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Special Report

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PROGRAM BALLOC: A MIXED-WEAPON ALLOCATION MODEL AGAINST MULTIPLE NON-OVERLAPPING AREA DEFENSES

By: R. de SOBRINO B. J. RIPPLE N. J. LEMONS

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PROGRAM BALLOC: A MIXED-WEAPON ALLOCATION MODEL AGAINST MULTIPLE NON-OVERLAPPING AREA DEFENSES

By: R. de SOBRINO B. J. RIPPLE N. J. LEMONS

Prepared for:

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SRI Project 8777

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ABSTRACT

Program BALLOC is a model designed to optimally allocate a mixed-weapon offensive force over a set of multiple-valued targets defended by multiple nonintersecting random area and subtractive local defenses.

The program will maximize the expected damage over the total target set, with the restriction that no more than one weapon type be allocated to any randomly defended island or target subset.

This report presents the concept on which the model is based, and describes the implementation of this concept as a computer program. It also contains a users manual, and an example of the use of the model, employing fictitious data to avoid the necessity of security classification.

PREFACE

This report is submitted under Contract N00014-71-C-0015 to the Office of Naval Research under the task, "Programming a Strategic Bomber Allocation Model." This report contains a description of the model as well as a users guide for running the program.

The work reported here has been performed in the Systems Evaluation Department, Engineering Systems Division of Stanford Research Institute, under the supervision of Dr. Ricardo de Sobrino, Staff Scientist, Mrs. Barbara J. Ripple, Mathematician, acted as project leader, and Mrs. Nancy J. Lemons, Mathematician, did the programming.

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DD Form 1473

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I INTRODUCTION AND PURPOSE

During the past few years, models used to evaluate the effectiveness of strategic systems have been highly developed and widely used. In particular, one general class of such models, which will be called here the "aggregated type"* has become attractive in the rapid evaluation of relative effectiveness of alternative systems. In addition, these models are useful in investigating the sensitivity of the results to the values of system parameters, and to the interactions of offense and defense.

SRI is currently under contract with OSD(SA) to develop techniques to improve the representation of airborne strategic systems in effectiveness models of the aggregated type. As a result of that work a weapons-allocation model against targets defended by random type area defenses with certain restrictions has been made possible.

The purpose of this report is to describe BALLOC, a weapons-allocation model programmed for the Office of the Chief of Naval Operations.

* For a more complete discussion, see Ref. 1. References are listed at the end of the report.

II MODEL DESCRIPTION

A. General

The allocation model described here has some unique features that are not available in currently existing models of the aggregated type, such as CODE 50, AEM, and similar ones.

The model assumes a number of corridors (or islands) defended by area defenses (fighters) that do not overlap. It also assumes that no more than one type of bomber (more specifically, payload type) will be used within each island. These are the main limitations. It does not appear easy to eliminate the first. Methods to remove the second are well under development,² though this can only be done at the expense of increased running time.

Distinctive features of this model are as follows:

- (1) Bomber penetration probabilities are a function of the attack size on an island (or corridor).
- (2) They also vary within each island as a function of the penetration distance; in fact, they may be different for each individual target.
- (3) They are accepted as inputs in tabular or functional form and may be obtained from detailed simulations if desired.

B. Problem Formulation

We assume here that a set of targets is defended by non-overlapping multiple random fighter area defenses. Since the defense coverages are nonoverlapping, the targets are in fact divided into N disjoint subsets (or corridors). Each corridor is defended by a known random fighter defense. In addition, subtractive local defense may also exist for some (or all) targets in the corridor. We further assume that each corridor will be attacked by at most one type of weapon.

We should note that the model allocates the weapons, not the carriers. This self-imposed restriction is needed to achieve acceptable computation times, and is generally assumed in models of this type. Once a weapon allocation is obtained, weapons could, in the real case, be loaded on specific carriers that could then be routed to specific targets.

Let B_{ij} be the number of type j weapons allocated to the i^{th} corridor. The penetration probabilities of the weapons are given inputs in tabular form, $P_{ij}(B_{ij}, R)$, where R is the distance from the entry point to each island. Thus, and in general, penetration probabilities are different for different targets. Then for a given value of B_{ij} , the penetration probability of each weapon can be obtained from the prescribed penetration probability function $P_{ij}(B_{ij})$, which in turn determines the damage function of each target; the optimal allocation of B_{ij} that maximizes the total expected damage function of the island can be efficiently generated by the use of Lagrange multipliers.

Let $f_{ij}(B_{ij})$ be the total expected damage function to the i^{th} island caused by type j weapons. We note that f_{ij} is a function in tabular form since it corresponds to the sum of the expected damages of all the targets in the i^{th} corridor with each target having in general a different damage function, because the targets either belong to different exemplar groups, or have different penetration probabilities due to geographic location.

The problem may be expressed mathematically as follows:

$$\text{Maximize}_{(U_{ij})(B_{ij})} \sum_{i=1}^N \sum_{j=1}^J U_{ij} f_{ij}(B_{ij})$$

$$\text{Subject to } \sum_{j=1}^J U_{ij} \leq 1, \quad i = 1, 2, \dots, N$$

$$\sum_{i=1}^N B_{ij} \leq B_j, \quad j = 1, 2, \dots, J$$

$$B_{ij} \geq 0 \text{ for all } i, j$$

$$U_{ij} = 0 \text{ or } 1 \text{ for all } i, j$$

where J is the total number of weapon types, and U_{ij} equals 1 if the type j weapon is assigned to the i^{th} corridor, and equals 0 otherwise.

The generalized Lagrange multiplier method is readily applicable to this problem. The method consists of two parts:

- (1) For a given set of values of the Lagrange multipliers $\lambda = (\lambda_1, \dots, \lambda_J)$, let $B^* = (B_{ij}^*)$ be the weapon allocation matrix that maximizes the **Lagrangian**:

$$L(\lambda, B) = \sum_{i=1}^N \sum_{j=1}^J \left[f_{ij}(B_{ij}) - \lambda_j B_{ij} \right] = \sum_{i=1}^N \sum_{j=1}^J L_{ij}(\lambda_j, B_{ij}) .$$

For the i^{th} corridor, let j_i be the weapon type that maximizes

$$L_{ij}(\lambda_j, B_{ij}^*), \text{ i.e.,}$$

$$L_{ij_i}(\lambda_{j_i}, B_{ij_i}^*) = \max_j L_{ij}(\lambda_j, B_{ij}^*) .$$

Let $U_{ij}^* = 1$ if $j = j_i$

= 0 otherwise,

i.e., assign weapons of type j_i to the i^{th} corridor and let

$$B_j^* = \sum_{i=1}^N U_{ij}^* B_{ij}^* .$$

Then U_{ij}^* and B_{ij}^* are optimal for the assignment problem, with B_j^* in place of B_j for the total number of type j weapons.

- (2) Using an existing iterative procedure, the values of λ_j may be systematically adjusted so that the weapon resource vector (B_j^*) converges to its desired values (B_j) .

III MODEL IMPLEMENTATION

A. Introduction

The program consists basically of three steps: (1) finding the damage functions for each attacker type on each corridor, (2) optimally allocating the offense force on the corridors, and (3) adjusting the optimal allocation to be identical with the desired allocation when the latter is not exactly obtained. This last step will be denoted by "closing."

B. Generating the Corridor Damage Curves

1. General

Because the probability of bomber penetration to each target (and the corresponding damage function) depends on the total attack size to a corridor, due to the assumption of random area defenses, the following steps are necessary to obtain each point on the damage curve of a given weapon type on a given corridor:

- (1) For each desired attack size, find the penetration probability corresponding to that attack size.
- (2) Find the individual damage functions for each target given the penetration probability.

- (3) Using Lagrange multipliers, find the optimal allocation for the desired attack size.

Each of these three steps is discussed in more detail below.

The number of points on each curve, as well as the maximum attack size for each curve, are user inputs. Due to computer storage requirements, however, a maximum of 20 points per curve cannot be presently exceeded.

2. Finding Penetration Probabilities

To find the probability of a weapon penetrating to a target, t , the great-circle distance, d , from the corridor entrance to that target is found using:

$$\begin{aligned} c &= \cos^{-1} [\sin(LA_{p1}) \sin(LA_T) + \cos(LA_{p1}) \cos(LA_T) \cos(LO_T - LO_{p1})] \\ e &= \cos^{-1} [\sin(LA_{p1}) \sin(LA_{p2}) + \cos(LA_{p1}) \cos(LA_{p2}) \cos(LO_{p2} - LO_{p1})] \\ B &= \cos^{-1} [\sin(LA_T) - \cos(c) \sin(LA_{p1})] / [\sin(c) \cos(LA_{p1})] - \\ &\quad \cos^{-1} [\sin(LA_{p2}) - \cos(e) \sin(LA_{p1})] / [\sin(e) \cos(LA_{p1})] \\ d &= 3400 \sin^{-1} [\sin(c) \sin(B)] \end{aligned} \quad (1)$$

where

LA_T, LO_T = Latitude and Longitude of target t

$LA_{p1}, LO_{p1}, LA_{p2}, LO_{p2}$ = Latitudes and Longitudes of corridor entry boundaries

d = Great-circle distance between target t and corridor entry line defined by $p1$ and $p2$.

Given this distance and the attack size of interest, a table lookup procedure is used to obtain the penetration probability. These tables are inputs that must be generated externally.⁵ Linear interpolation is used to obtain the desired attack size from the tables.

3. Target Damage Functions

The square-root-law damage function is used for each target. For a locally undefended target with penetration probability equal to one, this is of the following form:

$$\theta_i(a_{j,i}) = v_i \left[1 - e^{-k_{j,i} \sqrt{a_{j,i}}} (1 + k_{j,i} \sqrt{a_{j,i}}) \right] \quad (2)$$

where

v_i = Target value

$a_{j,i}$ = Number of type j weapons arriving at target i

$k_{j,i}$ = A damage constant that depends on the target's hardness and size and the weapon's yield and CEP

θ_i = Expected damage.

Given a penetration probability (P_{ij}) for attacker j on target i , a new value of k , k' is found such that

$$P_{i,j} \theta_i(1) = v_i \left[1 - e^{-k'_{j,i} (1 + k'_{j,i})} \right] \quad (3)$$

This k' value then has the effect of "stretching" the undefended damage function to allow for the effects of the penetration probability through the area defenses, and the expected damage is found by using this k' value in Eq. (2).

If there is a local defense at target i , the $\sqrt{a_{j,i}}$ term in Eq. (2) is replaced by $\sqrt{a_{j,i} - Y_{j,i}}$, where

$$Y_{j,i} = I_{j,i} R_j k P_{j,i} \quad (4)$$

and

$Y_{j,i}$ = Equivalent price of the target i for weapon type j

$I_{j,i}$ = Interceptors at target i effective against weapon j

R_j = Interceptor kill probability against weapon type j

k = An input constant associated with the leakage through the area defenses³

$P_{j,i}$ = Penetration probability through the area defenses, a function of the target location and attack size.

