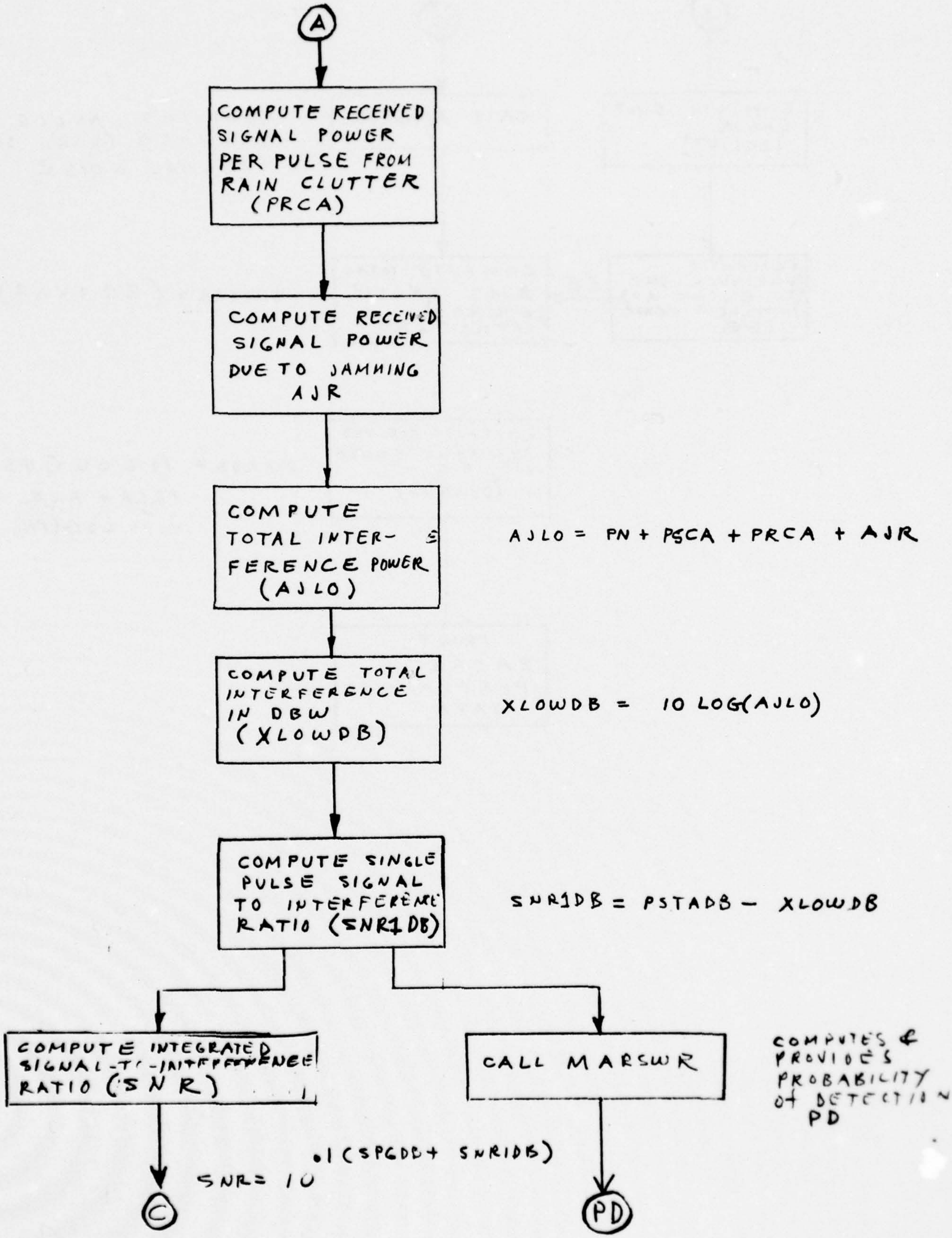
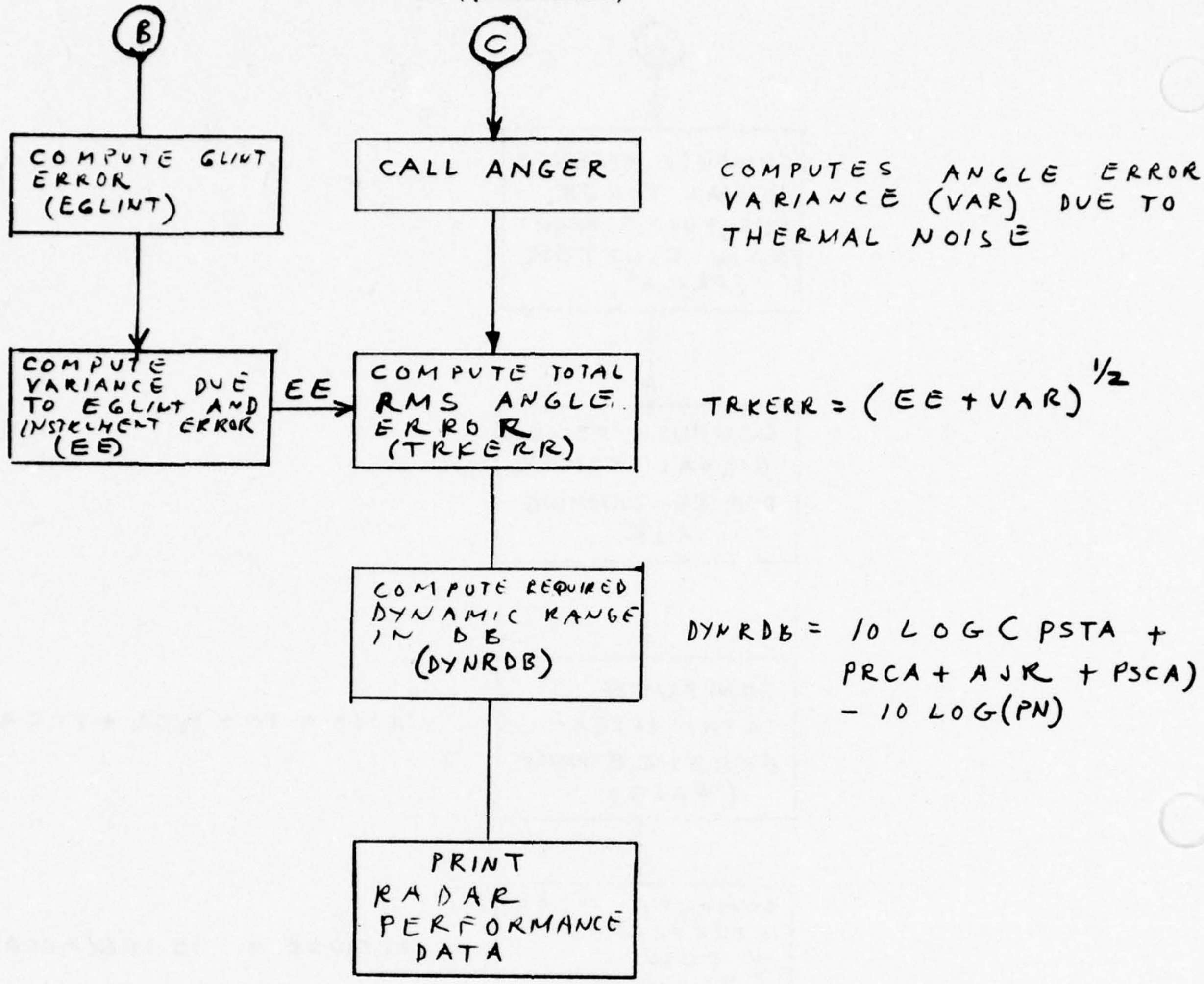


TABLE III (Concluded)



III. PERFORMANCE EQUATIONS

A. Signal-to-Interference Ratio

(U) An important parameter in determining radar performance is the signal-to-interference ratio (S/I).

$$S/I = \frac{PSTA}{PN + PSCA + PRCA + AJR} \quad (1)$$

where

PSTA = Signal return from the target, watts

PN = Radar system noise (internal), watts

PSCA = Signal return due to sea clutter, watts

PRCA = Signal return from rain clutter in the radar resolution cell, watts

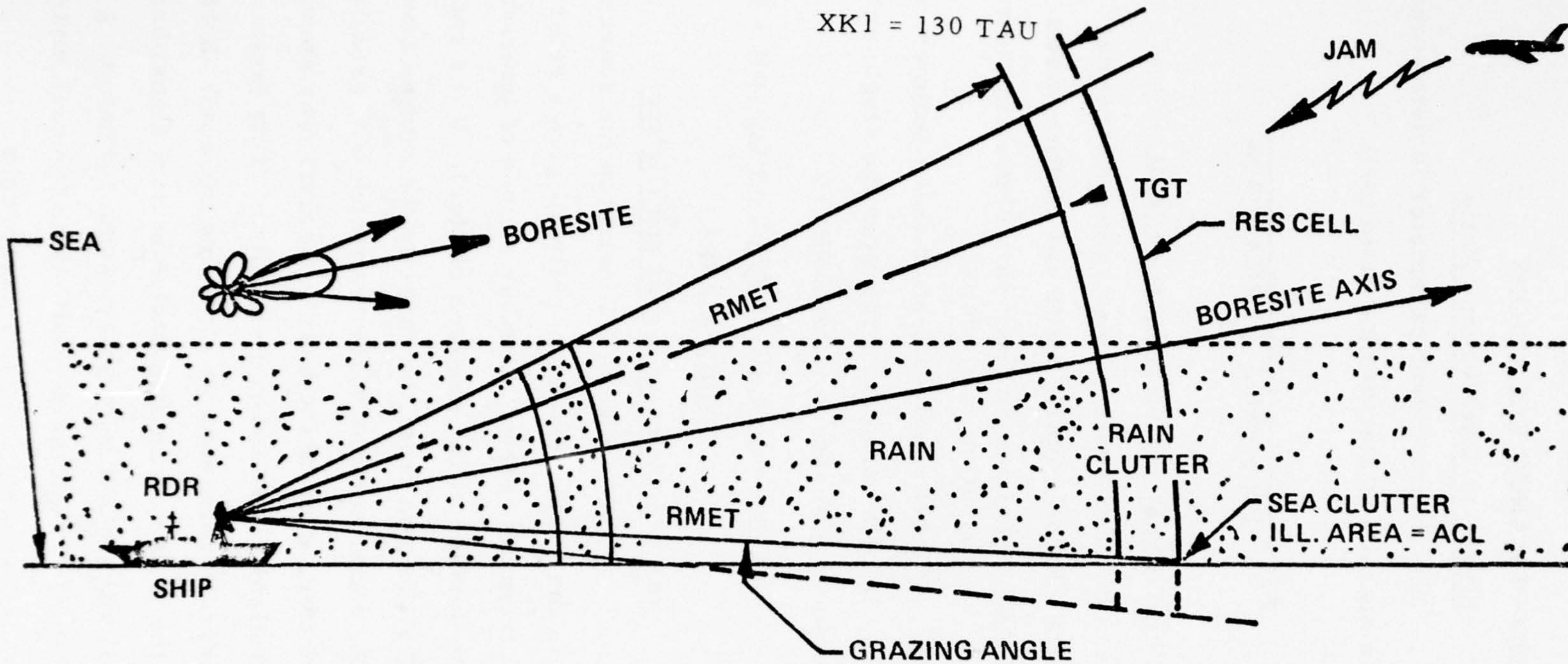
AJR = Signal received from a noise jammer, watts

In both computer programs the single pulse S/I ratio is computed in decibels (db) and is called SNRlDB.

$$SNRlDB = 10 \text{ Log } (PSTA) - 10 \log (PN + PSCA + PRCA + AJR) \quad (2)$$

(a) Sources of Signal and Clutter

(U) Figure 1 illustrates the sources of signal and cultter. Rain in the radar resolution cell will give a return which competes with the signal from the target. Another source of interference is the return from the surface of the sea (sea clutter). If the radar antenna is elevated enough, the path from the radar to the clutter area (ACL) will pass through the radar antenna sidelobes which will greatly reduce the effect of sea clutter. One of the hostile aircraft may stand-off a distance of about 100 nautical miles and radiate noise. This tactic is used to screen missiles or aircraft which may be attacking the ship. If rain exists between the radar and the target, then attenuation of both signal and clutter returns will occur. All attenuation is two way except for jamming which is one way only. The parameters and their relationship for each source of signal and cultter are discussed in the following paragraphs.



RMET = RANGE TO TGT, SEA CLUTTER AREA, AND RAIN CLUTTER

RJ = RANGE TO JAMMER

TAU = PULSE WIDTH, MICROSECONDS

FIGURE 1 SOURCES OF SIGNAL AND CLUTTER

(b) Signal Return From the Target

(U) Figure 2 illustrates the radar-target geometry and the direct and reflected paths for the radar signal. The signal return is given by

$$PSTA = XK \frac{(SIGMAT)(ATT)(FF)^4}{(RMET)^4} \tag{3}$$

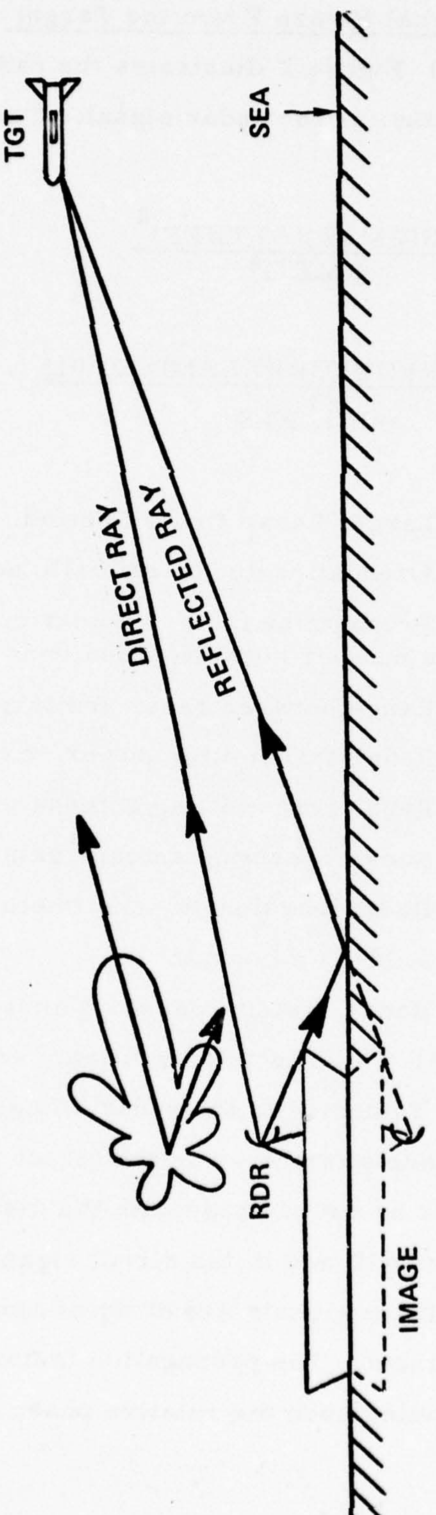
where

$$XK = \frac{(PR)(GT)(GR)(XLAMDAX.01)}{(4PI)^3 \ XLS} \tag{4}$$

and

SIGMAT	= Target Radar Cross Section, square meters
ATT	= Attenuation due to rainfall, numeric (1)
FF	= Propagation factor, numeric. This factor is a number between 0 and two.
RMET	= Range between radar and target, meters.
PR	= Radar transmitter power, watts
GT	= Radar transmitting antenna gain, numeric.
GR	= Radar receiving antenna gain, numeric
XLAMDA	= Radar wavelength, centimeters.
PI	= 3.1416, a constant
XLS	= Radar system losses, numeric ($\geq$1)

(U) The effects of multipath are due to signals arriving at the target and returning to the radar along two separate paths. Since the reflected ray travels farther than the direct ray the signal due to reflection may be in phase or out of phase with the direct ray. If in phase, the signal due to reflection will add to the direct signal and enhance the return from the target. If the signals are of equal amplitude but out of phase, the signals will cancel. The propagation factor FF may take on values from 0 to 2, depending upon the relative phase and amplitude of the two signals.



$$\bullet\ PSTA = XK\left[\frac{(SIGMAT)\,(ATT)\,(FF)^4}{RMET^4}\right]$$

$$WHERE\ XK = \left[\frac{(PR)\,(GT)\,(GR)\,(XLAMDA)^2}{(4\,PI)^3\,(XLS)}\right]$$

FIGURE 2 SIGNAL RETURN FROM TARGET

(U) The magnitude of the reflected signal depends upon the gain of the antenna along the path from the radar to the point of reflection and the reflection coefficient of the sea. The magnitude of the direct ray is effected by the gain of the antenna in the direction of radiation.

(c) Signal Return from Rain Clutter

(U) Figure 3 illustrates the return from rain in the radar's resolution cell (volume). The volume of the radar's resolution cell for a symmetrical beam is given by

$$VRN = (PI/4)(RMET)^2(THETA1)^2 XK1 \tag{5}$$

where

THETA1 = Antenna pattern half-power beamwidth, radians

$$XK1 = 130\ TAU,\ Meters \tag{6}$$

where

TAU = Radar pulsewidth, microseconds.

