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THE SWEM (STRATEGIC WEAPONS EXCHANGE
MODELS) ALLOCATION MODEL: VERSION II

R. Arms, et al

Research Analysis Corporation

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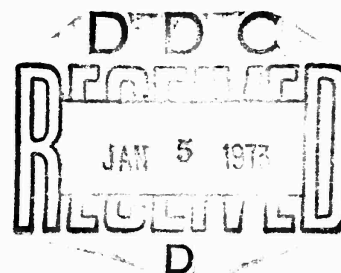
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The SWEM Allocation Model

Version II

by R. Ams
D. Grissmer
L. Lyons



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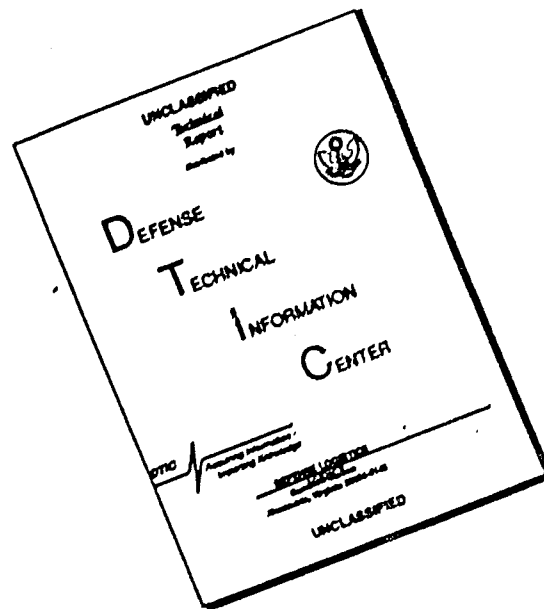
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The SWEM Allocation Model is a mathematical optimization model which allocates strategic weapons in a two-sided nuclear exchange and provides damage results and specific allocations. The model is useful in defining levels of parity between the nuclear arsenals of two nations. Version II of this model expands the allocation matrix to include attack on defense installations and provides the optimal tradeoff between attack of defense installations, weapon targets (silos) and cities. This document describes a mathematical optimization model which provides allocations and damage levels in a two-strike nuclear war. It is an extension of an allocation model (Strategic Weapons Exchange Allocation Model-Version I) which has been documented in manuals mentioned in the Introduction. The new allocation model allows attack on defense installations as well as cities and weapon targets, and provides optimal trade-offs in allocation between defense installations, cities, and weapon targets. This document describes the capabilities and limitations of the model, gives the format of the input and output of the model, provides example problems and contains the annotated Fortran listing of the program.			

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FOREWORD

The model described in this document is an extension of one of the Strategic Weapons Exchange Models (SWEM) which have been programmed to aid in decision making concerning the procurement, deployment, and allocation of strategic weapons. As detailed further in the Introduction, these models were documented in a recent series of documents by the Research Analysis Corporation. The document provides the basic information necessary to run the model, but is not intended to be used independently of the other documentation of the SWEM models.

This model, SWEM Allocation Model, Version II, is an extension of the allocation optimization model to include defense installations as targets. The model will be an aid in the decision making process regarding the allocation optimization of offensive strategic nuclear weapons against defense installations. It is useful in defining levels of parity between the nuclear arsenals of two nations and provides the optimum tradeoff between attack of defense installations, weapon targets (silos), and cities.

J. ROSS HEVERLY
Vice President
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Chapter 1

INTRODUCTION

The model described in this document (SWEM Allocation Model - Version II) is another member of the set of Strategic Weapons Exchange Models (SWEM) which have been produced and documented by the Research Analysis Corporation. This model is an extension of the SWEM Allocation Model which was used in the SWEM Second Strike Model (Version II) and documented in the manual, A Planners Guide and Users/Programmer Manual for Strategic Weapons Exchange (SWEM) Second Strike Model - Version II, RAC-CR-43. The model user should also be familiar with the SWEM Allocation Model - Version I which is documented in the manual, The Strategic Weapons Exchange Models Users Manual, RAC-CR-14, and the general description of the SWEM models which is contained in the document, Strategic Weapons Exchange Model Planners Guide, RAC-CR-36. The model uses the same nonlinear mathematical algorithm for solution, the Sequential Unconstrained Minimization Technique (SUMT), as other SWEM models. This algorithm is documented in the manual, A SWEM System/Programmer's Guide to SUMT - Version IV, RAC-CR-34. The present manual is meant to serve as an annex to the above documents and is not self-contained.

This model extends the capability of the SWEM Allocation Model - Version I in several ways. The major change is the inclusion of defense installations as target classes. The model now gives optimal allocation of offensive strategic weapons against city targets, weapon targets (ICBM silos), and the defense installation of each of the city and weapon targets. In addition, this new allocation model which was included in the SWEM second strike model has several features which were not available in the earlier version of the SWEM Allocation Model. These features include:

- . More than a single type of each level of defensive weapon: area missile defender, terminal missile defender, bomber interceptor and SAM, can be input into the model.
- . Options for the employment of defense against the attack can span the range from a randomly committed defense to a proportional defense which attacks incoming missiles on the basis of damage capability. Thus a range of defense effectiveness can be investigated with the model.
- . First strike offensive weapons are designated as countervalue only or countervalue and counterforce. This feature reduces the number of variables in the model and allows more geographical areas or target classes to be included.
- . Bombers are allocated optimally instead of on the basis of population.

This manual documents the model changes for the strategic analyst, user, and programmer. The first section contains a description of model characteristics, assumptions, and uses for the strategic analyst interested in applying the model to strategic problems. The mathematical formulation of the model is also provided in App. A. The second section contains for the user a detailed description of the model input, a sample force table with all information needed to run the model, and a sample Fortran code sheet containing the model input from the force table. Output from the model for a series of six sample problems using the sample input data is given in the fourth section.

For the programmer, a Fortran listing of the program that contains extensive comment cards is provided in App. B, together with a partial Fortran glossary which references the most important Fortran variables with their counterpart in the mathematical notation in App. D.

Chapter 2

MODEL CHARACTERISTICS, ASSUMPTIONS, AND USES

Two types of problems arise when considering attacks on defense installations. The problem of the offensive planner is to determine if defense installation should be attacked and if so, which installations should be attacked and at what level in order to achieve his strategic objectives. The second problem is for the defense planner who must deploy defenses geographically and determine the level of defenders at each installation in order to achieve his strategic objectives. This model is designed to study some of the tradeoffs involved in decisions of this type at the strategic rather than the tactical level.

The current scenario of the SWEM Allocation Model does not allow for a direct attack by the first striker on the defensive installations of the second striker. Such attack scenarios are feasible since an attack on defense installations might result in more damage to value targets. This additional damage is caused by the remaining attackers which survive the degraded defenses.

The new model is an optimization model which considers the optimal allocation of offensive strategic weapons in a two-strike nuclear war against city targets, weapon targets, and defense installations. Side one is assumed to have an inventory of different types of offensive weapons which attack target classes of side two which can be weapon classes such as ICBM silos, geographical city regions, or defense installations of each of the weapon or target classes. Side two is then assumed to strike back with all of his remaining weapons on side one cities. Side one weapons can be optimally allocated against side two targets in the model according to a range of criteria. The objective function of the model involves the difference in value damage to the two nations

and the first striker objective can range from maximizing damage to side two, to maximizing the difference in damage, to minimizing his own damage. Model output includes the damage to both nations, the optimal set of allocations against value targets and defense installations, and many other detailed characteristics of the exchange.

The model takes into account two main effects of the attack on defenses.

1. The attrition of defenders due to attack on their defense installation, thereby allowing more attackers through the defenses.
2. The missiles actually attacking the defense installation are deleted from attack on other targets.

The new model feature allows the user to select up to four side one weapon types which can attack specific types of defense installations of side two. Thus a side one missile type can be chosen to attack side two SAM bases prior to the attack on cities, or a side one missile can be specified to attack hard site defense of ICBMs prior to an attack. The model will determine if the attack on defense will achieve the strategic objectives of side one and what the optimal level of attack would be to achieve these objectives. The model will simultaneously optimize attack on all types of defense installations for each city class or weapon target and the attack on cities and weapons. The model also can handle several different defense installations defending a certain region as well as multiple defense installations of the same type in the same region.

The attack on defense installations is formulated on an expected value basis. Damage curves as a function of the level of attack for each defense installation are calculated based on calculating the probability that a single missile will be reliable, penetrate the defense, and hit the target for each level of attack. The number of surviving defenders free to counteract the attack on values is just the total original number at the defense installation times the probability that a single missile will impact to destroy the targets. Of course, the probability of impacting on target increases the greater the level of attack on the defense installation. These damage

curves are generated inside the program and then an analytic function is fit in order to provide the main optimization routine with the defense damage curves.

The methodology for including attack on defense installation contains the following limitations and assumptions.

1. Single type of offensive weapon can be targeted against a given type of defense installation. The model allows either missiles or bombers to attack any type of defense installation, but only a single type of weapon can attack a given type of installation.
2. The first impacting missile on the target defense installation will destroy the defenders associated with that installation.
3. The geographical regions chosen are non-overlapping and must be the same for each defense installation type.
4. The attack on defenses is one sided in that only the defenses of the second striker are subject to attack.
5. The solutions obtained by the model are not guaranteed to be globally optimal because of the non-convex nature of the problem, thus different starting points may have to be used to obtain the globally optimal solution.

The first assumption is made to reduce the number of allocation variables and does not represent a serious limitation. In general a single type of weapon with high kill probability against a particular defense installation will be chosen to attack. The second assumption indicates that an impacting warhead will destroy either all defenders or the command and control system necessary to target defenses. This assumption is probably valid for all defenses except aircraft with AWACS. In this case the aircraft would simply not be input into the model as being destroyable at the defense installation. The third assumption is the most stringent in the current model. The geographical regions for the model must be the same for each defense type. That is, for each defense type the defense is assumed to operate over the same geographical region. This will usually entail certain compromises with realism in the choice of geographic regions and footprints of the actual weapon system. Attacks against only one type of defense installation, for instance, airbases, can be realistically modeled. In general the compromise will be defense conservative since usually defense regions will

be larger than they actually are. The damage and allocations that come out of the model will generally be defense conservative.

The fourth assumption can be overcome to a certain extent by a series of runs where side one and side two are interchanged to model the situation where both side one and two attack defenses.

The fifth item is not a serious limitation of the model. It means in certain instances, primarily for the cases where the damage difference is being optimized, that more than a single run may have to be made to insure a globally optimal solution. This is usually best done by running different values of the K parameter, say .1, 1.0, 10 instead of only the value of 1.

The model can be used to address either the problems of the offensive planner planning an attack which can include attack on defenses or the defensive planner who must deploy defenses so they are not vulnerable to attack by the offense. Some of the tradeoffs which occur in this type of analysis and which can be studied with the model include:

1. The degree of defense dispersal and the number of defenders at each installation, i.e., the number of missile radars, airfields necessary to make the offense indifferent to whether he does or does not attack the defense.
2. The proper balance of different types of defense, i.e., bomber and missile defense, to defend value targets.
3. The type and proper level of allocation of strategic weapons against defended targets between the value target itself and the defense installation.

In general these types of studies can be carried out with the model by parametrically varying the following model parameters.

1. The area or region of defense effectiveness for defender types.
2. The number of defense installations for value targets and the number of defenders at different installations.
3. The overall level of defense against different types of threats.

One of the limitations of the SWEM models generally is a noninteger weapon allocation to individual silos. Thus less than a single missile can be allocated to a single silo and cause damage. The damage to silos

from an attack is accurate when survival probabilities are large enough to cause at least one missile allocated per silo. However with very small survival probabilities, less than one on one allocation will result and the damage will be overestimated. The current model limits survival probabilities to be $> .01$ to partially overcome this problem. Thus in the calculation of S_{ij} which is done in subroutine READIN, if S_{ij} comes out to be less than $.01$, it is set to $.01 + S_{ij}$. This value of $.01$ could be adjusted so as to obtain at least one on one allocation of offensive missiles on silos.

Chapter 3

MODEL INPUT

INPUT DATA FOR THE ALLOCATION MODEL

1. First card - SUMT parameter card
2. Next set of cards - Starting point cards
3. Next set of cards - Data for the allocation model
4. Last three cards - SUMT option and additional parameters

Details concerning the groups of cards will be discussed in order. The reader may find it convenient to examine the sample input data contained on the coding sheets in conjunction with the discussion.

1. First card - SUMT parameter card

COLUMNS	01-12	12-24	25-36	37-48	49-60	61-64	65-68	69-72
FORMAT	E12.0	E12.0	E12.0	E12.0	E12.0	14	14	14
NAME OF INPUT	EPSI	RHOIN	THETAO	RATIO	TMAX	MC	NV	MZ
SUGGESTED VALUE	.01	.05	.00001	2.0	1800.			

where MC = the number of inequality constraints

NV = the number of variables

MZ = 0 or blank

2. Next set of cards - Starting point cards

This set of data contains $[NV/6] + 1$ cards. For the sample problem $NV = 87$ and we have 15 cards. The starting point cards have the format 6E12.0. By setting $NUL = 1$ (column 60) on the first card after the last starting point card STARTB will select a feasible starting point, thus enabling the user to free himself of this task. A set of $[NV/6] + 1$ blank cards may then be substituted for the starting point data.

For those preferring to select their own starting points, the information is read in the following order: first the non defense allocations are read in by columns i.e., $x(i,1)$ ($i = 1, \dots, II$), $x(i, JJ)$ ($i = I + 1, \dots, II$), next the values of the first striker defense allocation variables are read in by rows $u(1,k)$ ($k = 1, \dots, D$), $u(II,k)$ ($k = 1, \dots, D$). If $D \leq 0$ then there are no allocations of side one weapons against side two defenses.

3. Next set of cards - Data for the allocation model

The input data for the allocation model is read in once per problem. For convenience of reference the input data is discussed in the order it is read in and by the type of data it is.

(3-1) Problem Size and Option Inputs

Format	{	I	II	M	J	JJ	K	L	N	D	NDEFS	IB1	NUL	NU3	NU4	(1st card)
13I5	}	D1	D2													(2nd card)

where

I = total number of side 2 CF targets (ICBMs)

II = total number of side 2 targets (ICBMs + Cities)

M = total number of side 2 weapon types (ICBMs, SLBM, Bombers)

J = total number of side 1 weapon types with CF and CV capability

JJ = total number of side 1 weapon types

K = total number of side 2 defender types

L = total number of side 1 geographic areas

N = total number of side 1 defender types

D = total number of side 2 defender types which can be attacked

NDEFS = side 2 defense allocation doctrine

{	≤ 1 is proportional
	2 is uniform
	≥ 3 the user must read in his own

IB1 = side one defense allocation doctrine

$$\left\{ \begin{array}{l} \leq 1 \text{ is proportional} \\ 2 \text{ is uniform} \\ \geq 3 \text{ the reader must read in his own} \end{array} \right.$$

NU1 = If NU1 = 1 a starting feasible point is calculated automatically, otherwise the starting point is read in

NU3 = If NU3 = 1 a printout of the first strikers allocations occurs for every point of the SUMT algorithm

NU4 = The total number of strategies (different ratios of k_2/k_1) to be considered for a problem set

D1 = The maximum number of types of side 2 defensive weapon types which can be attacked by side one weapon type 1

$$0 \leq D1 \leq 4$$

D2 = The maximum number of types of side 2 defensive weapon types which can be attacked by side one weapon type 2

$$0 \leq D2 \leq 2 \quad D1 + D2 \leq 4 \text{ and } D1 \geq D2$$

(3-2) Damage Curve Fit Parameters and Fractional Populations

Format $\left\{ \begin{array}{l} A(1), \dots, A(II-I) \\ \bar{A}(1), \dots, \bar{A}(L) \\ P(1), \dots, P(II-I) \\ \bar{P}(1), \dots, \bar{P}(L) \end{array} \right. \quad \text{each line is one card}$
 10F8.0

where

A_i = fitting constants for side 2 populations ($i = 1, \dots, II-I$)

$\bar{A}_\ell$ = fitting constants for side 1 populations ($\ell = 1, \dots, L$)

P_i = fraction of side 2 populations in i th area ($i = 1, \dots, II-I$)

$\bar{P}_\ell$ = fraction of side 1 populations in ℓ th area ($\ell = 1, \dots, L$)

(3-3) Side Two Offensive Systems and Single Shot Survival Probabilities Against Side One Defensive Weapon Types

Format $\left\{ \begin{array}{l} n_m \quad \bar{r}_m \quad w_m^2 \quad PSI_m \quad ZN_m^2 \quad TITLE2_m \\ \bar{P}_{mn} \quad (n = 1, \dots, N) \end{array} \right. \quad \left\{ \begin{array}{l} \text{First } I \text{ side 2 offensive} \\ \text{weapon systems (weapons} \\ \text{in hard sites)} \end{array} \right.$
 5E8.0, A8
 10F8.0

Format $\left\{ \begin{array}{l} n_m \quad \bar{r}_m \quad w2_m \quad ZN2_m \quad TITLE2_m \\ 10F8.0 \quad \bar{p}_{mn} \quad (n = 1, \dots, N) \end{array} \right\} \quad \left. \begin{array}{l} \text{Next } M-I \text{ side 2 offensive} \\ \text{weapon systems} \end{array} \right\}$

where

n_m = total inventory of side 2 mth type offensive weapon

$\bar{r}_m$ = force reliability of side 2 mth type offensive weapon

$w2_m$ = warhead yield (MT) of side 2 mth type offensive weapon

ISI_m = hardness (P.S.I.) of base (or side 2 mth type offensive weapon ($m = 1, \dots, I$))

$ZN2_m$ = number of warheads delivered by side 2 mth type offensive weapon

$TITLE2_m$ = name of side 2 mth type weapon

$\bar{p}_{mn}$ = single shot survival probability of side 2 mth type weapon engaged by side 1 nth type defender ($n = 1, \dots, N$)

(3-4) Side One Offensive Systems and Single Shot Survival
Probabilities Against Side Two Defensive Weapon Types

Format $\left\{ \begin{array}{l} m_j \quad r_j \quad e_j \quad w1_j \quad CEP_j \quad FPP_j \quad ZN1_j \quad TITLE1_j \\ 10F8.0 \quad p_{jk} \quad (k = 1, \dots, K) \end{array} \right\} \quad \left. \begin{array}{l} \text{First } J \text{ weapons} \\ \text{with both CV and} \\ \text{CF capability} \end{array} \right\}$

Format $\left\{ \begin{array}{l} m_j \quad r_j \quad e_j \quad w1_j \quad ZN1_j \quad TITLE1_j \\ 10F8.0 \quad p_{jk} \quad (k = 1, \dots, K) \end{array} \right\} \quad \left. \begin{array}{l} \text{Next } JJ-J \\ \text{weapons with} \\ \text{CV capability} \\ \text{only} \end{array} \right\}$

where

m_j = total inventory of side 1 jth type offensive weapon

r_j = force reliability of side 1 jth type offensive weapon

e_j = number of independently targetable warheads per each side 1 attacker

$w1_j$ = warhead yield per side 1 weapon type j

CEP_j = radius of circle (N. Mi) of error probability .5 for side 1 weapon type j ($j = 1, \dots, J$ only)

FPP_j = number of cluster warheads for side 1 weapon type j ($j = 1, \dots, J$ only)

$ZN1_j$ = number of warheads per side 1 weapon type j

$TITLE1_j$ = name of each side 1 j th type weapon

p_{jk} = single shot survival probability of side 1 j th type attacker
when engaged by side 2 k th type defender ($k = 1, \dots, K$)

(3-5) Side One Offensive Weapon Inventory Which Can Be Used For
Other Military Targets (i.e., held back from the first strike)

Format 10F8.0 $\left\{ uu_j \right. (j = 1, JJ)$

where

uu_j = number of each side 1 weapon assigned to other military targets
($j = 1, \dots, JJ$)

(3-6) Strategies to be Investigated for the Problem Set
(Ratio of (k_2/k_1))

Format 10F8.0 $\left\{ RAT(i) = \text{ratio of } k_2/k_1 \text{ for case } i, i = 1, \dots, NU4 \right.$

(3-7) Side One Reliable Defensive Weapons Inventory For Each
Side One City Class ℓ ($\ell = 1, L$)

Format 10F8.0 $\left\{ \bar{d}_{\ell n} \right. (n = 1, \dots, N)$

where

$\bar{d}_{\ell n}$ = number of reliable side 1 defenders of side 1 ℓ th target
($\ell = 1, \dots, L$) ($n = 1, \dots, N$)

(3-8) Side Two Defensive Weapons Systems Force Reliability

Format 10F8.0 $\left\{ r'_k \right. (k = 1, \dots, K)$

where

r'_k = reliability of k th type side 2 defender ($k = 1, \dots, K$)

(3-9) Side Two Defensive Weapons Inventory for Side Two Weapons
Which Are Not Attacked by Side 1

Note: If $D \leq 0$ there is not an attack on side two defensive
weapons and all side two defensive weapons inventories
are read in at this point.