4. Find the Desired Attack Size

Given the individual target damage functions at a corridor, it is then possible to obtain the attack size of interest. This is done using Lagrange multipliers in an iterative technique. Starting with a very large value of a single

scalar multiplier and a very small one, two attack levels that bracket the desired attack size are obtained. A new value for the multiplier is found by taking the average of the two previous ones. The new allocation is obtained and replaces the old point on the same side of the desired allocation. This averaging procedure continues until either the desired point is found or the values of the multipliers do not coalesce into a single value resulting in the desired number of weapons, in which case the solution is in a "gap." When this occurs, the point closest to the desired point is used.

C. Optimal Weapon Allocation

To optimally allocate the offensive force, (i.e., maximize the expected damage destroyed over all the corridors) the program again utilizes the Lagrange multiplier method.⁴ In this case, the Lagrange multiplier is a vector in j space where j is the number of weapon types.

Given the multiplier vector, the problem of finding the optimum force allocation is quite simple, since the damage functions are in tabular form and the corridors do not overlap. Each corridor can be treated independently, and the "best" weapon type (and the number of weapons of this type) to use on the corridor is found by searching each damage table to find the point that maximizes $F(A) - \sum_j A = L_j$ for payload type j , and then choosing the type with the largest L_j .

After each allocation, the multiplier vector is adjusted until either the desired attack size (to within the granularity of the damage table) is obtained, or, the change in the values of the multipliers is very small, or a maximum number of iteration is reached. If the desired attack size is obtained, the run is complete; otherwise, a closing procedure is required to adjust the optimal attacks to match the desired one.

To adjust the multiplier vector, the following standard algorithm is used.* Along with the λ_j associated with each attacking payload type is a $\Delta\lambda_j$. It is the $\Delta\lambda_j$ that is adjusted to find the new λ_j . If $\Delta\lambda_j'$ is going in the right direction but the obtained allocation is still not at the desired value, then $\Delta\lambda_j' = c_1 \Delta\lambda_j'$, where c_1 is an input constant > 1.0 . If in the last iteration the desired allocation was crossed, the $\Delta\lambda_j' = c_2 \Delta\lambda_j'$, where c_2 is also an input constant, negative, and < 1.0 . Also, a Δx term is applied to all λ_j 's. This term is modified at each iteration by the same constants as the $\Delta\lambda_j$'s, depending on whether $\sum_j \lambda_j W_D$ is greater or less than $\sum_j \lambda_j W_A$ (W_D = desired allocation; W_A = obtained allocation). Thus,

$$\lambda_j' = (1 + \Delta\lambda_j') (1 + \Delta x) \lambda_j$$

The values of c_1 and c_2 have been obtained heuristically.

* This algorithm was originated by Dr. H. Everett of Lambda Corp.

D. Closing Procedure

The closing procedure is a heuristic method used to slightly change an obtained optimal allocation to reach the desired one when the latter lies in a "gap" and is not obtainable by the Lagrange multiplier method.

In Program BALLOC, two procedures are needed; the first adjusts the allocation among the corridors until the desired allocation is obtained. The second procedure then adjusts the individual corridor allocations among the targets within that corridor.

The first step in performing the first closing is to select the "best" allocation to close on.⁵ This is done by finding the allocation that minimizes:

$$\sum_j \left[\left(W_{A_j} - W_{D_j} \right) W_{D_j} \right]^2 \quad (5)$$

where

W_{A_j} = Obtained number of type j weapons

W_{D_j} = Desired number of type j weapons.

The routine imposes the restriction that each corridor must use the weapon type assigned in the optimal allocation; thus, for each type-j weapon, if $W_{A_j} > W_{D_j}$, the routine selects from the corridors that are assigned this type the one receiving

the least damage per attacker, and reduces the allocation to this corridor. Similarly, if $w_{A_j} < w_{D_j}$, the corridor that will receive the most damage per attacker is selected to receive the additional weapons.

If a weapon type was not allocated at all, the routine selects from the unattacked corridors the one that would receive the most damage and allocates the weapons to that corridor. After the exact allocation to each corridor is obtained, the procedures described previously in Section B-4 are used to allocate the weapons among the targets within the corridor. If the desired allocation to that corridor is not exactly obtained, an algorithm similar to that used in the first closing is used for slight adjustments.

IV PROGRAM DESCRIPTION

A. Introduction

BALLOC is written in Fortran IV for use on the SRI CDC 6400 computer as well as the CNA CDC 3600. The core storage requirement is approximately 50,000 words. The running time can be broken into two parts--the time required to generate the damage curves for each corridor, and, given the curves, the time required to obtain a given allocation. To generate a curve with 20 points for one weapon type on one corridor requires approximately 10 seconds on the CDC 6400.* The running time to obtain the desired weapon allocation depends on the number of corridors and the number of weapon types. For two weapon types and nine corridors, the time is approximately 5 seconds.

Section IV-B contains flow charts of the main program and of the more complicated subroutines. Section IV-C gives a description of the user input to the program, along with typical sample values. In Section IV-D are several figures showing various representative sections of the output of this program.

The target values and damage functions used to calculate the examples shown are fictitious to avoid security classification.

* This is an average value assuming 40 targets per corridor and obtained from a total time of about 180 sec for 400 targets located in 9 corridors.

B. Program Flow

Figure 1 is a flow chart of the main program flow. Figure 2 shows the allocation subroutine, and Figure 3 the closing procedure.

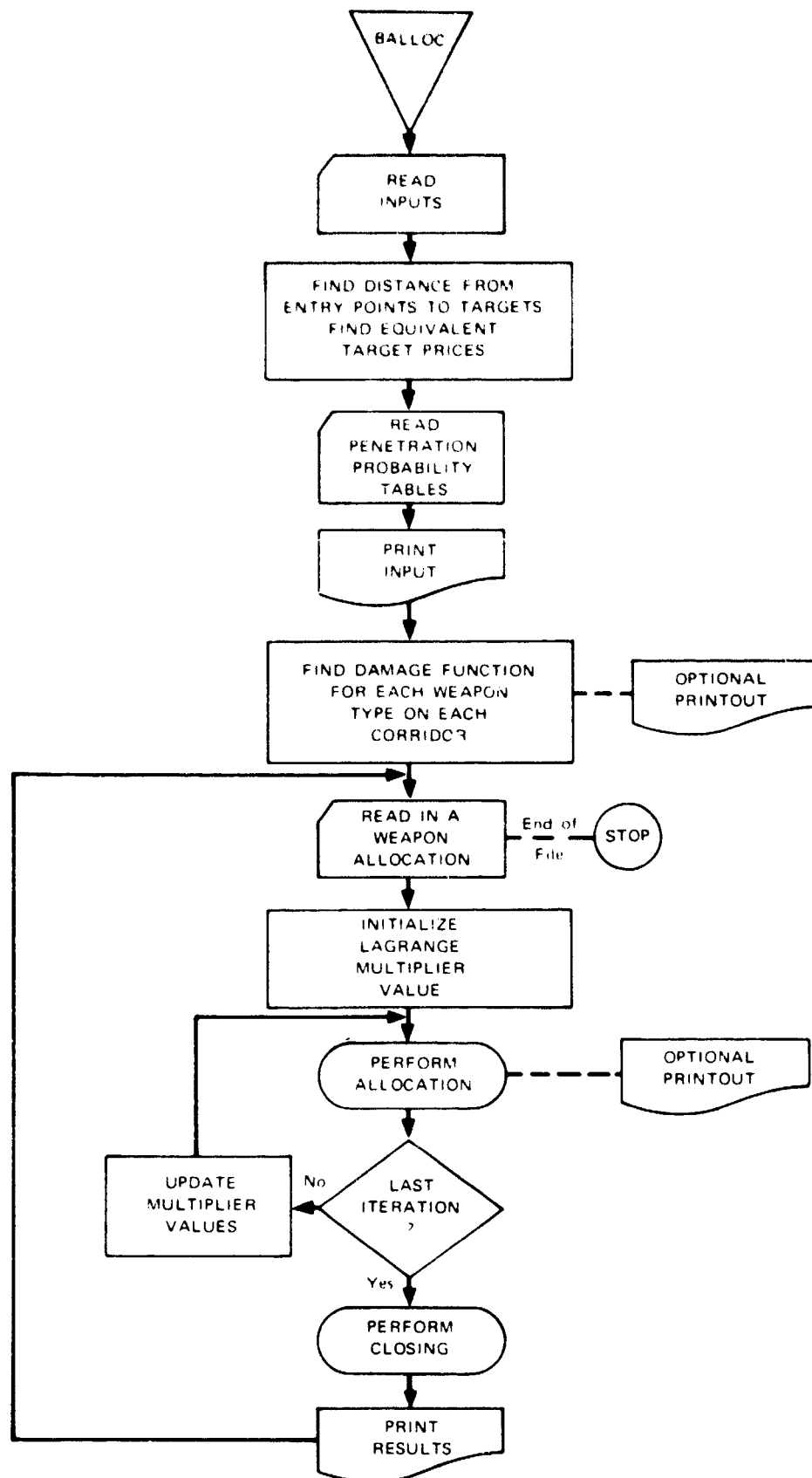
C. Data Input

1. Data-Card Deck Set-up

The following cards are required to run the program:

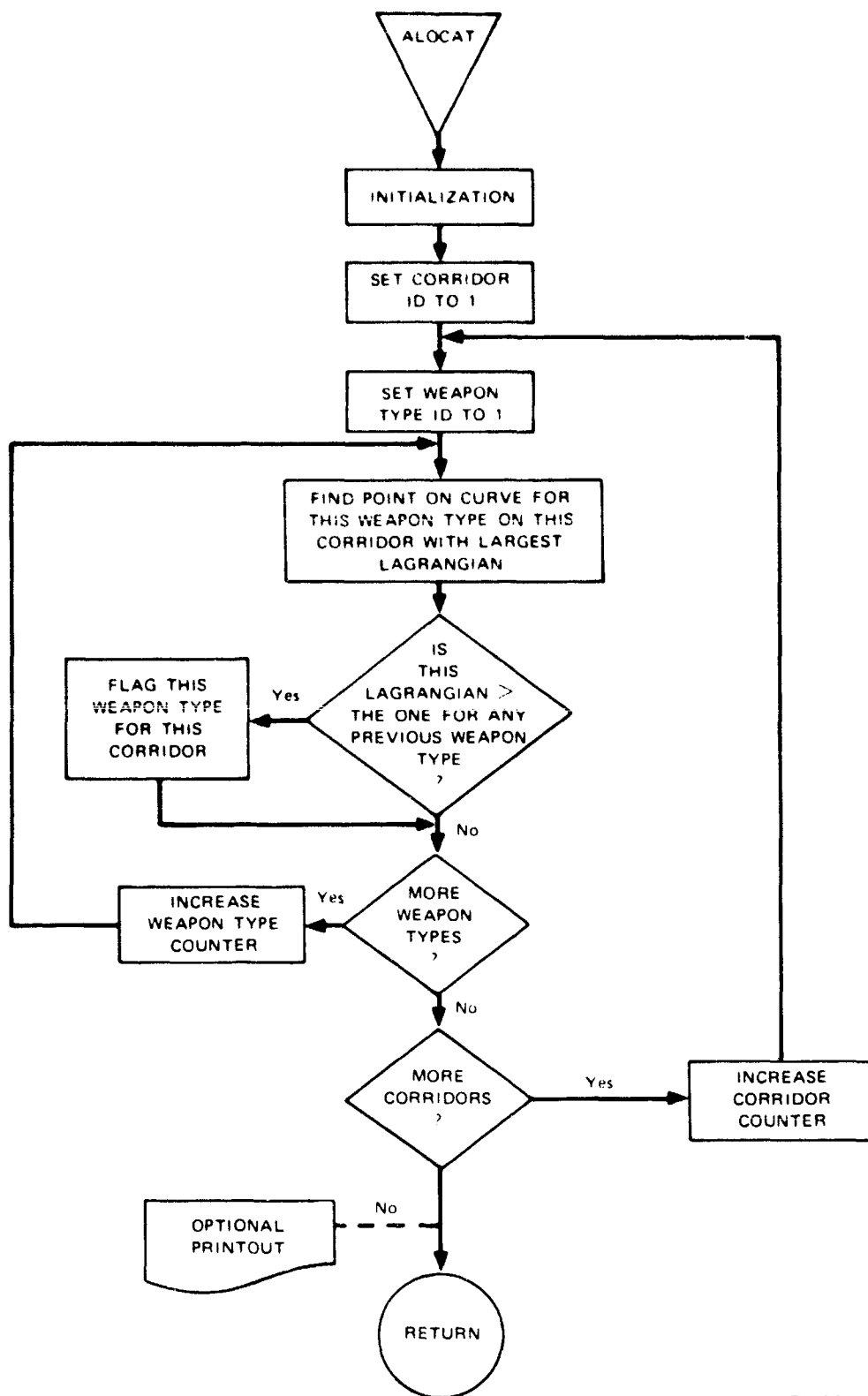
Card ID	Number of Cards	Description
1	1	Variable size card
2	1	Number of points on damage curves for each weapon type
3	1	Maximum number of weapons of each type to be used in computing damage curves
4	1	λ adjustment card
5	A set for each weapon type	"k" values for each exemplar group
6	One for each locally defended target	Local-defense card
7	1	Number of targets in each corridor
8	One for each target	Target-description card*
9	One for each corridor	Corridor entry points
10	1	Interceptor constants

* These cards are ordered so that all Corridor -1 cards are first, followed by all Corridor-2 cards, etc.



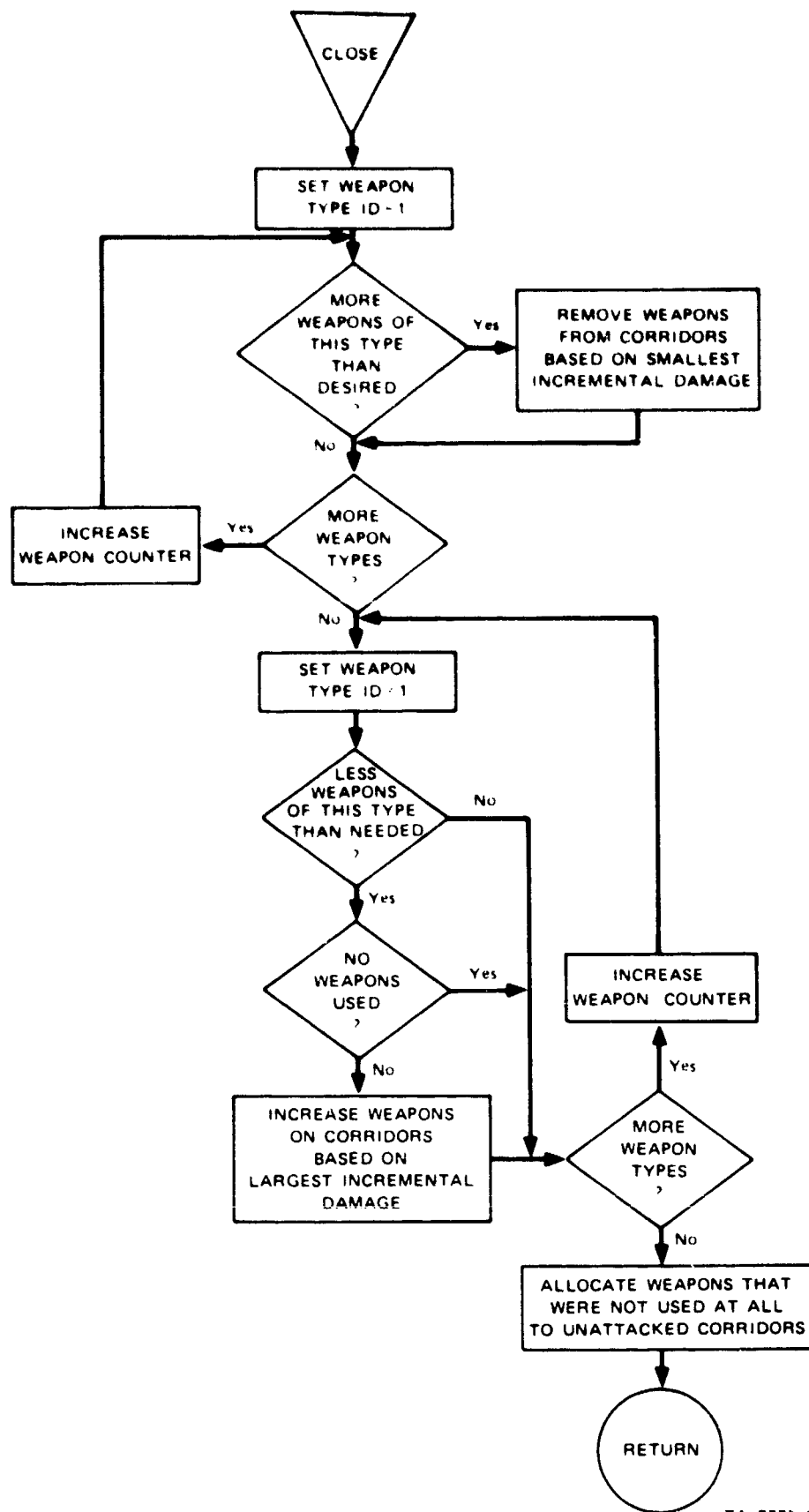
TA-8777-1

FIGURE 1 BALLOC FLOW CHART



TA-8777-2

FIGURE 2 ALLOCATION SUBROUTINE



TA-8777-3

FIGURE 3 CLOSING SUBROUTINE

<u>Card ID</u>	<u>Number of Cards</u>	<u>Description</u>
11	1	Interceptor reliability against each weapon type
12*	1	Attack-size table
13*	As many as needed	Distance from entry-line table
14*	As many as needed	Penetration probabilities as a function of the attack size and distance
15	One for each case to be run	Desired-allocation card

2. Input-Card Formats

Figures 4 through 18 describe the input card formats. The first row contains the number type (I = right justified integer, R = a real number, and A is an alpha format). The second row contains the field on which the number is to appear. The third row describes the input, and the fourth row gives sample values.

Figure 4 contains the size limitations for the various parameters as well as giving three print options. If the Option 1 field is not blank or 0, damage curves for each weapon type on each island will be plotted. Option 2 will print out the allocation to the corridors for each iteration, unless the field is blank or 0. Similarly, a blank or 0 for Option 3 will suppress the printing of the allocation summary for each cycle.

Figure 7 contains the constants for increasing or decreasing the Lagrange multiplier vector to converge on the desired solution, as well as the cutoff point to stop the iterations.

* These are inserted in the above order for each corridor.

Each target is assigned to an exemplar group, however, there may be up to 400 groups so that each target can be treated independently. The damage constant ("k") (Figure 8) is given for each weapon type and each exemplar group.

The target cards (Figure 11) are ordered so that all of the targets in Corridor 1 are first, followed by Corridor 2, etc. Figure 10 gives the number of targets in each corridor. The last corridor contains all of the targets not covered by any area defense.

For each city with local defense, a card (Figure 9) showing the number of interceptors against each weapon type is used. Also, a constant determined by the leakage through the area defense is needed for each weapon type (Figure 13). Interceptor kill probabilities are given against each weapon type (Figure 14), and to obtain the equivalent intercepts of weapon j against target i the program uses

$$E_{ij} = I_{ij} R_j K_j \frac{1}{P_p}$$

where

I_{ij} = Interceptors at target i against weapon type j

R_j = Interceptor kill probability against weapon type j

K_j = An input constant associated with the leakage through the area defenses.³

P_p , the penetration probability to a given target, is a function of the total attack size to the corridor and the distance of the target from the corridor entrance. Figures 16, 17, and 18 contain the tables describing these functions.

D. Sample Output

Figures 19 through 23 are samples of the output available from BALLOC. Figure 19 contains the program inputs. Figure 20 shows the plots of the individual damage functions for each weapon type on each corridor. This printout is optional, as is Figure 21, which contains the output available after each iteration. Figures 22 and 23 show the final program output.

[illegible]

FIGURE 4 VARIABLE-SIZE CARD

15	15	15	15	• • • up to 5 weapon types
1	5	6	11	
number of points to be used in damage curves for weapon 1	number of points to be used in damage curves for weapon 2	number of points to be used in damage curves for weapon 3	15	
15 (maximum of 20)	20	12		

FIGURE 5 DAMAGE-CURVE-POINT LIMITS

15		15		15		• • • up to 5 weapon types
1	5	6	10	11	15	
maximum number of type 1 weapons to be used in calculating damage curves		maximum number of type 2 weapons to be used in calculating damage curves		maximum number of type 3 weapons to be used in calculating damage curves		
100		450		35		

FIGURE 6 DAMAGE-CURVE-SIZE LIMITS

R		R		R	
1	10	11	20	21	30
$\Delta\lambda$ decrease constant		$\Delta\lambda$ increase constant		$\Delta\lambda$ cutoff	
-0.25		1.3		0.005	

FIGURE 7 λ ADJUSTMENT CARD

R			R			R			... up to 400 exemplar groups									
1			10			11				20			21			30		
"K" for exemplar group 1			"K" for exemplar group 2			"K" for exemplar group 3				"K" for exemplar group 3			"K" for exemplar group 3			"K" for exemplar group 3		
1.2			0.8			2.5				2.5			2.5			2.5		

FIGURE 8 "K" VALUE CARD

• • • up to 5 weapon types									
15		15		15		15		15	
1		5		6		10		20	
target ID number				interceptors against weapon type 1		interceptors against weapon type 2		interceptors against weapon type 3	
5				10		8		10	

FIGURE 9 LOCAL-DEFENSE CARD

15	15	15	number of targets in corridor 3	number of targets in corridor 2	number of targets in corridor 1
1	5	6			
10	15	8			