The return from the clutter cell is

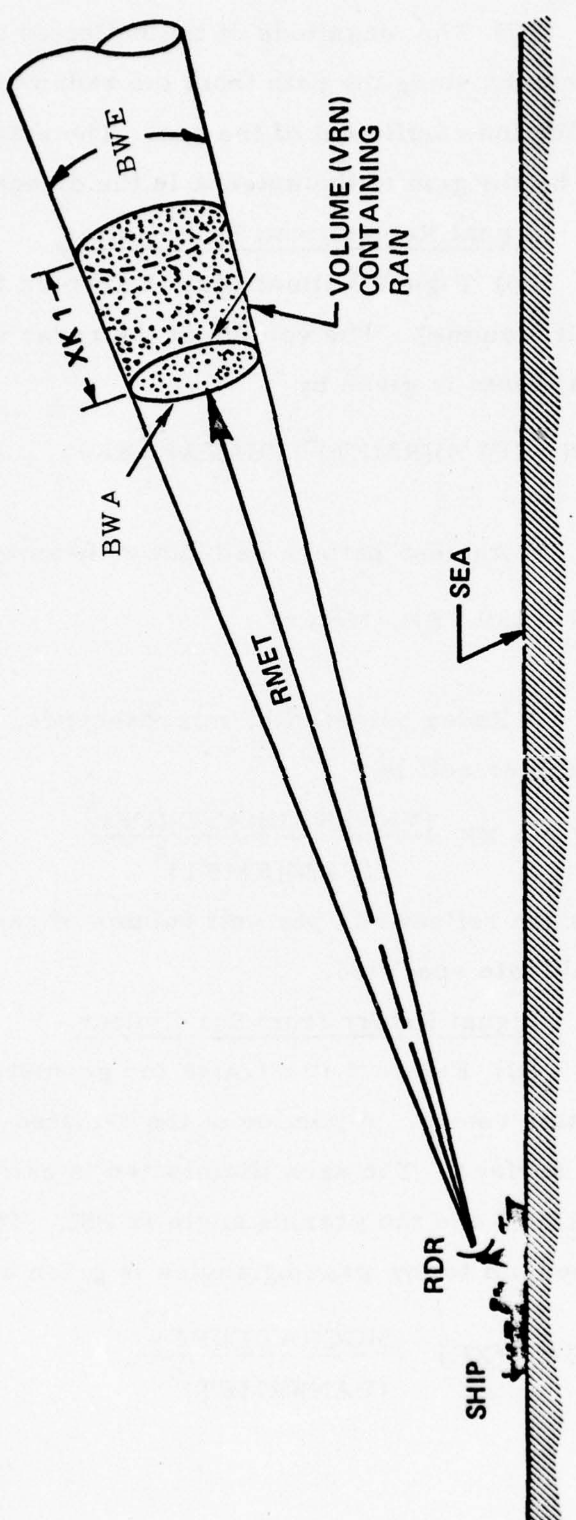
$$PRCA = XK\ \frac{(VRN)(XRN)(ATT)(FF)^4}{(FAN)(RMET)^4} \tag{7}$$

In equation (7) XRN is the reflectivity per unit volume of rainfall at the wavelength and rainfall rate specified.

(d) Signal Return from Sea Clutter

(U) Figure 4 illustrates the geometry involved in obtaining a sea clutter return. A portion of the radiated beam illuminates a portion of the sea's surface. The area illuminated is called ACL. The path to the target is RMET and the grazing angle is PSI. The return from the clutter patch at medium to low grazing angles is given by

$$PSCA = (XK)\ \frac{(SIGC)(ATT)(FC)^4}{(FAN)(RMET)^4} \tag{8}$$

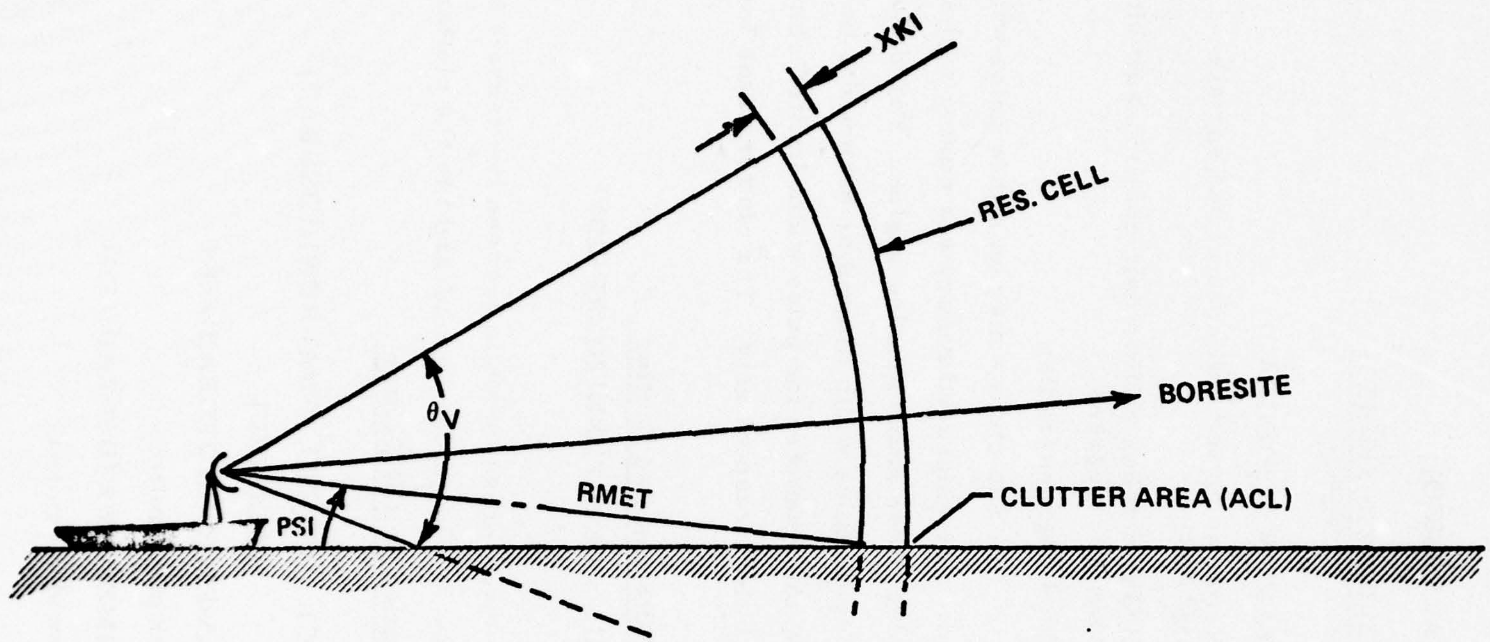


• $PRCA = (XK)\left[\frac{(VRN)\,(XRN)\,(ATT)\,(FF)^4}{(FAN)\,(RMET)^4}\right]$

WHERE: XRN = RADAR CROSS SECTION PER UNIT VOLUME

$VRN = \left[(PI/4)(RMET)^2(BWA)(BWE)/(DEGRAD)^2\right](XK1)$

FIGURE 3 SIGNAL RETURN FROM RAIN CLUTTER



$$\bullet\ PSCA = (XK)\,\frac{(SIGC)\,(ATT)\,(FC)^4}{(FAN)\,(RMET)^4}$$

WHERE SIGC = (ACL) (SIGO)

$$ACL = \frac{(2)\,(RMET)\,(XKI)\,(TI)}{COS\,(PSI)}$$

$$T1 = TAN\,(BWA/2DEGRAD)$$

FIGURE 4 SIGNAL RETURN FROM SEA CLUTTER

where:

$$SIGC = (ACL)(SIGO) \qquad (9)$$

$$ACL = \frac{(2)(RMET)(XK1)(T1)}{COS(PSI)} \qquad (10)$$

$$T1 = TAN(BWA/2DEGRAD) \qquad (11)$$

SIGO = Reflectivity per unit area of sea surface (M^2/M^2)

BWA = Radar antenna pattern half-power beamwidth in azimuth, degrees

DEGRAD = 57.3 degrees/radian

(U) Sea clutter may be either pulse width limited or beamwidth limited. For shipbased radars sea clutter will always be pulse-width limited due to the small grazing angles. For the airborne radars the clutter may be pulse width limited or beamwidth limited. Figures 5 and 6 show the geometry for pulse width limited clutter and beamwidth limited clutter, respectively. The clutter areas for the two cases are:

Pulse Width Limited Clutter

$$ACL = (RMET)(XK1)SEC(PHID) \qquad (12)$$

where

PHID is the depression angle between the radar's local horizontal and the radar line-of-sight to the clutter area.

Beamwidth Limited Clutter

$$ACL = (RMET)^2(BWA)(BEW)/(DEGRAD)^2 \; CSC(PHID) \qquad (13)$$

if TAN(PHID) > RMET(BWE/DEGRAD)/XK1

then clutter is beamwidth limited.

if TAN(PHID) < RMET(BWE/DEGRAD)/XK1

then clutter is pulsewidth limited.

(MEDIUM TO LOW GRAZING ANGLES)

SIN(PHID) = HIMET/RMET

TAN(PHID) <(BWE)(RMET)/XK1

ACL = (RMET)(BWA/DEGRAD)XK1 SEC (PHID)

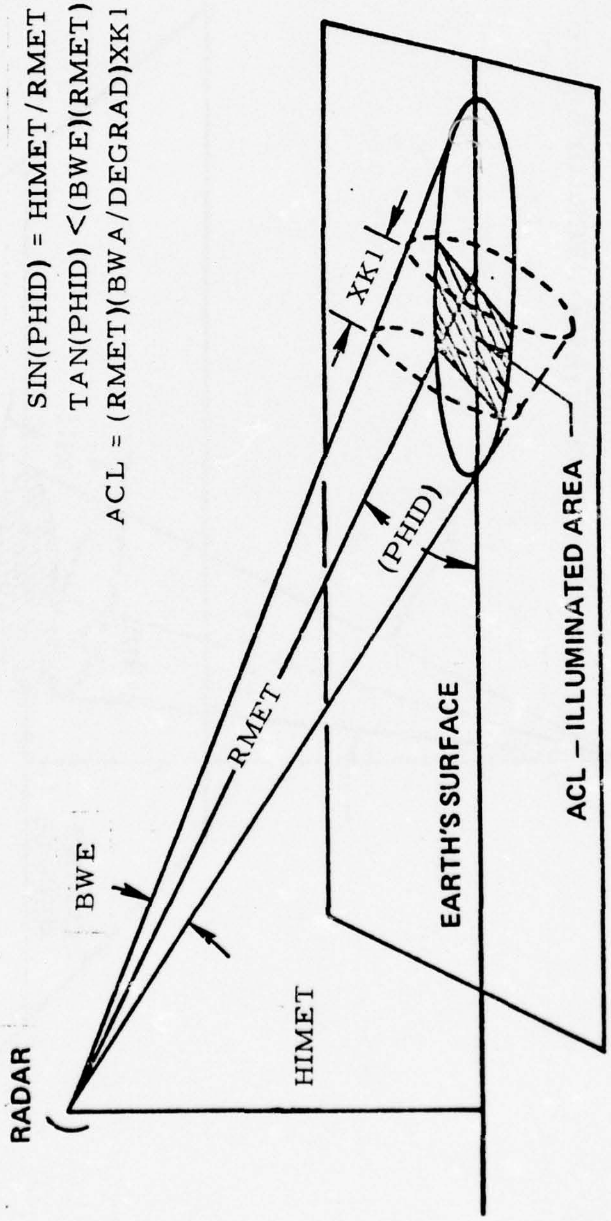


FIGURE 5 PULSE WIDTH LIMITED SEA CLUTTER AREA

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(HIGH GRAZING ANGLES)

SIN(PHID) = HIMET / RMET

TAN(PHID) > (BWE)(RMET)/(XK1)

ACL = (RMET)^2(BWA/DEGRAD)(BWE/DEGRAD) CSC (PHID)

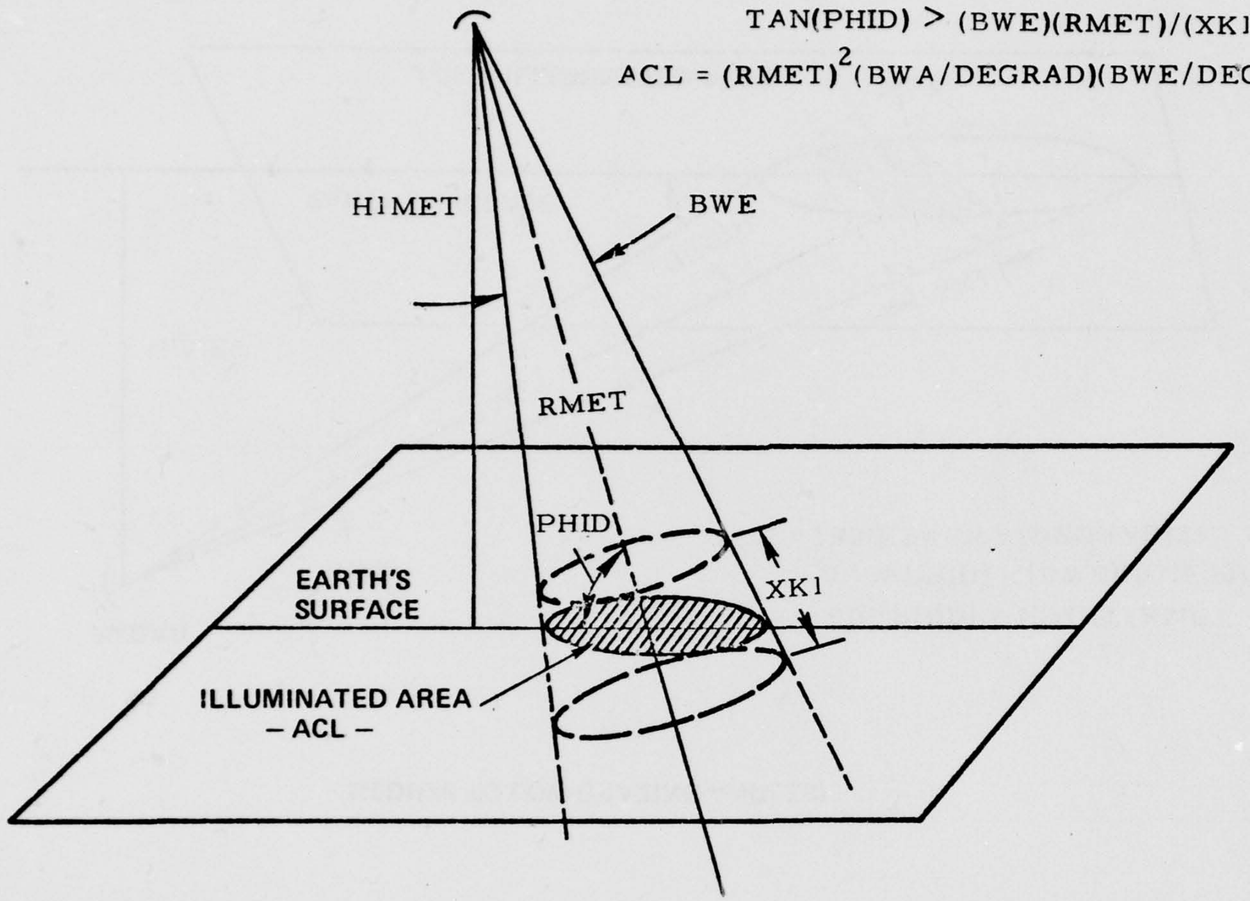


FIGURE 6 BEAMWIDTH LIMITED SEA CLUTTER AREA

(e) Signal Input from Noise Jammer

(U) Figure 7 illustrates the radar-jammer geometry. The jammer may be a standoff jammer or colocated with target. The jammer may use an omnidirectional antenna, or may use a directional antenna. The radiated signal follows a one way path from the jammer to the shipboard radar. For a standoff jammer the missile or aircraft is screened until the skin return as received by the radar is equal to or greater than the jamming signal, AJR. The expression for the received jamming signal is

$$AJR = \frac{(PJ)(GJ)(GR)(BR)(XLAMDA\ \ .01)^2(ATT1)(FF)^2}{(4PI)^2(RJ)^2(BJ)(XLJ)(XLR)} \tag{14}$$

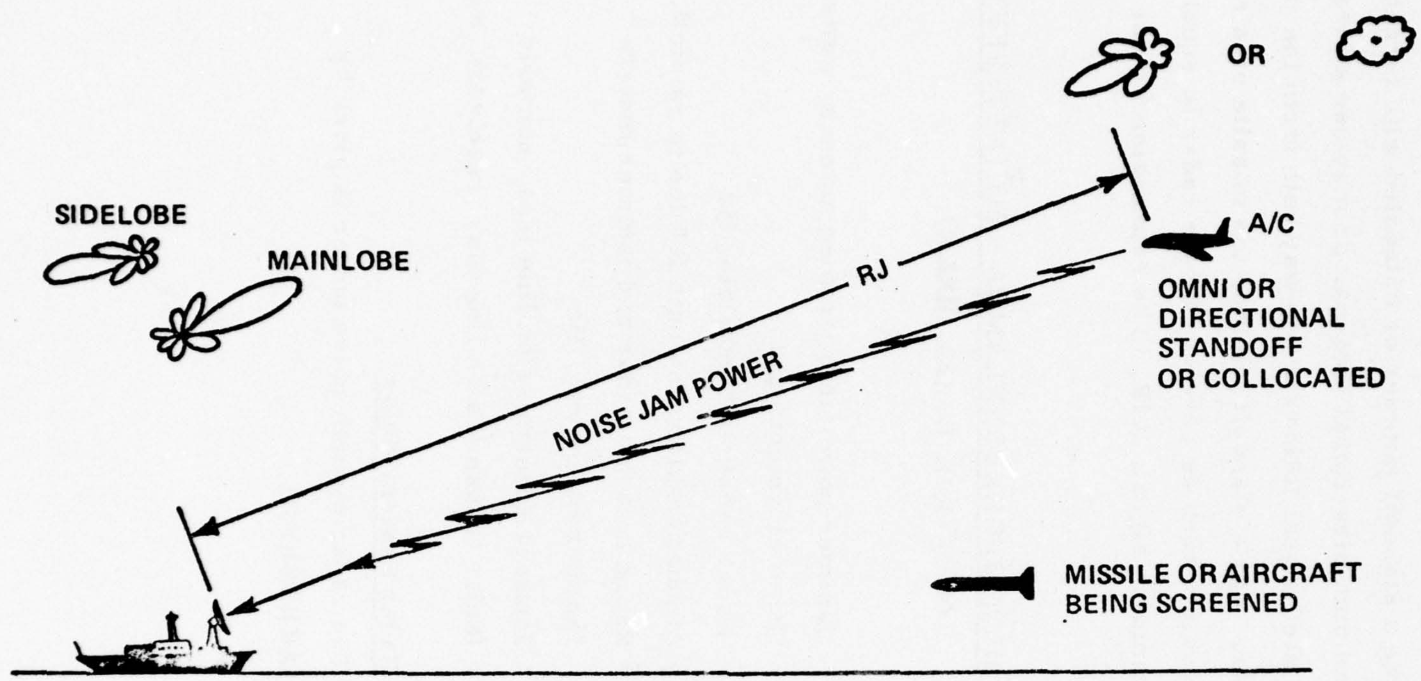
where

PJ = Jammer power into jammer antenna, watts
GJ = Jammer antenna gain
BR = Radar receiver bandwidth, Hz
ATT1 = Atenuation along the path RJ due to rainfall, numeric
RJ = Range between radar and jammer,meters
BJ = Jammer bandwidth, Hz
XLJ = Jammer transmission line loss, numeric
XLR = Radar transmission line loss (receiver), numeric

(f) Radar System Noise

The radar system noise power is given by

$$PN = (AK)(TS)(BR) \tag{15}$$



- $$AJR = \frac{(PJ)\,(GJ)\,(GR)\,(BR)\,(XLAMDA \times .01)^2\,(ATT1)\,(FF)^2}{(4\,PI)^2\,(RJ)^2\,(BJ)\,(XLJ)\,(XLR)}$$

FIGURE 7 RECEIVED SIGNAL POWER FROM NOISE JAMMER where

AK = Boltzmann's Constant 1.38×10^{-23} Joules/°K

TS = System temperature, °K

$$TS = TA/XLR + ((XLR - 1.)/XLR)\, 290 + (XNF - 1)290, \text{ degrees Kelvin} \quad (16)$$

TA = Antenna temperature, °K

XLR = Transmission line loss (Receiver), numeric

XNF = Receiver noise figure, numeric

IV. DERIVATION OF DEPRESSION AND ELEVATION ANGLES

(U) Two important parameters involved in the computer algorithms are the depression and elevation angles, α and E, respectively. The derivation of these quantities is discussed in the following text. A third parameter, the grazing angle, PSI, is computed using an expression given in Reference 3. Figures 8 and 9 are used to develop expressions for the depression and elevation angles from the horizontal (at the radar) to the Target (TGT). RE is 4/3 earth's radius in meters. H1MET and H2MET are the altitudes of the radar and target in meters, respectively. R is the line-of-sight range in meters between the radar and the target. RGMET is the equivalent ground range.