Format 10F8.0 $\left\{ \begin{array}{l} \text{For each side two resource } i (i = 1, \dots, II) \\ d'_{ik} (k = D + 1, \dots, K) \end{array} \right.$

where

d'_{ik} = number of side 2 defensive weapon type k defending side 2
ith type resource

FOR ATTACK ON DEFENSES ONLY

(3-10) Side One Offensive Weapon Survival Probability Against
Side Two Base Defenders

Format $\{ \bar{S}_k \text{ (k = 1, \dots, I)} \}$
10F8.0

where

$\bar{S}_k$ is the survival probability of the side one offensive weapon
which attacks side two defenders of type k

(3-11) Detailed Side Two Defense Structure (for defenses which
can be attacked)

For each side two defensive weapon type k (k = 1, ..., D)

(3-11-1)

Format $\left\{ \begin{array}{l} \text{Read for each side two resource type i (i = 1, \dots, II)} \\ \text{NBASE, IFIT, LLO, LLL} \end{array} \right\}$
(13I5)

where

NBASE = total number of defense installation of resource type i

IFIT = 1 if user wants to select points LLO and/or LLL over which
least squares curve fit will be made

LLO = starting point for curve fit (1 unless user overrides)

LLL = final point for curve fit (the last value for which the expected
number of surviving side 2 defenders is less than 1 unless
user overrides)

Note: If we chose to place no kth type defenders of a particular
resource i a blank card is inserted.

(3-11-2) Defense Installation Information (where applicable NBASE ≥ 1)

For each defense installation associated with defensive weapon
type k and resource i

Read

Format $\{ \text{HARD}(\ell) \text{ DCAP}(\ell) \text{ ACAP}(\ell) \}$ $\ell = 1, \dots, \text{NBASE}$
(10F8.0) 1 card per each ℓ

where

HARD(ℓ) = the hardness (P.S.I.) of defense installation ℓ

DCAP(ℓ) = the number of defenders associated with defense installation ℓ

ACAP(ℓ) = the number of defenders of defense installation ℓ

4. Last three cards - SUMT option and additional parameters

CARD 1*	COLUMN	7	14	21	28	35	42	49	56	63	70	77
Format												
(11I7)	VALUE	3	1	2	1	2	1	1	1	3	2	1
									(no			
									sensitivity)**			

CARD 2	COLUMN	01 - 12	13 - 24
Format			
(6E12.0)	VALUE	.01	.00001

CARD 3	COLUMN	7	14
Format			
(11I7)	VALUE	1	1

* See RAC-CR-34 for discussion of SUMT (version 4) options.

** See section VIII of RAC-CR-14 for discussion of sensitivity.

USER'S OPTIONS FOR THE ALLOCATION MODEL

The options available to the user can be classified as SUMT options and model options. The SUMT options are discussed in RAC-CR-34. Special SUMT option available for use with the model are discussed in RAC-CR-14 Section VIII.

The model options available to the user are as follows:

1. Option of attacking or not attacking side two defenses.
2. Option of selecting defense allocation doctrines for both sides.
3. Option of selecting strategies (objective) to be considered.
4. Option of having program compute starting point.

Explicit details on how to initiate these options are discussed in the sections (3-1) and (3-6) of Input Data for the Allocation Model.

The choice of strategies is made by selecting the ratio r_2/K_1 of the parameters K_1, K_2 in the objective function $K_1\bar{\beta} - K_2\beta$ as follows:

<u>Ratio K_2/K_1</u>	<u>Objective Function</u>	<u>Strategy</u>
0	$\bar{\beta}$	First striker minimized damage to himself (CF attack)
1	$\bar{\beta} - \beta$	First striker minimizes difference in damage
$> 10^7$	$-\beta$	First striker maximizes damage to side two cities (CV attack)

These values of the ratio represent extreme points of interest when developing "fish-tail" type curves. Ranges from .1 to 100 should be considered when sorting out local solutions particularly for the case when ratio = 1 since the objective function is not globally strictly convex.

SAMPLE INPUT DATA

Tables 1, 2, 3, 4, and 5 contain the force table data necessary for input into the model. Following these tables in Table 6 are Fortran coding sheets containing the correct data input for the model using the data in the force tables.

Table 1

FORCE TABLE FOR SIDE ONE OFFENSIVE

System	Inventory	Force Reliability	Yield Per Warheads (mi)	Warheads Per Carrier	No. of Independently Targetable Warheads	No. of Cluster Warheads	CEP (N. Mi.)
ICBMH	850.00	.8000	2.300	1	1	1	.15
ICBME	60.00	.8000	2.200	1	1	1	.35
ICBMG	40.00	.7500	20.000	1	1	1	.25
ICBMI	175.00	.7500	4.000	3(MIRV)	3	1	.25
ICBMJ	100.00	.8000	1.400	6(MIRV)	6	1	.15
ICBMK	175.00	.8000	1.400	6(MIRV)	6	1	.15
ICBMA	70.00	.7500	5.000	1	1	1	
ICBMB	30.00	.7000	4.000	1	1	1	
ICBMC	65.00	.8000	1.300	1	1	1	
ICBMD	75.00	.7500	.500	1	1	1	
ICBMF	140.00	.7000	2.100	1	1	1	
SLBMA	30.00	.7500	2.100	1	1	1	
SLBMB	500.00	.7500	2.300	1	1	1	
SLBMC	400.00	.7500	1.800	1	1	1	
BOMBA	425.00	.7500	1.000	2	1	1	

SINGLE SHOT SURVIVAL PROBABILITIES FOR SIDE ONE OFFENSE VERSUS SIDE TWO DEFENDERS

System	1 Anti-Missile	2 Anti-Missile	3 Anti-Bomber	4 Anti-Bomber	Survival Probability Against Base Defenders			
					1	2	3	4
ICBMH	.1000	.1000	.9999	.9999	.05	.05	.05	.05
ICBME	.1000	.1000	.9999	.9999				
ICBMG	.1000	.1000	.9999	.9999				
ICBMI	.1000	.1000	.9999	.9999				
ICBMJ	.1000	.1000	.9999	.9999				
ICBMK	.1000	.1000	.9999	.9999				
ICBMA	.1000	.1000	.9999	.9999				
ICBMB	.1000	.1000	.9999	.9999				
ICBMC	.1000	.1000	.9999	.9999				
ICBMD	.1000	.1000	.9999	.9999				
ICBMF	.1000	.1000	.9999	.9999				
SLBMA	.1000	.1000	.9999	.9999				
SLBMB	.1000	.1000	.9999	.9999				
SLBMC	.1000	.1000	.9999	.9999				
BOMBA	.9999	.9999	.2500	.3200				

Table 2

FORCE TABLE FOR SIDE TWO OFFENSE

System	Inventory	Force Reliability	Warhead Yield (MT)	No. of Warheads	Hardness (P.S.I.)
ICMB3	600.00	.7800	.150	3	300.00
ICBM2	400.00	.8000	1.000	1	300.00
ICBM1	30.00	.7400	6.000	1	300.00
SLBM1	150.00	.6200	.200	3	
SLBM2	375.00	.6000	.020	10	
BOMB1	40.00	.7200	10.000	10	
BOMB2	125.00	.7200	1.000	2	
BOMB3	40.00	.7200	.150	20	
BOMB4	40.00	.7200	.150	20	
BOMB5	50.00	.7200	.150	4	

SINGLE SHOT SURVIVAL PROBABILITIES FOR SIDE TWO OFFENSE VERSUS SIDE ONE DEFENDERS

System	1 Anti-Missile	2 Anti-Missile	3 Anti-Bomber	4 Anti-Bomber
ICMB3	.1500	.2800	.9999	.9999
ICMB2	.1500	.2800	.9999	.9999
ICMB1	.1500	.2800	.9999	.9999
SLBM1	.1500	.2800	.9999	.9999
SLBM2	.1500	.2800	.9999	.9999
BOMB1	.9999	.9999	.0800	.0900
BOMB2	.9999	.9999	.0800	.0900
BOMB3	.9999	.9999	.0800	.0900
BOMB4	.9999	.9999	.0800	.0900
BOMB5	.9999	.9999	.0800	.0900

Table 3

FORCE TABLE FOR SIDE TWO DEFENSE

Target Class Defended (Counterforce)

Side Two Defender Type	ICBM3	ICBM2	ICMB1																																				
	No. of Defense Installations 2	No. of Defense Installations 2	No. of Defense Installations 2																																				
1 Anti- Missile	<table> <tr> <td>Base No.</td><td>Hard-ness (PSI)</td><td>Dfdrs. of Base</td><td>Dfdrs. at Base</td></tr> <tr> <td>1</td><td>50</td><td>55</td><td>322</td></tr> <tr> <td>2</td><td>50</td><td>50</td><td>302</td></tr> </table>	Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base	1	50	55	322	2	50	50	302	<table> <tr> <td>Base No.</td><td>Hard-ness (PSI)</td><td>Dfdrs. of Base</td><td>Dfdrs. at Base</td></tr> <tr> <td>1</td><td>50</td><td>54</td><td>264</td></tr> <tr> <td>2</td><td>50</td><td>47</td><td>144</td></tr> </table>	Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base	1	50	54	264	2	50	47	144	<table> <tr> <td>Base No.</td><td>Hard-ness (PSI)</td><td>Dfdrs. of Base</td><td>Dfdrs. at Base</td></tr> <tr> <td>1</td><td>50</td><td>40</td><td>121</td></tr> <tr> <td>2</td><td>50</td><td>40</td><td>121</td></tr> </table>	Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base	1	50	40	121	2	50	40	121
Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base																																				
1	50	55	322																																				
2	50	50	302																																				
Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base																																				
1	50	54	264																																				
2	50	47	144																																				
Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base																																				
1	50	40	121																																				
2	50	40	121																																				
2 Anti- Missile	No. of Defense Installations 0	No. of Defense Installations 0	No. of Defense Installations 0																																				
3 Anti- Bomber	No. of Defense Installations 0	No. of Defense Installations 0	No. of Defense Installations 0																																				
4 Anti- Bomber	No. of Defense Installations 0	No. of Defense Installations 0	No. of Defense Installations 0																																				

Table 4

FORCE TABLE FOR SIDE TWO DEFENSE

Target Class Defended (Countervalue)

Side Two Defender Type	City Class 1	City Class 2	City Class 3
1 Anti- Missile	No. of Defense Installations 7 Base No. Hard-ness (PSI) Dfdrs. of Base Dfdrs. at Base 1 50 21 84 2 50 78 312 3 50 12 48 4 50 13 52 5 50 80 358 6 50 18 72 7 50 8 32	No. of Defense Installations 13 Base No. Hard-ness (PSI) Dfdrs. of Base Dfdrs. at Base 1 50 16 48 2 50 52 148 3 50 15 44 4 50 58 177 5 50 20 60 6 50 16 48 7 50 10 30 8 50 44 134 9 50 36 109 10 50 19 56 11 50 24 74 12 50 20 62 13 50 15 45	No. of Defense Installations 3 Base No. Hard-ness (PSI) Dfdrs. of Base Dfdrs. at Base 1 50 38 115 2 50 55 225 3 50 10 30
2 Anti- Missile	No. of Defense Installations 0	No. of Defense Installations 0	No. of Defense Installations 0

Table 4 (Cont'd.)

Side Two Defender Type	City Class 1	City Class 2	City Class 3
3 Anti- Bomber	No. of Defense Installations 1	No. of Defense Installations 1	No. of Defense Installations 1
	Hard- ness (PSI)	Hard- ness (PSI)	Hard- ness (PSI)
	Dfdrs. of Base	Dfdrs. of Base	Dfdrs. of Base
4 Anti- Bomber	No. of Defense Installations 3	No. of Defense Installations 3	No. of Defense Installations
	Base No.	Base No.	Base No.
	Dfdrs. at Base	Dfdrs. at Base	Dfdrs. at Base
	1 50 40 200	1 50 50 300	1 50 40 200
	1 50 35 200	1 50 20 100	1 50 20 100
	2 50 20 50	2 30 25 150	2 50 15 50
	3 50 20 100	3 50 15 50	3 50 20 75

FORCE RELIABILITY OF SIDE TWO DEFENDER TYPES

Type 1 - .95

Type 2 - .95

Type 3 - .95

Type 4 - .95

Table 5

FORCE TABLE FOR SIDE ONE DEFENSE

Side One Defender Type	Inventory of Reliable Defenders Target Class Defended
1 Anti- Missile	450
2 Anti- Missile	375
3 Anti- Bomber	200
4 Anti- Bomber	400

PUNCHED INPUT TO THE MODEL

SYMBOLIC AND FORTRAN CODING SHEET

3-16

6400
SYMBOLIC AND FORTRAN CODING SHEET

3-18

RAC

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SHEET 4 OF 6

3-19

Table 6 (Contd)

6400
SYMBOLIC AND FORTRAN CODING SHEET

RAC

[illegible]

Table 6 (Contd)

RAC

SYMBOLIC AND FORTRAN CODING SHEET

[illegible]

Chapter 4

MODEL OUTPUT AND SAMPLE PROBLEM

The output for the allocation optimization model can be classified as follows:

- (1) Total damage to each side
- (2) Side one counterforce strike characteristics
- (3) Side one countervalue strike characteristics
- (4) Side one counterdefense strike characteristics (when applicable)
- (5) Side two second strike characteristics

The output is fairly self-explanatory and reference to the output given in next section is suggested.

TOTAL DAMAGE TO EACH SIDE

The damage summed over all population classes of each side is printed--first side one, then side two.

SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

The attack by each side one counterforce missile type on each side two ICBM type is characterized in the following fashion:

- (a) Number of each side one missile allocated against each side two ICBM.
- (b) Number of each side one missile arriving over each side two ICBM type.
- (c) Number of warheads from each side one missile type arriving over each side two ICBM type.

(d) Number of warheads from each side one missile type impacting on each side two ICMB type.

(e) Number of warheads from each side one missile type impacting on each ICBM silo.

(f) Survival probability of each side two ICBM attack by each side one missile type.

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

The attack by each side one countervalue weapon type on each side two population class is characterized as follows:

(a) Number of each side one countervalue weapon allocated against each side two population class.

(b) Number of each side one countervalue weapon arriving over each side two population class.

(c) Number of each side one countervalue weapon impacting on each side two population class.

(d) Number of 1 MT equivalents from each side one countervalue weapon impacting on each side two population class.

SIDE ONE COUNTERDEFENSE STRIKE CHARACTERISTICS

When the option of attacking side two's defenses is used the following information is provided:

(a) Total number of side one weapons allocated against each side two defender type by resource defended.

(b) Total number of side one weapons arriving over each side two defender type by resource defended.

(c) Original number of side two defenders of each type before side one's attack.

(d) Number of side two defenders of each type one by resource defended surviving side one's attack.

SIDE TWO SECOND STRIKE CHARACTERISTICS

The second strike by side two against side one's population classes is characterized as follows:

- (a) Number of side two offensive weapons of each type before side one's counterforce strike.
- (b) Number of side two offensive weapons of each type surviving side one's counterforce strike.
- (c) Number of side two offensive weapons of each type arriving over side one's population classes.
- (d) Number of side two offensive weapons of each type impacting on each of side one's population classes.
- (e) Number of 1 MT equivalents delivered by each side two weapon type on each of side one's population classes.

SAMPLE PROBLEMS

The following set of problems is presented both as illustrative of the model capability and to familiarize the users with the model output.

The nuclear arsenal and level of defense for two nations is given. The problem is to derive the optimal set of allocations and the resultant damages in a two-strike nuclear war under various scenarios. In particular, a comparison is to be made of the different damages and allocations under two sets of assumptions:

- a. side one (first strike) is allowed to attack and destroy the defenses of side two.
- b. side one is not allowed to attack and destroy the defenses of side two.

Scenario:

A two strike war is assumed with side one attacking side two with a specified portion of his input arsenal, and side two striking back with all surviving weapons. The target structure of side two is divided into six different classes of targets: three city classes and three ICBM

weapon classes. The city classes are aggregated geographically into an Eastern, Midwestern, and Western region with the division roughly along the 85 and 105 axes. The three weapon targets are hardened ICBM silos. The defense of each target is assumed independent of other targets -- no overlap. The level of defense of target class is given below.

<u>Target class</u>	<u>Level of missile defense</u>	<u>No. of missile defense sites</u>	<u>Level of bomber defense</u>	<u>No. of bomber defense sites</u>
ICBM3	624	2	0	0
ICBM2	408	2	0	0
ICBM1	242	2	0	0
East	958	7	550	4
Midwest	1035	13	600	4
West	370	3	425	4

For the first set of cases run, side one has the option of attacking the defensive sites of each target class before attacking the target in each case, or of directly attacking the targets without first attacking the defenses. If the defenses are attacked, he must pay the price of the number of missiles required to destroy the defenses. On the other hand, if the defenses are not destroyed, part of his force is attrited by the defense. For the second set of cases run, no attack on defense was allowed.