FIGURE 19 TARGETS-PER-CORRIDOR CARD

110	110	R	13	12	12	12	13	12	12	12							
1	10	11	20	21	30	34	36	37	38	39	40	41	46	47	48	49	50
target ID			exemplar group		value		latitude degrees	latitude minutes	latitude seconds		latitude degrees	longitude minutes	longitude seconds		longitude minutes	longitude seconds	
1			3		4000.0		56	30		45		120			27		32

FIGURE 11 TARGET-DESCRIPTION CARD

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.																																																																																																			

FIGURE 12 CORRIDOR-ENTRY-POINT CARD

• • • up to 5 weapon types		
R	R	R
1	11	21 30
interceptor constant for weapon type 1	interceptor constant for weapon type 2	interceptor constant for weapon type 3
1.0	1.2	1.6

FIGURE 13 INTERCEPTOR CONSTANTS

R		R		R		• • • up to 5 attacker types
1	10	11	20	21	30	
reliability against attacker type 1		reliability against attacker type 2		reliability against attacker type 3		
0.9		0.75		0.8		

FIGURE 14 INTERCEPTOR RELIABILITY

R		R		R		• • • up to 5 attack levels
1	10	11	20	21	30	
first attack level		second attack level		third attack level		
10.0		20.0		50.0		

FIGURE 15 ATTACK-SIZE TABLE

R			R			• • • up to 12 distances		
1	10	11	20	21	30			
first distance cutoff-nmi		second distance cutoff		third distance cutoff				
50.0		100.0		150.0				

FIGURE 16 DISTANCE TABLE

R		R		R		• • • up to 12 entries
1	10	11	20	21	30	
penetration probability for first distance cutoff		p _p for second cutoff		p _p for third cutoff		
0.8		0.7		0.6		

FIGURE 17 PENETRATION-PROBABILITY TABLE

R		R		R		• • • up to 5 weapon types
1	10	11	20	21	30	
desired number of weapon type 1		desired number of weapon type 2		desired number of weapon type 3		
50.0		100.0		50.0		

FIGURE 18 DESIRED-ALLOCATION CARD

CARRIOT NUMBER 5			INTERESTS		
ID	VALUE	CIST	K		
4	2000.00	275.71	.5000	0.0000	0.0000
10	1000.00	1223.74	.5000	0.0000	0.0000
15	1000.00	1166.25	.5000	0.0000	0.0000
43	600.00	207.64	.5500	0.0000	0.0000
47	500.00	1061.54	.4000	0.0000	0.0000
51	500.00	63.44	.4000	0.0000	0.0000
61	400.00	1487.91	.4500	0.0000	0.0000
67	400.00	1645.90	.4500	0.0000	0.0000
73	400.00	369.32	.4500	0.0000	0.0000
84	300.00	1007.05	.4500	0.0000	0.0000
90	300.00	761.98	.4500	0.0000	0.0000
98	300.00	1684.77	.5000	0.0000	0.0000
130	200.00	1809.03	.4000	0.0000	0.0000
142	200.00	670.17	.4000	0.0000	0.0000
156	200.00	361.60	.7500	0.0000	0.0000
190	200.00	252.30	.7000	0.0000	0.0000
210	100.00	299.10	1.0000	0.0000	0.0000
256	100.00	252.04	.9000	0.0000	0.0000
259	100.00	790.42	.9000	0.0000	0.0000
260	100.00	913.30	.9000	0.0000	0.0000
267	100.00	1246.32	.9000	0.0000	0.0000
277	100.00	1213.28	1.0500	0.0000	0.0000
284	100.00	204.01	1.0500	0.0000	0.0000
285	100.00	1147.02	1.0500	0.0000	0.0000
301	100.00	1079.62	1.2000	0.0000	0.0000
326	100.00	1143.27	1.2000	0.0000	0.0000
331	100.00	922.32	1.2000	0.0000	0.0000
332	100.00	1460.95	1.2000	0.0000	0.0000
343	100.00	124.01	1.2000	0.0000	0.0000
344	100.00	243.21	1.2000	0.0000	0.0000
349	100.00	1742.60	1.2000	0.0000	0.0000
350	100.00	1658.42	1.2000	0.0000	0.0000
354	100.00	1648.92	1.2000	0.0000	0.0000
355	100.00	218.67	1.2000	0.0000	0.0000
363	60.00	979.42	.2500	0.0000	0.0000

FIGURE 19 PROGRAM INPUT

CORRIDOR NUMBER 7
WEAPON NUMBER 1

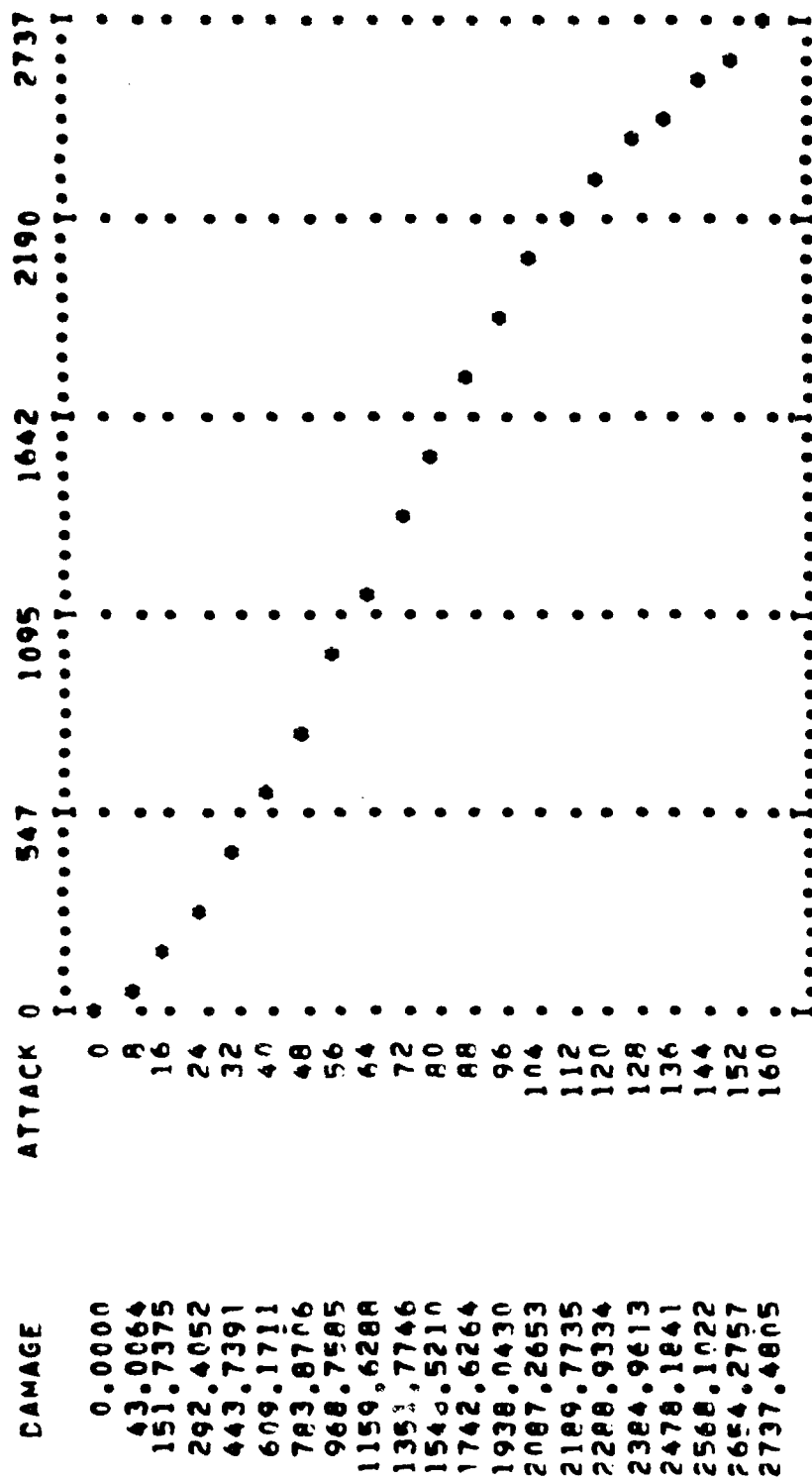


FIGURE 20 CORRIDOR DAMAGE FUNCTIONS

CORRIDOR NUMBER 7
WEAPON NUMBER 2

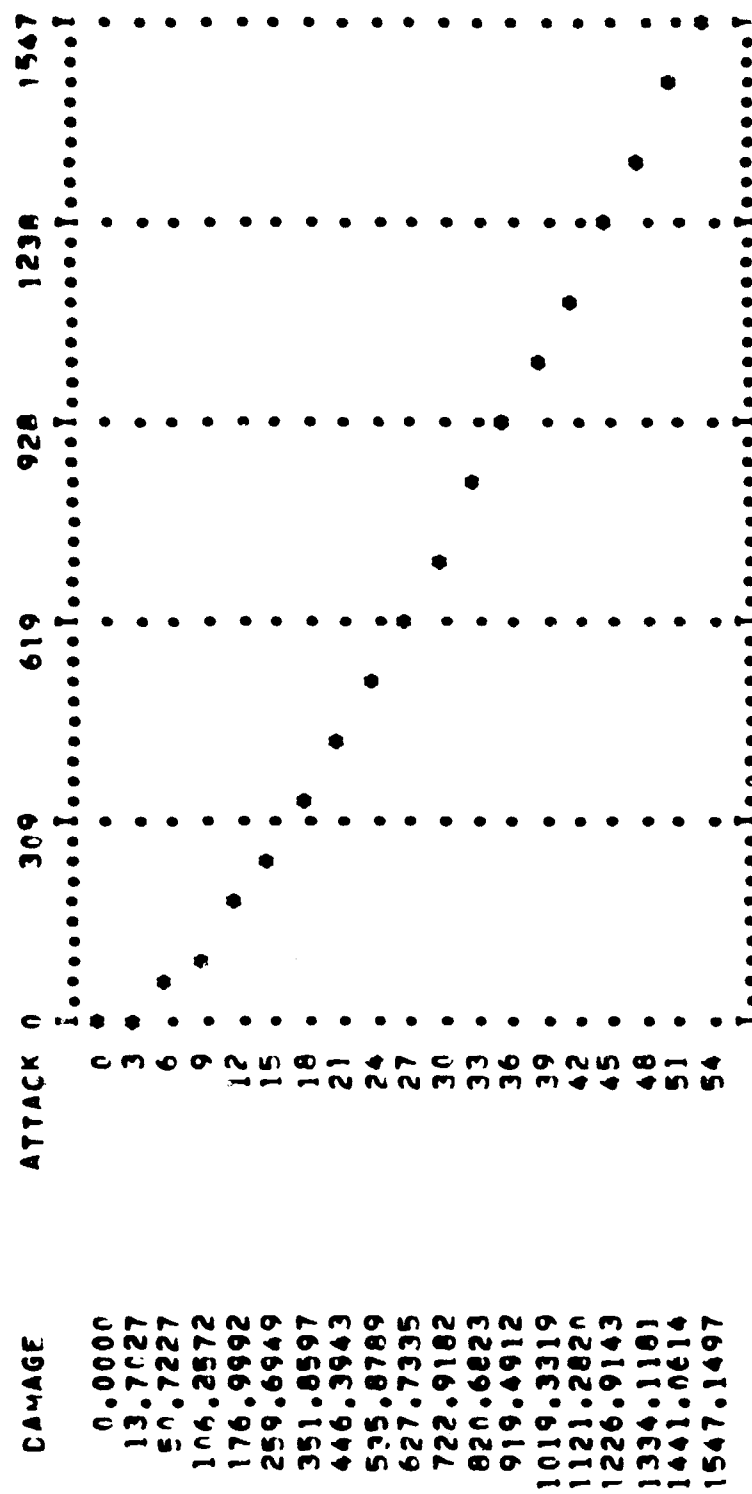


FIGURE 20 CORRIDOR DAMAGE FUNCTIONS (Concluded)