Distances

Let RE + H2MET = b

Let RE + H1MET = c

Let R = a

Angles

Let γ = A (radians)

Let θ = B (radians)

Let Ψ = C (radians)

(a) Solve for γ

(U) By law of cosines:

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc} \tag{17}$$

Substituting in values for A, b, c, and a

$$\cos(\gamma) = \frac{(RE + H2MET)^2 + (RE + H1MET)^2 - R^2}{2\,(RE + H2MET)(RE + H1MET)} \tag{18}$$

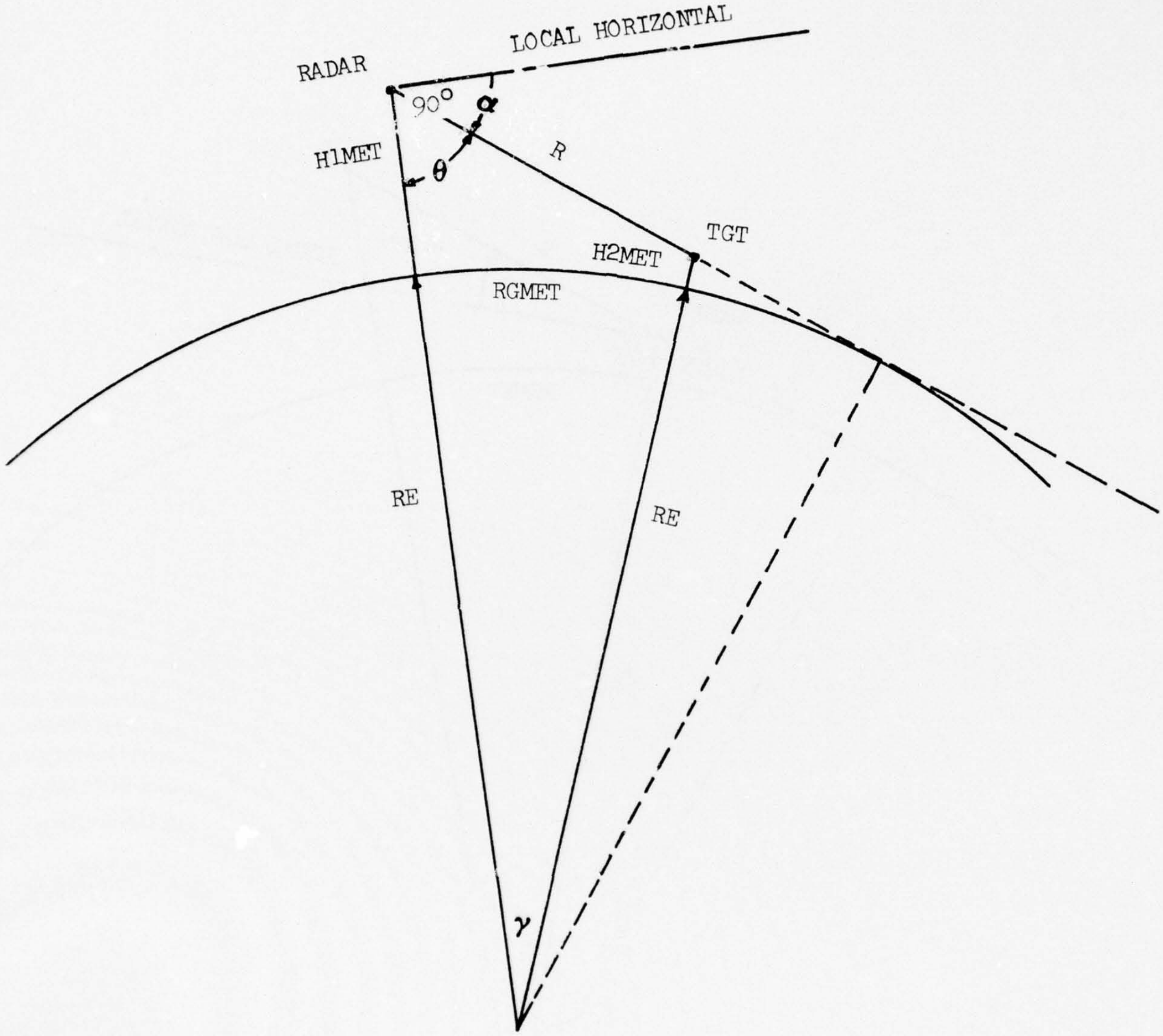


FIGURE 8. TARGET-RADAR GEOMETRY (H1MET > H2MET)

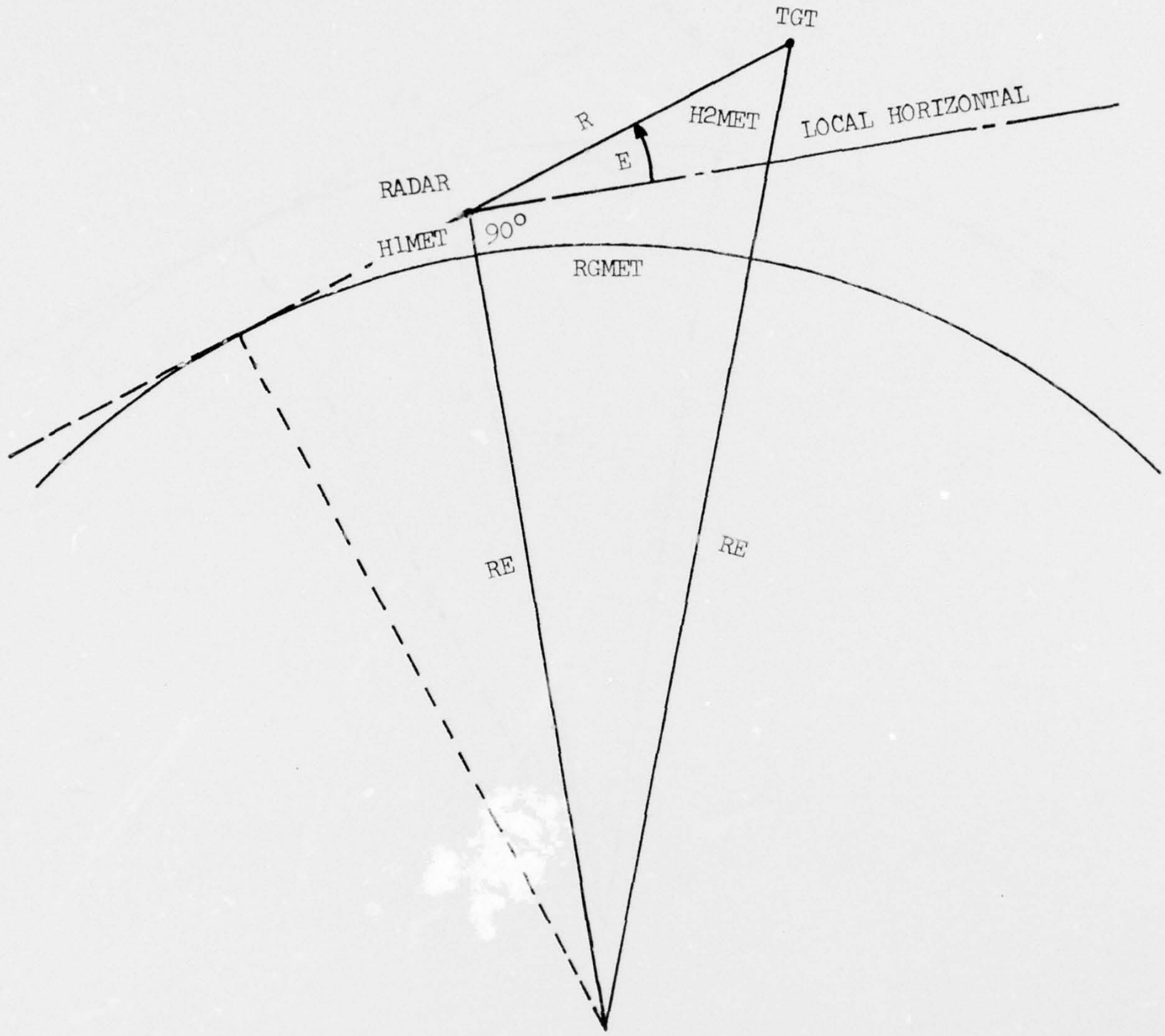


FIGURE 9. TARGET-RADAR GEOMETRY (H1MET < H2MET)

Since all of the quantities on the right hand side of equation (18) are known, the γ can be computed.

The ground range, RGMET, is given by

$$RGMET = (RE)(\gamma) \tag{19}$$

It has already been shown previously that

$$\cos(\gamma) = \frac{(RE + H2MET)^2 + (RE + H1MET)^2 - R^2}{2\,(RE + H2MET)(RE + H1MET)} \tag{20}$$

Let $\pi/2 + E = \theta$ (radians)

θ is angle opposite side (RE + H2MET)

(b) Solve for θ

(U) Relationships between angles and sides of the triangle with angles A, B, and C and sides opposite a, b, and c, respectively, are shown by

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = \text{diameter of the circum-}$$

scribed circle; thus,

$$\frac{b}{\sin B} = \frac{a}{\sin A} \tag{21}$$

Putting in values of a, b, A which are known

$$\frac{RE + H2MET}{\sin(\theta)} = \frac{R}{\sin(\gamma)} \tag{22}$$

$$\sin(\theta) = \left[\frac{(RE + H2MET)}{R}\right] \sin(\gamma) \tag{23}$$

Now that θ and γ are known (radians), α is given by

$$\alpha = \pi/2 - \theta \text{ , radians} \tag{24}$$

$$\alpha = \pi/2 - \sin^{-1}\left[\frac{(RE + H2MET)}{R}\right]\sin(\gamma) \tag{25}$$

As previously shown

$$\sin(\theta) = \left[\frac{RE + H2MET}{R}\right]\sin(\gamma) \tag{26}$$

$$E = \theta - \pi/2$$

$$E = -\pi/2 + \sin^{-1}\left\{\left[\frac{RE + H2MET}{R}\right]\sin(\gamma)\right\} \tag{27}$$

From equations (25) and (27), it is seen that

$$\alpha = -E, \text{ or} \tag{28}$$

$$E = -\alpha \tag{29}$$

E is positive above the horizontal, and negative below the horizontal.

α is positive below the horizontal and negative above the horizontal.

V. SEA CLUTTER DATA

Values of sea clutter cross-section per unit area of sea surface ($\sigma°$) as a function of frequency, sea state and grazing angle are available in tabular form in Nathanson (reference 3, pages 231 through 238). Using this data, curves of $\sigma°$ versus grazing angle for various sea states and frequencies were constructed. These curves were smoothed and extrapolated and the data stored in the computer program in a subroutine entitled SIGOS. SIGOS uses a table look-up routine TLU23 to provide the necessary values of SIGO ($\sigma°$) for computing the return from sea clutter. TLU23 uses interpolation to find values of SIGO corresponding to intermediate values of wavelength. The data is stored in bordered tables, one table for each sea state. The make-up of bordered tables is explained in Appendix G. Row 1 contains the grazing angle in radians. Column 1 contains the frequency as wavelength in centimeters. Sea clutter cross-section per unit area of sea surface is given in db.

LIST OF REFERENCES

1. Blake, L. V., A Guide to Basic Pulse-Radar Maximum-Range Calculation - Part I, NRL Report 6930, Naval Research Laboratory, Washington, D.C., 23 December 1969 (U).

2. Skolnik, M. L., Introduction to Radar Systems, McGraw-Hill, New York, 1962 (U).

3. Nathanson, F. E., Radar Design Principles, McGraw-Hill, New York, 1969 (U).

APPENDIX D

SURFACE SHIP RADAR CROSS SECTION MODEL

TITLE

SURFACE SHIP RADAR CROSS SECTION MODEL

NO. Appendix D

DATE

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PREPARED BY L.D. Gregory

APPROVED BY LDG

APPENDIX D

SURFACE SHIP RADAR CROSS SECTION MODEL

1. INTRODUCTION

The purpose of this appendix is to derive a simplified radar cross section model to account for the fact that as a surface ship comes over the actual horizon only a fraction of the actual cross section appears at first.

2. APPROACH

Assume a radar at height H1 at a range R from a target of total height HS above the surface (see Figure 1). Let RH1 be the range

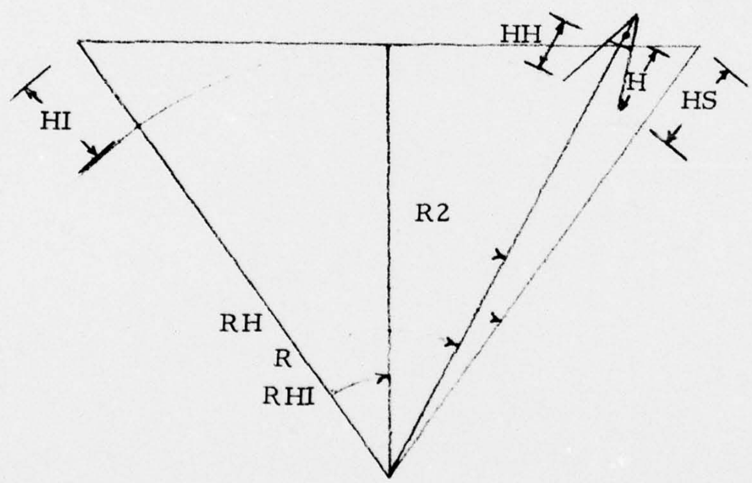


Figure 1

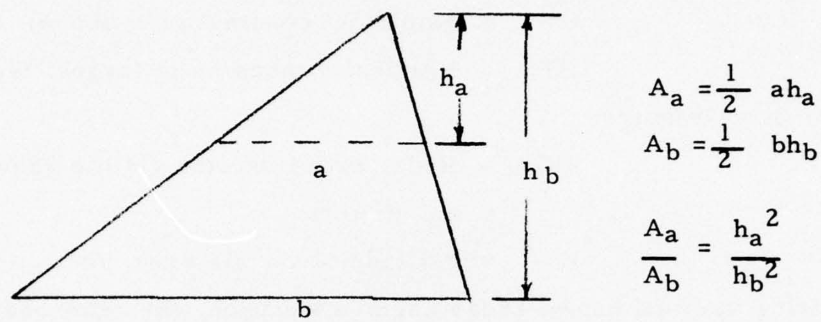
RADAR HORIZON DEFINITIONS

from the radar to the earth tangency point. Then if the target is closer than RH1, all of its cross section is presented. Let RH be the "radar horizon" for the target. For ranges between RH1 and RH, only a fraction of the target will be visible, and none beyond RH.

For a triangular distribution of target area (see Figure 2), the visible fraction of the total area varies as the square of the fraction of the

Figure 2

TRIANGULAR DISTRIBUTION OF AREA



vertical dimension above the horizon. In the notation of Figure 2

$$A_a / A_b = (h_a / h_b)^2 \tag{1}$$

We point out that if the area distribution had been rectangular, the exponent in equation (1) would have been unity. Thus we adopt for our simple model the function

$$A_a / A_b = (h_a / h_b)^c \tag{2}$$

where c is a number to be chosen empirically but will be arbitrarily restricted to values between 1 and 2 in the belief that slender masts and small antennas will give negligible radar cross section (hence c will not be greater than 2).