For each option, three different cases have been run corresponding to an attack by side one maximizing damage on the cities of side two (countervalue), an attack which would minimize the damage to side one (counterforce), and an attack which minimized the difference in damage between the two nations.

The entire input arsenal and characteristics are given first, then the curve fits for attack on defenses, and finally the output for the six cases in the following order:

Attack on defenses option

Yes
Yes
Yes

Objective

Max damage side two
Min damage side one
Max difference in damage

No	Max damage side two
No	Min damage side one
No	Max difference in damage

In the output to the cases, the following numbering scheme is given to the targets and defender types.

<u>Target class</u>	<u>Side two resource</u>
1	ICBM3
2	ICBM2
3	ICBM1
4	City class (East)
5	City class (Midwest)
6	City class (West)

<u>Defender number</u>	<u>Defender type</u>
1	Anti-missile
2	Anti-missile
3	Anti-bomber
4	Anti-bomber

INPUT DATA

*****STRATEGIC WEAPONS EXCHANGE MCDELS (SWEH) *****

ALLCCATION OPTIMIZATION MOCFL

**INPUT CONDITIONS FOR THIS RUN **

ATTACK CN DEFENSES OPTICA USEC

NDEFS 1 .IB1= 1 NU1=-0 NU3=-0 NU4= 1

SIDE 2 -- 3 CF TARGETS 6 TARGETS 10 WEAPON TYPES 4 DEFENDER TYPES

SIDE 1 -- 6 CF + CV WEAPON TYPES 1 GEOGRAPHIC AREAS 15 WEAPON TYPES 4 DEFENDER TYPES

4 4 0

FITTING CONSTANTS FOR SIDE 2 POPULATION
.0024 .0926 .1277

FITTING CONSTANTS FOR SIDE 1 POPULATION
.1450

FRACTION OF SIDE 2 POPULATION IN ITH AREA
.5100 .3100 .1800

FRACTION OF SIDE 1 POPULATION IN LTH AREA
1.0000

Side two population divided into three areas. These are K factors.

Side one population is one geographical region.

Percentage of population in East, Midwest, West respectively

FORCE STRUCTURE AND WEAPONS CHARACTERISTICS

OFFENSIVE SYSTEMS

SIDE TWO

TYPE	SYSTEM	INVENTORY	FORCE REL.	WARHEAD YIELD	NC. OF WH	P.S.I.
1	ICBM3	500.00	.7800	.150	3	300.00
2	ICBM2	400.00	.8300	1.000	1	300.00
3	ICBM1	300.00	.7400	5.000	1	300.00
4	SLBM1	150.00	.6200	.200	3	
5	SLBM2	375.00	.6000	.020	10	
6	ROMB1	40.00	.7200	10.000	10	
7	ROMB2	125.00	.7200	1.000	2	
8	ROMB3	40.00	.7200	.150	20	
9	ROMB4	40.00	.7200	.150	20	
10	ROMB5	50.00	.7200	.150	4	

These first three weapons are the counterforce targets for side one

SIDE ONE

TYPE	SYSTEM	INVENTORY	FORCE REL.	WARHEAD YIELD	NC. OF WH	NO. IND.	TAR. WH	NO. CLUSTER WH	CEF
1	ICBMH	350.00	.8000	2.300	1	1	1	1	.15
2	ICAME	60.00	.8000	2.200	1	1	1	1	.35
3	ICBPG	40.00	.7500	20.000	1	1	1	1	.25
4	ICBPI	175.00	.7500	4.000	3	3	3	1	.25
5	ICBPJ	100.00	.8000	1.400	6	6	6	1	.15
6	ICBPK	175.00	.8000	1.400	6	6	6	1	.15
7	ICBMA	70.00	.7500	5.000	1	1	1	1	
8	ICBMB	30.00	.7000	4.000	1	1	1	1	
9	ICBMC	65.00	.8000	1.300	1	1	1	1	
10	ICBMD	75.00	.7500	.500	1	1	1	1	
11	ICBME	140.00	.7000	2.100	1	1	1	1	
12	SLBMA	30.00	.7500	2.100	1	1	1	1	
13	SLBMB	50.00	.7500	2.300	1	1	1	1	
14	SLBMC	40.00	.7500	1.800	1	1	1	1	
15	ROMEA	425.00	.7500	1.000	2	1	1	1	

The first six weapons are both counterforce and countervalue

The last nine are countervalue only

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO ICBMS VS SIDE ONE MISSILES) ***

SIDE TWO ICBMS (DOWN)	ICBMH	ICBME	ICBMG	ICBHI	ICBMJ	ICBMK
ICBM3	.1104	.2525	.0100	.0180	.0139	.0139
ICBM2	.0104	.2525	.0100	.0180	.0139	.0139
ICBM1	.1104	.2525	.0100	.0180	.0139	.0139

A lower limit of .01 has been placed
on the survival probability of side two silos

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO OFFS. VS SIDE ONE DEFORS.) ***

SIDE TWO OFFS. (DOWN)	1	2	3	4
ICBM3	.1500	.2800	.9599	.9999
ICBM2	.1500	.2800	.9599	.9999
ICBM1	.1500	.2800	.9599	.9999
SLBM1	.1500	.2800	.9599	.9999
SLBM2	.1500	.2800	.9599	.9999
ICBM1	.9999	.9999	.0800	.0900
ICBM2	.9999	.9999	.0800	.0900
ICBM3	.9999	.9999	.0800	.0900
ICBM4	.9999	.9999	.0800	.0900
ICBM5	.9999	.9999	.0800	.0900

These numbers give the defense interaction survival probability.
Defense type 1 and 2 is missile defense
Defense type 3 and 4 is bomber defense
so ICBM3 has a .15 chance of surviving an encounter with Defense type 1

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE ONE ICBMS VS SIDE TWO DEFORS.) ***

SIDE ONE ICBMS (DOWN)	1	2	3	4
ICBMH	.1000	.1000	.9599	.9999
ICBME	.1000	.1000	.9599	.9999
ICBMG	.1000	.1000	.9599	.9999
ICBHI	.1000	.1000	.9599	.9999
ICBMJ	.1000	.1000	.9599	.9999
ICBMK	.1000	.1000	.9599	.9999
ICBM4	.1000	.1000	.9599	.9999
ICBM5	.1000	.1000	.9599	.9999
ICBM6	.1000	.1000	.9599	.9999
ICBM7	.1000	.1000	.9599	.9999
ICBM8	.1000	.1000	.9599	.9999
ICBM9	.1000	.1000	.9599	.9999
ICBM0	.1000	.1000	.9599	.9999
ICBM1	.1000	.1000	.9599	.9999
ICBM2	.1000	.1000	.9599	.9999
ICBM3	.1000	.1000	.9599	.9999
ICBM4	.1000	.1000	.9599	.9999
ICBM5	.1000	.1000	.9599	.9999
ICBM6	.1000	.1000	.9599	.9999
ICBM7	.1000	.1000	.9599	.9999
ICBM8	.1000	.1000	.9599	.9999
ICBM9	.1000	.1000	.9599	.9999
ICBM0	.1000	.1000	.9599	.9999
ICBM1	.1000	.1000	.9599	.9999
ICBM2	.1000	.1000	.9599	.9999
ICBM3	.1000	.1000	.9599	.9999
ICBM4	.1000	.1000	.9599	.9999
ICBM5	.1000	.1000	.9599	.9999
ICBM6	.1000	.1000	.9599	.9999
ICBM7	.1000	.1000	.9599	.9999
ICBM8	.1000	.1000	.9599	.9999
ICBM9	.1000	.1000	.9599	.9999
ICBM0	.1000	.1000	.9599	.9999

Same interpretation as above

This is the inventory of side one weapons
of each type withheld from the attack

NUMBER OF EACH SIDE 1 WEAPON ASSIGNED TO OTHER MILITARY TARGETS	100.0000	30.0000	40.0000	15.0000	30.0000	40.0000
100.0000	30.0000	40.0000	15.0000	30.0000	40.0000	40.0000
70.0000	0.0000	250.0000	250.0000	250.0000	250.0000	250.0000

DEFENSE DAMAGE CURVE DATA

DEFENSIVE SYSTEMS

SIDE ONE

NUMBER OF RELIABLE SIDE 1 DEFENDERS OF SIDE 1 LTH TARGET
450.0000 375.0000 200.0000 400.0000

Inventory of side one defenders

SIDE TWO

RELIABILITY OF KTH TYPE SIDE 2 DEFENDER
.9500 .9500 .9500

SURVIVAL PROB. OF SIDE ONE OFFS. VS. BASE DEFENDERS.
.0500 .0500 .0500

This section gives the defense characteristics of side two and the damage curves for attacking defenses.

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 1 NO. OF BASFS DEFENDED BY WEAP. TYPE 2

BASE NO.	HAPDNESS(PSI)	NO. OF DEFENDERS	CF BASE	NO. DEFENDERS	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PRICE.
1	50.00	55.0			322.0	.9025	.0000
2	50.00	50.0			302.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE
NO. ATTACKERS EXP. NO. SURV. CURVE FIT VALUE

1	592.60	592.79
2	563.16	563.14
3	534.83	534.98
4	508.25	508.22
5	482.68	482.81
6	458.70	458.86
7	435.62	435.72
8	413.97	413.93
9	393.15	393.23
10	373.61	373.56
11	354.81	354.88
12	337.18	337.13
13	320.22	320.27
14	304.31	304.25
15	289.00	289.03
16	274.64	274.58
17	260.82	260.85
18	247.86	247.80
19	235.39	235.41
20	223.70	223.63
21	212.44	212.45
22	201.88	201.82
23	191.73	191.73
24	182.20	182.14
25	173.03	173.03
26	164.44	164.38
27	156.16	156.16
28	148.40	148.35
29	140.94	140.93
30	133.93	133.88
31	127.20	127.14

This says that defense weapon type 1 (anti-missile) defending target class 1 (ICBM3) has two sites. The number of dedicated defenders of the radar site and number of defenders at the sites is given as well as the base survival probability against an attack by a single attacker.

The columns give the curve fit value as well as actual expected value of surviving defenders for different attack sizes.

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120.88
114.73
109.09
103.60
98.45
93.50
88.85
84.38
80.19
76.16
72.37
68.71
65.32
62.03
58.95
55.98
53.20
50.51
48.01
45.64
43.33
41.15
39.11
37.14
35.29
33.52
31.85
30.25
28.75
27.30
25.94
24.64
23.42
22.24
21.13
20.07
19.07
18.11
17.21
16.35
15.53
14.75
14.02
13.31
12.65
12.02
11.42
10.84
10.31
9.79
9.29
8.83
8.39
7.97
7.58
7.19
6.84
6.49
6.17
5.86
5.57
5.29
5.03
4.77
4.54
4.31

120.32
114.78
109.04
103.59
98.41
93.48
88.81
84.37
80.15
76.14
72.33
68.71
65.28
62.01
58.91
55.96
53.17
50.51
47.98
45.58
43.30
41.14
39.08
37.12
35.27
33.50
31.83
30.24
28.72
27.29
25.92
24.63
23.39
22.22
21.11
20.06
19.05
18.10
17.20
16.34
15.52
14.74
14.01
13.30
12.64
12.01
11.41
10.84
10.29
9.78
9.29
8.83
8.38
7.96
7.57
7.19
6.83
6.49
6.16
5.85
5.56
5.28
5.02
4.77
4.53
4.30

The next few pages give the same information for the attack on defense installations for each target class. There are six target classes. For the first three target classes (ICBMs) there is one type of missile defense only. For the last three target classes (cities) there is both missile and bomber defense.



2		1		1		2		NO. OF BASES DEFENDED BY WEAP. TYPE		2	
DEF. WEAP. TYPE		1		1		2		NO. OF DEFORS. OF BASE		NO. DEFORS. AT BASE	
BASE NO.		HARDNESS (PSI)		NO. OF DEFORS.		NO. OF DEFORS.		NO. OF DEFORS.		NO. OF DEFORS.	
1	2	50.00	54.0	54.0	54.0	54.0	54.0	54.0	54.0	54.0	54.0
2		50.00	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0
EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE											
NO. ATTACKERS											
1	2	382.26	386.70	382.26	386.70	382.26	386.70	382.26	386.70	382.26	386.70
2	3	359.03	366.52	359.03	366.52	359.03	366.52	359.03	366.52	359.03	366.52
3	4	339.06	347.38	339.06	347.38	339.06	347.38	339.06	347.38	339.06	347.38
4	5	319.14	329.25	319.14	329.25	319.14	329.25	319.14	329.25	319.14	329.25
5	6	302.07	312.06	302.07	312.06	302.07	312.06	302.07	312.06	302.07	312.06
6	7	286.66	291.78	286.66	291.78	286.66	291.78	286.66	291.78	286.66	291.78
7	8	272.62	280.34	272.62	280.34	272.62	280.34	272.62	280.34	272.62	280.34
8	9	258.71	265.70	258.71	265.70	258.71	265.70	258.71	265.70	258.71	265.70
9	10	246.04	251.83	246.04	251.83	246.04	251.83	246.04	251.83	246.04	251.83
10	11	233.48	238.69	233.48	238.69	233.48	238.69	233.48	238.69	233.48	238.69
11	12	222.05	226.23	222.05	226.23	222.05	226.23	222.05	226.23	222.05	226.23
12	13	210.72	214.42	210.72	214.42	210.72	214.42	210.72	214.42	210.72	214.42
13	14	200.40	203.23	200.40	203.23	200.40	203.23	200.40	203.23	200.40	203.23
14	15	190.17	192.62	190.17	192.62	190.17	192.62	190.17	192.62	190.17	192.62
15	16	189.86	182.56	189.86	182.56	189.86	182.56	189.86	182.56	189.86	182.56
16	17	171.67	173.03	171.67	173.03	171.67	173.03	171.67	173.03	171.67	173.03
17	18	163.22	164.00	163.22	164.00	163.22	164.00	163.22	164.00	163.22	164.00
18	19	154.90	155.44	154.90	155.44	154.90	155.44	154.90	155.44	154.90	155.44
19	20	147.31	147.33	147.31	147.33	147.31	147.33	147.31	147.33	147.31	147.33
20	21	139.79	139.64	139.79	139.64	139.79	139.64	139.79	139.64	139.79	139.64
21	22	132.95	132.35	132.95	132.35	132.95	132.35	132.95	132.35	132.95	132.35
22	23	126.16	125.44	126.16	125.44	126.16	125.44	126.16	125.44	126.16	125.44
23	24	119.99	118.89	119.99	118.89	119.99	118.89	119.99	118.89	119.99	118.89
24	25	113.86	112.69	113.86	112.69	113.86	112.69	113.86	112.69	113.86	112.69
25	26	108.29	106.80	108.29	106.80	108.29	106.80	108.29	106.80	108.29	106.80
26	27	102.76	101.23	102.76	101.23	102.76	101.23	102.76	101.23	102.76	101.23
27	28	97.73	95.94	97.73	95.94	97.73	95.94	97.73	95.94	97.73	95.94
28	29	92.74	90.94	92.74	90.94	92.74	90.94	92.74	90.94	92.74	90.94
29	30	88.20	86.19	88.20	86.19	88.20	86.19	88.20	86.19	88.20	86.19
30	31	83.70	81.69	83.70	81.69	83.70	81.69	83.70	81.69	83.70	81.69
31	32	79.60	77.43	79.60	77.43	79.60	77.43	79.60	77.43	79.60	77.43
32	33	75.54	73.38	75.54	73.38	75.54	73.38	75.54	73.38	75.54	73.38
33	34	71.84	69.55	71.84	69.55	71.84	69.55	71.84	69.55	71.84	69.55
34	35	68.17	65.92	68.17	65.92	68.17	65.92	68.17	65.92	68.17	65.92
35	36	64.84	62.48	64.84	62.48	64.84	62.48	64.84	62.48	64.84	62.48
36	37	61.53	59.22	61.53	59.22	61.53	59.22	61.53	59.22	61.53	59.22
37	38	58.51	56.13	58.51	56.13	58.51	56.13	58.51	56.13	58.51	56.13
38	39	55.53	53.20	55.53	53.20	55.53	53.20	55.53	53.20	55.53	53.20
39	40	52.81	50.42	52.81	50.42	52.81	50.42	52.81	50.42	52.81	50.42
40	41	50.11	47.79	50.11	47.79	50.11	47.79	50.11	47.79	50.11	47.79
41	42	47.66	45.30	47.66	45.30	47.66	45.30	47.66	45.30	47.66	45.30
42	43	45.23	42.93	45.23	42.93	45.23	42.93	45.23	42.93	45.23	42.93
43	44	43.01	40.69	43.01	40.69	43.01	40.69	43.01	40.69	43.01	40.69
44		40.82	38.57	40.82	38.57	40.82	38.57	40.82	38.57	40.82	38.57

45	38.82	36.55
46	36.84	34.64
47	35.03	32.94
48	33.25	31.12
49	31.62	29.50
50	30.01	27.96
51	28.54	26.50
52	27.08	25.12
53	25.75	23.80
54	24.44	22.56
55	23.24	21.38
56	22.06	20.27
57	20.98	19.21
58	19.91	18.21
59	18.93	17.26
60	17.97	16.36
61	17.09	15.50
62	16.21	14.69
63	15.42	13.93
64	14.63	13.20
65	13.92	12.51
66	13.21	11.86
67	12.56	11.24
68	11.92	10.65
69	11.33	10.10
70	10.76	9.57
71	10.23	9.07
72	9.71	8.60
73	9.23	8.15
74	8.76	7.72
75	8.33	7.32
76	7.91	6.94
77	7.52	6.57
78	7.14	6.23
79	6.79	5.91
80	6.44	5.60
81	6.12	5.31
82	5.81	5.03
83	5.52	4.77
84	5.25	4.52
85	4.99	4.28
86	4.73	4.06
87	4.50	3.85
88	4.27	3.65
89	4.06	3.46
90	3.86	3.27
91	3.67	3.10
92	3.48	2.94
93	3.31	2.79
94	3.14	2.64
95	2.99	2.50
96	2.83	2.37
97	2.70	2.25
98	2.56	2.13
99	2.43	2.02
100	1.27	1.92
101	1.15	1.82
102	1.04	1.72
103	-.00	1.63

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DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 3 NO. OF BASES DEFENDED BY WEAP. TYPE 2
 BASE NO. HARDNESS(PSSI) NO. OF DEFENDERS. OF BASE NO. DEFENDERS. AT BASE UNDEFENDED BASE
 SURVIVAL PROB. SURVIVAL PROB.