ITERATION NUMBER A

DX	DLAMRCA	LAMRDA	WEAP DES	WEAP CRT	DAMAGE	LAGRAN
-.1882	-.3137	11.1419	21	63	726.9694	95.0311
-.1882	-.6121	46.5663	37	37	4497.0828	2774.1298

TOTAL ATTACKERS = 100
 TOTAL DAMAGE = 5284.0522
 TOTAL LAGRANGIAN = 2859.1617
 TOTAL VALUE = 110200.00

CCPRIC	TYPE	WEAP	DAMAGE
1	0	0	0.00
2	1	21	310.45
3	1	21	236.87
4	0	0	0.00
5	0	0	0.00
6	0	0	0.00
7	1	21	239.65
8	0	0	0.00
9	2	37	4497.08

FIGURE 21 ITERATION SUMMARY

FINAL ALLOCATION TO TARGETS IN CORRIDOR 2
THIS CORRIDOR WAS ATTACKED BY WEAPON 1

TOTAL ATTACKERS TO CORRIDOR = 21
TOTAL DAMAGE TO CORRIDOR = 309.9591
TOTAL VALUE OF CORRIDOR = 11300.00

TARGET	ATTACK	DAMAGE
3	0	0.0000
20	2	26.4272
21	8	120.2752
30	7	109.1215
32	1	13.5355
54	2	28.0465
55	0	0.0000
62	0	0.0000
64	0	0.0000
71	1	12.5532
87	0	0.0000
100	0	0.0000
104	0	0.0000
120	0	0.0000
123	0	0.0000
129	0	0.0000
132	0	0.0000
149	0	0.0000
175	0	0.0000
200	0	0.0000
207	0	0.0000
208	0	0.0000
212	0	0.0000
238	0	0.0000
245	0	0.0000
249	0	0.0000
250	0	0.0000
279	0	0.0000
294	0	0.0000
333	0	0.0000
340	0	0.0000
359	0	0.0000
371	0	0.0000
383	0	0.0000
389	0	0.0000
394	0	0.0000
399	0	0.0000

FIGURE 22 FINAL CORRIDOR ALLOCATION

SUMMARY OF FINAL ALLOCATION

CORRIDOR	WEAP TYP	ATTACK	DAMAGE	VALUE
1	0	0	0.00	3000
2	1	21	309.96	11300
3	0	0	0.00	10920
4	0	0	0.00	23700
5	0	0	0.00	10360
6	0	0	0.00	7200
7	0	0	0.00	5200
8	0	0	0.00	6360
9	2	37	4497.08	23200

WEAP TYP	ATTACK	DAMAGE
1	21	309.9591
2	37	4497.0828

TCTAL ATTACKERS = 50
 TCTAL DAMAGE = 4807.0419
 TCTAL VALUE = 110200.0000

FIGURE 23 SUMMARY

Appendix
PROGRAM LISTING

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C      PROGRAM HALLOC (INPUT,OUTPUT,TAPER=INPUT,TAPE=OUTPUT)

      COMMON/CFDAM/LAMDA,K(500,5),V(500),CRITLM(500,5),IFIRST,ILAST,
1ATTACK,DAMAGE,ATT(500),DAM(500),NINTER(500,5)
      COMMON/CALLOC/WD(5),LAMRDA(5),ITYPE(15),RWEAP(15),EDAM(15),
1ATTCRV(15,5,21),DAMCRV(15,5,21),LAMMAX(15,5),INTERV(15),
2TOTALA(5),TOTALD(5),TOTAL(5),VALUE(15)
      COMMON/CBEST/TWJ,TOTAB(5),ITYPEB(15),RWEAPB(15),EDAMB(15),
1INTRVR(15),LAMBAR(5),ITERA,ITER

C      DIMENSION NTARG(15),TDIST(500),IPOINT(15),AP(5),DIST(12),
1PP(12,5,5),A(21,5),NP(21,5),KAY(500,5),IPRINT(3),WEAPMX(15),
2IDIST(500),X(21),Y(21),DLAMDA(5),SAM(500,5),LAT(500),
3LONG(500),CLAT(15,2),CLONG(15,2),KAY1(400,5),REL(5),
4ID(500),NINCR(5),NINCRP(5),INCR(5),NWEPMX(5),C(5),INTER(5)

C      REAL KAY,K,LAMDA1,LAMDA2,LAMDA,LAMRDA,LAMMAX,LTOTAL,LAMDAB,
1LAT,LONG,KAY1

C      READ 100, NCORID,NATTYP,NAP,NDIST,ITERMX,(IPRINT(I),I=1,3),NEXEMP,
1NLDEF
      IF (NATTYP.GT.NCORID) GO TO 650
      READ 100, (NINCR(IW),IW=1,NATTYP)
      READ 100, (NWEPMX(IW),IW=1,NATTYP)
      DO 203 IW=1,NATTYP
      NINCRP(IW)=NINCR(IW)+1
203 INCR(IW)=(FLOAT(NWEPMX(IW))/NINCR(IW)+0.999)
      READ 105, FRACT1,FRACT2,DLLIM
      DO 201 IW=1,NATTYP
201 READ 105, (KAY1(IE,IW),IE=1,NEXEMP)
      DO 204 IT=1,400
      DO 204 IW=1,NATTYP
204 NINTER(IT,IW)=0
      DO 206 IL=1,NLDEF
      READ 100, IDT,(INTER(IW),IW=1,NATTYP)
      DO 206 IW=1,NATTYP
206 NINTER(IDT,IW)=INTER(IW)
      READ 100, ITARG(IC),IC=1,NCORID)
      IPOINT(1)=1
      DO 200 IC=2,NCORID
200 IPOINT(IC)=IPOINT(IC-1)+NTARG(IC-1)
      ITARG=IPOINT(NCORID)+NTARG(NCORID)-1
      DO 202 IT=1,ITARG
      READ 106, ID(IT),NEX,V(IT),LAT1,LAT2,LAT3,LONG1,LONG2,LONG3
      LAT(IT)=(LAT1+(LAT2+LAT3/60.)/60.)*0.017453
      LONG(IT)=(LONG1+(LONG2+LONG3/60.)/60.)*0.017453
      IDT=ID(IT)
      DO 202 IW=1,NATTYP
      SAM(IT,IW)=NINTER(IDT,IW)
202 KAY(IT,IW)=KAY1(NEX,IW)
      DO 205 IC=1,NCORID
      READ 108, CLAT1,CLAT2,CLAT3,CLONG1,CLONG2,CLONG3,CLAT4,CLAT5,CLAT6
1,CLONG4,CLONG5,CLONG6
      CLAT(IC,1)=(CLAT1+(CLAT2+CLAT3/60.)/60.)*0.017453

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CLAT(IC,2)=(CLAT4+(CLAT5+CLAT6/60.)/60.)*0.017453
CLONG(IC,1)=(CLONG1+(CLONG2+CLONG3/60.)/60.)*0.017453
CLONG(IC,2)=(CLONG4+(CLONG5+CLONG6/60.)/60.)*0.017453
205 CONTINUE
READ 105, (C(IW),IW=1,NATTYP)
READ 105, (REL(IW),IW=1,NATTYP)
VEE=0.0
DO 215 IC=1,NCORID
  IFIRST=IPOINT(IC)
  ILAST=IFIRST+NTARG(IC)-1
  VALUE(IC)=0.0
  D=ACOS(SIN(CLAT(IC,1))*SIN(CLAT(IC,2))+COS(CLAT(IC,1))*COS(CLAT(IC,2))
    *COS(CLONG(IC,2)-CLONG(IC,1)))
  GAMMA=ACOS((SIN(CLAT(IC,2))-COS(D)*SIN(CLAT(IC,1)))/(SIN(D)*COS(
    CLAT(IC,1))))
  DO 212 IT=IFIRST,ILAST
    R=ACOS(SIN(CLAT(IC,1))*SIN(LAT(IT))+COS(CLAT(IC,1))*COS(LAT(IT))*
      COS(CLONG(IT)-CLONG(IC,1)))
    ALPHA=ACOS((SIN(LAT(IT))-COS(R)*SIN(CLAT(IC,1)))/(SIN(R)*COS(CLAT(
      IC,1))))
    BETA=ALPHA-GAMMA
    TDIST(IT)=3440.*ASIN(SIN(R)*SIN(BETA))
    DO 210 IW=1,NATTYP
      IF (SAM(IT,IW).EQ.0.) GO TO 209
      NINTER(IT,IW)=(SAM(IT,IW)*C(IW)*REL(IW)+0.5)
      GO TO 210
209 NINTER(IT,IW)=0
210 CONTINUE
212 VALUE(IC)=VALUE(IC)+V(IT)
215 VEE=VEE+VALUE(IC)
DO 221 IC=1,NCORID
  IFIRST=IPOINT(IC)
  ILAST=IFIRST+NTARG(IC)-1
  PRINT 100, IC
  DO 221 IT=IFIRST,ILAST
221 PRINT 105, ID(IT),V(IT),TDIST(IT),(KAY(IT,IW),IW=1,5),(NINTER(IT,
  IW),IW=1,5)
  PRINT 110
DO 300 IC=1,NCORID
  IF (IC.EQ.NCORID) GO TO 223
  READ 105, (AP(M),M=1,NAP)
  READ 105, (DIST(I),I=1,NDIST)
DO 220 IW=1,NATTYP
DO 220 M=1,NAP
220 READ 105, (PP(I,M,IW),I=1,NDIST)
223 DO 222 IW=1,NATTYP
  ATTORV(IC,IW,1)=0.0
222 DAMORV(IC,IW,1)=0.0
  IFIRST=IPOINT(IC)
  ILAST=IFIRST+NTARG(IC)-1
  IF (IC.EQ.NCORID) GO TO 255
DO 230 IT=IFIRST,ILAST
DO 225 I=2,NDIST