Next consider the centroid of the visible area. If the distribution of the area is triangular this is at a distance $h_a/3$ above the horizon; if rectangular, then $h_a/2$ above the horizon. Thus we linearize so that the centroid is at a distance d above the horizon where

$$d = h_a/(c + 1) \tag{3}$$

3. EQUATIONS

In the notation of Figure 1, assume we are given:

H1 = Radar height, feet

R = Range to target, N.M.

SIG = Radar cross section of target, sq. meters

C = empirical constant (see above)

HS = Vertical dimension of target, feet

Then we require:

SIGA = Radar cross section visible above the horizon, sq. meters

H = Altitude of visible area, feet

Using the well known radar horizon equation, the relations of Section 2, and the geometry of Figure 1, we then get in FORTRAN notation:

```
RH1  = 1.2289*SQRT(H1)
R2   = R - RH1, > 0
HH   = (R2/1.2289)**2
HA   = HS - HH, > 0
SIGA = SIG*(HA/HS)**C
H    = HH + HA/(C + 1.0)
```

APPENDIX E

SONAR DETECTION MODEL

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PREPARED BY J. R. Matthews

APPROVED BY L. D. Gregory

APPENDIX E

SONAR DETECTION MODEL

1. INTRODUCTION

(U) The purpose of this appendix is to derive a simplified sonar detection model to estimate target detection range and detection probability by surface ship and submarine sonars.

2. APPROACH

(U) The approach used is based on that presented in Naval Operations Analysis, Operations Committee, Naval Science Department, U. S. Naval Institute, Annapolis, Maryland, 1968. The fifty percent probability of detection range is computed based on total propagation loss in decibils. The propagation loss includes allowance for target radiated noise, background noise, and required signal to noise ratio for recognition. Once the fifty percent probability of detection range is computed, a normal curve is established using the 50% point computed with the following expression:

$$P_D = \exp[-.693(R/R_{50})^2]$$

where: P_D = probability of detection

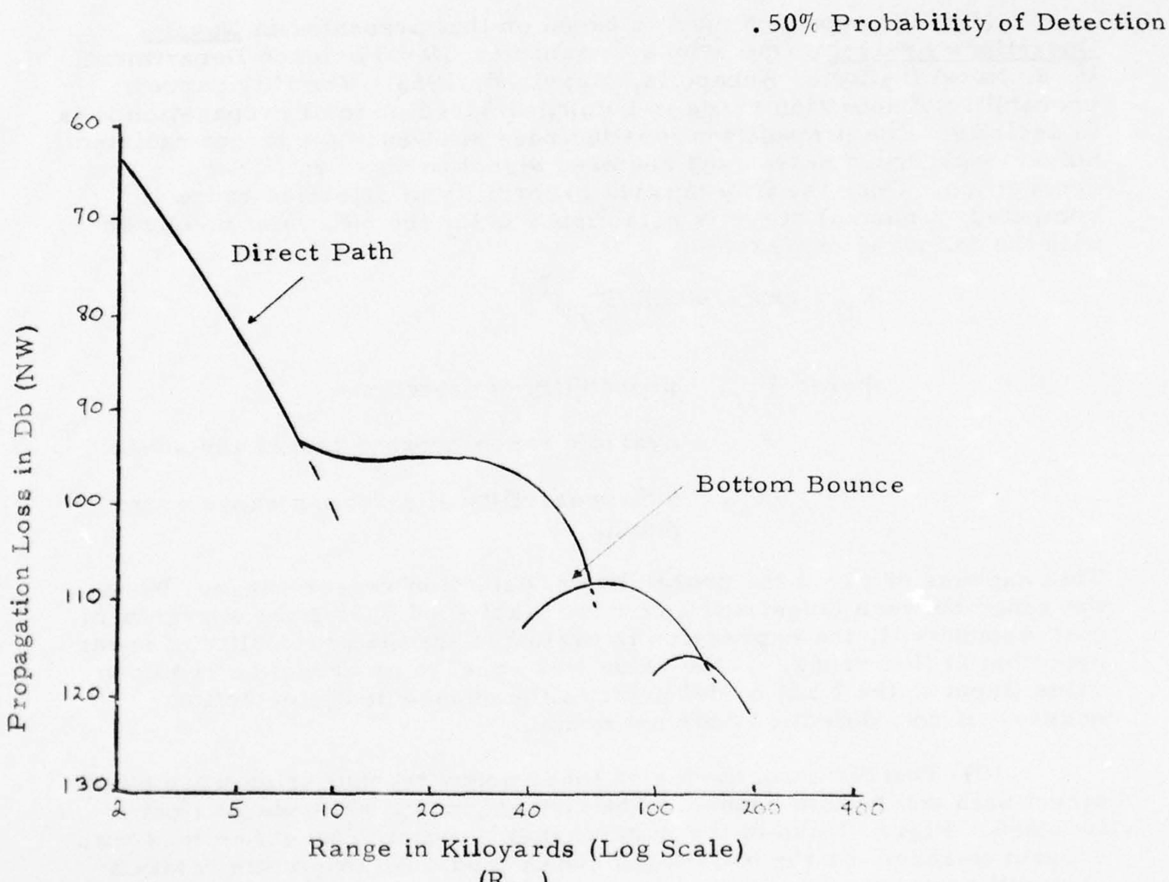
R = dynamic range between target and sonar

R_{50} = 50% probability of detection range computed.

This expression gives the probability of detection versus range. When the range between target and sonar is established during the engagement (see Appendix I), the expression is evaluated for the probability of sonar detection at that range. If the value lies equal to or above the required value (input to the NEM model prior to the engagement), detection occurs. If not, detection does not occur.

(U) Two different modes of sonar sound transmission were used: direct path and bottom bounce. The convergence zone mode was not included. Figure 1 shows the relationship between propagation loss with respect to range for the two modes considered. Although this relationship will vary with sea depth, summer layer depth, sonic depth, and receiver position, the model assumes for all engagements a sea depth of 2000 fathoms, summer layer depth of 100 feet, source depth of 50 feet, and the receiver to be below the summer layer.

FIGURE 1 - PROPAGATION LOSS VERSUS RANGE TO TARGET



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3. EQUATIONS

(U) Two different sonar modes were considered: active and passive. Although some sonars may operate in either or both, the model assumed each to be independent.

3.1 Active Sonar

(U) The active sonar 50% detection range equation is as follows:

$$NW = \frac{L_S + N_{TS} - (L_N - N_{DI}) - N_{RD}}{2}$$

where:

NW = total propagation loss in db, used to enter figure 1 for range solution.

L_S = radiated signal from pinging sonar ship in db.

NT_S = target signal strength (return) in db.

L_N = omnidirectional self noise in db.

N_{DI} = directivity index.

N_{RD} = required signal to noise ratio for recognition in db.

Naval Operations Analysis suggested the following values as typical for an active sonar on station:

L_S = 140 db.

NT_S = 15 db.

L_N = -43 db. (sea state 2)

N_{DI} = 25 db.

N_{RD} = 27 db.

The values were input to all active sonars used in the model and can be changed by the User if desired.

3.2 Passive Sonar

(U) The passive sonar 50% detection range equation is as follows:

$$NW = L_S - (L_N - N_{DI}) - N_{RD}$$

where:

NW = total propagation loss in db. used to enter figure 1 for range solution.

L_S = target radiated noise in db.

L_N = ominidirectional background noise in db.

N_{DI} = directivity index.

N_{RD} = required signal to noise ratio for recognition in db.

Naval Operations Analysis suggested the following values as typical for a passive sonar on station:

	Older Sonars	Newer Sonars
L_S =	14 db.	14 db.
L_N =	-43 db.	-43 db.
N_{DI} =	12 db.	21 db.
N_{RD} =	-3 db.	-15 db.

These values were input to all passive sonars used in the model and can be changed by the User if desired.

APPENDIX F

SIMPLIFIED RADAR DETECTION MODEL

TITLE

SIMPLIFIED RADAR DETECTION MODEL

NO. Appendix F

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PREPARED BY L.D. Gregory

APPROVED BY (LDA

APPENDIX F

SIMPLIFIED RADAR DETECTION MODEL

1. INTRODUCTION

The purpose of this appendix is to derive a simplified radar detection model which embraces both the clear and the jamming environment. Multi-path, clutter, and other effects on detection are ignored in this treatment and are dealt with elsewhere.

2. STANDARD RADAR RANGE EQUATION

The commonly used radar range equation, see Reference (1), is

$$R^4 = \frac{P G^2 \lambda^2 \sigma}{(4 \pi)^3 P_m} \quad (1)$$

where

R = detection range, meters

P = transmitted power, watts

G = gain, (antenna, etc.)

λ = wavelength, meters

σ = target radar cross section, sq. meters

P_m = minimum power required at the receiver for detection at some desired probability level

This equation is best understood as applying to the detection based on a single pulse in a clear (unjammed) environment. For a large surface radar typical values might be: (Using FORTRAN Notation)

Reference (1). Airborne Radar, D. J. Povejsil, R. S. Raven, and Peter Waterman. *Boston Technical Publishers.* Cambridge, Massachusetts, 1965

$P = 1.E6$ watts

$G = 1000 \sim 30$ db

$\lambda = 1.0$ meters $\sim$ 300 Megahertz

$P_m = 5.E-13$ watts

$\sigma = 1$ Sq. Meter

then

$R = 178{,}000$ meters $\sim$ 90 Nautical Miles

The value of P_m is usually determined in relation to the radar receiver noise, i.e. (with typical values):

$$P_m = \left\{\frac{S}{N}\right\}_c N_r \qquad (2)$$

where

$\left\{\frac{S}{N}\right\}_c$ = critical signal to noise ratio = 5, to give required probability

N_r = Receiver noise, watts

$= (k)(T)(BR)(XNF) \qquad (3)$

where

k = Boltzmann's constant = (1.37E-23) joule/^{o}K

$T = 290^{o}K$

$(k)(T) = 3.97E-21 \doteq 4.E-21$

BR = Receiver bandwidth, Hz = 5.E6 Hertz

XNF = Receiver noise figure, num. = 5

then

$N_r = (4.E-21)(5.E6)(5.) = 100.E-15 = 1.E-13$ watts

$P_m = \frac{S}{N}_c NR \doteq 5.E-13$ watts

$$R^4 = \frac{(1.E6)(1.E6)(1.)}{(1984)(5.E-13)}\sigma = \frac{1}{992} \quad (1.E24)$$

and

$$R = .178E6 = 178,000 \text{ meters}$$

$$R \text{ in Naut. Mi.} = (5.412E-4)(17.8E4)$$

$$= 90 \text{ N.M.}$$

Note that the critical signal-to-noise ratio of 5 is sometimes expressed in db, i.e.,

$$SNRODB = 10 \log (SN)$$

$$= 10 \log (5) = 7$$

and Receiver Noise is sometimes expressed in DBM (decibels referenced to milliwatts), i.e.,

$$NRDBM = 10 \log N + 30 \quad (4)$$

$$= 10 \log (1.E -13) +30$$

$$= 10(-13) + 30$$

$$= -100$$

i.e.,

$$NR(Watts) = (10)^{-3} \quad (10)^{.1(NRDBM)} \quad (5)$$

Wavelength is related to frequency by

$$F = 300/\lambda \text{ in Megahertz for } \lambda \text{ in meters}$$

3. DETECTION PROBABILITY FOR A PULSE RADAR

For clarity, assume a pulse radar with a fan beam which scans by rotating in azimuth at a constant angular rate AZR and a pulse repetition frequency PRF. For each "look", i.e., each scan of the beam there will be n pulses hitting the target. Due to the random fluctuations of noise and target reflectivity some of the pulse returns may be detected and some may not. Thus detection becomes a random variable and we now speak of the single scan probability of detection, PSS.

In Reference (1) is derived an equation for PSS in terms of range R and other parameters. The assumptions include:

a. A pulse radar with small duty cycle (a thousandth or less)

b. Antenna pattern with constant gain over a beamwidth ,
and zero gain outside the beam.

c. A square law detector.

d. An additive pulse integrator

e. A decision element consisting simply of a defined threshold (bias).

f. Fluctuating target signal with a Rayleigh distribution, constant during each scan, but independent from scan to scan.

From Reference (1)

PSS(R) = Single scan probability of detection at Range R

$$= \exp\left[-K(R/R_o)^4\right] \quad (6)$$

where

$$R_o = \left[\frac{P\,G^2\,\lambda^2\,\sigma}{(4\pi)^3\,N}\right]^{1/4} \quad (7)$$

R = Range to target

K = A factor for each radar which is a function of n and η

where

n = No. of pulses per look (scan)

η = False Alarm number

$$\doteq \frac{1}{\text{False Alarm Probability}}$$

3.1 CALCULATION OF THE K-FACTOR

Now n is a function of the scan pattern, antenna beam size, and pulse repetition frequency; while η is a design and/or an operational choice determined by changing the detector threshold or bias level b. Typical values for η range from 10^2 to 10^{12}. The K factor is plotted in Figure 3-7 of Reference (1) as a family of curves for n and η. A curve fit to these is obtained by using the approximation $K \doteq Cn^{-.6}$ and determining C as shown in Figure 1. This yields the relations:

A: When $(6 \leq \log \eta \leq 12)$

$$K_{db} = 10 \log K$$

$$= -6 \log n + .4 \log \eta + 7.2 \quad (8)$$

B: When $(2 \leq \log \eta \leq 6)$

$$K_{db} = -6 \log n + .9 \log \eta + 4.2 \quad (9)$$

Note:

$$K = 10^{.1(K_{db})} \quad (10)$$

Example: For $n = 10$, $\eta = 10^{12}$, $R = R_o$

$$K_{db} = -6 + 4.8 + 7.2 = 6$$

$$K = 4.$$

$$PSS = \exp\left[-4. (1)^4\right] = .018$$

and for $R/R_o = \frac{1}{2}$, $PSS = .78$

Example: For $n = 10$, $R = R_o$ and various false alarm numbers

log η	2	4	6	8	10	12
PSS	.36	.22	.105	.068	.036	.018

3.2 CALCULATION OF NUMBER OF PULSES

The number of pulses n per scan used in equation for PSS above can be calculated for many regular scan patterns. For a fan beam sweeping in azimuth, this is

$$n = \frac{(ST)(PRF)(BA)}{SFOV} \quad (11)$$

where

ST = Scan time = 360/AZR, sec

AZR = Antenna azimuth scan rate, deg/sec

PRF = Pulse repetition frequency, pulses/sec

BA = Beam area = (BAZ)(BEL), square degrees

BAZ = Antenna azimuth beam width, deg.

BEL = Antenna elevation beam width, deg.

SFOV = Search field-of-view, square degrees

= 360^{o} (BEL)

Example:

$AZR = 60$ deg/sec

$PRF = 240$ pulses per second

$BAZ = 2.5$ deg.

$BEL = 20$ deg.

then

$ST = 360/60 = 6$ sec.

$BA = (2.5)(20) = 50$ square degrees

$SFOV = (360)(20) = 7200$ square degrees

and

$$n = \frac{(6)(240)(50)}{7200} = 10 \text{ pulses/scan}$$

Then for false alarm number = 10^{12}, the probability of detection at range $R = R_o$ is

$$PSS(R_o) = \exp\left[-K(R_o/R_o)^4\right]$$

$$= \exp\left[-4\right] = .018 \qquad (12)$$

3.3 RELATION OF (S/N), PSS, FALSE ALARM, AND BIAS

The critical signal-to-noise ratio $(S/N)_c$ was introduced in equation (2) and R_o was defined in equation (7) with $(S/N)_c = 1$. Suppose that the bias level in the receiver is set so that at R_o the false alarm number is 10^{12}. Then we see in the example above that at $R = R_o$ the single scan detection probability is .018. From Figure 3-3 in Reference (1) we see that for number of pulses n = 10, then the bias level b = 50(2N) = 100N (N = Noise power). If we decrease the bias level to about 36N the false alarm number is 10^2, and the probability of false alarm is increased from 10^{-12} to 10^{-2}. Now what happens to detection probability PSS?

First let us note that for a given radar and target, R_o is fixed and is independent of bias level b or the false alarm number η. Also as shown in Reference (1) the received signal-to-noise ratio at any range R is

$$\frac{S}{N} = \left\{ \frac{R_o}{R} \right\}^4 \tag{13}$$

i.e.,

$$R = (S/N)^{-1/4} R_o \tag{14}$$

Then when the signal equals the bias level

$$R_1 = (36)^{-1/4} R_o = .41 R_o \quad \left[\text{for } \eta = 10^2, (S/N)_c = 36 \right]$$

$$R_2 = (100)^{-1/4} R_o = .31 R_o \quad \left[\text{for } \eta = 10^{12}, (S/N)_c = 100 \right]$$

Thus we pay for decreased false alarm probabilities by decreasing the "detection" range from $.41 R_o$ to $.31 R_o$ in this example. Let us now find the detection probabilities at R_1 and R_2.

From equations (6) and (13) we have

$$PSS(R) = \exp \left[-K(N/S) \right]$$

where K is a function of false alarm number η and number of pulses n i.e., for n = 10 as before

$$K(n, \eta) = 10** \left[.1(-6 + 1.8 + 4.2) \right] = 1, \ \eta = 10^2$$

$$= 10** \left[.1(-6 + 4.8 + 7.2) \right] = 4, \ \eta = 10^{12}$$

Thus

$$PSS(R_1) = \exp \left[-1/(36) \right] = \exp \left[-.028 \right] = .972$$

$$\text{for } \eta = 10^2, (S/N)_c = 36$$

$$PSS(R_2) = \exp \left[-4/100 \right] = \exp \left[-.04 \right] = .961$$

$$\text{for } \eta = 10^{12}, (S/N)_c = 100$$

We interpret this by saying that although range R_1 is greater than R_2 the detection probability at R_1 is greater than at R_2 but so is the number of false alarms. The selection of a bias level (and hence a false alarm rate) is a design choice and varies from one application to another, see Reference (1).