50.00
50.00

40.0
40.0

121.0
121.0

9025
9025

.0000
.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE
NO. ATTACKERS EXP. NO. SURV. CURVE FIT VALUE

1	230.20	229.90
2	218.41	218.41
3	207.76	207.49
4	197.11	197.12
5	187.50	187.27
6	177.89	177.91
7	169.22	169.01
8	160.55	160.57
9	152.72	152.54
10	144.89	144.91
11	137.83	137.67
12	130.77	130.79
13	124.39	124.25
14	118.02	118.04
15	112.26	112.14
16	106.51	106.53
17	101.32	101.21
18	96.13	96.15
19	91.44	91.34
20	86.75	86.78
21	82.52	82.44
22	78.30	78.32
23	74.48	74.40
24	70.66	70.68
25	67.22	67.15
26	63.77	63.79
27	60.66	60.61
28	57.55	57.58
29	54.75	54.70
30	51.94	51.96
31	49.41	49.37
32	46.90	46.90
33	44.59	44.55
34	42.31	42.33
35	40.25	40.21
36	38.18	38.20
37	36.32	36.29
38	34.46	34.48
39	32.78	32.75
40	31.10	31.12
41	29.58	29.56
42	28.07	28.04
43	26.76	26.68
44	25.33	25.35
45	24.10	24.08
46	22.86	22.88
47	21.75	21.73
48	20.63	20.65
49	19.63	19.61
50	18.62	18.63
51	17.71	17.70
52	16.81	16.82
53	15.99	15.98
54	15.17	15.18
55	14.33	14.42
56	13.69	13.75
57	13.02	13.01
58	12.35	12.36
59	11.75	11.75
60	11.15	11.16
61	10.61	10.60

DEF. WEAP. TYPE	1	REGION OR CITY	CLASS DEFENDED	4	NO. OF DEFENDERS	CF BASE	NO. DEFENDERS	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PRCB.
62	10.06	62	21.0	84.0	.9025	.0000				
63	9.57	63	78.0	312.0	.9025	.0000				
64	9.09	64	12.0	48.0	.9025	.0000				
65	8.63	65	13.0	52.0	.9025	.0000				
66	8.20	66	18.0	358.0	.9025	.0000				
67	7.79	67	18.0	72.0	.9025	.0000				
68	7.40	68	8.0	32.0	.9025	.0000				
69	7.03	69								
70	6.68	70								
71	6.35	71								
72	6.03	72								
73	5.73	73								
74	5.44	74								
75	5.17	75								
76	4.91	76								
77	4.67	77								
78	4.43	78								
79	4.21	79								
80	4.00	80								
81	3.80	81								
82	3.61	82								

4 1

DEF. WEAP. TYPE	1	REGION OR CITY	CLASS DEFENDED	4	NO. OF DEFENDERS	CF BASE	NO. DEFENDERS	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PRCB.
1	50.00	21.0	84.0	.9025	.0000					
2	50.00	78.0	312.0	.9025	.0000					
3	50.00	12.0	48.0	.9025	.0000					
4	50.00	13.0	52.0	.9025	.0000					
5	50.00	18.0	358.0	.9025	.0000					
6	50.00	18.0	72.0	.9025	.0000					
7	50.00	8.0	32.0	.9025	.0000					

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP.	NO. SURV.	CURVE	FIT VALUE
1	923.10	891.59	936.64	915.75
2	891.59	861.17	895.33	875.36
3	861.17	832.74	855.84	836.75
4	832.74	805.29	818.09	799.85
5	805.29	779.63	782.01	764.57
6	779.63	754.85	747.52	730.85
7	754.85	731.70	714.55	698.61
8	731.70	709.32	683.03	667.80
9	709.32	688.44	652.91	638.35
10	688.44	668.25	624.11	610.19
11	668.25	649.39	596.58	583.28
12	649.39	631.18	570.27	557.55
13	631.18	614.16	545.12	532.96
14	614.16	597.72	521.08	509.46
15	597.72	582.36		
16	582.36	567.52		
17	567.52	553.66		
18	553.66	540.27		
19	540.27	527.76		
20	527.76	515.67		
21	515.67	504.38		
22	504.38	493.47		
23	493.47	483.28		
24	483.28	473.44		
25	473.44	464.24		
26	464.24	455.36		
27	455.36	447.06		
28	447.06			

29	438.87	498.10
30	430.85	486.99
31	423.36	476.13
32	415.97	465.51
33	408.73	455.13
34	401.71	444.96
35	394.95	435.05
36	388.28	425.35
37	381.75	415.87
38	375.42	406.59
39	369.32	397.52
40	363.29	388.66
41	357.40	379.99
42	351.68	371.52
43	346.18	363.23
44	340.74	355.13
45	335.43	347.21
46	330.26	339.47
47	325.19	331.90
48	320.22	324.50
49	315.32	317.26
50	310.52	310.18
51	305.84	303.27
52	301.18	296.50
53	296.61	289.89
54	292.12	283.43
55	287.70	277.11
56	283.37	270.93
57	279.14	264.88
58	274.94	258.98
59	270.61	253.20
60	266.76	247.55
61	262.77	242.03
62	258.86	236.64
63	255.05	231.36
64	251.25	226.20
65	247.53	221.15
66	243.87	216.22
67	240.27	211.40
68	236.74	206.69
69	233.30	202.08
70	229.88	197.57
71	226.51	193.16
72	223.21	188.86
73	219.98	184.64
74	216.78	180.53
75	213.66	176.50
76	210.55	172.56
77	207.46	168.72
78	204.43	164.95
79	201.45	161.27
80	198.51	157.68
81	195.64	154.16
82	192.83	150.72
83	190.02	147.36
84	187.23	144.08
85	184.50	140.86
86	181.81	137.72
87	179.16	134.65
88	176.57	131.65
89	174.02	128.71
90	171.50	125.84
91	168.98	123.03
92	166.51	120.29
93	164.08	117.61
94	161.69	114.99

95	159.35	112.42
96	157.06	109.91
97	154.78	107.46
98	152.50	105.07
99	150.27	102.72
100	149.08	100.43
101	145.93	98.19
102	143.81	96.00
103	141.74	93.86
104	139.68	91.77
105	137.63	89.72
106	135.62	87.72
107	133.65	85.76
108	131.70	83.85
109	129.79	81.98
110	127.92	80.15
111	126.07	78.37
112	124.22	76.62
113	122.40	74.91
114	120.62	73.24
115	118.80	71.61
116	117.14	70.01
117	115.45	68.45
118	113.77	66.92
119	112.10	65.43
120	110.46	63.97
121	109.86	62.54
122	107.27	61.15
123	105.72	59.78
124	104.20	58.45
125	90.11	57.15
126	88.60	55.87
127	74.58	54.63
128	73.07	53.41
129	71.59	52.22
130	57.89	51.05
131	56.44	49.91
132	55.01	48.80
133	53.61	47.71
134	52.25	46.65
135	50.94	45.61
136	49.64	44.59
137	48.38	43.60
138	47.15	42.63
139	35.79	41.67
140	34.61	40.75
141	33.44	39.84
142	32.30	38.95
143	31.24	38.08
144	30.18	37.23
145	20.44	36.40
146	19.41	35.59
147	18.45	34.79
148	17.52	34.02
149	16.65	33.26
150	15.81	32.52
151	15.03	31.79
152	14.27	31.08
153	13.56	30.39
154	12.88	29.71
155	12.24	29.05
156	11.62	28.40
157	11.05	27.77
158	10.49	27.15
159	9.97	26.54
160	9.47	25.95



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5 1					DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 5 NO. OF BASES DEFENDED BY WEAP. TYPE 13				
BASE NO.	HARDNESS(PSI)	NO. OF DEFENDERS	CF BASE	NC. DEFENDERS	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.		
1	50.00	16.0			48.0	.9025	.0000		
2	50.00	52.0			148.0	.9025	.0000		
3	50.00	15.0			44.0	.9025	.0000		
4	50.00	58.0			177.0	.9025	.0000		
5	50.00	20.0			60.0	.9025	.0000		
6	50.00	16.0			48.0	.9025	.0000		
7	50.00	10.0			30.0	.9025	.0000		
8	50.00	44.0			134.0	.9025	.0000		
9	50.00	36.0			109.0	.9025	.0000		
10	50.00	19.0			56.0	.9025	.0000		
11	50.00	24.0			74.0	.9025	.0000		
12	50.00	20.0			62.0	.9025	.0000		
13	50.00	15.0			45.0	.9025	.0000		
EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE									

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	1017.74	1025.19
2	1002.17	1015.47
3	987.74	1005.84
4	973.68	996.31
5	960.62	986.87
6	947.59	977.51
7	934.91	968.24
8	923.12	959.07
9	911.36	949.98
10	899.91	940.97
11	889.27	932.05
12	878.64	923.21
13	868.04	914.46
14	857.70	905.80
15	848.10	897.21
16	838.51	888.70
17	828.94	880.28
18	819.61	871.93
19	810.94	863.67
20	802.29	855.48
21	793.65	847.37
22	785.27	839.34
23	777.41	831.38
24	769.60	823.50
25	761.90	815.70
26	754.20	807.96
27	746.99	800.31
28	739.67	792.72
29	732.88	785.21
30	725.84	777.76
31	718.99	770.39
32	712.47	763.09
33	706.10	755.85
34	699.74	748.69
35	693.79	741.59
36	687.20	734.56
37	681.16	727.60
38	675.28	720.70
39	669.47	713.87
40	663.68	707.10
41	657.94	700.40
42	652.21	693.76
43	646.62	687.18
44	641.16	680.67
45	635.71	674.22
46	630.40	667.83
47	625.12	661.50
48	619.93	655.22
49	614.75	649.01
50	609.58	642.86
51	604.54	636.77
52	599.61	630.73
53	594.69	624.75
54	589.50	618.83
55	585.14	612.96
56	580.45	607.15
57	575.77	601.40
58	571.09	595.70
59	566.42	590.05
60	561.75	584.46
61	557.20	578.92
62	552.75	573.43
63	548.21	567.99
64	543.92	562.61
65	539.60	557.28

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304.51
302.13
299.76
297.42
295.10
292.78
290.50
288.21
285.93
283.65
281.37
279.15
276.90
274.62
272.37
270.13
268.42
266.33
264.23
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216.92
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211.86
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203.61
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198.86
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294.39
291.60
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283.39
280.70
278.04
275.41
272.79
270.21
267.65
265.11
262.60
260.11
257.64
255.20
252.77
250.38
248.01
245.66
243.33
241.03
238.74
236.48
234.24
232.02
229.82
227.64
225.48
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217.05
214.99
212.86
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197.33
195.46
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186.37
184.60
182.85
181.12
179.40
177.70
176.02
174.35
172.70
171.06
169.44
167.83
166.24
164.67
163.11
161.56
160.03
158.51

198	188.18	157.01
199	186.67	155.52
200	185.20	154.05
201	183.76	152.59
202	182.32	151.14
203	180.89	149.71
204	179.47	148.29
205	178.08	146.88
206	176.69	145.49
207	175.30	144.11
208	173.93	142.74
209	172.56	141.39
210	171.20	140.05
211	169.83	138.72
212	168.47	137.41
213	167.14	136.11
214	165.84	134.82
215	164.54	133.54
216	163.24	132.27
217	161.98	131.02
218	160.71	129.78
219	159.46	128.55
220	158.21	127.33
221	156.97	126.12
222	155.74	124.92
223	154.51	123.74
224	153.27	122.57
225	152.04	121.41
226	150.84	120.25
227	149.67	119.11
228	148.50	117.99
229	147.34	116.87
230	136.58	115.76
231	135.43	114.66
232	134.29	113.57
233	133.16	112.50
234	132.03	111.43
235	130.91	110.38
236	129.80	109.33
237	128.69	108.29
238	127.57	107.27
239	126.46	106.25
240	125.38	105.24
241	124.32	104.24
242	123.27	103.26
243	122.22	102.28
244	121.17	101.31
245	111.54	100.35
246	110.52	99.40
247	109.50	98.45
248	100.05	97.52
249	99.05	96.60
250	98.04	95.68
251	88.74	94.77
252	87.74	93.88
253	78.44	92.99
254	77.44	92.10
255	76.43	91.23
256	75.46	90.37
257	74.50	89.51
258	73.55	88.66
259	72.62	87.82
260	71.70	86.99
261	70.79	86.16
262	69.89	85.35
263	68.98	84.54

264	68.10	83.74
265	67.24	82.94
266	59.27	82.16
267	58.41	81.39
268	50.44	80.61
269	49.60	79.84
270	48.77	79.09
271	41.06	78.34
272	40.24	77.59
273	39.42	76.86
274	38.60	76.13
275	37.81	75.41
276	37.05	74.69
277	36.31	73.98
278	35.58	73.29
279	34.84	72.59
280	34.12	71.90
281	33.44	71.22
282	27.13	70.54
283	26.46	69.88
284	25.80	69.21
285	25.13	68.56
286	24.49	67.91
287	23.88	67.26
288	23.28	66.63
289	22.68	65.99
290	22.10	65.37
291	21.56	64.75
292	21.01	64.13
293	20.47	63.52
294	19.94	62.92
295	19.45	62.33
296	18.96	61.74
297	18.48	61.15
298	18.00	60.57
299	17.56	60.00
300	17.12	59.43
301	16.67	58.87
302	16.24	58.31
303	15.85	57.76
304	15.45	57.21
305	15.05	56.67
306	14.66	56.13
307	14.30	55.60
308	13.94	55.07
309	13.58	54.55
310	13.23	54.03
311	12.91	53.52
312	12.58	53.01
313	12.26	52.51
314	11.94	52.01
315	11.65	51.52
316	11.35	51.03
317	8.64	50.55
318	8.35	50.07
319	8.16	49.59
320	7.80	49.12
321	7.53	48.66
322	7.28	48.19
323	7.04	47.74
324	6.80	47.29
325	6.57	46.84
326	6.35	46.39
327	6.14	45.95
328	5.93	45.52
329	5.73	45.09

DEF. WEAP. TYPE	1	REGION OR CITY CLASS DEFENDED	6	NO. OF BASES DEFENDED BY WEAP. TYPE	3
BASE NO.	1	50.00	38.0	5.54	44.66
	2	50.0	55.0	5.35	44.24
	3	50.0	10.0	5.17	43.82
				5.00	43.40
				4.83	42.99
				4.67	42.58
				3.25	42.18
				3.04	41.78
				2.89	41.38
				2.75	40.99
				2.61	40.60
				2.48	40.22
				2.35	39.84
				2.24	39.46
				2.12	39.08
				2.02	38.71
				1.92	38.35
				1.82	37.98
				1.73	37.62
				1.64	37.27
				1.56	36.91
				1.48	36.56
				.77	36.22

5 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 6 NO. OF BASES DEFENDED BY WEAP. TYPE 3

BASE NO.	HARDNESS (PSI)	NO. OF DEFENDERS	OF BASE	NC. DEFENDERS	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	38.0		115.0		.9025	.0000
2	50.0	55.0		225.0		.9025	.0000
3	50.0	10.0		30.0		.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS EXP. NO. SURV. CURVE FIT VALUE

1	348.06	353.84
2	328.26	338.39
3	310.40	323.61
4	294.27	309.47
5	279.72	295.96
6	266.58	283.03
7	254.73	270.67
8	243.51	258.05
9	232.82	247.54
10	222.70	236.73
11	213.04	226.39
12	203.91	216.50
13	195.19	207.05
14	186.95	198.00
15	179.09	189.36
16	171.65	181.08
17	164.55	173.18
18	157.84	165.61
19	151.43	158.38
20	145.37	151.46
21	139.59	144.85
22	134.12	138.52
23	128.91	132.47
24	123.97	126.68
25	119.26	121.15
26	114.81	115.86
27	110.56	110.80
28	106.54	105.96
29	102.71	101.33
30	99.08	96.91

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95.62
92.34
89.22
86.27
83.34
80.52
77.85
75.21
72.67
70.26
67.88
65.58
63.41
61.26
59.19
57.23
55.29
53.42
51.65
49.90
48.21
46.61
45.03
43.51
42.07
40.64
39.27
37.97
36.68
35.44
34.27
33.10
32.15
31.23
30.17
29.16
18.20
17.29
16.43
15.61
14.83
14.08
13.38
12.71
12.08
11.47
10.90
10.35
9.84
9.34
8.88
8.43
8.01
7.61
7.23
6.87
6.53
6.20
5.89
5.59
5.32
5.05
4.80
4.47
2.22
2.01

92.67
88.63
84.76
81.05
77.51
74.13
70.89
67.79
64.83
62.00
59.29
56.70
54.23
51.86
49.59
47.43
45.36
43.38
41.48
39.67
37.94
36.28
34.70
33.18
31.73
30.34
29.02
27.75
26.54
25.38
24.27
23.21
22.20
21.23
20.30
19.41
18.57
17.76
16.98
16.24
15.53
14.85
14.20
13.58
12.99
12.42
11.88
11.36
10.86
10.39
9.94
9.50
9.09
8.69
8.31
7.95
7.60
7.27
6.95
6.55
6.16
5.88
5.81
5.56
5.32
5.08

DEF. WEAP. TYPE	3	REGION OR CITY CLASS DEFENDED	4	NO. OF BASES OFFENDED BY WEAP. TYPE	1
BASE NO.	HARDFESS(PST)	NO. OF DEFENDERS	OF BASE	NO. DEFENDERS AT BASE	DEFENDED BASES SURVIVAL PROB. .9025
1	50.00	40.0	200.0		UNDEFENDED BASE SURVIVAL PRCE. .0000
1	2	1.81	4.86		
2	2	1.64	4.65		
3	2	1.48	4.45		
4	2	1.33	4.25		
5	2	1.20	4.07		
6	2	1.09	3.89		
7	2	.98	3.72		
8	2				
9	2				
10	2				
11	2				
12	2				
13	2				
14	2				
15	2				
16	2				
17	2				
18	2				
19	2				
20	2				
21	2				
22	2				
23	2				
24	2				
25	2				
26	2				
27	2				
28	2				
29	2				
30	2				

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DEF. WEAP. TYPE 3 REGION OR CITY CLASS OFFENDED E NO. OF BASES DEFENDED BY WEAP. TYPE 1

BASE NO. HARDNESS (PSI) NO. OF DEFORS. OF BASE NO. DEFORS. AT BASE DEFENDED BASE SURVIVAL PROB. UNDEFENDED BASE SURVIVAL PROB. .0000

1 50.00

50.0

300.0

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE
NO. ATTACKERS EXP. NO. SURV. CURVE FIT VALUE

31	8.22	8.21
32	7.50	7.50
33	6.77	6.76
34	6.11	6.10
35	5.52	5.51
36	4.98	4.97
37	4.45	4.49
38	4.06	4.05
39	3.66	3.65
40	3.30	3.30
41	.00	2.98