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      IF (TDIST(IT).GE.DIST(I)) GO TO 225
      IDIST(IT)=I
      GO TO 230
225  CONTINUE
      IDIST(IT)=NDIST
230  CONTINUE
      DO 250 IW=1,NATTYP
      MINCRP=NINCRP(IW)
      DO 250 M=2,MINCRP
      A(M,IW)=(M-1)*INCR(IW)
      DO 245 IA=2,NAP
      IF (A(M,IW).GE.AP(IA)) GO TO 245
      NP(M,IW)=IA
      GO TO 250
245  CONTINUE
      NP(M,IW)=NAP
250  CONTINUE
255  DO 300 IW=1,NATTYP
      XLM=0.0
      MINCRP=NINCRP(IW)
      DO 290 M=2,MINCRP
      JR=NP(M,IW)
      JA=JR-1
      CLMAX=0.0
      DO 260 IT=IFIRST,ILAST
      IF (IC.NE.NCORID) GO TO 257
      K(IT,IW)=KAY(IT,IW)
      GO TO 259
257  KB=IDIST(IT)
      KA=KB-1
      PPROR1=RINT(DIST(KA),DIST(KB),PP(KA,JA,IW),PP(KB,JA,IW),TDIST(IT))
      PPROR2=RINT(DIST(KA),DIST(KB),PP(KA,JR,IW),PP(KB,JR,IW),TDIST(IT))
      PPROR=RINT(AP(JA),AP(JB),PPROR1,PPROR2,A(M,IW))
      IF (PPROR.GT.1.0) PPROR=1.0
      IF (PPROR.LT.0.0) PPROR=0.0
      K(IT,IW)=BRKAY(KAY(IT,IW),PPROR)
      IF (NINTER(IT,IW).EQ.0) GO TO 259
      IF (PPROR.EQ.0.0) GO TO 259
      NINTER(IT,IW)=(NINTER(IT,IW)/PPROR+.5)
259  CRITLM(IT,IW)=V(IT)*K(IT,IW)**2/2.
260  CLMAX=AMAX1(CLMAX,CRITLM(IT,IW))
      LAMDA1=CLMAX
      LAMDA2=1.0
270  LAMDA=(LAMDA1+LAMDA2)/2.
      IF ((LAMDA1-LAMDA2).LT.0.001) GO TO 283
      CALL FDAM(IW)
      IF (ATTACK=A(M,IW)) 275,287,280
275  LAMDA1=LAMDA
      GO TO 270
280  LAMDA2=LAMDA
      GO TO 270
283  LAMDA=LAMDA1
      CALL FDAM(IW)
      ATFMP=ATTACK

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DTEMP=DAMAGE
LAMBDA=LAMBDA?
CALL FDAM(IW)
A1=ARS(ATEMP-A(M,IW))
A2=ARS(ATTACK-A(M,IW))
IF (A2.LE.A1) GO TO 285
ATTACK=ATEMP
DAMAGE=DTEMP
285 MO=M-1
API=A(M,IW)+INCR(IW)
IF (ATTACK.GT.ATTCRV(IC,IW,MO).AND.ATTACK.LT.API) GO TO 287
ATTCRV(IC,IW,M)=ATTCRV(IC,IW,MO)
DAMCRV(IC,IW,M)=DAMCRV(IC,IW,MO)
GO TO 288
287 ATTCRV(IC,IW,M)=ATTACK
DAMCRV(IC,IW,M)=DAMAGE
288 CONTINUE
IF (ATTACK.EQ.0.) GO TO 290
XLM2=DAMAGE/ATTACK
XLM=AMAX1(XLM,XLM2)
290 CONTINUE
291 LAMMAX(IC,IW)=XLM
IF (IPRINT(1).EQ.0) GO TO 300
MINCRP=NINCRP(IW)
DO 298 M=1,MINCRP
X(M)=ATTCRV(IC,IW,M)
298 Y(M)=DAMCRV(IC,IW,M)
PRINT 135, IC,IW
YMIN=0.0
YMAX=Y(MINCRP)
N3=1
LINE=3
CALL PLOTN (Y,X,YMIN,YMAX,N3,MINCRP,LINE)
300 CONTINUE
CALL SECOND (TIME)
PRINT 190, TIME
301 READ 105, (WD(IW),IW=1,NATTYP)
IF (EOF,5) 999,302
302 DO 303 IW=1,NATTYP
IF (WD(IW).LE.NWEPMX(IW)) GO TO 303
PRINT 199, IW,NWEPMX(IW),WD(IW)
GO TO 301
303 CONTINUE
DO 304 IW=1,NATTYP
LAMBDA(IW)=0.0
DO 304 IC=1,NCORID
304 LAMBDA(IW)=AMAX1(LAMBDA(IW),LAMMAX(IC,IW))
IFLAG=0
CALL ALLOCAT (NATTYP,NCORID,NINCRP,IFLAG)
DX=-0.03
DO 315 IW=1,NATTYP
IF (TOTALA(IW).LT.WD(IW)) GO TO 305
DLAMBDA(IW)=0.05

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GO TO 310
305 DLAMDA(IW)=-0.05
310 LAMBDA(IW)=(LAMBDA(IW)*(1.+DLAMDA(IW))+(1.+DX)
315 CONTINUE
ITER=1
IWJ=10.F40
320 CALL ALOCAT (NATTYP,NCORID,NINCRP,IPRINT(2))
CALL RESTCY (NATTYP,NCORID)
IF (IPRINT(3).EQ.0) GO TO 323
ATOTAL=0.0
DTOTAL=0.0
LTOTAL=0.0
PRINT 115, ITER
PRINT 120
DO 322 IW=1,NATTYP
ATOTAL=ATOTAL+TOTALA(IW)
DTOTAL=DTOTAL+TOTALD(IW)
LTOTAL=LTOTAL+TOTALL(IW)
322 PRINT 125, DX,DLAMDA(IW),LAMBDA(IW),WD(IW),TOTALA(IW),TOTALD(IW),
ITOTAL(IW)
PRINT 130, ATOTAL,DTOTAL,LTOTAL,VFE
323 DLMAX=0.0
DO 325 IW=1,NATTYP
325 DLMAX=AMAX1(DLMAX,ABS(DLAMDA(IW)))
IF (DLMAX.LT.DLLIM) GO TO 450
DO 330 IW=1,NATTYP
330 IF (ABS(TOTALA(IW)-WD(IW)).GE.FLOAT(INCR(IW))) GO TO 335
DO 332 IW=1,NATTYP
332 IF (TOTALA(IW).NE.WD(IW)) GO TO 500
GO TO 505
335 DO 345 IW=1,NATTYP
IF (DLAMDA(IW).GT.0.) GO TO 345
IF (TOTALA(IW).GE.WD(IW)) GO TO 340
DLAMDA(IW)=FRACT1*DLAMDA(IW)
GO TO 340
340 DLAMDA(IW)=FRACT2*DLAMDA(IW)
GO TO 355
345 IF (TOTALA(IW).GT.WD(IW)) GO TO 350
DLAMDA(IW)=FRACT2*DLAMDA(IW)
GO TO 340
350 DLAMDA(IW)=FRACT1*DLAMDA(IW)
355 DLAMDA(IW)=AMAX1(DLMAX/20.,AMIN1(DLAMDA(IW),0.5))
GO TO 345
360 DLAMDA(IW)=AMIN1(-DLMAX/20.,AMAX1(DLAMDA(IW),-0.8))
365 CONTINUE
TS=0.0
TA=0.0
DO 370 IW=1,NATTYP
TS=TS+LAMBDA(IW)*TOTALA(IW)
370 TA=TA+LAMBDA(IW)*WD(IW)
IF (DX.GT.0.) GO TO 380
IF (TS.GT.TA) GO TO 375
DX=FRACT1*DX

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      GO TO 395
375 DX=FRACT2*DX
      GO TO 390
380 IF (YS.GT.TA) GO TO 395
      DX=FRACT2*DX
      GO TO 395
385 DX=FRACT1*DX
390 DX=AMAX1(DLMAX/20.,AMIN1(DX,0.5))
      GO TO 400
395 DX=AMIN1(-DLMAX/20.,AMAX1(DX,-0.8))
400 DO 410 IW=1,NATTYP
410 LAMBDA(IW)=(1.+DLAMDA(IW))*(1.+DX)*LAMBDA(IW)
      ITER=ITER+1
      IF (ITER.GT.ITERMX) GO TO 450
      GO TO 320
450 DO 460 IW=1,NATTYP
      LAMBDA(IW)=LAMBDA(IW)
460 TOTALA(IW)=TOTAR(IW)
      DO 470 IC=1,NCORID
      ITYPE(IC)=ITYPER(IC)
      RWEAP(IC)=RWEAPR(IC)
      EDAM(IC)=EDAMH(IC)
470 INTERV(IC)=INTRVH(IC)
      ITER=ITERR
500 CALL CLOSE (NATTYP,NCORID,NINCRP)
505 DO 510 IW=1,NATTYP
      TOTALD(IW)=0.0
510 TOTALL(IW)=0.0
      DO 520 IC=1,NCORID
      IW=ITYPE(IC)
      IF (IW.EQ.0) GO TO 520
      TOTALD(IW)=TOTALD(IW)+EDAM(IC)
      TOTALL(IW)=TOTALL(IW)+EDAM(IC)-LAMBDA(IW)*RWEAP(IC)
520 CONTINUE
      PRINT 140,ITER
      ATOTAL=0.0
      DTOTAL=0.0
      DO 541 IW=1,NATTYP
      TOTALA(IW)=0.0
541 TOTALD(IW)=0.0
      DO 600 IC=1,NCORID
      IW=ITYPE(IC)
      IF (IW.EQ.0) GO TO 595
      WEAPD=RWEAP(IC)
      CLMAX=0.0
      IFIRST=IPPOINT(IC)
      ILAST=IFIRST+NTARG(IC)-1
      IF (IC.EQ.NCORID) GO TO 547
      DO 542 IA=2,NAP
      IF (WEAPD.GE.AP(IA)) GO TO 542
      NPD=IA
      GO TO 543