4. COMPUTING SUMMARY FOR CLEAR (UNJAMMED) CASE

For computational and programming convenience the above is summarized:

4.1 RADAR INPUTS

For each radar type and mode of operation:

(1)	XLAMDA	=	Wavelength, cm
(2)	PR	=	transmitted power, watts
(3)	GTDB	=	transmitter gain, db
(4)	GRDB	=	receiver gain, db
(5)	XNF	=	receiver noise figure, numeric
(6)	BR	=	receiver bandwidth, Hz
(7)	FR	=	PRF = pulse repetition frequency, pulses/sec
(8)	RATE1	=	AZR = antenna azimuth scan rate, deg/sec
(9)	BWE	=	BAZ = antenna azimuth beam width, deg.
(10)	BWD	=	BEL = antenna elevation beam width, deg.
(11)	TA	=	T = antenna temperature, deg. K
(12)	PFA	=	Probability of false alarm = 1/false alarm number
(13)	SIGMAT	=	σ = target radar cross section, square meters

4.2 **COMPUTATION**

If we let

λ = XLAMDA/100

P = PR

G_r = 10.**(.1*GTDB)

N_r = (4.E-21)*(BR)*(XNF)

η = 1/PFA

n = ((360/RATE1)*FR*BWE*BWD)/(360*BWD))
= FR*BWE/RATE1

KDB = -6 log n + .4 log η + 7.2
for ($6 \leq \log \eta \leq 12$)

= -6 log n + .9 log η +4.2
for ($2 \leq \log \eta \leq 6$)

K = 10.**(.1*KDB)

Then

$$\beta = \left[\frac{P\, G_r^2\, \lambda^2}{(4\pi)^3\, N_r} \right]^{1/4} \tag{15}$$

$$R_o = \beta \cdot \sigma^{1/4} \tag{16}$$

$$PSS(R) = \exp\left[-K(R/R_o)^4\right] \tag{17}$$

Normally β and K can be computed once for a given radar type and then only R and σ varies during the problem.

Note if N_r is given in DBM

N_r = 10**(.1*DBM - 3)

5. EFFECTS OF POWER JAMMING

Assume a broad band jammer which is emitting with a power of P_j watts per hertz in the frequency band of the radar receiver. Then from equations (3-2) and (3-4) of Reference (1) we find that the jamming signal N_j seen by the radar receiver is

$$N_j = \frac{P_j B_r G_j G_r \lambda^2}{(4\pi)^2 R_j^2} \tag{18}$$

where

P_j = jammer power, watts per hertz
B_r = BR = radar receiver bandwidth, hertz
G_j = jammer gain (antenna focusing)
G_r = radar antenna gain
λ = wavelength, meters
R_j = range from jammer to radar, meters
R_t = range from target to radar, meters.

The assumption is then made that the jammer signal N_j is additive with the receiver noise N_r. Then the signal to noise ratio in the receiver is

$$\frac{S}{N} = \frac{S}{N_r + N_j} = \frac{\dfrac{P G_r^2 \lambda^2 \sigma}{(4\pi)^3 R_t^4}}{N_r + \dfrac{P_j G_j G_r \lambda^2 B_r}{(4\pi)^2 R_j^2}} \tag{19}$$

Using the definition of R_o as before and defining

$$R_k = \left[\frac{P_j G_j}{(4\pi)^2} \cdot \frac{G_r \lambda^2 B_r}{N_r} \right]^{1/2} \tag{20}$$

then

$$\frac{S}{N} = \frac{(R_o/R_t)^4}{1 + (R_k/R_j)^2} \tag{21}$$

Thus we see that if $R_j = R_k$ then the signal-to-noise is cut in half, which is equivalent to reducing R_o by a factor of the fourth root of 2. The probability of detection in a single scan now becomes

$$PSS(R_t) = \exp\left[-K/(S/N)\right] \tag{22}$$

where K is the same as given in equations (6) and (17), and S/N is given in equation (21). Note that the jamming degrades the range by a factor of

$$\left[\frac{1}{1 + (R_k/R_j)^2} \right]^{1/4} \tag{23}$$

In many cases (R_k/R_j) is a large number so that in effect in equations (21) and (22)

$$\frac{S}{N} = \left[\frac{R_o}{R_t} \right]^4 \left[\frac{R_j}{R_k} \right]^2 \tag{24}$$

$$\sim \frac{P_t G_t G_r \lambda^2}{N_r} \cdot \frac{R_j^2}{R_t^4} \cdot \frac{N_r}{P_j G_j G_r \lambda^2 B_r}$$

$$\sim \frac{P_t}{P_j B_r} \frac{G_t}{G_j} \cdot \frac{R_j^2}{R_t^4} \tag{25}$$

From this we can make the following approximate statements: For a given number of hits per scan n and a given false alarm number η and a given probability of detection in a single scan (PSS):

a. Radar transmitting power P_t offsets jammer power one-for-one.

b. Forcing the jammer to stand off at twice the range increases the range to target (for same detection probability) by a factor of $(4)^{1/4} = 1.414$, i.e., an increase of 41% in R_t.

c. Cutting the jammer power to one-fourth is equivalent to doubling the jammer stand-off range or to increasing the detection range by 41%.

d. Cutting the jammer power to one-tenth is equivalent to trebling the jammer stand-off range or to increasing detection range by a factor of $10^{1/4} = 1.78$ (an increase of 78%)

6. COMPUTING SUMMARY FOR JAMMING CASE

In addition to the inputs in Section 4, above, include the following:

6.1 <u>JAMMER INPUTS</u>

For each jammer type and each band:

(1) PJ = Jammer power, watts/MHz

(2) GJDB = Jammer antenna gain, db

(3) BJ = Jammer signal bandwidth, Hz (equal to or greater than BR)

(4) RJ = Range, radar to jammer, N.Mi.

6.2 COMPUTATION

If we let

λ = XLAMDA/100, meters

P_j = PJ/1.E6, watts/Hz

G_j = 10**(.1 GJDB)

B_r = BR, Hz

G_r = 10**(.1 GRDB)

R_j = RJ/5.4118E-4 = 1.848E3*RJ, meters

N_r = (4.E-21)*(BR)*(XNF)

R_t = 5.4118E4*R, meters

then

$$R_k = \left[\frac{P_j G_j}{(4\pi)^2} \cdot \frac{G_r \lambda^2 B_r}{N_r}\right]^{1/2}, \text{ meters} \tag{26}$$

$$SN = \frac{(R_o/R_t)^4}{1 + (R_k/R_j)^2} \tag{27}$$

$$RKJ = 1 + (R_k/R_j)^2 \tag{28}$$

$$PSS(R_t) = \exp\left[-K*RKJ*\left\{\frac{R_t}{R_o}\right\}^4\right] \tag{29}$$

NOTE: For each radar can compile

$$\alpha = \left[\frac{G_r \lambda^2 B_r}{(4\pi)^2 N_r}\right]^{1/2} \quad (5.4118E-4)$$

Then to get R_k in N. Mi.

$$R_k = (P_j G_j)^{1/2}$$

$$= (PJ*(1.E-6)*G_j)^{1/2}* \quad \alpha$$

$$= (PJ*G_j)^{1/2}*(1.E-3)* \quad \alpha$$

Let

$$ALFA = (1.E-3)* \quad = (5.4118E-7)* \left[\frac{G_r \lambda^2 B_r}{(4^{\pi})^2 N_r} \right]^{1/2}$$

Then

$$R_k = (PJ*G_j)^{1/2}*ALFA$$

7. EXAMPLE No. 1 - NO JAMMING

In the notation of Section 4, let

XLAMDA	= 145 cm	λ	= 1.45 meters
PR	= 1.8E5 watts	P	= 1.8E5 watts
GTDB	= 23 db	G_r	= 200.
GRDB	= 23 db	G_r	= 200.
XNF	= 2.	N_r	= (4. E-21)(3. E5)(2)
BR	= 3. E5 Hz		= 24. E-16
FR	= 230 pps		
RATE1	= 60 deg/sec	n	$= \frac{230*7}{60} \doteq 27$ pulses/scan
BWE	= 7 deg		
BWD	= 20 deg		
PFA	= 1. E-12	η	= 1. E12
SIGMAT	= 1 sq. meter	σ	= 1

Then,

$$KDB = -6 \log n + .4 \log \eta + 7.2$$

$$= -8.58 + 4.8 + 7.2 = 3.42$$

$$K = 10**(.1KDB) = 2.2$$

$$\beta = \left[\frac{P\, G_r^2\, \lambda^2}{(4\pi)^3\, N_r}\right]^{1/4} = \left[\frac{(1.8E5)(200)^2(1.45)^2}{1984(24.E-16)}\right]^{1/4} = \left[\frac{15.1E9}{4.75E-12}\right]^{1/4}$$

$$= \left[3.18E21\right]^{1/4} = 2.37E5 = 23.7E4$$

$$R_o = \beta \bullet \sigma^{1/4} = 23.7E4, \text{ meters}$$

$$(5.4118E-4)(23.7E4) = 129 \text{ N.M.}$$

$$PSS(R) = \exp\left[-K(R/R_o)^4\right] = \exp\left[-2.2(R/129)^4\right]$$

$$PSS(R_o) = \exp\left[-2.2\right] = .11$$

R	200	150	100	50	30
$(R/R_o)^4$	5.70	1.8	.36	.0215	.0029
$K(R/R_o)^4$	12.5	4.	.79	.0475	.0064
PSS(R)	3.7E-6	.018	.45	.954	.9936

For η = 1.E6, KDB = 1.02, K = 1.26, $PSS(R_o)$ = .284

R	200	150	100	50	30
PSS(R)	7.5E-4	.103	.635	.973	.9964

8. EXAMPLE NO. 1A - WITH JAMMING

In the notation of Sections 4. and 6. let

PJ = 500 watts/MHz

GJDB = 0 db

BJ = 7.5E6 Hz

RJ = 100 N.M.

Using the above and the data of Section 7

λ = XLAMDA/100 = 1.45 meters

P_j = PJ/1.E6 = 500.E-6 watts/Hz

G_j = 10**(.1 GJDB) = 1.

B_r = BR = 3.E5 Hz

G_r = 10**(.1 GRDB) = 200.

R_j = RJ = 100 N.M.

N_r = = 24.E-16

K = = 2.2

R_o = = 129 N.M.

Then

$$R_k = \left[\frac{(5.E-4)(1.)}{157.5} \quad \frac{(200)(1.45)^2(3.E5)}{(4.E-1)(3.E5)(2)} \right]^{1/2}$$

$$= \left[(3.18E-6)\ (5.25E22)\right]^{1/2} = \left[16.7E16\right]^{1/2} = 4.09E8 \text{ meters}$$

R_k = (5.4118E-4)(4.098E8) = 20.9E4 = 209E3 N.M.

RKJ = $1 + (R_k/R_j)^2 = 1 + (2.09E3)^2 = 4.35E6$

K*RKJ = 9.55E6, PSS(R_t) = exp $\left[-9.55E6\ (R_t/R_o)^4\right]$

R_t	1.29	12.9	6.45	3.	2.	1.7	1.5
$(R_t/R_o)^4$	1.E-8	1.E-4	6.25E-6	3.6E-7	5.7E-8	3.03E-8	1.85E-8
-K*RKS* $\left(\frac{R_t}{R_o}\right)^4$	-9.55E-2	-9.5E+2	60.	3.45	.545	.29	.177
PSS	.909	0.	0.	.031	.58	.748	.837

$$ALFA = (5.4118E\text{-}7)\left[\frac{G_r\ \lambda^2\ B_r}{(4\pi)^2\ N_r}\right]^{1/2} = (5.4118E\text{-}7)\left[\frac{5.25E22}{157.5}\right]^{1/2}$$

$$= 9.9E{+}3$$

9. EXAMPLE NO. 2 - NO JAMMING

In the notation of Section 4, let

XLAMDA	= 5.5 cm	λ	=	.055 meters
PR	= 2.83E5 watts	P	=	2.85E5 watts
GTDB	= 23 db	G_t	=	1000
GRDB	= 23 db	G_r	=	1000
XNF	= 25	N_r	=	(4.E-21)(5.E6)(25)
BR	= 5.E6 Hz		=	5.E-13
FR	= 610 pps			
RATE1	= 102 deg/sec	n	=	$\frac{610*1.8}{102}$ = 10.8 pulses/scan
BWE	= 1.8 deg			
BWD	= 16. deg.			
PFA	= 1.E-12	η	=	1.E12
SIGMAT	= 1 sq. meters	σ	=	1

Then

$$KDB = -6 \log n + .4 \log \eta + 7.2$$

$$= -8.58 + 4.8 + 7.2 = 3.42$$

$$K = 10**(.1\ KDB) = 2.2$$

$$\beta = \left[\frac{P\ G_r^2\ \lambda^2}{(4\ \pi)^3\ N_r}\right]^{1/4} = \left[\frac{(2.85ES)(1.E6)(.055)^2}{1984(5.E\text{-}13)}\right]^{1/4} = \left[\frac{8.7E8}{9.9E\text{-}10}\right]^{1/4}$$

$$= \left[8.84E17\right]^{1/4} = 3.06E4$$

$$R_o = \beta \bullet \sigma^{1/4} = 3.06E4 \text{ meters}$$

(5.4118E-4)(3.06E4) = 16.6 N. MI.

$PSS(R) = \exp\left[-K(R/R_o)^4\right] = \exp\left[-2.2(R/16.6)^4\right]$

$PSS(R_o) = \exp\left[-2.2\right] = .11$

R	20	15	10	8.3	5
$(R/R_o)^4$	2.07	.658	.13	.062	.008
$K(R/R_o)^4$	4.6	1.41	.286	.136	.0176
PSS(R)	.01	.24	.75	.87	.925

10. EXAMPLE NO. 2A - WITH JAMMING

In the notations of Sections 4 and 6 let

PJ = 500 watts/MHz

GJDB = 0 db

BJ = 7.5E6 Hz

RJ = 100 N.M.

Using the above and the data of Section 9.

λ = XLAMDA/100 = .055 meters

P_j = PJ/1.E6 = 500.E-6 watts/Hz

G_j = 10**(.1GJDB) = 1.

B_r = BR = 5.E6 Hz

G_r = 10**(.1GRBD) = 1000

R_j = RJ = 100 N.M.

N_r = = 5.E-13

K = = 2.2

R_o = = 16.6 N.M.

then

$$ALFA = (5.412E-7) \left[\frac{G_r \lambda^2 B_r}{(4\pi)^2 N_r} \right]^{1/2} = (\quad) \left[\frac{(1000)(.055)^2(5.E6)}{(157.5)(5.E-13)} \right]^{1/2}$$

$$= (\quad) \left[\frac{1.5E7}{.787E-10} \right]^{1/2} = (5.412E-7) \left[1.91E17 \right]^{1/2}$$

$$= (5.412E-7)(4.37E8) = 23.7E1 = 237$$

$$R_k = (PJ*G_j)^{1/2} * ALFA = 22.3*237 = 5.3E3$$

Let

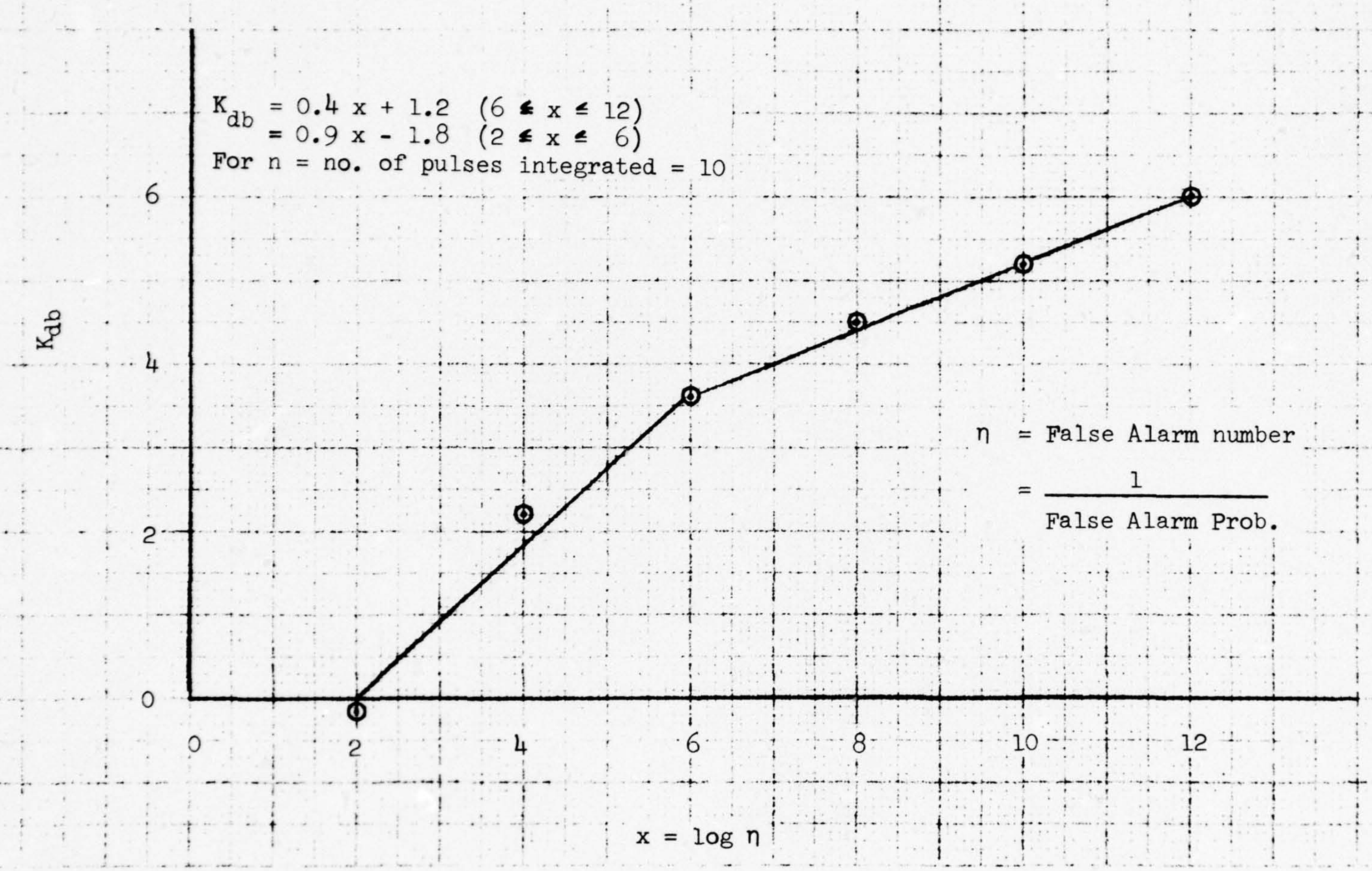
$$RKJ = 1 + (R_k/R_j)^2 = 1 + (53)^2 = 2821 = 2.82E3$$

$$K*RKJ = 6.2E3 \qquad PSS(R_t) = \exp\left[-6.2E3(R_t/R_o)^4 \right]$$

R_t	1.66	1.7	2.	2.5
$(R_t/R_o)^4$	E-4	1.1E-4	2.07E-4	
$K*RKJ(R_t/R_o)^4$	6.2E-1	6.85E-1	12.8E-1	
PSS	.54	.504	.28	

Figure 1

K-FACTOR CURVE FIT



APPENDIX G

SAM INTERCEPT MODEL

TITLE	
SAM INTERCEPT MODEL	NO. Appendix G DATE

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PREPARED BY L.D. Gregory

APPROVED BY

APPENDIX G

SAM INTERCEPT MODEL

1. INTRODUCTION

A simplified Surface-to-Air Missile intercept model is developed which requires tabular input of time of flight in a local coordinate system centered at the launcher, and an allowed firing sector similarly defined.