1	270.75	270.75
2	244.35	244.35
3	220.53	220.52
4	199.03	199.02
5	179.62	179.62
6	162.11	162.10
7	146.30	146.30
8	132.04	132.03
9	119.16	119.16
10	107.55	107.54
11	97.06	97.05
12	87.60	87.59
13	79.06	79.05
14	71.35	71.34
15	64.39	64.39
16	58.11	58.11
17	52.45	52.44
18	47.33	47.33
19	42.72	42.71
20	38.55	38.55
21	34.79	34.79
22	31.40	31.40
23	28.34	28.34
24	25.58	25.57
25	23.08	23.08
26	20.83	20.83
27	18.80	18.80
28	16.97	16.97
29	15.31	15.31
30	13.82	13.82
31	12.47	12.47
32	11.26	11.25
33	10.16	10.16
34	9.17	9.17
35	8.27	8.27
36	7.47	7.47
37	6.74	6.74
38	6.08	6.08
39	5.49	5.49
40	4.95	4.95
41	4.47	4.47
42	4.04	4.03
43	3.64	3.64
44	3.29	3.29

[illegible]

DEF. WEAP. TYPE	4	REGION OR CITY CLASS DEFENDED	4	NO. OF BASES DEFENDED BY WEAP. TYPE	3	
BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PRCB.	
1	50.00	35.0	200.0	.9025	.0000	
2	50.00	20.0	50.0	.9025	.0000	
3	50.00	20.0	100.0	.9025	.0000	
EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE						
NO. ATTACKERS		EXP. NO. SURV.	CURVE FIT VALUE			
1		330.50	336.05			
2		312.90	322.65			
3		297.02	309.79			
4		282.68	297.44			
5		269.75	285.59			
6		258.07	274.20			
7		247.54	263.27			
8		237.79	252.78			
9		228.28	242.70			
10		219.48	233.03			
11		210.89	223.74			
12		202.95	214.82			
13		195.21	206.26			
14		188.04	198.04			
15		181.05	190.14			
16		174.58	182.57			
17		168.27	175.29			
18		162.42	168.30			
19		156.74	161.59			
20		151.47	155.15			
21		146.33	148.97			
22		141.46	143.03			
23		136.70	137.33			
24		132.07	131.85			
25		127.67	126.60			
26		123.37	121.55			
27		119.19	116.71			
28		115.22	112.06			
29		111.35	107.59			
30		107.57	103.30			
31		103.98	99.18			
32		100.49	95.23			
33		97.08	91.43			
34		93.85	87.79			
35		90.69	84.29			
36		87.61	80.93			
37		84.70	77.70			
38		81.85	74.61			
39		79.07	71.63			
40		76.44	68.78			
41		73.87	66.04			
42		71.36	63.40			
43		68.99	60.89			
44		66.67	58.45			
45		64.41	56.12			
46		62.26	53.88			
47		60.17	51.74			
48		58.17	49.67			
49		56.19	47.69			
50		54.30	45.79			
51		52.46	43.97			
52		50.71	42.21			
53		49.01	40.53			
54		47.34	38.92			



DEF. WEAP. TYPE 4 REGION OR CITY CLASS DEFENSEC 5 NO. OF BASES DEFENDED BY WEAP. TYPE 3					DEFENDED BASE SURVIVAL PROB.		UNDEFENDED BASE SURVIVAL PRCE.	
BASE NO.	HARDNESS (PSI)	NO. OF DEFORS.	CF BASE	NO. DEFORS.	AT BASE			
1	50.00	20.0			100.0	.9025	.0000	
2	50.00	25.0			150.0	.9025	.0000	
3	50.00	15.0			50.0	.9025	.0000	
EXPECTED NO. CF SURVIVING DEFENSES VS. ATTACK SIZE								
NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE						
1	285.38	288.68						
2	272.18	277.78						
3	260.26	267.30						
4	249.51	257.21						
5	239.74	247.51						
6	230.06	238.16						
7	221.26	228.18						
8	212.50	220.53						
9	204.56	212.20						
10	196.66	204.20						
11	189.49	196.49						
12	182.38	189.07						
13	175.89	181.94						
14	169.46	175.07						
15	163.62	168.47						
16	157.81	162.11						
17	152.54	155.99						
18	147.30	150.10						
19	142.42	144.44						
20	137.67	138.99						
21	132.94	133.74						
22	128.54	128.69						
23	124.25	123.84						
24	119.97	119.16						
25	116.00	114.67						
26	112.13	110.34						
27	108.28	106.18						
28	104.69	102.17						
29	101.20	98.31						

55	45.77	37.36
56	44.23	35.88
57	42.73	34.45
58	41.30	33.07
59	39.92	31.75
60	37.06	31.49
61	25.71	29.27
62	24.42	28.11
63	23.20	26.99
64	22.04	25.91
65	20.94	24.88
66	19.89	23.89
67	18.90	22.93
68	17.96	22.02
69	17.06	21.14
70	16.20	20.30
71	15.39	19.49
72	14.62	18.71
73	13.89	17.97
74	13.20	17.25
75	6.77	16.56
76	6.11	15.90
77	5.52	15.27
78	.00	14.66

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS.	OF BASE	NC.	DEFORS.	AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFEATED BASE SURVIVAL PRCE.
1	50.00	20.0					.9025	.0000
2	50.00	15.0					.9025	.0000
3	50.00	20.0					.9025	.0000
EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE								
NO. ATTACKERS	EXP.	NO. SURV.	CURVE	FIT	VALUE			
1	215.25				216.86			
2	206.45				209.01			
3	198.51				201.44			
4	191.20				194.15			
5	184.03				187.13			
6	177.43				180.36			
7	170.96				173.83			
8	165.01				167.54			
9	159.17				161.47			
10	153.79				155.63			
11	148.52				150.00			
12	143.65				144.57			
13	138.80				139.34			
14	134.04				134.29			
15	129.64				129.43			
16	125.26				124.75			
17	120.97				120.24			
18	117.00				115.68			
19	113.05				111.69			

20	109.18	107.65
21	105.60	103.75
22	102.03	100.00
23	98.53	96.38
24	95.30	92.89
25	92.08	89.53
26	88.93	86.29
27	86.01	83.17
28	83.10	80.16
29	80.26	77.26
30	77.62	74.46
31	75.00	71.76
32	72.43	69.17
33	70.05	66.66
34	67.69	64.25
35	65.37	61.93
36	63.22	59.68
37	61.09	57.52
38	59.00	55.44
39	57.06	53.44
40	55.13	51.50
41	53.24	49.64
42	51.50	47.84
43	49.76	46.11
44	48.05	44.44
45	46.48	42.83
46	44.91	41.28
47	43.37	39.79
48	41.94	38.35
49	40.52	36.96
50	39.14	35.62
51	26.29	34.33
52	25.00	33.09
53	23.72	31.89
54	22.57	30.74
55	11.83	29.63
56	10.68	28.56
57	9.64	27.52
58	.00	26.53

NUMBER OF K TH TYPE SIDE 2 DEFORS. (ACROSS) OF I TH TYPE TARGET (DOWN)

1	624.0	.0	.0	.0
2	418.0	.0	.0	.0
3	242.0	.0	.0	.0
4	958.0	.0	200.0	350.0
5	1035.0	.0	300.0	300.0
6	370.0	.0	200.0	225.0

CURVE FIT VALUES FOR Q(I,K), K(ACROSS), I(DOWN)

1	.9500	1.0000	1.0000	1.0000
2	.9478	1.0000	1.0000	1.0000
3	.9500	1.0000	1.0000	1.0000
4	.9777	1.0000	.9025	.9601
5	.9905	1.0000	.9025	.9623
6	.9563	1.0000	.9025	.9638

These give the total inventory of each defender type for each target class.

This case uses the attack on defense option and the objective is to maximize damage to side two cities. All allocations are thus countervalue. The actual allocations show that the missiles are allocated to the East and West Coast and the bombers are allocated to the Midwest. The corresponding defenses are also attacked and almost entirely destroyed. There are small miscellaneous allocations again because the marginal return of further missile allocations to the East and West is very small, and there are not sufficient missiles left to overcome the missile defense of the Midwest. The damage is .730 to side one and .703 to side two.

*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) *****

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .730

***** DAMAGE TO SIDE TWO ***** .703

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROP. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTRIES

	ICBMH	ICBME	ICENG	ICBHI	ICEMJ	ICBMK
	1.0	.9	.8	.5	.3	.3
	.8	.8	.6	.4	.2	.2
ICBM3	.8	.8	.6	1.2	1.5	1.3
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
						Essentially no counterforce attack.
	1.0	.9	.8	.5	.3	.3
	.8	.8	.6	.4	.2	.2
ICBM2	.8	.8	.6	1.2	1.5	1.3
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
	1.0	.9	.8	.5	.3	.3
	.8	.8	.6	.4	.2	.2
ICBM1	.8	.8	.6	1.2	1.5	1.3
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

CITY CLASS	INTERPRETATION OF EACH SET OF ENTRIES														
	WEAPONS OF TYPE (COLUMN) ALLCATED AGAINST CITY CLASS (ROW)														
	WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)														
	NO. OF 1 MT. EOS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)														
	ICBPH	ICBME	ICBNG	ICBNI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMO	ICBMF	ICBMA	ICBMB	ICBMC	ICBMA
1	73.3	9.1	20.0	52.5	70.0	58.2	.6	.4	.2	.1	8.6	.6	.4	.2	9.0
	58.7	7.2	15.0	39.4	56.0	46.6	.5	.3	.1	.1	6.0	.5	.3	.1	7.4
	55.9	6.9	14.3	37.6	53.3	44.4	.5	.2	.1	.1	5.7	.5	.2	.1	7.0
	94.8	10.2	64.0	225.3	378.7	315.3	1.0	.5	.1	.1	8.3	1.0	.5	.1	10.2
2	6.4	5.2	3.0	2.1	1.4	1.1	1.7	.6	.2	.1	2.4	1.7	.6	.2	.6
	5.1	4.2	2.2	1.6	1.1	.9	1.2	.4	.1	.1	1.7	1.2	.4	.1	.4
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	82.2	9.4	14.6	18.8	15.7	14.8	27.0	13.8	34.6	34.7	58.4	27.0	13.8	34.6	19.5
	65.7	7.5	11.0	14.1	12.6	11.8	20.3	9.6	27.7	26.0	40.9	20.3	9.6	27.7	14.7
	61.6	7.1	10.3	13.2	11.5	11.1	19.0	9.0	26.0	24.4	38.3	19.0	9.0	26.0	13.7
	93.5	10.5	66.0	79.4	83.8	78.7	42.5	18.1	29.6	15.4	55.5	42.5	18.1	29.6	19.9

	SLPMB	SLPMC	80PBA
1	235.8	173.2	.3
	176.8	129.9	.2
	168.6	123.8	.0
	255.7	166.1	.0
2	.6	1.9	174.6
	.4	1.4	130.8
	.0	.0	122.0
	.0	.0	244.0
3	13.5	24.5	.3
	10.1	18.4	.2
	9.5	17.2	.0
	14.4	21.1	.0

SIDE CME (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY DFOR. TYPE (COLS.)			
(ARRIVALS)			
SIDE TWO (ORIG. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.			
SIDE TWO (SURV. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.			
1	2	3	4
.9	.9	.9	.9
.7	.7	.7	.7
624.0	.0	.0	.0
621.7	.0	.0	.0
.9	.9	.9	.9
.7	.7	.7	.7
408.0	.0	.0	.0
392.0	.0	.0	.0
.9	.9	.9	.9
.7	.7	.7	.7
242.0	.0	.0	.0
233.4	.0	.0	.0
242.2	4.4	5.0	5.6
194.6	3.5	3.7	4.2
958.0	.0	200.0	350.0
11.9	.0	136.1	294.9
4.7	4.4	69.0	132.2
3.8	3.5	51.7	59.2
1035.0	.0	300.0	300.0
990.4	.0	1.5	6.6
105.5	4.4	4.7	4.7
84.4	3.6	3.6	3.6
370.0	.0	200.0	225.0
8.5	.0	135.9	197.4

This matrix gives the counterdefense strike characteristics. The rows are the target classes from 1-6. The columns are the defense types. So this matrix shows a heavy attack on defense type one (anti-missile) for target class 4 and 6 (East, Midwest). The numbers for the attack on defender type one in target class 4 are that 243 missiles were allocated to the attack, 195 arrived. There were originally 958 defenders and 11.9 survived the attack.

SIDE TWO SECOND STRIKE CHARACTERISTICS											
INTERPRETATION OF EACH SET OF ENTRIES		NO. OF SIDE TWO WEAPONS OF TYPE (COLUMNS) BEFORE COUNTERFORCE STRIKE	NO. OF SIDE TWO WEAPONS OF TYPE (COLUMNS) SURVIVING COUNTERFORCE STRIKE	NO. OF SIDE TWO WEAPONS OF TYPE (COLUMNS) ARRIVING OVER CITIES	NO. OF SIDE TWO WEAPONS OF TYPE (COLUMNS) IMPACTING ON SIDE ONE CITIES	NO. OF 1 MT. EOS. FROM EACH WEAPON TYPE (COLUMNS) IMPACTING ON CITIES					
ICBM3	ICBM2	ICBM1	SLBM1	SLEM2	BOM1	BOM2	BOM3	BOM4	BOM5		
600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0		
600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0		
469.0	320.0	22.2	93.0	225.0	28.8	90.0	28.8	28.8	36.0		
143.8	98.4	6.8	28.6	69.2	.0	.1	.0	.0	.0		
121.7	98.4	16.7	29.3	50.9	.9	.2	.2	.2	.0		

This case uses the attack on defenses option and the objective is to minimize damage to side one. The attack is entirely counterforce and all ICBMs are destroyed. The defenses of the ICBMs are also attacked and almost entirely destroyed. The minimum damage is .053 which is to be contrasted with .485 damage with no attack on defenses.

*****STRATEGIC WEAFENS EXCHANGE MODELS (SWEH) *****

ALLCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** CAPAGE TO SIDE ONE ***** .053

***** DAMAGE TO SIDE TWO ***** .036

NEW SIDE CNF ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROP. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTRIES

	ICBM	ICBMF	ICBMG	ICBMT	ICBMJ	ICBMK
ICBM3	.0	19.1	.0	55.9	74.7	24.1
	.0	15.3	.0	42.7	59.7	19.3
	.0	15.3	.0	128.0	358.4	115.8
	.0	14.5	.0	120.8	338.5	109.3
	.030	.224	.000	.271	.564	.182
	1.000	.967	1.000	.445	.090	.459
ICBM2	171.6	.0	39.9	.0	11.9	42.7
	105.3	.0	29.9	.0	9.5	34.2
	105.3	.0	29.9	.0	56.9	205.1
	100.3	.0	28.5	.0	54.2	195.5
	.251	.000	.071	.000	.136	.489
	.318	1.000	.723	1.000	.563	.124
ICBM1	47.7	.1	.0	.0	.4	7.5
	38.1	.0	.0	.0	.3	6.7
	38.1	.0	.0	.0	1.7	36.0
	14.4	.0	.0	.0	.6	13.6
	.491	.001	.000	.000	.021	.455
	.111	.999	1.000	.999	.912	.143

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
 EACH SET OF ENTRIES WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
 NO. OF 1 MT. EQS. FROM WFAFCN TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMW	ICBMF	ICBMG	ICBHI	ICBMJ	ICBPK	ICBMA	ICBMH	ICBMN	ICBMF	SLBMA
1	6.2 5.0 .0 .0	2.5 2.0 .0 .0	.0 .0 .0 .0	5.6 4.2 .0 .0	.1 .1 .0 .0	.1 .1 .0 .0	7.5 5.6 .0 .0	8.7 7.0 .0 .0	8.7 6.6 .0 .0	12.5 12.2 .0 .0	7.5 5.6 .0 .0
2	6.2 5.0 .0 .0	2.5 2.0 .0 .0	.0 .0 .0 .0	6.1 4.6 .0 .0	.1 .1 .0 .0	.1 .1 .0 .0	7.5 5.6 .0 .0	8.3 7.0 .0 .0	8.8 6.6 .0 .0	12.5 12.3 .0 .0	7.5 5.6 .0 .0
3	6.2 5.0 .1 .2	2.5 2.0 .0 .1	.0 .0 .0 .0	6.1 4.6 .1 .6	.1 .1 .0 .0	.1 .1 .0 .0	7.5 5.6 .1 .3	8.7 7.0 .1 .2	8.7 6.6 .1 .1	12.5 12.3 .3 .4	7.5 5.6 .1 .2

	SLBMB	SLBMC	SLBMA
1	62.5 46.9 .0 .0	50.0 37.5 .0 .0	43.7 32.8 .0 .0
2	62.5 46.9 .0 .0	50.0 37.5 .0 .0	43.7 32.8 .0 .0
3	62.5 46.9 1.0 1.5	50.0 37.5 .8 1.1	43.7 32.8 .0 .0

SIDE CNE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY OFDR. TYPE (COLS.)
 (ARRIVALS)
 SIDE TWO (OPIG. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.
 SIDE TWC (SURV. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.

	1	2	3	4
1	125.8 103.6 624.0 3.6	10.9 8.7 .0 .0	12.8 9.6 .0 .0	12.8 9.6 .0 .0
2	108.2 86.6 438.3 3.9	12.0 9.6 .0 .0	12.8 9.6 .0 .0	12.8 9.6 .0 .0
3	61.1 48.9 242.0 19.7	12.1 9.7 .0 .0	12.9 9.7 1.0 .0	12.9 9.7 .0 .0
4	12.2 5.8 958.0 768.6	12.2 5.8 .0 .0	13.0 9.8 203.0 73.4	13.0 9.8 350.0 235.3
5	12.2 9.8 1035.0 943.1	12.2 5.8 .0 .0	13.0 9.8 300.0 110.2	13.0 9.8 300.0 206.1
6	12.2 5.8 370.0 239.2	12.2 9.8 .0 .0	13.0 9.8 200.0 73.4	13.0 9.8 225.0 157.0

This matrix gives the counterdefense strike characteristics. The rows are the target classes from 1-6. The columns are the defense types. So this matrix shows a heavy attack on defense type 1 (anti-missile) for target class 1, 2, and 3 (ICBM). The numbers for the attack on defender type 1 in target class 1 are that 125.8 missiles were allocated to the attack, 100.6 arrived. There were originally 624 defenders and 3.6 survive the attack.

INTERPRETATION OF
EACH SET OF ENTRIES

SIDE TWO SECOND STRIKE CHARACTERISTICS

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING OVER CITIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES

NO. OF 1 MT. EOS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

ICBM3	ICPM2	ICBM1	SLRM1	SLPM2	COMB1	BOMB2	BOMB3	BOMB4	BOMB5
620.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
10.6	6.4	.4	150.0	375.0	40.0	125.0	40.0	40.0	50.0
8.2	5.1	.3	93.0	225.0	20.8	90.0	20.8	20.8	36.0
.1	.1	.0	1.7	4.1	.0	.1	.0	.0	.0
.2	.1	.0	1.7	3.0	.9	.2	.2	.2	.0

This case uses the option of attack on defenses and minimizes the differences in damage between the two nations (attack is both counterforce and countervalue). To obtain the minimum damage difference several values of K were run between .1 and 10. This case was for a value of $K = .2$ and was the minimum difference for the runs performed.