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542 CONTINUE
NPD=NAID
543 CONTINUE
JR=NRD
JA=JR-1
547 DO 546 IT=IFIRST,ILAST
IF (IC.EQ.ACONID) GO TO 544
KR=IDIST(IY)
KA=KR-1
PPROR1=RINT(DIST(KA),DIST(KR),PP(KA,JA,IW),PP(KR,JA,IW),TDIST(IT))
PPROR2=RINT(DIST(KA),DIST(KR),PP(KA,JR,IW),PP(KR,JR,IW),TDIST(IT))
PPROR=RINT(AP(JA),AP(JR),PPROR1,PPROR2,WEAPD)
IF (PPROR.GT.1.0) PPROR=1.0
IF (PPROR.LT.0.0) PPROR=0.0
K(IT,IW)=RRKAY(KAY(IT,IW),PPROR)
IF (NINTER(IT,IW).EQ.0) GO TO 544
IF (PPROR.EQ.0.0) GO TO 544
NINTER(IT,IW)=(NINTER(IT,IW)/PPROR+0.5)
544 CRITLM(IT,IW)=V(IT)*K(IT,IW)**2/2.
CLMAX=AMAX1(CLMAX,CRITLM(IT,IW))
546 CONTINUE
LAMDA1=CLMAX
LAMDA2=0.0
545 LAMDA=(LAMDA1+LAMDA2)/2.
CALL FOAM(IW)
IF (ATTACK=WEAPD) 550,580,555
550 LAMDA1=LAMDA
GO TO 540
555 LAMDA2=LAMDA
560 IF ((LAMDA1-LAMDA2).LT.0.001) GO TO 570
GO TO 545
570 CALL CLOSE2(IW,WEAPD)
580 PRINT 140, IC,IW
PRINT 142, ATTACK,DAMAGE,VALUE(IC)
ATOTAL=ATOTAL+ATTACK
DTOTAL=DTOTAL+DAMAGE
TOTALA(IW)=TOTALA(IW)+ATTACK
TOTALD(IW)=TOTALD(IW)+DAMAGE
EDAM(IC)=DAMAGE
DO 590 IT=IFIRST,ILAST
590 PRINT 145, IC(IT),ATT(IT),DAM(IT)
GO TO 600
595 PRINT 170, IC
600 CONTINUE
PRINT 194
PRINT 150
DO 603 IC=1,NCORID
603 PRINT 155, IC,ITYPE(IC),RWEAP(IC),EDAM(IC),VALUE(IC)
PRINT 193
DO 605 IW=1,NATTYP
605 PRINT 195, IW,TOTALA(IW),TOTALD(IW)
PRINT 196, ATOTAL,DTOTAL,VFF
GO TO 301

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650 PRINT 19A
100 FORMAT (1A15)
105 FORMAT (8F10.4)
106 FORMAT (2I10,F10.0,2(3X,I3,2I2),5F5.0)
108 FORMAT (4(3X,F3.0,2F2.0))
110 FORMAT (1H1)
115 FORMAT (1H1,*, ITERATION NUMBER *,I2)
120 FORMAT (///*, DX, DLAMBDA, LAMBDA, WEAP DFS, WEAP OBT
1 DAMAGE, LAGRAN*//)
125 FORMAT (1H,*,F6.4,2F10.4,2F10.0,2F12.4)
130 FORMAT (///*, TOTAL ATTACKERS = *,F6.0/* TOTAL DAMAGE = *,F10.4/
1* TOTAL LAGRANGIAN = *,F10.4/* TOTAL VALUE = *,F10.2)
135 FORMAT (///*, CORRIDOR NUMBER *,I2/* WEAPON NUMBER *,I2)
140 FORMAT (1H1,*,FINAL ALLOCATION FOUND AFTER CLOSING ON ITERATION *,
I12)
150 FORMAT (////////*, CORRIDOR, WEAP TYP, ATTACK, DAMAGE, VALUE*
1/)
155 FORMAT (1H,*,I5,I12,F12.0,F12.2,F10.0)
160 FORMAT (1H1,*,FINAL ALLOCATION TO TARGETS IN CORRIDOR *,I2/* THIS C
ORRIDOR WAS ATTACKED BY WEAPON *,I2//)
162 FORMAT (* TOTAL ATTACKERS TO CORRIDOR = *,F5.0/* TOTAL DAMAGE TO C
ORRIDOR = *,F12.4/* TOTAL VALUE OF CORRIDOR = *,F10.2/* TARGET
2 ATTACK, DAMAGE*//)
165 FORMAT (1H,*,I5,F12.0,F15.4)
170 FORMAT (1H1,*,CORRIDOR *,I2,* WAS NOT ATTACKED*)
180 FORMAT (1H1,*,CORRIDOR NUMBER *,I2/* IN, VALUE, DIST
1 X*,50X*,INTERCEPTORS*//)
185 FORMAT (1H,*,I5,2F10.2,5F10.4,5I8)
190 FORMAT (* TIME = *,F10.4)
193 FORMAT (////////*, WEAP TYP, ATTACK, DAMAGE*//)
194 FORMAT (1H1,*, SUMMARY OF FINAL ALLOCATION*)
195 FORMAT (1H,*,I5,F12.0,F13.4)
196 FORMAT (///*, TOTAL ATTACKERS = *,F5.0/* TOTAL DAMAGE = *,F12.4/
1* TOTAL VALUE = *,F12.4)
198 FORMAT (1H1,*,ERROR IN INPUT VALUES,*/* NUMBER OF ATTACKER TYPES EX
CEEDS THE NUMBER OF CORRIDORS*)
199 FORMAT (1H1,*,ERROR IN INPUT,*/* THIS CASE WILL NOT BE RUN,*//
1* NUMBER OF WEAPONS OF TYPE *,I1,* CANNOT EXCEED *,I5//
2* THIS CASE REQUESTED *,F5.0,* WEAPONS OF THAT TYPE*)
999 STOP
END

```



```

5 INPT(10) = XRAY(XRAY,PP)
  DEPRD(1,0) = AD(0,XRAY) + (1,0,XRAY)
  XZ(1,0)
  IF=1
6 IF AD=EP(0)
  D1=1,0-IF=2*(1,0,0X)=0
  IF (ASS(1,0)) .IF. 1,0E-5) GO TO 10
  IF (IF,0,1,0) GO TO 20
  IF=IF+1
  DP=2*TEMP
  XZ(1,0)=1/DP
  GO TO 5
10 XRAY=XZ
  DEPRD(1,0)
20 DEPRD(1,0)=XZ(1,0)
1000 DEPRD(1,0)=EP(0) + INRAY(0,3)+(2,0)
  XZ=DEPRD
  END

```

```

FUNCTION FINT(X1,X2,Y1,Y2,X)
PERFORMS LINEAR INTERPOLATION
RETURN Y1-(X1-X)*(Y2-Y1)/(X2-X1)
END

```

```

SUBROUTINE PLOT (Y1,AX,YMIN,YMAX,IB,NPP,LINE)
Y1,AX ARE ARRAY NAMES
NPP = NUMBER OF POINTS PLOTTED
CURVE PLOTTED IN POSITIONS 30 TO 40
DIMENSION Y1(1),AX(1),YICK(1)
INTEGER SPACE(1:1),BLANK,OUT
DATA BLANK,OUT,MARK/14,14,14%/
3 IF (NPP,20,1) RETURN
Y0=50./(YMAX-YMIN)
YICK(1)=YMIN
Y010=10./Y0
DO 30 I=1,5
20 YICK(I+1)=YICK(I)+Y010
PRINT 100, (YICK(I),I=1,6)
100 FORMAT (//AX,0DAMAGE0,AX,0ATTACK0,F2.0,5F10.0)
WRITE (5,100)
104 FORMAT(29(1H15(10H.....)))
NL=530/NPP
LI=1/NL+1
DO 4 I=1,51

```

```

6 SPACE(1)=BLANK
C SPLITTING UP GRIJ LINES
GOTO (1,11,12,13), LI
13 DO 130 I=1,51,1
130 SPACE(I)=0
12 SPACE(51)=0
11 SPACE(1)=0
10 DO 50 NP=1,NL,13
   X=AX(NP)
   NC1=1
   IY1=(Y1(NP)-Y1(1))*YU+1.5
   IF (IY1.LE.0.04, IY1.GE.52) NC1=0
   IF (NC1.EQ.0) GO TO 1
   ISP1=SPACE(IY1)
   SPACE(IY1)=MARK
1 WRITE (6,133) Y1(NP),X, (SPACE(I), I = 1,51)
103 FORMAT (2X,13.0,F13.0,1A51A1)
60 IF (NC1.NE.0) SPACE(IY1)=ISP1
50 CONTINUE
WRITE (6,134)
RETURN
END

```

SUBROUTINE ALLOCAT (NATTYP,NCORID,NINCRP,IFLAG)

```

C COMMON/CALLOC/ND(5),LAMHDA(5),ITYPE(15),HWEAP(15),EDAM(15),
C PATCHRV(15,5,21),DAMCRV(15,5,21),LAMMAX(15,5),INTERV(15),
C TOTALA(5),TOTALD(5),TOTALL(5),VALUE(15)
C
C DIMENSION NINCRP(5)
C
C REAL LAM(1),LAMMAX
C
C DO 200 I=1,NATTYP
  TOTALA(I)=0.0
  TOTALD(I)=0.0
200 TOTALL(I)=0.0
  DO 300 IC=1,NCORID
    ITYPE(IC)=1
    HWEAP(IC)=0.0
    EDAM(IC)=0.0
    INTERV(IC)=0
    LAMAX=0.0
  DO 240 IW=1,NATTYP
    IF (LAMHDA(IW).GT.LAMMAX(IC,IW)) GO TO 240
    LAM(I)=0.0
    NINCRP=NINCRP(IW)
  DO 210 K=2,NINCRP
    FLAG=DAMCRV(IC,IW,K)-LAMHDA(IW)*PATCHRV(IC,IW,K)

```

```

10 (HLAS,LF,HLA4) GO TO 210
11 HLA4=HLA3
12 K4=4
210 CONTINUE
13 HLAATCHV(IC,I4,K4)
14 HLAAMCHV(IC,I4,K4)
15 (HLA,LE,HLA1) GO TO 240
16 HLA4=HLA1
17 GO 220 K4=2,4,1,4
18 (HLA,G1,ATCHV(IC,I4,K4)) GO TO 220
19 K4=4
20 GO TO 230
220 CONTINUE
230 K4=K4-1
240 HLAATCHV(IC,I4,K4),ATCHV(IC,I4,K4),HLAAMCHV(IC,I4,K4),
250 HLAAMCHV(IC,I4,K4),HLA4
260 (HLA,LF,HLA4) GO TO 230
270 TYPE(I)=I
280 HLAEDAM(IC)=HLA
290 HLAATCHV(IC)=K4
300 HLA4=HLA4
310 CONTINUE
320 TYPE(I)=I
330 TOTALA(I)=TOTALA(I)+HLEAD(IC)
340 TOTALB(I)=TOTALB(I)+EDAM(IC)
350 TOTALC(I)=TOTALC(I)+HLA4
360 CONTINUE
370 (HLA,LF,HLA4) GO TO 399
380 HLA4=HLA4
390 PRINT I,IC,TYPE(I),HLEAD(IC),EDAM(IC)
400 PRINT I,HLA4,TYPE I,LEAD DAMAGE(I)
410 PRINT I,HLA4,HLA4,HLA4,HLA4,HLA4
420 HLA4=HLA4
430

```

STIMULI[12] = BESTLY(NATYP, COMID)

C

COMMON/CALC/40(5), LAMDA(5), TYPE(15), MWEP(15), EDAM(15),
INTERV(15,5,2), DAMCH(15,5,2), LAMMAX(15,5), INTERV(15),
TOTALA(5), TOTAL(5), TOTALL(5), VALHE(15),
COMMON/CHES/14(5), TOTAH(5), TYPEH(15), MWFAPE(15), EDAMH(15),
INTERVH(15), LAMDAH(5), IFEH, IFEH

C

REAL LAMDA3, LAMDA4

C

C

TAJ1=0.0
DO 250 JJ=1, NATYP
IF (ND(JJ).EQ.0.0) GO TO 200
TAJ1=TAJ1+((TOTALA(JJ)-ND(JJ))/ND(JJ))**2
GO TO 250
200 TAJ1=TAJ1+TOTALA(JJ)**2
250 CONTINUE
IF (TAJ1.LE.1E-5) GO TO 500
TAJ1=1E-5
DO 400 JJ=1, NATYP
LAMDAH(JJ)=LAMDA(JJ)
400 TOTAH(JJ)=TOTALA(JJ)
DO 450 JJ=1, NCOMIP
TYPEH(JJ)=TYPE(JJ)
MWFAH(JJ)=MWFAPE(JJ)
EDAMH(JJ)=EDAM(JJ)
450 INTERVH(JJ)=INTERV(JJ)
IFEH=IFE
500 RETURN
END