2. TIME OF FLIGHT

As in Figure 1, assume a polar coordinate system with the origin at the launcher L. For the point P with polar coordinates P = (A, R) let the contours of constant time of flight be given for two times T_1 and T_2 which bound the point P and tabulated for the four points.

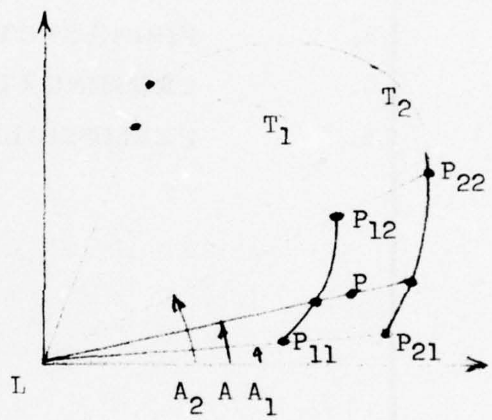

FIGURE 1
TIME OF FLIGHT CONTOURS

$$P_{11} = (A_1, R_{11})$$
$$P_{12} = (A_2, R_{12})$$
$$P_{21} = (A_1, R_{21})$$
$$P_{22} = (A_2, R_{22})$$

Let:

$$p = (A-A_2)/(A_1-A_2)$$
$$q = 1 - p$$
$$R_1 = p\,R_{11} + q\,R_{12}$$
$$R_2 = p\,R_{21} + q\,R_{22}$$
$$s = (R-R_2)/(R_1-R_2)$$
$$t = 1 - s$$

Then the interpolated time of flight T to the point P will be

$$T = s\,T_1 + t\,T_2$$

Let the contours for the time of flight be tabulated in a "bordered" table as follows:

TABLE I

BORDERED TABLE FORMAT - TIME OF FLIGHT

	Col. 1	Col. 2				
Row 1	D			A_1	A_2	
Row 2						
	T_1			R_{11}	R_{12}	
	T_2			R_{21}	R_{22}	

where the entry in the first row and first column is D = 100 M + N where

M = No. of rows including the border containing the angles A_j as tabulated

N = No. of columns including the border containing the times T_i as tabulated.

The entries are the radii R_{ij} to the points on the contours.

3. FIRING SECTOR

The allowed firing sector will be determined by a maximum range, a minimum range, and elevation and azimuth limits. Consider the following local spherical coordinate system centered at the launcher L

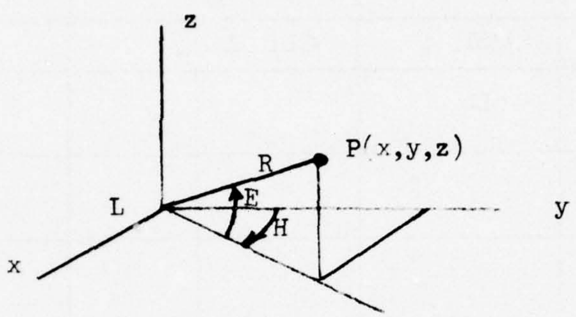

FIGURE 2

FIRING SECTOR SPHERICAL COORDINATES

Let the y-axis be north, the x-axis east, the z-axis vertical, and let H be the clockwise angle from north, and E the elevation angle. Then, for the Point P(x, y, z) the spherical coordinates and x, y z are related by:

$$x = R \cos E \sin H$$

$$y = R \cos E \cos H$$

$$z = R \sin E$$

$$\left.\begin{array}{l} R = \sqrt{x^2 + y^2 + z^2} \\ E = \text{ATAN2}\,(z, \sqrt{x^2 + y^2}\,) \\ H = \text{ATAN2}\,(x, y) \end{array}\right\} \quad \begin{array}{l} R \geq 0 \\ -\pi/2 \leq E \leq \pi/2 \\ 0 \leq H \leq 2\pi \end{array}$$

Then the firing sector is defined by a set of constraints:

$$E_a \leq E \leq E_b$$

$$H_a \leq H \leq H_b$$

$$R_a \leq R \leq R_b$$

$$\sqrt{x^2 + y^2} \leq x_b$$

$$0 \leq z \leq z_b$$

where care must be taken in defining H_a and H_b if north is to be included in the sector. Note that all or a portion of a hemisphere may be selected as the firing sector, as shown schematically in Figure 3.

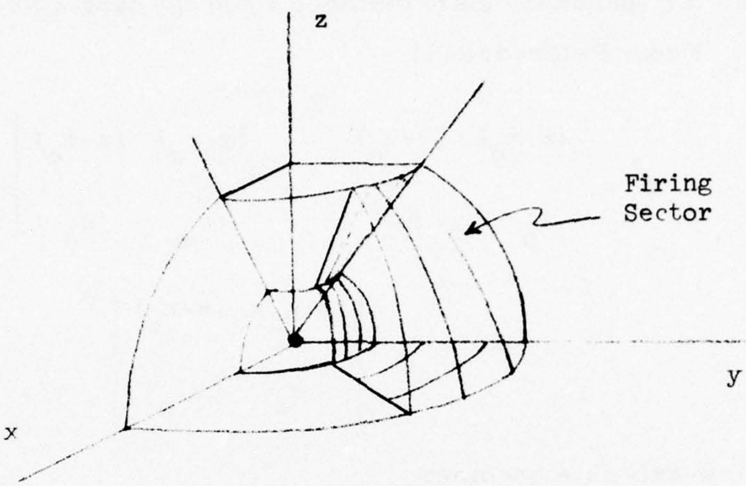

FIGURE 3

TYPICAL FIRING SECTOR

4. CROSSING COURSE GEOMETRY

If the SAM target is not flying directly at the launcher, then there is a time and point of minimum separation of the launcher and target. Under the assumption that the launcher motion is zero or negligible and that a linear extrapolation of target velocity is appropriate, the location and time to the crossing point is as follows.

In the local x, y, z coordinate system of Figure 2, let the target position be x_1, y_1, z_1 at time t_1, with velocity vector components u, v, w. Then the extrapolated target position T(x, y, z) at any time t is:

$$x = x_1 + u(t - t_1)$$
$$y = y_1 + v(t - t_1)$$
$$z = z_1 + w(t - t_1)$$

This then is a directed line with direction numbers (u:v:w). Consider now the z-axis as a directed line thru the local origin (x_o, y_o, z_o) with direction numbers$(l_o:m_o:n_o)$. Then

$$x_o = 0,\ y_o = 0,\ z_o = 0$$

$$l_o = 0,\ m_o = 0,\ n_o = 1$$

Let d be the (perpendicular) distance from the target at (x, y, z) to the z-axis. From Reference (1)

$$d^2 = \begin{vmatrix} (x-x_o) & (y-y_o) \\ l_o & m_o \end{vmatrix}^2 + \begin{vmatrix} (y-y_o) & (z-z_o) \\ m_o & n_o \end{vmatrix}^2$$

$$+ \begin{vmatrix} (z-z_o) & (x-x_o) \\ n_o & l_o \end{vmatrix}^2$$

For the z-axis this becomes

$$d^2 = x^2 + y^2$$

$$= \left[x_1 + u(t-t_1) \right]^2 + \left[y_1 + v(t-t_1) \right]^2$$

Let $\tau = t-t_p$ be the time increment, then

$$d^2 = (u^2 + v^2)\tau^2 + 2(ux_1 + vy_1)\tau + (x_1^2 + y_1^2)$$

Differentiation with respect to τ shows that d^2 is a minimum (hence d is a minimum) when

$$\tau = \tau_z = \frac{-(ux_1 + vy_1)}{u^2 + v^2}$$

and

$$d = dz = \frac{|uy_1 - vx_1|}{\sqrt{u^2 + v^2}}$$

This of course is not precisely the same time that the closest approach to the launcher occurs. This is given as follows:

----

(1) Solid Analytical Geometry, by John M. H. Olmstead, D. Appleton-Century, N.Y. 1947

Let d be the distance at any time t from the launcher to the target. Let the time increment be τ, i.e.,

$$\tau = t - t_1$$

then

$$\begin{aligned} d^2 &= x^2 + y^2 + z^2 \\ &= (x_1 + u\tau)^2 + (y_1 + v\tau)^2 + (z_1 + w\tau)^2 \\ &= a\tau^2 + b\tau + c \end{aligned}$$

where

$$\begin{aligned} a &= u^2 + v^2 + w^2 \\ b &= 2(ux_1 + vy_1 + wz_1) \\ c &= x_1^2 + y_1^2 + z_1^2 \end{aligned}$$

Differentiation of d^2 with respect to τ gives a minimum for

$$\tau = \tau_o = \frac{-(ux_1 + vy_1 + wz_1)}{u^2 + v^2 + w^2}$$

with a minimum distance d_o, where

$$d_o^2 = x_1^2 + y_1^2 + z_1^2 - \frac{(ux_1 + vy_1 + wz_1)^2}{u^2 + v^2 + w^2} .$$

Note that when w = 0 (i.e., constant altitude target motion), then

$$\tau_o = \tau_z .$$

We shall be concerned with both. To distinguish between the two points we define:

a. Crossing Course Point (at time $\tau_z = t_z - t_1$)

$$P_z = P(x_z, y_z, z_z; t_z) = P(R_z, E_z, H_z; t_z)$$

b. Minimum separation point (at time $\tau_o = t_o - t_1$)

$$P_o = P(x_o, y_o, z_o; t_o) = P(R_o, E_o, H_o; t_o)$$

c. Target position at time t_1

$$P_1 = P(x_1, y_1, z_1; t_1) = P(R_1, E_1, H_1; t_1)$$

5. PERMISSIBLE LAUNCH TIMES

A permissible launch time is defined to be a time at which the SAM can be launched so that an intercept can be made in the firing sector. Using the definitions in the preceding sections we ascertain the earliest and latest permissible launch times (t_a and t_b) as follows:

a. If the target is not in the firing sector, find the points where it enters (and leaves, if it does).

b. For the segment of the target trajectory which is in the firing sector, find those points for which the SAM time of flight is less than the time for the target to move from its present position P_1. These are permissible intercept points and the launch times are found by subtracting off the SAM time of flight to these points.

This is done in subroutine SAMLT by a series of calculations and tests using the firing sector definition in polar coordinates and the time of flight tables previously discussed.

APPENDIX H

MIDCOURSE NAVIGATION ERROR MODELS FOR CRUISE MISSILES

TITLE

MIDCOURSE NAVIGATION ERROR MODELS
FOR CRUISE MISSILES

NO. Appendix H

DATE

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PREPARED BY B.G. Kibby

APPROVED BY CLS

APPENDIX H

MIDCOURSE NAVIGATION ERROR MODELS FOR CRUISE MISSILES (U)

1. INTRODUCTION

(U) The purpose of this appendix is to present the midcourse navigation error models for cruise missiles as used in the SEATIDE model. It specifically includes:

a. All Inertial System

b. Airspeed and Magnetic Heading

c. Doppler Radar and Magnetic Heading

These are discussed below.

2. INERTIAL NAVIGATION ERROR MODEL

2.1 Introduction

(U) The Inertial position error equations are presented for cruise vehicle operating conditions. The solutions are valid for time intervals up to 2 hours. A latitude-longitude mechanization has been assumed with the platform X-axis level and east, y-axis level and north, and Z-axis up. The orientation of this set is shown in Figure 1.

(U) A list of symbols utilized is presented in Table I. The Inertial system error descriptions are given in Table II. The values for constants utilized in the error model are shown in Table III. In Table IV the Inertial System Error Values are presented for current and projected technology systems. Equations used are in Section 2.4.

2.2 Initial Platform Alignment

(U) The alignment of the platform prior to launch consists of leveling the X and Y platform axes using the accelerometers. Upon completion of leveling the Z-axis is gyrocompassed to north. The major error sources that contribute to platform leveling are the accelerometer biases. The major error sources affecting azimuth alignment are the

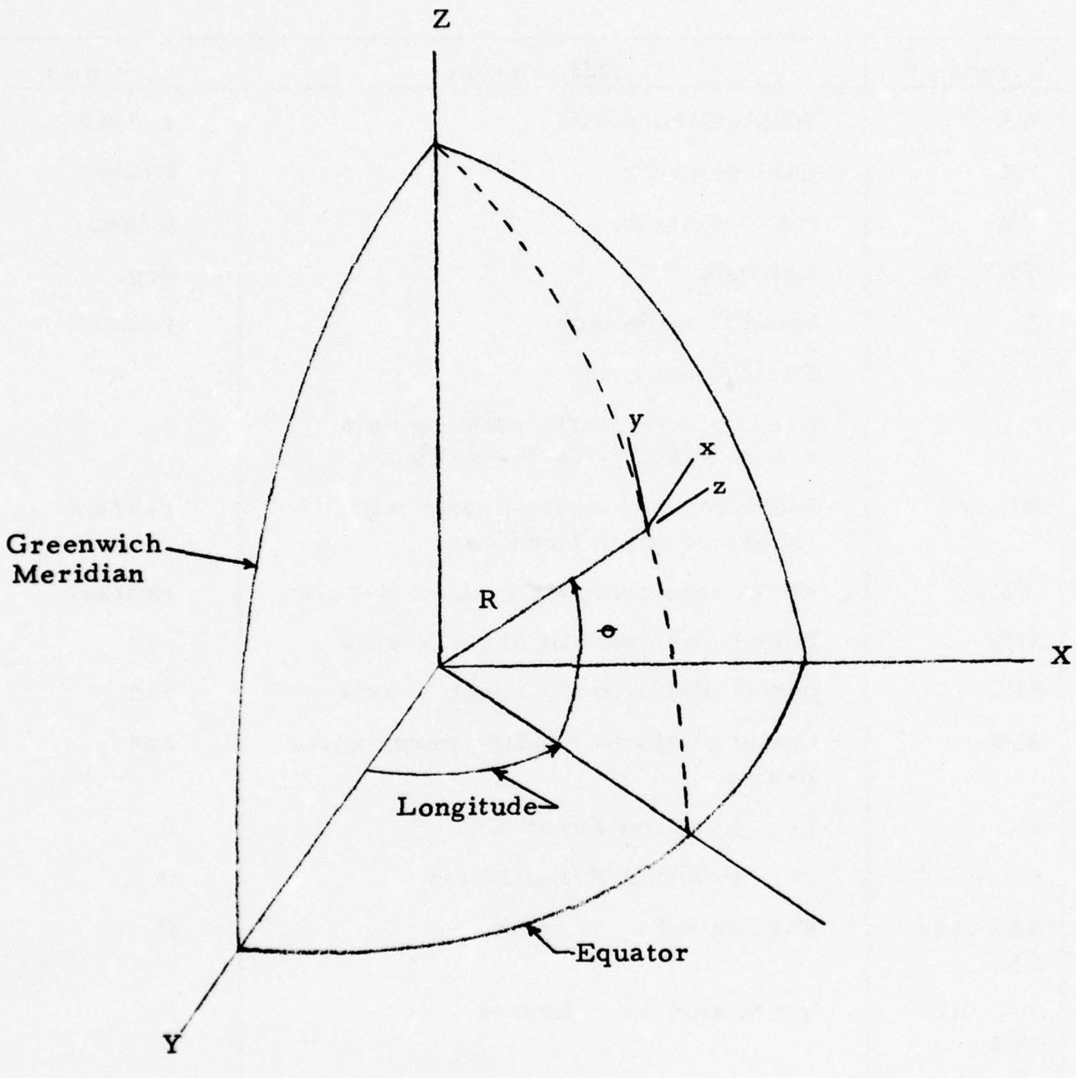


Figure 1

AXIS SYSTEM

TABLE I. LIST OF SYMBOLS

Symbol	Description	Units
WS	Schuler frequency	rad/sec
VX	East velocity	ft/sec
VY	North velocity	ft/sec
THETA	Latitude	deg.
T	Time from launch	seconds
X,Y,Z	Earth fixed axis	
x, y, z	Locally level north pointing axis set: x-East, y-North, z-Up	
RHOZ	Platform rate about Z-axis with regard to earth fixed set	rad/sec
WEY	Earth rate component about Y-axis	rad/sec
SPX	Initial platform tilt about X-axis	rad
SPY	Initial platform tilt about Y-axis	rad
SPZ	Initial platform heading error about Z-axis	rad
SX	1- Position Error East	ft
SY	1- Position Error North	ft
SX1 thru SX7	East axis 1- Errors	ft
SY1 thru SY6	North axis 1- Errors	ft
CEP	Circular Error Probable	ft

TABLE II. INERTIAL SYSTEM ERRORS

Symbol	Description (1- Errors)	Units
SDXP	x-component of accelerometer bias	g's
SDYP	y-component of accelerometer bias	g's
SKXP	x-component of accelerometer scale factor	%
SKYP	y-component of accelerometer scale factor	%
SEXP	x-component of gyro drift rate	deg/hr
SEYP	y-component of gyro drift rate	deg/hr
SKX	x-component of gyro scale factor	%
SKY	y-component of gyro scale factor	%
SDRX	x-component of reference position error	ft
SDRY	y-component of reference position error	ft
SDRXD	x-component of reference velocity error	ft/sec
SDRYD	y-component of reference velocity error	ft/sec

TABLE III. LIST OF CONSTANTS

Symbol	Description	Value
R	Earth radius	2.0926388×10^7 ft
WE	Earth rate	7.2921152 rad/sec
G	Gravity acceleration	32.17 ft/sec^2
P	Pi	3.1416
A0	Conversion factor	0.675617
A1	Conversion factor	-0.115956
A2	Conversion factor	1.65078
A3	Conversion factor	-1.54296
A4	Conversion factor	0.509798

east gyro drift rate and the north reference velocity error. The initial tilt and azimuth alignment errors are modeled as Equations 5, 6, and 7. The values calculated are representative of the steady state tilts and azimuth values achievable for 15 to 30 minutes of alignment time.