The results show a counterforce attack against all three ICBMs which destroys them, and an attack against the defenses of the ICBM which are also almost entirely destroyed. The allocation of the countervalue missiles is to the Western cities (because of higher defense) and the bombers are allocated to the East. There are miscellaneous missile allocations because more damage can be done to the West by further allocation and there are essentially not enough missiles left to overcome the strong missile defense of the East and Midwest. The damages are .067 to side one and .315 to side two. This is to be contrasted to the case of .485 to side one and .082 to side two with no attack on defenses. By attacking the defenses we have substantially decreased damage to side one and substantially increased damage to side two.

*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) *****

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .067

***** DAMAGE TO SIDE TWO ***** .315

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTRIES

	ICBMH	ICBNE	ICRMG	ICBHI	ICBMJ	ICBPK
ICBM3	132.6	.0	40.0	74.6	30.2	41.7
	107.0	.0	30.0	56.0	24.2	33.3
	70.6	.0	30.0	167.9	145.1	199.9
	.116	.000	19.8	110.7	95.7	131.9
	.585	1.000	.033	.184	.159	.220
ICBM2	76.1	.0	.0	.477	.516	.391
	63.9	.0	.0	.0	57.7	25.3
	28.4	.0	.0	.0	46.2	20.2
	.096	.000	.000	.000	277.0	121.2
	.645	1.000	1.000	1.000	174.9	76.6
ICBM1	69.4	.0	.0	.0	.437	.191
	55.5	.0	.0	.0	.154	.441
	55.5	.0	.0	.0	.0	.7
	20.9	.0	.0	.0	.1	.5
	.667	.000	.600	.000	.0	3.3
	.042	1.000	1.000	1.000	.001	1.2
					.041	.041
					.995	.639

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES
 WEAPONS OF TYPE (COLUMN) ALLCATED AGAINST CITY CLASS (ROW)
 WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
 WEAPONS OF TYPE (COLUMN) IMPACTING ON CITY CLASS
 NO. OF 1 MI. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBHE	ICBMG	ICBHI	ICBMJ	ICBMK	ICBMA	ICBM8	ICBMC	ICBMD	ICBMF	SLBMA
1	1.0	0.5	.0	.1	.0	.3	5.0	3.0	1.8	.0	6.7	4.8
	.8	6.8	.0	.1	.0	.2	3.7	2.1	1.4	.0	4.7	3.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	8.4	6.7	.0	.1	.0	.6	4.9	3.1	1.8	.0	7.0	4.8
	6.7	5.4	.0	.1	.0	.7	3.7	2.1	1.4	.0	4.9	3.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	13.1	5.1	.0	.1	.0	6.3	15.1	5.0	29.6	34.9	49.4	15.6
	10.6	4.1	.0	.1	.0	5.0	11.4	4.1	23.7	26.2	34.5	11.7
	0.2	3.2	.0	.1	.0	3.9	0.8	3.2	18.4	20.4	26.9	9.1
	12.4	4.7	.0	.4	.0	27.7	19.6	6.4	21.0	12.8	39.0	13.2

SLBMA	SLBMC	SLBMA	SLBMA
1	11.0	21.0	172.3
	0.3	15.7	129.2
	.0	.0	112.0
	.0	.0	223.9
2	10.9	17.1	1.4
	8.2	12.9	1.0
	.0	.0	.0
	.0	.0	.0
3	217.1	143.3	.0
	162.8	107.5	.0
	126.8	81.7	.0
	192.2	112.3	.0

SIDE ONE COUNTER DEFENSE STRIKE CHARACTERISTICS									
SIDE ONE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY OFOR. TYPE (COLUMNS) ---									
(ARRIVALS)									
SIDE TWO (ORIG. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.									
SIDE TWO (SURV. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.									
1	2	3	4	5	6	7	8	9	10
62.7	4.0	4.2	4.2						
50.1	3.2	3.2	3.2						
624.0	.0	.0	.0						
47.7	.0	.0	.0						
62.7	4.1	4.4	4.4						
57.0	3.3	3.3	3.3						
438.0	.0	.0	.0						
28.7	.0	.0	.0						
55.3	4.1	4.4	4.4						
44.2	3.3	3.3	3.3						
242.0	.0	.0	.0						
25.0	.0	.0	.0						
1.7	1.4	43.1	122.5						
1.2	1.1	32.4	91.9						
958.0	.0	200.0	350.0						
429.4	.0	7.2	8.3						
.5	.5	.5	.5						
.4	.4	.4	.4						
1035.0	.0	300.0	300.0						
1031.4	.0	269.0	295.6						
58.4	3.3	3.6	3.6						
46.7	2.7	2.7	2.7						
370.0	.0	200.0	225.0						
45.9	.0	152.0	203.9						

Attack on defenses is to destroy missile defense of ICBM, missile defense of West Coast, and bomber defense of East Coast.

SIDE TWO SECOND STRIKE CHARACTERISTICS

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
 NO. CF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
 NO. CF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
 NO. CF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING CN SIDE ONE CITIES
 NO. OF 1 MT. EOS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

INTERPRETATION OF
 EACH SET OF ENTRIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLEM2	80M81	80M82	80M83	80M84	80M85
1	600.0	400.0	30.0	150.0	275.0	40.0	125.0	40.0	40.0	50.0
	28.4	17.6	1.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	22.1	14.0	.8	93.0	225.0	28.8	93.0	28.8	28.8	36.0
	.5	.3	.0	2.2	5.3	.9	.1	.0	.0	.0
	.4	.3	.0	2.2	3.9	.9	.2	.2	.2	.0

This case uses the no attack on defense option and the objective is to maximize the damage to side two. The allocation is all countervalue and the missiles are allocated to the East Coast while the bombers are allocated to the West Coast. The damage is .730 to side one and .320 to side two.

*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) *****

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .730

***** DAMAGE TO SIDE TWO ***** .320

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROP. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTITIES

	ICRMH	ICRME	ICRMG	ICRMI	ICRMJ	ICRPMK
ICRM3	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000
ICRM2	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000
ICRM1	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
 EACH SET OF ENTRIES WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
 WEAPONS OF TYPE (COLUMN) IMPACTING ON CITY CLASS
 NO. OF 1 MT. EOS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICAMH	ICRME	ICBMG	ICBKI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBPA
1	750.0	30.0	40.0	75.0	88.0	75.0	30.0	15.0	35.0	35.0	70.0	30.0
	600.0	24.0	30.0	56.3	70.4	60.0	22.5	10.5	28.0	26.3	49.0	22.5
	125.1	5.0	6.3	11.7	14.7	12.5	4.7	2.2	5.0	5.5	10.2	4.7
	189.8	7.4	28.0	70.4	104.2	88.8	10.5	4.4	6.7	3.4	14.8	6.8
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

	SLBMB	SLBMC	ROHBA
1	250.0	200.0	.0
	187.5	150.0	.0
	39.1	31.3	.0
	59.3	42.0	.0
2	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
3	.0	.0	175.0
	.0	.0	131.3
	.0	.0	2.8
	.0	.0	5.5

SIDE TWO SECOND STRIKE CHARACTERISTICS											
INTERPRETATION OF EACH SET OF ENTRIES		NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE		NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE		NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING OVER CITIES		NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES		NO. OF 1 MT. BOMBS FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES	
ICBM3	ICBM2	ICBM1	SLRM1	SLRM2	ROMR1	ROMR2	ROMR3	ROMR4	ROMR5		
600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0		
600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0		
468.0	320.0	22.2	93.0	225.0	28.8	90.0	28.8	28.8	36.0		
143.8	98.4	6.8	28.6	69.2	.0	.1	.0	.0	.0		
121.7	98.4	16.7	29.3	50.9	.3	.2	.2	.2	.0		

This case uses the option of not allowing attack on defenses. The objective is to minimize the damage to side one (first strike) so the attack will be counterforce. The results show that the attack is against ICBM2 and ICBM1 which are both completely destroyed, while ICBM3 is not attacked. All side one missiles which have counterforce capability are used in the attack. The minimum damage is .485.

*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) *****

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .485

This is the minimum damage for side one which can be obtained by allocating all counterforce weapons to a counterforce attack.

***** DAMAGE TO SIDE TWO ***** .000

Damage is zero because no value was input for damage to side two.

~~NEW SIDE ONE ATTACK~~

SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTRIES

	ICRMH	ICRME	ICRMG	ICRMI	ICRMJ	ICRMK
ICRM3	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000	.0 .0 .0 .0 1.000
ICRM2	543.5 434.8 434.8 105.9 .265 .299	10.5 8.5 8.5 2.1 .005 .993	19.9 14.9 14.9 3.6 .009 .959	65.3 49.0 147.0 35.8 .090 .698	84.5 67.5 405.5 98.8 .247 .348	71.5 57.2 343.2 83.5 .209 .409
ICRM1	206.5 165.2 165.2 13.1 .435 .137	19.4 15.5 15.5 1.2 .041 .945	20.1 15.1 15.1 1.2 .040 .833	9.7 7.3 21.8 1.7 .057 .794	3.5 2.8 16.9 1.3 .044 .827	3.5 2.8 16.8 1.3 .044 .827

This shows results of counterforce attack.



SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EOS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

INTERPRETATION OF
EACH SET OF ENTRIES

CITY CLASS	ICBMH	ICBME	ICBMG	ICBNI	ICBNJ	ICBNK	ICBNA	ICBNB	ICBNC	ICBND	ICBNF	SLBNA
1	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	6.7	17.5	7.5
	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	8.8	17.5	7.5
	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	8.8	17.5	7.5
	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

	SLBNA	SLBMC	BOMBA
1	62.5	50.0	43.7
	46.9	37.5	32.8
	.0	.0	.0
2	62.5	50.0	43.7
	46.9	37.5	32.8
	.0	.0	.0
3	62.5	50.0	43.7
	46.9	37.5	32.8
	.1	.1	.0
	.1	.1	.0

Countervalue only weapons are not optimized because no value was attached to damage to side two.

INTERPRETATION OF
EACH SET OF ENTRIES

SIDE TWO SECOND STRIKE CHARACTERISTICS

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EOS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

ICBM3	ICBM2	ICRM1	SLRM1	SLRM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
600.0	11.3	1.8	150.0	375.0	40.0	125.0	40.0	40.0	50.0
468.0	9.0	1.3	93.0	225.0	28.8	90.0	28.8	28.8	36.0
88.0	1.7	.2	17.5	42.3	.0	.1	.0	.0	.0
74.5	1.7	.6	17.9	31.1	.3	.2	.2	.2	.0

This case uses the no attack on defense option and minimizes the difference in damage between the two nations. Several cases were run for values of K between .1 and 10. This case ($K = .2$) gave the minimum difference. The counterforce attack is allocated to ICBM2 and ICBM1 which are almost completely destroyed, and the countervalue attack is to the West Coast. The damages are .485 to side one and .082 to side two.

*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) *****

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .485

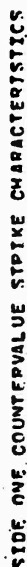
***** DAMAGE TO SIDE TWO ***** .082

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) IMPACTING OVER TARGET (ROW)
WEAPONS OF MISSILE TYPE (COLUMN) IMPACTING OVER TARGET
WEAPONS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WEAPONS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROP. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

INTERPRETATION OF
EACH SET OF ENTRIES

	ICPMH	ICPMF	ICPMG	ICPMI	ICPMJ	ICPMK
ICPM3	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000
ICPM2	542.3	11.0	20.5	65.6	84.5	71.5
	433.8	8.8	15.4	49.2	67.6	57.2
	433.8	8.8	15.4	147.7	405.4	343.1
	195.7	2.1	3.8	36.0	98.8	83.6
	.264	.005	.000	.090	.247	.209
	.300	.001	.058	.697	.348	.409
ICPM1	207.7	19.3	19.5	9.4	3.5	3.5
	166.2	15.2	14.6	7.0	2.8	2.6
	166.2	15.2	14.6	21.1	17.0	16.0
	13.1	1.2	1.2	1.7	1.3	1.3
	.438	.040	.038	.056	.045	.044
	.136	.046	.078	.800	.826	.827



SIDE ONE COUNTERVALUE STIPIKE CHARACTERISTICS

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)

WEAPONS OF TYPE (COLUMN)	ACCUMULATED AGAINST CITY CLASS (ROW)	ABSTYING OVER CITY CLASS (ROW)
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	101	102
103	104	105
106	107	108
109	110	111
112	113	114
115	116	117
118	119	120
121	122	123
124	125	126
127	128	129
130	131	132
133	134	135
136	137	138
139	140	141
142	143	144
145	146	147
148	149	150
151	152	153
154	155	156
157	158	159
160	161	162
163	164	165
166	167	168
169	170	171
172	173	174
175	176	177
178	179	180
181	182	183
184	185	186
187	188	189
190	191	192
193	194	195
196	197	198
199	200	201
202	203	204
205	206	207
208	209	210
211	212	213
214	215	216
217	218	219
220	221	222
223	224	225
226	227	228
229	230	231
232	233	234
235	236	237
238	239	240
241	242	243
244	245	246
247	248	249
250	251	252
253	254	255
256	257	258
259	260	261
262	263	264
265	266	267
268	269	270
271	272	273
274	275	276
277	278	279
280	281	282
283	284	285
286	287	288
289	290	291
292	293	294
295	296	297
298	299	300
301	302	303
304	305	306
307	308	309
310	311	312
313	314	315
316	317	318
319	320	321
322	323	324
325	326	327
328	329	330
331	332	333
334	335	336
337	338	339
340	341	342
343	344	345
346	347	348
349	350	351
352	353	354
355	356	357
358	359	360
361	362	363
364	365	

IMPACTING ON CITY CLASS

NO. OF 1 MT. FOS. FROM WEAPON TYPE (COLUMN) IMPACTING CN CITY CLASS (ROW)

[illegible]

	SLPMA	SLRMC	ROMPA
1	0	0	0
	0	0	0
	0	0	0
	0	0	0
2	0	0	0
	0	0	0
	0	0	0
	0	0	0
3	250.0	200.0	175.0
	187.5	150.0	131.2
	36.7	29.4	2.8
	55.2	30.4	5.5

SIDE TWO SECOND STRIKE CHARACTERISTICS											
INTERPRETATION OF											
FACH SET OF ENTITIES											
	ICRM3	ICRM2	ICRM1	SLRM1	SLRM2	FCMR1	RCMR2	FCMR3	RCMR4	RCMR5	
1	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0	
	600.0	11.3	1.8	150.0	375.0	40.0	125.0	40.0	40.0	50.0	
	468.0	9.0	1.3	93.0	225.0	28.8	90.0	28.8	28.8	36.0	
	88.0	1.7	.2	17.5	42.3	.0	.1	.0	.0	.0	
	74.5	1.7	.6	17.9	31.1	.3	.2	.2	.2	.0	

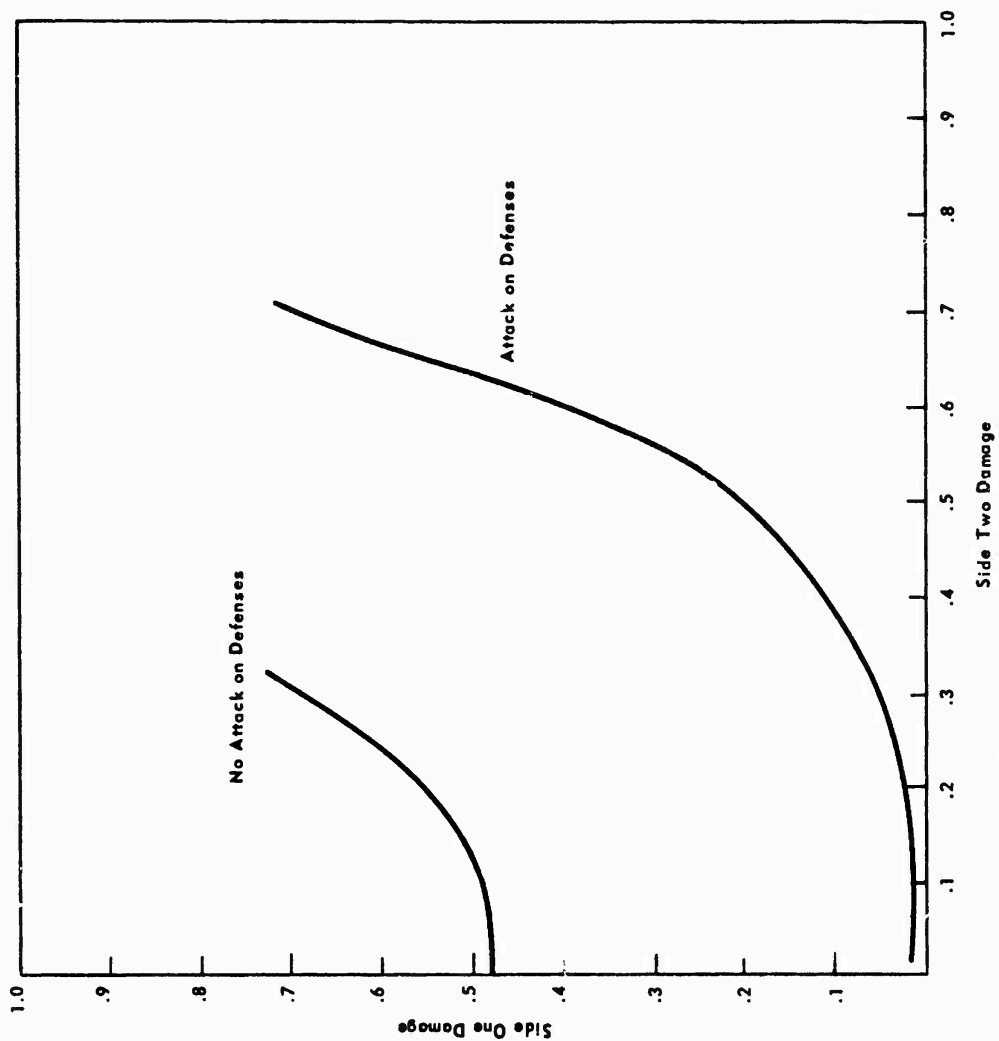


Fig. 1 - Comparison of Damages to Two Nations
Using Two Different Offensive Strategies

Appendix A

MATHEMATICAL FORMULATION

Appendix A

MATHEMATICAL FORMULATION

MATHEMATICAL STATEMENT OF THE ALLOCATION OPTIMIZATION MODEL WITH ATTACK ON DEFENSES OPTION

A. General Statement of Model

The mathematical statement of the allocation optimization model is as follows:

$$\text{Minimize } (K_1 \bar{\beta} - K_2 \beta)$$

$$\text{over } x_{ij}, u_{ik}$$

subject to

$$\text{II} \quad \sum_{i=1}^{D1-1} (x_{ij} + \sum_{k=0}^{D1-1} u_{ij+k}) \leq r_1 m_1 \text{ for } j=1 \quad D1 \leq D$$

$$\text{II} \quad \sum_{i=1}^{D1-1} (x_{ij} + u_{ij+D1-1}) \leq r_2 m_2 \text{ for } j=2, \dots, D-(D1-1) \text{ if } D1 < D \quad \text{if } D2 \neq 2$$

no constraint if $D1=D$

$$\text{II} \quad \sum_{i=1}^2 (x_{ij} + \sum_{k=1}^2 u_{ij+k}) \leq r_2 m_2 \text{ for } j=2 \quad \text{if } D2=2 \text{ and } D1=2$$

$$\text{II} \quad \sum_{i=1} x_{ij} \leq r_j m_j \quad \text{for } j=D+1, \dots, J$$

$$\text{II} \quad \sum_{i=I+1} x_{ij} \leq r_j m_j \quad \text{for } j=J+1, \dots, JJ$$

$$x_{ij}, u_{ik} \geq 0$$

where

u_{ik} = number of reliable side 1 weapon type (according to the constraint conventions above) allocated to the kth type side 1 defensive weapon of the ith type resource

x_{ij} = number of reliable side 1 jth type offensive weapons allocated to side 2 ith type resource

m_j = total number of side 1 jth type offensive weapons

r_j = force reliability of side 1 offensive weapon type j

β = fractioned damage to side 2 population

$\bar{\beta}$ = fractioned damage to side 1 population

K_1, K_2 = input parameters determining the strategic goals

I = total number of side 2 CF targets (ICBMs)

II = total number of side 2 targets (ICBMs + Cities)

J = total number of side 1 offensive weapon types with CF and CV capability

JJ = total number of side 1 offensive weapon types

D1 = maximum number of side 2 defensive weapon types that can be attacked by side 1 weapon type 1

D2 = maximum number of side 2 defensive weapon types that can be attacked by side 1 weapon type 2

D = total number of side 2 defensive weapon types that can be attacked by side 1

Note if $D=0$ there is no attack of defenses, i.e., no u_{ik} variables.