```

C      SUBROUTINE CLOSE (NATTYP,NCORID,MINCRP)
C
C      COMMON/CALLOC/ND(5),LAMMAX(5),ITYPE(15),RWEAP(15),EDAM(15),
1ATTCHRV(15,5,21),DAMCHRV(15,5,21),LAMMAX(15,5),INTERV(15),
2TOTALA(5),TOTALD(5),TOTALL(5),VALUE(15)
C
C      DIMENSION MINCRP(5)
C
C      REAL LAMMAX
C
C
C      DO 300 IW=1,NATTYP
C      IF (TOTALA(IW).LE.4D(IW)) GO TO 300
C      DEC=TOTALA(IW)-4D(IW)
200  SLOPE=10.E40
C      DO 250 IC=1,NCORID
C      IF (ITYPE(IC).NE.IW) GO TO 250
210  IF (INTERV(IC).EQ.1) GO TO 250
C      KK=INTERV(IC)
C      KJ=KK-1
C      IF (ATTCHRV(IC,IW,KK).NE.ATTCHRV(IC,IW,KJ)) GO TO 220
C      INTERV(IC)=INTERV(IC)-1
C      GO TO 210
220  SLOPE1=(DAMCHRV(IC,IW,KK)-DAMCHRV(IC,IW,KJ))/(ATTCHRV(IC,IW,KK)-
1ATTCHRV(IC,IW,KJ))
C      IF (SLOPE1.GT.SLOPE) GO TO 250
C      ICDEC=IC
250  CONTINUE
C      IC=ICDEC
C      KK=INTERV(IC)
C      KJ=KK-1
C      DIFF=RWEAP(IC)-ATTCHRV(IC,IW,KJ)
C      IF (DIFF.GE.DEC) GO TO 260
C      TOTALA(IW)=TOTALA(IW)-DIFF
C      RWEAP(IC)=ATTCHRV(IC,IW,KJ)
C      EDAM(IC)=DAMCHRV(IC,IW,KJ)
C      IF (RWEAP(IC).EQ.0.0) ITYPE(IC)=0
C      INTERV(IC)=INTERV(IC)-1
C      DEC=DEC-DIFF
C      GO TO 200
260  RWEAP(IC)=RWEAP(IC)-DEC
C      EDAM(IC)=MIN(ATTCHRV(IC,IW,KJ),ATTCHRV(IC,IW,KK),DAMCHRV(IC,IW,KJ),
1DAMCHRV(IC,IW,KK),RWEAP(IC))
C      TOTALA(IW)=TOTALA(IW)-DEC
300  CONTINUE
C      DO 400 IW=1,NATTYP
C      MINCRP=MINCRP(IW)
C      IF (TOTALA(IW).GE.4D(IW)) GO TO 400
C      IF (TOTALA(IW).EQ.0.) GO TO 400
C      XINC=4D(IW)-TOTALA(IW)
310  SLOPE=0.0
C      ICINC=0

```

```

DO 350 IC=1,NCORID
IF (ITYPE(IC).NE.IW) GO TO 350
320 IF (INTERV(IC).EQ.41INCRP) GO TO 350
KK=INTERV(IC)
KL=KK+1
IF (ATTCHV(IC,IW,KL).NE.ATTCHV(IC,IW,KK)) GO TO 330
INTERV(IC)=INTERV(IC)+1
GO TO 320
330 SLOPE1=(DAMCHV(IC,IW,KL)-DAMCHV(IC,IW,KK))/(ATTCHV(IC,IW,KL)-
ATTCHV(IC,IW,KK))
IF (SLOPE1.LT.SLOPE) GO TO 350
SLOPE=SLOPE1
ICINCR=IC
350 CONTINUE
IF (ICINCR.NE.0) GO TO 370
DO 350 IC=1,NCORID
IF (ITYPE(IC).NE.IW) GO TO 360
EXTRA=WD(IW)-TOTALA(IW)
RWEP(IC)=RWEP(IC)+EXTRA
TOTALA(IW)=TOTALA(IW)+EXTRA
NW=41INCRP
352 NW=NN-1
IF (ATTCHV(IC,IW,NW).NE.ATTCHV(IC,IW,NN)) GO TO 355
NN=NN+1
GO TO 352
355 EDAM(IC)=RINT(ATTCHV(IC,IW,NW),ATTCHV(IC,IW,MINCRP),DAMCHV(IC,IW,
INM),DAMCHV(IC,IW,41INCRP),RWEP(IC))
IF (EDAM(IC).GT.VALUE(IC)) EDAM(IC)=VALUE(IC)
GO TO 400
360 CONTINUE
370 IC=ICINCR
KK=INTERV(IC)
KL=KK+1
DIFF=ATTCHV(IC,IW,KL)-RWEP(IC)
IF (DIFF.GE.XINC) GO TO 390
TOTALA(IW)=TOTALA(IW)+DIFF
RWEP(IC)=ATTCHV(IC,IW,KL)
EDAM(IC)=DAMCHV(IC,IW,KL)
INTERV(IC)=INTERV(IC)+1
XINC=XINC-DIFF
GO TO 310
380 RWEP(IC)=RWEP(IC)+XINC
EDAM(IC)=RINT(ATTCHV(IC,IW,KK),ATTCHV(IC,IW,KL),DAMCHV(IC,IW,KK),
DAMCHV(IC,IW,KL),RWEP(IC))
TOTALA(IW)=TOTALA(IW)+XINC
400 CONTINUE
DO 450 IW=1,NATTYP
MINCRP=MINCRP(IW)
IF (TOTALA(IW).NE.0.) GO TO 450
ICREST=0
DAMR=0.0
DO 440 IC=1,NCORID

```

```

      IF (IIVD-(IC,IN,0)) GO TO 420
      DO 420 K=2,NICR2
      IF (ND(IK).GT.ATTCHV(IC,IN,K)) GO TO 420
      KK=K
      GO TO 430
420 CONTINUE
      KK=M(NCR2)
425 KJ=KK-1
      IF (ATTCHV(IC,IN,KJ).NE.ATTCHV(IC,IN,KK)) GO TO 430
      KK=KJ
      GO TO 425
430 KJ=KK-1
      DAM1=MIN(ATTCHV(IC,IN,KJ),ATTCHV(IC,IN,KK),DAMCHV(IC,IN,KJ),
      DAMCHV(IC,IN,KK),ND(IN))
      IF (DAM1.GT.VALUE(IC)) DAM1=VALUE(IC)
      IF (DAM1.LT.DAMH) GO TO 440
      DAMH=DAM1
      ICHEST=IC
440 CONTINUE
      IC=ICHEST
      RWFIP(IC)=ND(IN)
      EDAI(IC)=DAMH
      ITYPE(IC)=(R
      TOTALA(IN)=ND(IN)
450 CONTINUE
      RETURN
      END

```

STOP IF IF CLOSED (IF=4EAPD)

COMA=1/CEMAN/LAMDA,K(500,5),V(500),CHITLM(500,5),IFIRST,ILAST,
ATTACK,DAMAGE,ATT(500),DA(500),NINTER(500,5)

REAL LAMDA,CEMAN,LAMDA,CEMAN

IF (ATTACK.GT.4EAPD) GO TO 310
XINC=XEAPD-ATTACK
200 IF (XINC.EQ.0.) GO TO 500
SLOPE=0.
ITBEST=0
DO 250 IT=IFIRST,ILAST
IF (ATT(IT).EQ.0..AND).NINTER(IT,IV).NE.0) GO TO 250
ATT1=ATT(IT)
ATT2=ATT1+1.
DAM1=DAM(IT)
DAM2=DMGFNC(V(IT),K(IT,IV),ATT2)
SLOPE1=DAM1-DAM2
IF (SLOPE1.LE.SLOPE) GO TO 250
SLOPE=SLOPE1
ITBEST=IT
250 CONTINUE
ATT(ITBEST)=ATT(ITBEST)+1.
DAMTMP=DMGFNC(V(ITBEST),K(ITBEST,IV),ATT(ITBEST))
DAMINC=DAMTMP-DAM(ITBEST)
DAM(ITBEST)=DAMTMP
ATTACK=ATTACK+1.
DAMAGE=DAMAGE+DAMINC
XINC=XINC-1.
GO TO 200
300 XDEC=ATTACK-4EAPD
310 IF (XDEC.EQ.0.) GO TO 500
SLOPE=10.E+0
ITBEST=0
DO 350 IT=IFIRST,ILAST
IF (ATT(IT).EQ.0.) GO TO 350
IF (NINTER(IT,IV).NE.0) GO TO 350
ATT1=ATT(IT)
ATT2=ATT1-1.
DAM1=DAM(IT)
DAM2=DMGFNC(V(IT),K(IT,IV),ATT2)
SLOPE1=DAM1-DAM2
IF (SLOPE1.GT.SLOPE) GO TO 350
SLOPE=SLOPE1
ITBEST=IT
350 CONTINUE
ATT(ITBEST)=ATT(ITBEST)-1.
DAMTMP=DMGFNC(V(ITBEST),K(ITBEST,IV),ATT(ITBEST))
DAMDEC=DAM(ITBEST)-DAMTMP
DAM(ITBEST)=DAMTMP

ATTACK=ATTACK-1.
DAMAGE=DAMAGE-DAMDEC
XDEC=XDEC-1.
GO TO 310
500 RETURN
END

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Program BALLOC is a model designed to optimally allocate a mixed-weapon offensive force over a set of multiple-valued targets defended by multiple nonintersecting random area and subtractive local defenses. The program will maximize the expected damage over the total target set, with the restriction that no more than one weapon type be allocated to any randomly defended island or target subset. This report presents the concept on which the model is based, and describes the implementation of this concept as a computer program. It also contains a users manual, and an example of the use of the model, employing fictitious data to avoid the necessity of security classification.		

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