2.3 Error Model Assumptions

(U) At launch the vehicle has initial position errors SDRX and SDRY, and initial velocity errors SDRXD and SDRYD as determined by the launching craft. The cruise vehicle is assumed to accelerate to constant velocities VX and VY. The following error sources are assumed to be constant: accelerometer bias errors SDXP and SDYP, accelerometer scale factor errors SKXP and SKYP, gyro bias errors SEXP and SEYP, and gyro scale factor errors SKX and SKY. For flight times of less than 2 hours the error contribution of the azimuth gyro is negligible and is not considered.

(U) In the X-channel (east channel) the alignment errors and inertial component errors are propogated in time by equations 8 thru 14. These errors are considered uncorrelated and are root sum squared to obtain the one sigma easterly position error SX. Likewise equations 16 thru 21 propogate in time the Y-channel (north channel) errors which are root sum squared to obtain the one sigma northerly position error SY.

(U) The vehicle CEP is determined using equations 23 thru 25 which convert the easterly and northerly position errors to a position circular error probable.

2.4 Equations

(1) $WS = (G/R)^{1/2}$

(2) $THETAR = THETA \cdot 2 \cdot P/360$

(3) $RHOZ = \frac{VX}{R} \cdot \tan(THETAR)$

(4) $WEY = WE \cdot \cos(THETAR)$

(5) $SPX = SDXP$

(6) $SPY - SDYP$

(7) $$SPZ = \left[\left(\frac{SEXP\cdot 2\cdot P}{WEY\cdot 3600\cdot 360}\right)^2 \left(\frac{SDRYD}{R\cdot WEY}\right)^2\right]^{1/2}$$

(8) $$SX1 = SDRX$$

(9) $$SX2 = \frac{SKXP}{100}\cdot\frac{VX}{WS}\cdot \sin(WS\cdot T)$$

(10) $$SX3 = SDRXD\cdot\frac{1}{WS}\cdot \sin(WS\cdot T)$$

(11) $$SX4 = \frac{SKY}{100}\cdot VX\left[T - \frac{1}{WS}\cdot \sin(WS\cdot T)\right]$$

(12) $$SX5 = SPX\cdot RHOZ\cdot R\left[T - \frac{1}{WS}\cdot \sin(WS\cdot T)\right]$$

(13) $$SX6 = SEYP\cdot\frac{2\cdot P\cdot R}{3600\cdot 360}\left[T - \frac{1}{WS}\cdot \sin(WS\cdot T)\right]$$

(14) $$SX7 = SPZ\cdot VY\cdot T$$

(15) $$SX = \left(\sum_{N-1}^{7} SXN^2\right)^{1/2}$$

(16) $$SY1 = SDRY$$

(17) $$SYZ = \frac{SKYP}{100}\cdot\frac{VY}{WS}\cdot \sin(WS\cdot T)$$

(18) $$SY3 = SDRYD\cdot\frac{1}{WS}\cdot \sin(WS\cdot T)$$

(19) $$SY4 = \frac{SKX}{100}\cdot VY\left[T - \frac{1}{WS}\cdot \sin(WS\cdot T)\right]$$

(20) $$SY5 = SPY\cdot RHOZ\cdot R\left[T - \frac{1}{WS}\cdot \sin(WS\cdot T)\right]$$

(21) $$SY6 = SPZ\cdot VX\cdot T$$

(22) $$SY = \left(\sum_{N=1}^{6} SYN^2\right)^{1/2}$$

(23) If $(SY - SX) \leq 0$

then: $RA = SY/SX$

$S = SX$

(24) If (SY - SX) > 0

then: RA = SX/SY

S = SY

(25) $CEP = S(A0+A1 \cdot RA+A2 \cdot RA^2+A3 \cdot RA^3+A4 \cdot RA^4)$

3. AIRSPEED AND MAGNETIC HEADING ERROR MODEL

(U) Navigation utilizing airspeed and magnetic heading data provides a relatively simple and cheap navigation system at the expense of navigation accuracy. Any error in the knowledge of the air mass movement with respect to the ground (i.e., error in estimating wind speed and direction) results in position error propogation that is the time integral of the error of the wind vector. Additional errors result from the limited accuracy of magnetic heading references. Engineering estimates indicate one sigma along track (AT) and cross track (CT) errors of 2% of distance traveled. The resulting error equations are:

(26) $$SX = \left[(AT \sin \Psi)^2 + (CT \cos \Psi)^2 + (SRDX)^2\right]^{1/2}$$

(27) $$SY = \left[(AT \cos \Psi)^2 + (CT \sin \Psi)^2 + (SDRY)^2\right]^{1/2}$$

where: $VG = \left[(VX)^2 + (VY)^2\right]^{1/2}$

$AT = 0.02 \cdot VG \cdot T$

$CT = 0.02 \cdot VG \cdot T$

= Cruise vehicle heading

T, VX, VY, SX, SY, SDRX, SDRY as defined in Tables I and II

The CEP is determined by using equations 23, 24, and 25 of Section 2.4.

4. DOPPLER RADAR AND MAGNETIC HEADING ERROR MODEL

(U) Navigation utilizing a doppler radar and magnetic heading provides good along track accuracy with the cross track accuracy limited by the magnetic heading reference accuracy. Reference 1 indicates one sigma along track (AT) and cross track (CT) accuracies of 0.6% and 1.2%, respectively, of distance traveled. The resulting error equations are:

(28) $SX = \left[(AT \sin\Psi)^2 + (CT \cos\Psi)^2 + (SDRX)^2\right]^{1/2}$

(29) $SY = \left[(AT \cos\Psi)^2 + (CT \sin\Psi)^2 + (SDRX)^2\right]^{1/2}$

where: $VG = \left[(VX)^2 + (VY)^2\right]^{1/2}$

$AT = 0.006 \cdot VG \cdot T$

$CT = 0.012 \cdot VG \cdot T$

= Cruise missile heading

T,VX,VY,SX,SY,SDRS,SDRY as defined in Tables I and III.

The CEP is determined by using equations 23, 24, and 25 of Section 2.4.

5. INPUTS AND OUTPUTS

(U) The typical data shown in Table IV has been programmed into the SEATIDE Naval Engagement Model (NEM) into BLOCK DATA in Common Block CGUID. The manner in which the Error Model is used and the inputs to be supplied by the User is as follows.

(U) At time of missile launch the NEM supplies the range and heading to the target and missile average velocity. Prior to the run the User must supply the following four inputs:

(1) IG = 1 for Inertial Navigation
= 2 for Airspeed Navigation
= 3 for Doppler Navigation

(2) IE = 1 for 1970-1975 Era
= 2 for 1975-1980 Era

(3) PLP = Fraction of the position error interval shown in Table IV for the type of launch platform, e.g., for air launch, PLP = 0 gives SDRX = SDRY = 600 feet initial position error while PLP = 1 gives SDRX = SDRY = 6000 feet, and PLP = .074074 gives SDRX = SDRY = 1000 feet.

(4) PLV = Fraction of the velocity error interval shown in Table IV for the type of launch platform, e.g., for air launch, PLV = 0 gives SDRXD = SDRYD = 1 ft/sec.

TABLE IV. VALUES FOR INERTIAL SYSTEM ERROR

Error	1970-75 Time Period	1975-80 Time Period
SDXP	0.6×10^{-4} g's	0.3×10^{-4} g's
SDYP	0.6×10^{-4} g's	0.3×10^{-4} g's
SKXP	0.02%	0.01%
SKYP	0.02%	0.01%
SEXP	0.01 deg/hr.	0.005 deg/hr.
SEYP	0.01 deg/hr.	0.005 deg/hr.
SKX	0.03%	0.015%
SKY	0.03%	0.015%

Error	Land Launch[1]	Sea Launch[2]	Air Launch[3]
SDRX	0 to 600 ft.	600 to 6,000 ft.	600 to 6,000 ft.
SDRY	0 to 600 ft.	600 to 6,000 ft.	600 to 6,000 ft.
SDRXD	0 fps	0.25 to 1.0 fps	1.0 to 3.0 fps
SDRYD	0 fps	0.25 to 1.0 fps	1.0 to 3.0 fps

NOTES:

1. For land launch from a permanent installation, the initial position error approaches the lower end of the range. A temporary field installation approaches the upper end of the range. For either set-up the reference velocity error is zero.

2. For sea launch, the cruise vehicle guidance system alignment and initialization accuracy is somewhat dependent on the elapsed time from the last reset of the launching craft's navigation system. The values presented are launching craft time rms values which are a measure of the average system error. For strategic type launching craft, use values in the lower half of the range. For attack type launching craft, use values in the upper half of the range.

3. Same comments of Note 2 apply.

The format for inputing this to the NEM is discussed in the section on NEM inputs.

(U) Sample problems were run for the following cases and the output plotted in Figure 2 for the inertial system and Figure 3 for the airspeed and doppler systems:

(1) IG = 1, 2, and 3

(2) IE = 1, for 1970-75

(3) PLP = .074074 for 1000 ft. position error

(4) PLV = 0 for 1 ft/sec velocity error

(5) Air Launched

(6) Missiles velocities

(a) 528 ft/sec MN 0.8 at S. L.

(b) 1146 ft/sec MN 2.0 at 40 KFT

(c) 2005 ft/sec MN 3.5 at 70 KFT

This shows for example that at 200 NM to the target a MN=2. missile will have the following CEPs.

Type	CEP, ft.
Inertial	1500
Doppler	8000
Airspeed	17000

6. REFERENCES

(1) Avionics Navigation Systems, Myron Kayton and Walter Fried, John Wiley and Sons, Inc., 1969.

Figure 3

AIRSPEED & DOPPLER NAVIGATION ERROR

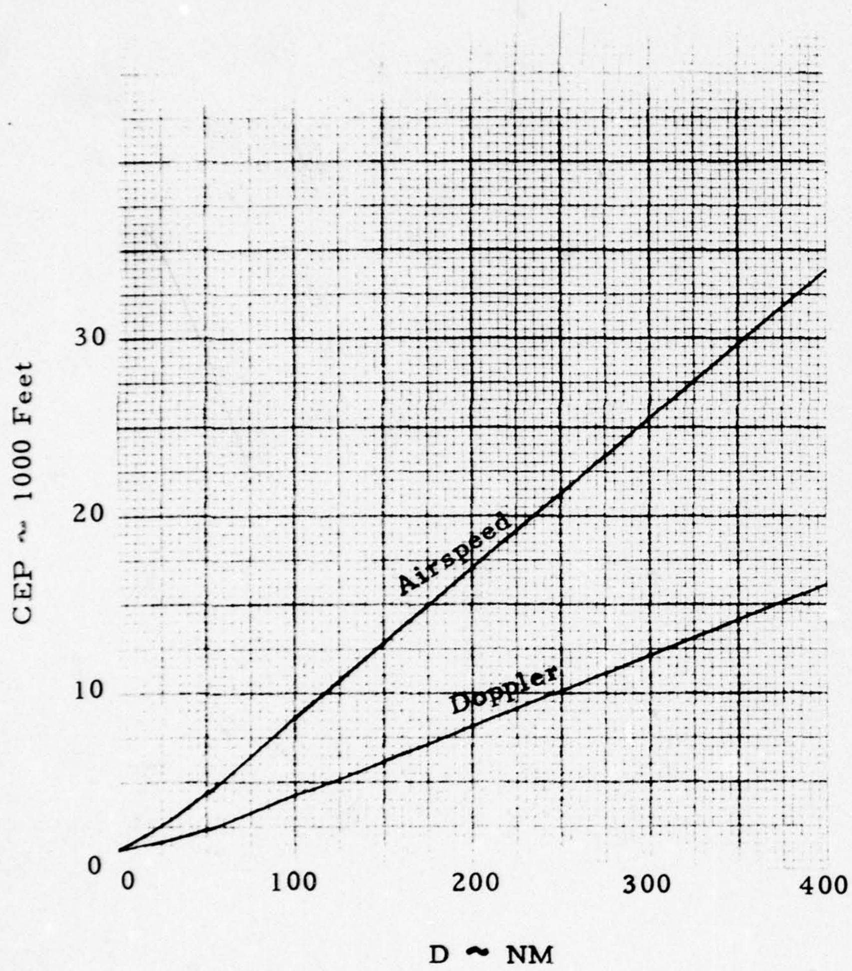
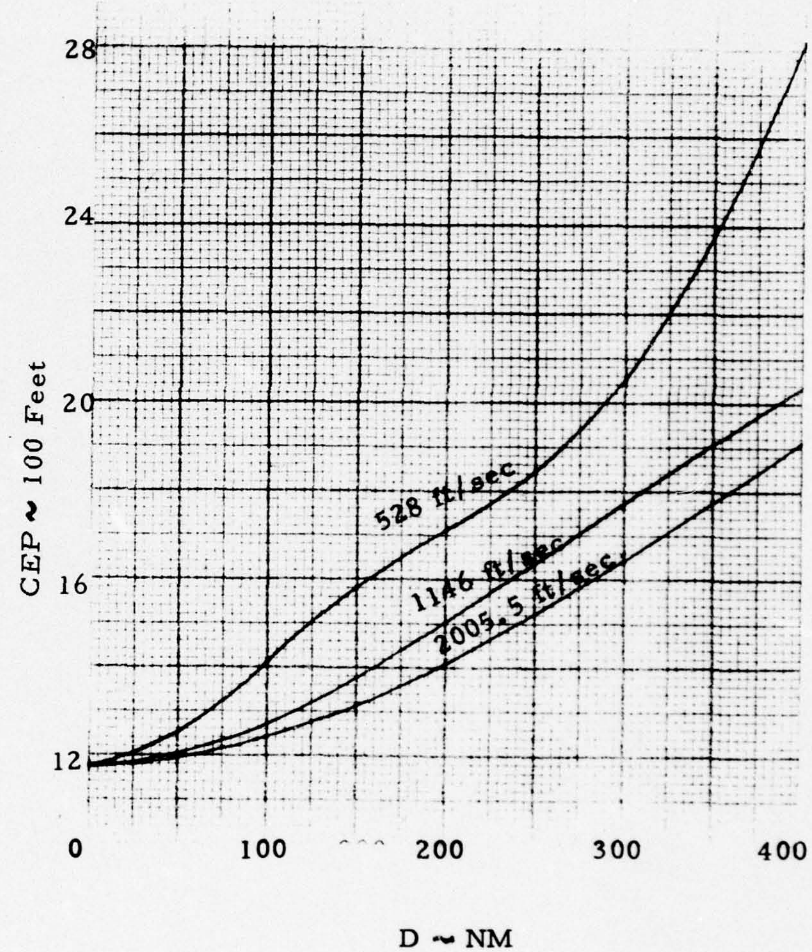


Figure 2

INERTIAL NAVIGATION ERROR



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APPENDIX I

ENGAGEMENT SIMULATION

APPENDIX I

ENGAGEMENT SIMULATION

TITLE

ENGAGEMENT SIMULATION

APPENDIX I

NO.

DATE 11 January 1974

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PREPARED BY R. E. Dyer

APPROVED BY L. D. Gregory

APPENDIX I

ENGAGEMENT SIMULATION

1. ENGAGEMENT DESCRIPTION

The Naval Engagement Model (NEM) simulates a two-sided (Red vs Blue) engagement on the open sea. The routine models the interaction between units of the opposing forces for a period of up to twenty-one hours. The engagement outcome is measured in terms of value lost by each side.

The force for each side is defined by a set of ship, submarine and aircraft units deployed on and following routes predetermined by input. Interaction between opposing units is limited only by the constraints of relative position, velocity and subsystem capability. The model is symmetric with respect to red or blue units. The same ground rules govern the action of similar units on either side.

The routine is primarily a Monte Carlo model. Several Monte Carlo passes through the simulation are executed to evaluate the engagement. Each pass differs in relative unit position with corresponding differences in unit interaction. Each Monte Carlo pass simulates the engagement over the period of time specified by input. Throughout this period, time is advanced by the integration step size specified by input. At each time step, the position and velocity of each unit is computed; all aspects of possible interaction between units are assessed; and the status of each unit is updated. Final engagement outcome is taken to be the arithmetic average of the results of the individual Monte Carlo passes. The top level flow diagram for the engagement simulation is given by Figure 1.