B. Details of Model

First Striker Attack on Second Striker Defenses

The effects of the first striker's attack on the second striker's defenses are modeled in the following way. Let

L_{ik} = total number of defense installations associated with defender type k of resource i

h_{ik}^l = total number of defenders of type k of resource i at base l
that can be destroyed by the attack ($l=1, \dots, L_{ik}$)

g_{ik}^l = total number of defenders of type k of resource i at base l
that specifically defend the installation

For each side 2 resource i and defensive weapon type k attacked by side 1
a parameter q_{ik} is defined such that the expected number of surviving
reliable side 2 defenders from an attack of w side 1 reliable attackers
is given by

$$d_{ik} = r_k^i d_{ik}' q_{ik}^w$$

The parameters q_{ik} are determined by a least squares fit to a maximum
damage curve as follows:

Let w = the number of side 1 reliable attackers

Define for each side 2 resource and defender type k

$$E_o^l = h_{ik}^l$$

$$\bar{E}_o = \sum_{l=1}^{L_{ik}} E_o^l$$

$$\bar{E}_w = \sum_{l=1}^{L_{ik}} E_w^l = \bar{E}_{w-1} - \max_{\{l=1, \dots, L_{ik}\}} \left\{ \bar{q}_{ikl} E_{w-1}^l \right\}$$

for $w=1, \dots, \bar{N}$ where $\bar{N}$ is the smallest w such that $\frac{\bar{E}}{\bar{N}} < 1$

and

$$\bar{q}_{ikl} = \begin{cases} (1 - S'_{ikl})(\bar{S}_{ikl} r_k^i + 1 - r_k^i) & \text{if } g_{ik}^l \geq w \\ (1 - S'_{ikl}) & \text{if } g_{ik}^l < w \end{cases}$$

where

$1 - S'_{ikl}$ = probability side 1 attacker kills base l given it has
penetrated the defense of the base

$\bar{S}_{1,k}$ = probability side 1 attacker arrives at the base given
it encounters side 2 base defender
 r'_k = force reliability of side 2 base defenders

The parameters $q_{1,k}$ are then defined by the Z that yields the minimum of

$$\min_Z \sum_{w=1}^{\bar{N}} (\bar{E}_w - \bar{F}_j Z^w)^2 .$$

In order to limit the number of variables, restrictions have been placed on the number of different types of side 1 weapons that can attack side 2 defenses. The following five matrices depict the permissible values of side 1 weapon types j which can attack side 2 defensive types k .

$j \backslash k$	1	2	3	4
1	x	x	x	x
2				
3				
4				
D=4 D1=4 D2=0				

$j \backslash k$	1	2	3	4
1	x	x	x	
2				x
3				
4				
D=4 D1=3 D2=1				

$j \backslash k$	1	2	3	4
1	x	x		
2			x	
3				x
4				
D=4 D1=2 D2=1				

$j \backslash k$	1	2	3	4
1	x			
2		x		
3			x	
4				x
D=4 D1=1 D2=1				

$j \backslash k$	1	2	3	4
1	x	x		
2			x	x
3				
4				
D=4 D1=2 D2=2				

The first type side 1 weapon is the only type which can attack four side 2 defender types. This is the case for the sample problem.

Thus the admissible index value of j in the equation

$$d_{1,k} = r'_k d'_{1,k} q_{1,k} u_{1,k,j} \quad \text{where} \quad d'_{1,k} = \sum_{\ell=1}^{L_{1,k}} h'_{1,k} \quad (k=1, \dots, D)$$

(where $u_{1,k,j}$ is the number of reliable side 1 j th type attackers allocated against defender type k of the i th side 2 resource) is limited to the above five situations. Once $D1$ and $D2$ (given $D=4$) are given the j index value is known and $u_{1,k,j}$ is designated by $u_{1,k}$.)

Second Striker Defenses

Let d_{1k} = number of reliable side 2 kth type defenders (area or terminal) of side 2 ith type target (geographic area of missile type), k is now permitted to be greater than 1

p_{jk} = single shot survival probability of side 1 jth type attacker when engaged by side 2 kth type defender

x_{1j} = number of reliable side 1 jth type weapons allocated to side 2 ith type target, (geographical area, missile type)

γ_{1jk} = allocation of side 2 kth type defender to side 1 jth type attacker of side 2 ith type target (geographical area, missile type)

JJ = total number of side 1 attacker types,

Note $\sum_{j=1}^{JJ} \gamma_{1jk} = 1.$

Different defense doctrines correspond to different rules for choosing the γ_{1jk} .

Example 1: Consider a "proportional" defense, where the defenders are assigned to attackers in numbers proportional to the fraction of the attack represented by a particular attacker type and to the capability of a defender to bring down a particular attacker.

Then

$$\gamma_{1jk} = \frac{x_{1j}(1-p_{jk})}{\sum_{j=1}^{JJ} x_{1j}(1-p_{jk})}.$$

Example 2: Consider a "uniform" defense, where the defenders are assigned to attackers in numbers proportional to the fraction of the attack represented by a particular attacker only.

Then

$$\gamma_{1jk} = \frac{x_{1j}}{\sum_{j=1}^{JJ} x_{1j}}.$$

A more general form to use would be

$$\gamma_{ijk} = \frac{x_{ij} a_{jk}}{\sum_{j=1}^J x_{ij} a_{jk}} \quad \begin{array}{l} a_{jk} = (1-p_{jk}) \\ \text{in example 1,} \end{array}$$

$$\begin{array}{l} a_{jk} = 1 \\ \text{in example 2.} \end{array}$$

The a_{jk} are constants to be read in (or calculated) at the beginning of the program.

The fraction of side 1 jth type attackers of side 2 ith type targets surviving the defenses is then given by

$$F_{ij} = \prod_{k=1}^K p_{ik} \left(\frac{\gamma_{ijk} d_{ik}}{x_{ij}} \right) = \exp \left(\sum_{k=1}^K \frac{\gamma_{ijk} d_{ik}}{x_{ij}} \ln p_{jk} \right)$$

In the general form this reduces to

$$F_{ij} = \exp \left(\sum_{k=1}^K \frac{a_{jk} d_{ik}}{\left(\sum_{j=1}^J x_{ij} a_{jk} \right)} \ln p_{jk} \right),$$

where K = total number of side 2 defender types.

Retaliators Surviving the First Strike

The number of side 2 mth type weapons retaliating on side 1 is

$$y_m = \bar{r}_m n_m S_m \quad m = 1, \dots, M,$$

where

$\bar{r}_m$ = reliability of side 2 mth type retaliator,

n_m = number of side 2 mth type weapon prior to side 1 CF attack,

S_m = fraction of side 2 mth type weapon surviving side 1 CF attack,

$$= \prod_{j=1}^J s_{mj} \left(\frac{x_{mj} F_{mj} e_j}{n_m} \right)$$

$$m = 1, \dots, I$$

where y_n = number of side 2 mth type weapons retaliating on side 1.

This done, constants $\bar{a}_{nn}$ can be read in, as was done for the side 2 defenses such that

$$\bar{y}_{lnn} = \frac{y_{ln} \bar{a}_{nn}}{\sum_{n=1}^M y_{ln} \bar{a}_{nn}}$$

represents the performance of side 1 defenses, whether uniform or proportional. The fraction of side 2 mth type retaliators on side 1 lth type targets is then given by

$$\bar{F}_{ln} = \exp \left(\sum_{n=1}^N \frac{\bar{a}_{nn} \bar{d}_{ln}}{\sum_{n=1}^M b_{ln} y_{ln} \bar{a}_{nn}} \ln \bar{p}_{nn} \right),$$

where N = total number of side 1 defender types.

In summary it should be pointed out that the single shot survival probabilities (1) p_{jk} , (2) s_{ij} , and (3) $\bar{p}_{nn}$ are instrumental in modeling the interaction of (1) the first striker offense with the second striker defense, (2) the first striker offense with the second striker CV targets, and (3) the second striker offense with the first striker defense, respectively. Of course information on the p_{jk} and $\bar{p}_{nn}$ may then be or not be used in determining the defense allocation doctrine constants a_{jk} and $\bar{a}_{nn}$.

Damage Determination

The number of LMT equivalents delivered on side two's ith type CV target is given by

$$EQ_i = \sum_{j=1}^J F_{ij} x_{ij} k_j + \sum_{j=J+1}^{JJ} F_{ij} x_{ij} k_j \quad i = 1, \dots, II-I$$

The number of LMT equivalents delivered on side one's j th type CV target is

$$\overline{EQ}_j = \sum_{s=1}^M \bar{F}_{js} Y_{js} \bar{k}_s$$

As noted previously the fraction damage to side two's i th type CV target is

$$\beta_i = 1 - (1 + A_i \sqrt{\overline{EQ}_i}) \exp(-A_i \sqrt{\overline{EQ}_i})$$

The fraction damage to side one's j th type CV target is

$$\bar{\beta}_j = 1 - (1 + \bar{A}_j \sqrt{\overline{EQ}_j}) \exp(-\bar{A}_j \sqrt{\overline{EQ}_j})$$

The total fraction population loss to side two is

$$\beta = \frac{1}{\text{TOTP}} \sum_{i=1}^{II-I} P_i \beta_i$$

and to side one

$$\bar{\beta} = \frac{1}{\overline{\text{TOTP}}} \sum_{j=1}^J \bar{P}_j \bar{\beta}_j$$

where TOTP = total population of side two,

$\overline{\text{TOTP}}$ = total populations of side one,

P_i = population in side two's i th area,

$\bar{P}_j$ = population in side one's j th area.

C. Remarks Concerning the First and Second Partial Derivatives With Respect to Allocations Against the Defenses

The first and second partial derivatives of the objective function with respect to side 2 defensive variable d_{1k} have been evaluated in a prior model (see RAC-CR-43). The same evaluation is made in the present

model even though the d_{ik} are not independent variables of the current model. The following equations apply in evaluating derivatives with respect to allocations against the defense u_{ik} in terms of known derivatives with respect to d_{ik} . These equations are used by the subroutines GRAD1 and MATRIX.

$$d_{ik} = r'_k d'_{ik} q_{ik}^{u_{ik}}$$

$$= r'_k d'_{ik} e^{b_{ik} u_{ik}} \quad \text{where} \quad q_{ik} = e^{b_{ik}}$$

$$\frac{\partial d_{ik}}{\partial u_{ik}} = b_{ik} d_{ik}$$

$$\frac{\partial^2 d_{ik}}{\partial u_{ik}^2} = b_{ik}^2 d_{ik}$$

For any function f we have

$$\frac{\partial f}{\partial u_{ik}} = \frac{\partial f}{\partial d_{ik}} (b_{ik} d_{ik})$$

$$\frac{\partial^2 f}{\partial u_{jn} \partial u_{ik}} = \frac{\partial^2 f}{\partial d_{jn} \partial d_{ik}} (b_{jn} d_{jn}) (b_{ik} d_{ik}) + \frac{\partial f}{\partial d_{ik}} \delta_{ij} \delta_{kn} b_{ik}^2 d_{ik}$$

$$\frac{\partial^2 f}{\partial x_{jn} \partial u_{ik}} = \frac{\partial^2 f}{\partial x_{jn} \partial d_{ik}} (b_{ik} d_{ik})$$

Appendix B

FORTRAN LISTING OF PROGRAM WITH COMMENTS

SUBROUTINE READIN

```

C
C ---- THIS SUBROUTINE READS IN THE INPUT CONSTANTS OF THE PROBLEM --
C
COMMON/SHAPE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IEN,IEN
1,IEX,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NDOFFS,NK,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWC/AA(6),AAB(2),FPOP(6),FPOP8(2),DL(9,7),ENL(10),RB(10),
1EK9(10),TITLE2(10),P(15,7),AB(10,15),B(2,10),DE(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
COMMON/THREE/PREFER,PREFIN,PREFINC,PREFET,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CB(10,15),FLNS(5,6)
COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),ETA(6),Y(6),
1BETAB(2),YB(2),BETB,BET
COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),YBX(6,15),
1DYD(6,7),DPD(6,7),BETPP(2),BETPP(6),BETBPP(2)
COMMON/EIGHT/DSX(5,6),DSO(5,7),DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),CF2D(10,5,7),DYBX(2,5,6),DYED(2,5,7)
COMMON/NINE/DBBX(5,6),DBBD(5,7)
COMMON/OUTIN/ PPR(20),7N1(20),ZN2(20),RAT(10)
COMMON/EGAL/ H,H1,M7
DIMENSION W2(20),PSI(20),W1(20),CEP(20),FFP(20),
CRL(20,20)
DIMENSION DCAP(20),ACAP(20),EJN(20),QBAR(20),SPRIME(20),EBAR(1000)
DIMENSION HARD(20),PSUR(5)
C
C ---DATA FOR THE ALLOCATION MODEL
C---SEE DESCRIPTION OF INPUT DATA FOR DETAILS ---
WRITE(6,655)
WRITE(6,660)
WRITE(6,250)
250 FORMAT (/45X,37H**INPUT CONDITIONS FOR THIS RUN ** )
C
C --(3-1)-PROBLEM SIZE AND OPTION CARDS ---
C
READ(5,1) NI,NII,NM,NJ,NJJ,NK,NL,NN,ND,NDEFS,IB1,NU1,NU3,NU4
READ(5,1) ND1,ND2
C
C ----- USER OPTIONS -----
C ***** IF NU1=1 PROGRAM SELECTS STARTING FEASIBLE POINT *****
C ***** IF NU3=1 A PRINTOUT OF ALL POINTS IS GIVEN DURING THE SOLUTION
C ***** NU4 IS THE TOTAL NUMBER OF STRATEGIES CONSIDERED WHERE RATIO
C ***** (K2/K1) EQUALS RAT(I) *****
C ----- NO LESS OR EQUAL ZERO NC ATTACK ON DEFENSES -----
C
IF(ND.GT.0) WRITE(6,246)
246 FORMAT(/48X,31HATTACK ON DEFENSES OPTION USED )
IF(ND.LE.0) WRITE(6,247)
247 FORMAT(/48X,29HSTANDARD DEFENSE OPTION USED )
WRITE(6,25)NDEFS,IB1,NU1,NU3,NU4
WRITE(6,3) NI, NII, NM, NK, NJ, NL, NJJ, NN
WRITE(6,700)ND,ND1,ND2
700 FORMAT(1H0,5X,5I5)
NI1 = NI + 1
NI2 = NII - NI

```

```

NIIJ = NII * NJ
NJ1 = NJ + 1
IF(NJJ.EQ.NJ) NJ1=NJ
NJ2 = NJJ - NJ
IEX = NI * NJ + NI2 * NJJ
IEX1 = IEX + 1
IF(ND.LT.0) ND=1
IED = IEX + NII * ND
I1 = ND
IF(ND2.NE.2.AND.ND.GT.0) I1= ND - ( ND1 - 1 )
IF(ND2.EQ.2.AND.ND.GT.0) I1= 2
I2 = NJ
I3 = NJJ
MC = I3
NV = IED
MZ = 0

```

C

C --(3-2)-DAMAGE CURVE FIT PARAMETERS AND FRACTIONAL POPULATIONS

C

```

READ(5,2) (AA(I),I=1,NI2)
WRITE(6,5)
WRITE(6,4) (AA(I),I=1,NI2)
READ(5,2) (AAB(I),I=1,NL)
WRITE(6,6)
WRITE(6,4) (AAB(I),I=1,NL)
READ(5,2) (FPOP(I),I=1,NI2)
WRITE(6,7)
WRITE(6,4) (FPOP(I),I=1,NI2)
READ(5,2) (FFOPB(I),I=1,NL)
WRITE(6,8)
WRITE(6,4) (FFOPB(I),I=1,NL)

```

WRITE (6,655)

WRITE (6,295)

295 FORMAT (/40X,53H

FORCE STRUCTURE AND WEAPONS CHARACTERIST

1ICS)

WRITE(6,9L60)

DO 109 I=1,NI

C

C --(3-3)-SIDE TWO OFFENSIVE SYSTEMS AND SINGLE SHOT SURVIVAL PROBS.