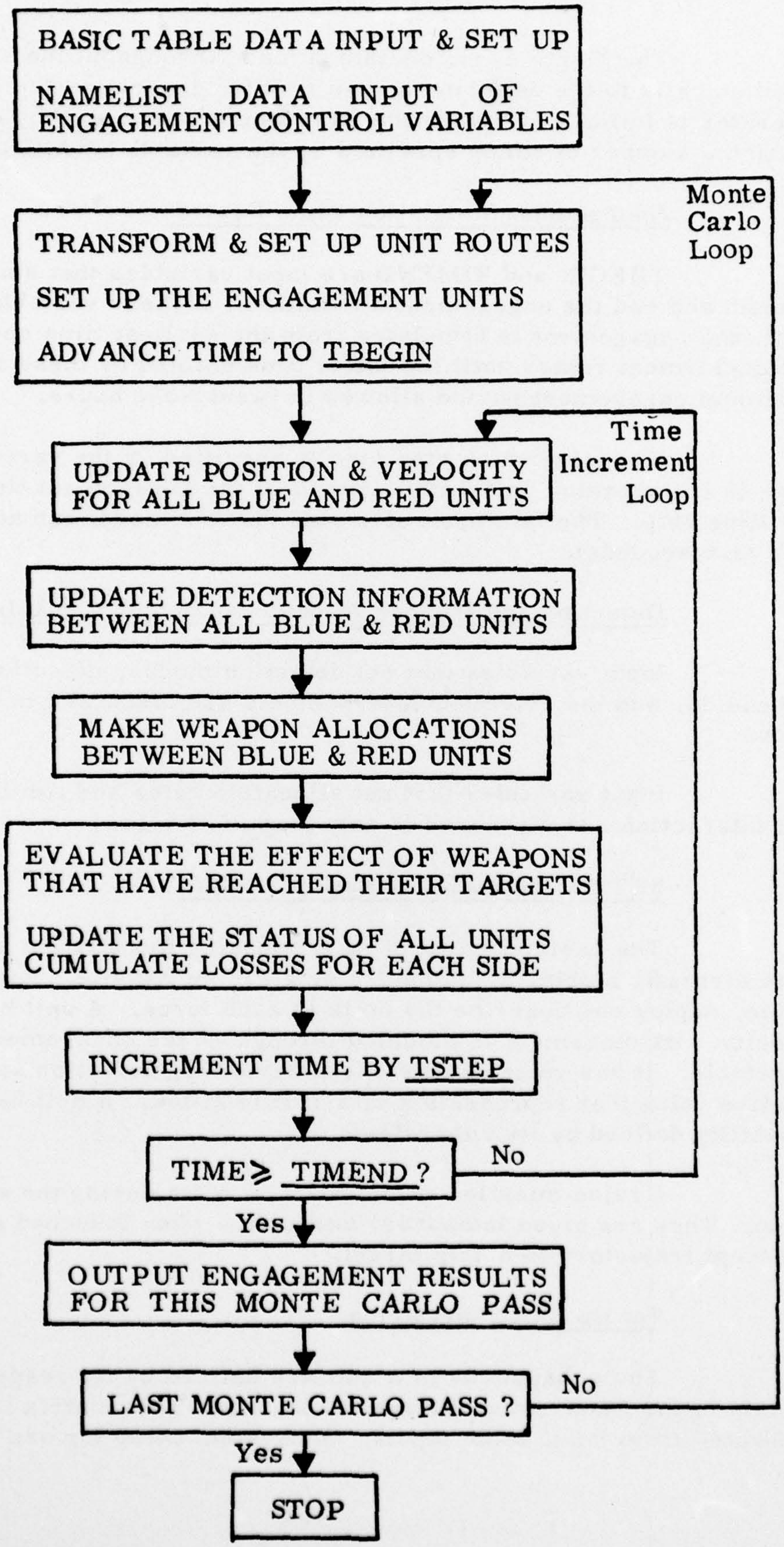
2. ENGAGEMENT CONTROL

Engagement control variables are input to the routine through Namelists &DIMENS and &NGAGE. The effect of these variables on various aspects of the simulation will be referred to throughout the remainder of this appendix. Specific definition of the variables and the mechanics of Namelist input are given in Section III. 3, Volume IIA, the NEM Users Manual.

2.1 Monte Carlo Passes

The number of Monte Carlo passes through the simulation is specified by the variable NCARLO. Since the computer run time is directly proportional to NCARLO, this variable should be kept small. Some aspects of the simulation are based on expected value probabilities to improve numerical stability with a small number of Monte Carlo passes.

FIGURE 1 NEM TOP LEVEL FLOW



The Monte Carlo decisions made throughout the simulation are based on calls to the uniform random number generation function. The generator is initialized before the first Monte Carlo pass by calling the function a number of times specified by the variable NRANDM.

2.2 Engagement Simulation Time Period

TBEGIN and TIMEND are input variables that specify the times to begin and end the engagement simulation. If these variables are not input, the engagement is simulated from the earliest time specified by the unit deployment routes until the latest time defined by these routes. The maximum engagement period allowed is twenty-one hours.

The integration step size is specified by the variable TSTEP. Time is incremented uniformly throughout the engagement time period by this time step. The minimum step size that the model can accept is .001 hour (3.6 seconds).

2.3 Detection and Weapon Allocation Control Variables

Input variables that set detection modes, detection requirement thresholds, and the detection environments are discussed in paragraph 5.1 below.

Input variables that set allocation rates and limit maximum unit interaction are discussed in paragraph 5.2 below.

3. SET UP THE ENGAGEMENT UNITS

The basic element of each opposing force is the unit. The unit is an aircraft, a ship, a submarine or a cruise missile. Basic table inputs define, deploy and describe the units in each force. A unit has position and velocity. Its movement is modeled throughout the engagement. A unit is targetable. It has vulnerability characteristics, detection signatures and a relative value that represents a loss if it is killed. A unit has an interaction capability defined by its subsystems.

Cruise missiles do not exist as units during the engagement setup. They are given temporary unit status when launched and flying an intercept trajectory to a ship target.

3.1 Set Up Unit Subsystems

The subsystems of a unit are defined by its respective platform column in the Platform vs Subsystem Matrix. This matrix is internally generated from basic table inputs. Subsystem setup for use in the engagement is executed at the start of each Monte Carlo pass. Subsystem capability is adjusted during the simulation to reflect partial damage to ship and submarine units.

3.1.1 Search Radars

Catalog Codes: (651X, 562X, 851X, 852X, 657X, 857X, 654X, 854X)

If the platform has more than one search radar, the radar with the maximum beta (range) factor is set up for engagement use.

3.1.2 SAM and BPDS Batteries

Catalog Codes: (track radars = 671X, 871X; launchers = 771X, 971X)

Surface to Air Missile and Basic Point Defense systems are set up with their track radar systems to form SAM batteries. Track radars are matched up with compatible launchers as defined by the Namelist input array MISRAD (2, 10). If no match is found, the SAM battery is not set up.

3.1.3 Sonar Systems

Catalog Codes: (653X, 655X, 853X, 855X)

If a unit has more than one sonar subsystem, the longest range subsystem is set up for use in the engagement.

3.1.4 Other Subsystems

All other subsystems are set up for a unit without restriction. The following is a list of the subsystems and their catalog codes.

Subsystem	Catalog Codes
. Aircraft	(62XX, 82XX)
. Cruise Missles	(761X, 781X, 961X, 981X)
. Surface-Air Guns	(751X, 752X, 951X, 952X)
. Air=Surface Missiles, not cruise missiles	(783X, 784X, 983X, 984X)
. Torpedoes	(721X, 921X)
. Anti-Submarine Weapons, not torpedoes	(731X, 741X, 931X, 941X)

Subsystem	Catalog Codes
. Air-Air Missiles	(791X, 991X)
. Air-Air Guns	(792X, 992X)
. ECM Radar Jammers	(681X, 881X)

4. UNIT MOVEMENT

The position and velocity of each unit is updated at every time increment throughout the engagement. Unit movement must be modeled in order for unit interaction to be simulated. The model used to simulate movement is linear. The units are projected along routes and trajectories defined by a series of linear segments or legs. Unit velocity (heading and speed) is considered constant on each leg.

Ship, submarine, and aircraft units follow routes predetermined by input. These routes are changed by transformation at the start of each Monte Carlo pass. Units may depart from their preplanned routes and follow an internally generated alternate route if either of the following two options is elected:

(a) Group Rendevous - When this option is elected, a group of units may proceed to a predetermined rendevous point (input) as soon as the mission of the group has been completed. Example: a group consisting of units with cruise missile subsystems would rendevous after all of the cruise missiles had been launched.

(b) High Value Target Pursuit - When this option is elected, a group of units will proceed from their current position toward the last known position of the high value target that the group has been assigned to pursue. The frequency for updating high value target classification and known position is controlled by the input variable HVTIME.

A cruise missile is given temporary unit status whenever it is launched and is put on an intercept trajectory to its target. An altitude-velocity profile for this type of trajectory is input for each cruise missile type.

If a fighter or attack aircraft leaves its route to intercept a target; it is put on a temporary trajectory to the target. This trajectory is generated internally as a lead-intercept path to the target. In some air-surface applications (i.e., Bullpup ASM), the attack aircraft follows an intercept trajectory generated from an altitude-velocity profile input.

5. UNIT INTERACTION

All possible interaction between opposing units is re-assessed at every time increment during the engagement. Interaction between two units will occur as soon as relative position, velocity and subsystem capability permit it.

During unit setup, a unit's subsystems are analyzed to compute a maximum radius of action between this unit and each type of unit (A/C, ship, sub) on the opposing side. These radii and the linearity of unit motion enable the model to predict the time intervals of possible interaction between units. Time consuming checks such as radar detection are eliminated between units while they are outside these interaction intervals.

Unit detection and unit weapon allocation (attack) are the two principle means of unit interaction. The routine executes these two types of interaction in separate phases. Detection information between all the units in the engagement is updated prior to the attack or weapon allocation phase.

5.1 Unit Detection and Classification

The routine employs three means of detection between units; radar, sonar and visual. In all cases, the single scan probability of detection (pd) is computed. If the computed Pd exceeds the minimum detection threshold (input as PDMIN), the unit is considered detected. If the computed Pd exceeds the threshold for target classification (PDCLAS), the target is designated as either a high value target or an ordinary target. The input variables HVTB and HVTR define the value limit and elect the high value target option. Ship units whose value exceeds the defined limit are considered to be high value targets as soon as they have been detected and classified. Opposing units give top priority to high value targets during the weapon allocation phase. In addition, opposing groups may converge on the nearest high value target if the vectoring pursuit option is elected.

5.1.1 Radar Detection

Radar detection is computed by the Radar Model described in Appendix C. The radar environment selected by input (IENV) remains constant over the entire engagement. Radar jammers are also either all on (JAM=1) or all off (JAM=0) throughout the engagement.

The effects of a jammer are included in the computation if the jammer is on and azimuth tests between the target, the jammer unit and the radar show the jammer to be in the radar beamwidth.

If the target unit is a ship, the SHIPXS subroutine, described in Appendix D, adjusts the radar cross-section for any partial masking below the horizon.

5.1.2 Sonar Detection

Sonar detection is the only method used to detect submerged submarines and also by submerged submarines to detect ships. The Sonar Model is described in Appendix E. Input variables (IACTIV, IBOTTM) select active or passive modes of operation and direct or bottom bounce detection criteria.

5.1.3 Visual Detection

Visual detection is used between surface units and air units in the absence of radar detection. Visual detection is determined by the following relationships:

R_{50} = .165 (target size, feet)

where R_{50} is the range in nautical miles where the probability of visual detection is taken to be 0.5 or 50%. (Visual resolution = one degree)

R_{50} is then used in the following shaping (normal) function:

$Pd = \exp(-.693\,(R/R_{50})^2)$ = computed probability of visual detection

Where R = current dynamic range between the units.

5.2 Unit Attack by Weapon Allocation

The weapon allocation phase of unit interaction is executed at each time increment during the engagement. Each weapon allocation implies an attack unit and a target unit.

Figure 2 presents the weapon systems that can be employed for each attack unit -target unit combination. Given such a combination, the model scans the subsystems of the attack unit for an appropriate weapon system. The weapon systems are searched for in the same order as listed in the figure.

FIGURE 2 WEAPON ALLOCATION MATRIX

TARGET UNIT	ATTACK UNIT: SHIP	AIRCRAFT	SUBMARINE
SHIP On Normal Route	1. Cruise Missiles 2. Torpedoes	1. Cruise Missiles 2. Air-Surface Missiles 3. Torpedoes	1. Cruise Missiles 2. Torpedoes
SUBMARINE On Normal Route	1. ASW Weapons 2. Torpedoes	1. ASW Weapons 2. Torpedoes	1. Torpedoes
AIRCRAFT On Normal Route		1. Air-Air Missiles 2. Air-Air Guns	
AIRCRAFT On Intercept Trajectory	1. Surface-Air Missiles 2. Surface-Air Guns	1. Air-Air Missiles 2. Air-Air Guns	
CRUISE MISSILE On Intercept Trajectory	1. Surface-Air Missiles 2. Surface-Air Guns	1. Air-Air Missiles 2. Air-Air Guns	

General ground rules governing weapon allocation are given by the following list:

- A unit must be detected before it can be targeted.
- The number of attack units that may simultaneously engage a target unit is limited. Namelist variables enable a separate limit to be set for each type of target unit.
- Each attack unit will engage a target with only one of its weapon systems at a time.
- Ship and submarine units do not leave their normal routes to attack target units. This also holds for an aircraft unit launching cruise missiles. The normal routes for these units may be altered such that the units proceed (in groups) on a route toward the nearest high value target. This option is elected by user imput. Alteration of a preplanned route for the purpose of converging on known high value targets is not considered to be an intercept trajectory as described below.
- Aircraft units depart from their normal routes and fly intercept trajectories to the target unit. An aircraft unit must be closer to the target than is its respective carrier (if any). The aircraft must be able to make the intercept within the time limit specified by the input variable (AIRCPT), hours). The aircraft station on the normal route is vacated until a replacement from the carrier (if any) arrives. After making an intercept, the attack aircraft returns to its carrier if any). An aircraft without a carrier returns to its route.
- When the target unit is a ship, a submarine or an aircraft on a normal route; priority for attack is based on the probability of detection. Higher probabilities of detection imply closer and/or larger targets with a higher priority for attack.
- Ship targets that have been classified as high value targets are given top priority during weapon allocation if the option was elected by user input. Allocation against non-high value ship targets is constrained until the high value targets have been engaged. Exception: Ship targets within half range of the attack unit's weapon systems will be engaged regardless of value.

- When the target unit is a cruise missile or an aircraft following an intercept trajectory; priority for attack is based on a first come first served basis. The ship or aircraft unit nearest the target that can engage the target does so. Allocation against these targets is considered defensive. The weapon units do not maneuver to intercept the targets. Allocation is made against the targets as they pass through the areas covered by the defensive systems. (SAMS; Surface-Air Guns; Air-Air Missiles and Guns). Search radar detection by any one member of a group is shared by all other members of the same group.

- When a cruise missile is launched, it is given temporary unit status and put on an intercept trajectory to its target. At the end of the cruise leg of the trajectory, the Radar Model is called to evaluate target acquisition by the cruise missile radar. Jamming effects etc., are the same as for search radar detection.

- Surface-Air Missile allocation requires an available track radar with a probability of detection (Pd) greater than the minimum track radar detection threshold. (PDTMIN, input). The target must also be in the SAM launch envelope. The Radar Model computes Pd. Jamming effects etc., are the same as for search radar detection. The track radar is not available for retargeting until the SAM has intercepted its target. The user can elect to constrain SAM and surface-air gun allocation such that launch and terminal intercept occur while the target maintains a constant velocity. (i.e., no assumed intercepts during which the target maneuvers through a velocity change). The user may also elect for a recheck of the SAM tracking radar performance at the time of terminal intercept by the missile.

If a detecting unit is an airborne radar unit coded 624X or 824X (i.e, an AEW), it may direct or vector other units to attack the target unit. Indirect vectoring is restricted by the following ground rules.

- The detecting unit must be an airborne radar unit of the 624X or 824X series.

- The detecting unit may vector other units in its own group and those units belonging to its associated group. These units must have cruise missile systems. (Groups are paired for this purpose through basic table inputs).

- The detecting unit may vector any attack or fighter aircraft unit that is on station. No group restrictions are imposed. If more than one aircraft is available, the one nearest the target is assigned. Figher and attack aircraft deployed with search radars do their own detecting and are not eligible for indirect vectoring by AEW units. An attack aircraft has air-surface weapons (not cruise missile) only. A fighter aircraft has air-air weapons only. An aircraft deployed with both air-surface and air-air weapons is considered to be a self-directing attack unit. Its air-air weapons are used in a defensive role only.

6. UNIT STATUS AND LOSSES

Unit status and losses are updated at each time increment throughout the engagement. Terminal effects are evaluated for all weapons that have reached their targets. The status of the target units is adjusted to reflect kill, survival or partial damage.

Subroutine KILLEX is called to evaluate the terminal effects of each weapon-target combination and computes cumulative losses on each side. The methodology used by this subroutine is given in Appendix L.

If a target unit is killed, it is removed from the engagement. A surviving target unit continues in the engagement unchanged. These are the only two states considered for aircraft and cruise missile units.

Ship and submarine units may sustain partial damage. Partial damage is reflected by adjusting the subsystem capability of the unit as shown below:

- All systems operative, no damage.
- Search Radars out
- Search Radars + SAMs out
- Search Radars + SAMs + Guns out + loss of launch capability for cruise missiles and carrier aircraft.
- All Systems out
- Killed

Whenever a cruise missile unit reaches its target, the probability of target acquisition that was computed at the end of its cruise leg is compared with the minimum required. (PDCMIN, input). If this test fails, the terminal effect of the warhead is not evaluated.

Whenever an aircraft unit on an intercept trajectory reaches its target, it launches its entire payload, if required, at the target unit. If the entire payload is not required to kill the target, the remaining stores are available for another assignment once the aircraft has returned to its normal route. An aircraft that returns to its carrier has its stores totally replaced.

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