C -----AGAINST SIDE ONE DEFENSIVE WEAPON TYPES

C

READ(5,91) EN(I),RB(I),W2(I),PSI(I),ZN2(I),TITLE2(I)

READ(5,2) (PR(I,J),J=1,NN)

109 CONTINUE

DO 111 I=NI1,NM

C

C --(3-3) CONTINUED

C

READ(5,10) EN(I),RB(I),W2(I),ZN2(I),TITLE2(I)

READ(5,2) (PR(I,J),J=1,NN)

111 CONTINUE

DO 736 M=1,NM

C

C -----COMPUTE DEFENSE ALLOCATION CONSTANTS FOR SIDE ONE -----

C

IF(IB1-2)751,733,735

751 DO 752 N=1,NN

752 AB(M,N) = 1. - PR(M,N)

```

      GO TO 736
733 DO 734 N=1,NN
734 AB(M,N) = 1.
      GO TO 736
735 READ(5,2) (AB(M,N),N=1,NN)
736 CONTINUE
      WRITE(6,211)
211 FORMAT(1H,40X,17H OFFENSIVE SYSTEMS)
      WRITE(6,216)
216 FORMAT(1H,30X, 8H SIDE TWO)
      WRITE(6,201)
201 FORMAT(1H,4X,76H TYPE SYSTEM INVENTORY FORCE REL. WARHEAD
1YIELD NO. OF WH P.S.I. )
206 FORMAT(1H ,5X,I2,4X,A6,3X,F8.2,6X,F5.4,9X,F8.3,7X,F4.0,6X,F6.2)
      DO 207 I=1,NI
207 WRITE(6,206)I,TITLE2(I),EN(I),RB(I),W2(I),ZN2(I),PSI(I)
      DO 212 I=NI1,NM
212 WRITE(6,206)I,TITLE2(I),EN(I),RB(I),W2(I),ZN2(I)
      DO 115 M=1,NM
      DO 115 N=1,NN
115 CB(M,N) = AB(M,N) * ALOG(PB(M,N))
      WRITE(6,221)
221 FORMAT(1H,30X, 8H SIDE ONE)
      WRITE(6,226)
226 FORMAT( /5X,108H TYPE SYSTEM INVENTORY FORCE REL. WARHEAD Y
1IELD NO. OF WH NO. IND. TAR. WH NO. CLUSTER WH CEP)
231 FORMAT(1H ,5X,I2,4X,A6,3X,F8.2,6X,F5.4,9X,F8.3,7X,F4.0,11X,F4.0,14
1X,F4.0,9X,F5.2)
      DO 131 I=1,NJ
C
C --(3-4)-SIDE ONE OFFENSIVE SYSTEMS AND SINGE SHOT SURVIVAL PROPS.
C -----AGAINST SIDE TWO DEFENSIVE WEAPON TYPES
C
      READ(5,94) EM(I),RBB(I),E(I),W1(I),CEP(I),FPP(I),ZN1(I),TITLE1(I)
      READ(5,2) (P(I,J),J=1,NK)
      WRITE(6,231)I,TITLE1(I),EM(I),RBB(I),W1(I),ZN1(I),E(I),FPP(I),CEP(
1I)
131 CONTINUE
      DO 132 I=NJ1,NJJ
C
C --(3-4) CONTINUED
C
      READ(5,91) EM(I),RBB(I),E(I),W1(I),ZN1(I),TITLE1(I)
      READ(5,2) (P(I,J),J=1,NK)
      WRITE(6,231)I,TITLE1(I),EM(I),RBB(I),W1(I),ZN1(I),E(I)
132 CONTINUE
      DO 136 I=1,NJJ
C
C -----COMPUTE DEFENSE ALLOCATION CONSTANTS FOR SIDE TWO -----
C
      IF (NDEFS - 2) 151,133,135
151 DO 152 J=1,NK
      AN(I,J) = 1. - P(I,J)
152 CONTINUE
      GO TO 136
133 DO 134 J=1,NK
      AN(I,J) = 1.
134 CONTINUE

```

```

      GO TO 136
135  READ(5,2) (AN(I,J),J=1,NK)
      WRITE(6,18)
      WRITE(6,4) (AN(I,J),J=1,NK)
136  CONTINUE
      DO 204 I=1,NI
      DO 204 J=1,NJ
      RL(I,J)=2.8*(W1(J)**0.333)*(PSI(I)-7.37)**(-0.352)
      SS(I,J)=0.5*((FPP(J))* (RL(I,J)/CFP(J))**2)
C
C -----COMPUTE SINGLE SHOT SURVIVAL PROBS. FOR SIDE TWO HARDSITES VS.
C -----SIDE ONE OFFENSE -----
C *** IF SINGLE SHOT SURV. PROB. IS LESS THAN .01 INCREASE IT BY .01 **
      IF(SS(I,J).LT.1.E-2) SS(I,J) = SS(I,J) + .01
C
      204 CONTINUE
395  FORMAT (/21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO ICBM
      1S VS SIDE ONE MISSILES) ***/5X,14HSIDE TWO ICBMS,26X,26HSIDE ONE M
      2ISSILFS (ACROSS)/9X,6H(DOWN))
400  FORMAT (7X,A6,12(4X,F6.4))
525  FORMAT ( /15X,12(4X,A6))
      WRITE (6,655)
      WRITE(6,9000)
      WRITE (6,395)
      WRITE (6,525) (TITLE1(J),J=1,NJ)
      DO 205 I=1,NI
235  WRITE (6,400) TITLE2(I), (SS(I,J),J=1,NJ)
795  FORMAT (/21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO OFFS
      1. VS SIDE ONE DEFDRS. ) ***/5X,14HSIDE TWO OFFS.,26X,26HSIDE ONE D
      2EFDRS. (ACROSS)/9X,6H(DOWN))
      WRITE(6,795)
      WRITE(6,625) (N,N=1,NN)
      DO 805 M=1,NN
805  WRITE(6,400) TITLE2(M), (FB(M,N),N=1,NN)
      DO 141 J=1,NJJ
      IF(W1(J).LE.1.0) EK(J)=ZN1(J)*W1(J)**0.667
      IF(W1(J).GT.1.0) EK(J)=ZN1(J)*W1(J)**.50
141  CONTINUE
      DO 142 J=1,NM
      IF(W2(J).GT.1.0) EKR(J)=ZN2(J)*W2(J)**0.50
      IF(W2(J).LE.1.0) EKR(J)=ZN2(J)*W2(J)**0.667
142  CONTINUE
      WRITE(6,495)
495  FORMAT (/21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE ONE ICBM
      1S VS SIDE TWO DEFDRS. ) ***/5X,14HSIDE ONE ICBMS,26X,26HSIDE TWO D
      2EFDRS. (ACROSS)/9X,6H(DOWN))
625  FORMAT ( /12X,12(4X,I6))
      WRITE(6,625) (K,K=1,NK)
      DO 606 J=1,NJJ
606  WRITE(6,400) TITLE1(J), (P(J,K),K=1,NK)
      DO 155 I=NI1,NM
155  S(I) = RF(I)
      DO 160 I=1,NI
      DO 160 J=1,NJ
      FLNS(I,J) = E(J) * ALOG(SS(I,J))
160  CONTINUE
      DO 165 J=1,NJJ
      DO 165 K=1,NK

```



```

165 C(J,K) = AN(J,K) * ALOG(P(J,K))
    WRITE(6,9000)
C
C --(3-5)- SIDE ONE OFFENSIVE INVENTORY USED FOR OTHER TARGETS
C
    READ(5,2) (UU(I),I=1,NJJ)
    WRITE(6,20)
    WRITE(6,4) (UU(I),I=1,NJJ)
    DO 143 J=1,NJJ
    IF( UU(J).LT.EM(J) ) EM(J) = EM(J) - UU(J)
143 CONTINUE
    DO 147 J=1,NJJ
147 EM(J)=R3B(J)*EM(J)
    WRITE(6,9000)
    NU8 = 1
    WRITE(6,797)
C
C --(3-6)-STRATEGIES TO BE INVESTIGATED (RATIO OF K2/K1)
C
    READ(5,2) (RAT(I),I=1,10)
    DO 799 I=1,NU4
799 WRITE(6,798)I,RAT(I)
797 FORMAT( //10X,28HRATIOS SELECTED FOR STRATEGY/15X,21HCASE VALU
1E(K2/K1))
798 FORMAT( 16X,I2,5X,E12.4)
    IF( RAT(1).GT.1.E+7)PRFBET = 100.
    IF( RAT(1).GT.1.E+7)PREFER=0.
    IF( RAT(1).GT.1.E+7) GO TO 937
    PREFER = 100.
    PRFBET = PREFER * RAT(1)
937 CONTINUE
    WRITE (6,655)
    WRITE(6,9000)
241 FORMAT(1H[,4X,17HDEFENSIVE SYSTEMS)
    WRITE(6,241)
    WRITE(6,221)
    WRITE(6,15)
    DO 130 I=1,NL
C
C --(3-7)-SIDE ONE RELIABLE DEFENSIVE WEAPONS SYSTEMS INVENTORY FOR
C -----POPULATION CLASS L -----
C
    READ(5,2) (DP(I,J),J=1,NN)
    WRITE(6,4) (DP(I,J),J=1,NN)
130 CONTINUE
    WRITE(6,216)
    WRITE(6,24)
C
C --(3-8)-SIDE TWO OFFENSIVE SYSTEMS FORCE RELIABILITY --
C
    READ(5,2) (RD(K),K=1,NK)
    WRITE(6,4) (RD(K),K=1,NK)
    IF(ND.EQ.NK) GO TO 253
    IF(ND.GT.0.AND.ND.LT.NK) ND3 = ND + 1
    IF(ND.LE.0) ND3 = 1
    DO 263 I=1,NII
C
C --(3-9)-SIDE TWO DEFENSIVE WEAPONS INVENTORY FOR SIDE TWO WEAPONS

```

```

C -----NOT ATTACKED BY SIDE ONE -----
C
263 READ(5,2) (DL(I,K),K=ND3,NK)
    IF(ND.LE.0) GO TO 107
C
C --(3-10)-SIDE ONE OFFENSIVE WEAPON SURVIVAL PROBABILITY VS. SIDE TWO
C -----DEFENSE INSTALLATION DEFENDERS ---
C
253 READ(5,2) (PSUR(K),K=1,ND)
    WRITE(6,971)
971 FORMAT(/10X,49HSURVIVAL PROB. OF SIDE ONE OFFS. VS. BASE DEFORS.)
    WRITE(6,4) (PSUR(K),K=1,ND)
C
C **** COMPUTATION OF MAXIMUM DAMAGE CURVE *****
C
    C1 = ( SQRT(5.) - 1.) / 2.
    C2 = 1. - C1
    DO 500 K=1,ND
    DO 500 I=1,NII
    L0 = 1
    WRITE(6,803) I,K
C
C --(3-11-1)-SIDE TWO RESOURCE I NO OF DEFENSE INSTALLATIONS
C
    READ(5,1) NBASE,IFIT,LL0,LL1
C
C ----- USER FITS CURVE OVER INTERVAL (LL0,LL1) IF IFIT = 1
C
    IF(NBASE.LE.0) Q(I,K) = 1.
    IF(NBASE.LE.0) DL(I,K) = .01
    IF(NBASE.LE.0) GO TO 500
    NIK = NBASE
    WRITE(6,256) K, I, NIK
256 FORMAT(1H0,4X,15HDEF. WEAP. TYPE,I3,31H REGION OR CITY CLASS DEFE
1NDED,I3,38H NO. OF BASES DEFENDED BY WEAP. TYPE,I3)
    IF(IFIT.EQ.1) L0=LL0
    IF(IFIT.EQ.1) NFIN = LL1
    IF(IFIT.EQ.1) WRITE(6,977) LL0,LL1
977 FORMAT(/10X,47HUSER CHOOSES TO FIT CURVE USING STARTING POINT ,I3
1 ,15H AND END POINT ,I4)
    SUM = 0.
    WRITE(6,261)
261 FORMAT(1H0,9X,106HBASE NO.    HARDNESS(PSI)    NO. OF DEFORS. OF BAS
1E    NO. DEFORS. AT BASE    DEFENDED BASE    UNDEFENDED BASE/84X,31H
2SURVIVAL PROB.    SURVIVAL PROB.)
    DO 210 J=1,NIK
C
C --(3-11-2)-SIDE TWO DEFENSE INSTALLATION INFORMATION
C
    READ(5,2) HARD(J),DCAP(J),ACAP(J)
    TERM = 2.0 * (W1(K)**.333) * ( HARD(J)-7.37) ** (-0.352)
    SPRIME(J) = .5 ** ((FFP(K)) * ( TERM / CFP(K)) **2)
    ORAR(J) = (1. - SPRIME(J)) * ( RD(K) * (PSUR(K) -1.) + 1.)
    IF(ACAP(J).LT.1.) CBAR(J) = 1. - SPRIME(J)
    EUN(J) = DCAP(J)
    VAL=1-ORAR(J)
    WRITE(6,266) J,HARD(J),ACAP(J),DCAP(J),VAL,SPRIME(J)
266 FORMAT(1H ,15X,I2,10X,F6.2,12X,F5.1,16X,F6.1,14X,F5.4,12X,F5.4)

```

```

210 SUM = SUM + EJJ(J)
    EBAR = SUM
    OL(I,K) = SUM
    DO 230 N=1,100
        BIG = 0.
        DO 220 J=1,NIK
            TERM = EJJ(J) * OBAR(J)
            IF(TERM.GT.BIG) JMAX = J
            IF(TERM.GT.BIG) BIG = TERM
220 CONTINUE
        EBAR(N) = SUM - BIG
        EJJ(JMAX) = EJJ(JMAX) - BIG
        SUM = EBAR(N)
        ACAP(JMAX) = ACAP(JMAX) - 1.
        IF(ACAP(JMAX).EQ.0.) OBAR(JMAX) = 1. - SPRIME(JMAX)
        IF(IFIT.EQ.1) GO TO 230
        IF(SUM.LT.1.) NFIN = N
        IF(SUM.LT.1.) GO TO 240
230 CONTINUE
        NFIN = 1000
        IF(IFIT.EQ.1) NFIN=LL1
C
C **** LEAST SQUARES FIT TO MAX. LIM. CURVE USING FIBONACCI SEARCH ****
C
240 TU = 1.
    TL = 0.
    TB = C1
    TA = C2
    ISET = 1
    VALB = 0.
    DO 305 N=LO,NFIN
305 VALB = VALB + ( EBAR * TB**N - EBAR(N))**2
    DO 410 L=1,6
        IF(ISET-2) 340,310,310
310 VALB = 0.
        DO 330 N=LO,NFIN
330 VALB = VALB + ( EBAR * TB**N - EBAR(N))**2
        IF(ISET-2) 340,360,340
340 VALA = 0.
        DO 350 N=LO,NFIN
350 VALA = VALA + ( EBAR * TA**N - EBAR(N))**2
360 IF(VALA - VALB) 370,390,380
370 TU = TB
    TB = TA
    TA = TL + C2 * (TU - TL)
    VALB = VALA
    ISET = 1
    GO TO 410
380 TL = TA
    TA = TB
    TB = TL + C1 * (TU - TL)
    VALA = VALB
    ISET = 2
    GO TO 410
390 TL = TA
    TU = TB
    IF (ABS(TL / TU - 1.) .LE. 1.E-3) GO TO 450
    TA = TL + C2 * (TU - TL)

```

```

      TB = TL + C1 * (TU - TL)
      ISET = 3
411 CONTINUE
422 FORMAT(1H0,6E16.8)
452 Q(I,K) = (TL + TU) / 2.
      WRITE(6,271)
271 FORMAT(1H0,38X,51HEXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK S
      IZE/38X,48HNO. ATTACKERS EXP. NO. SURV. CURVE FIT VALUE)
      DO 476 N= 1,NFIN
      VAL = EBARC * Q(I,K)**N
476 WRITE(6,276)N,FBAP(N),VAL
276 FORMAT(1H ,43X,I3,9X,F9.2,9X,F9.2)
500 CONTINUE
107 WRITE(6,9)
      WRITE(6,625)(K,K=1,NK)
      DO 806 I=1,NII
806 WRITE(6,825)I,(DL(I,K),K=1,NK)
      DO 100 I=1,NII
      DO 100 K=1,NK
      DL(I,K) = RD(K) * DL(I,K)
100 Q(I,K) = DL(I,K)
      IF(ND.LE.0) GO TO 1000
      DO 105 I=1,NII
      DO 105 K=1,ND
105 B1(I,K) = ALOG(Q(I,K))
      WRITE(6,193)
193 FORMAT(1H0, 41HCURVE FIT VALUES FOR Q(I,K), K(ACROSS) , I(DOWN))
      WRITE(6,625)(K,K=1,ND)
825 FORMAT( 7X,I6,12(4X,F6.1))
925 FORMAT( 7X,I6,12(4X,F6.4))
      DO 841 I=1,NII
841 WRITE(6,925)I,( Q(I,K),K=1,ND)
      WRITE(6,9000)
1000 IF(NU1.EQ.1) CALL STARTB
      RETURN
1 FORMAT(14I5)
2 FORMAT(10F8.0)
3 FORMAT(1H0,4X,9HSIDE 2 --,I7,11H OF TARGETS,10X,I7,8H TARGETS,
1 9X,I7,13H WEAPON TYPES,I7,15H DEFENDER TYPES //
2 5X,9HSIDE 1 --,I7,21H CF + CV WEAPON TYPES,I7,
3 17H GEOGRAPHIC AREAS,I7,13H WEAPON TYPES,I7,
4 15H DEFENDER TYPES)
4 FORMAT( 8X,10F12.4)
5 FORMAT(1H0,4X,39HFITTING CONSTANTS FOR SIDE 2 POPULATION)
6 FORMAT(1H0,4X,39HFITTING CONSTANTS FOR SIDE 1 POPULATION)
7 FORMAT(1H0,4X,41HFRACTION OF SIDE 2 POPULATION IN ITH AREA)
8 FORMAT(1H0,4X,41HFRACTION OF SIDE 1 POPULATION IN LTH AREA)
9 FORMAT(1H0,4X,47HNUMBER OF K TH TYPE SIDE 2 DEFDS. (ACROSS) OF,
123HI TH TYPE TARGET (DOWN))
10 FORMAT(4F8.0 ,A6)
11 FORMAT(1H0,4X,11HSIDE 2 TYPE,I2,22H WEAPON -- NUMBER ,F7.2,14H
1 RELIABILITY,F7.4,16H WARHEAD YIELD, F7.2, 18H
2 NO. OF WARHEADS,F7.2/ 5X,7HNAME - ,A6)
12 FORMAT(1H0,4X,44HSINGLE SHOT SUPVIVAL PROBABILITY ENGAGED BY ,
1 24HSIDE 1 NTH TYPE DEFENDER)
13 FORMAT(1H0,4X,35HSIDE 1 OFFENSE ALLOCATION CONSTANTS)
14 FORMAT(1H0,4X,37HSIDE 2 OFFENSIVE ALLOCATION CONSTANTS)
15 FORMAT(1H0,4X,44HNUMBER OF RELIABLE SIDE 1 DEFENDERS OF SIDE ,

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1          12H1 LTH TARGET)
16 FORMAT(1H0,4X,11H SIDE 1 TYPE,I2,24H WEAPON --NO. OF WEAPONS,F7.2,
114H RELIABILITY,F7.4,34H NO. OF IND. TARGETABLE WARHEADS,F7.2,
216H WARHEAD YIELD,F7.2/5X,7H NAME - ,A6,18H NO. OF WARHEADS,F7.
32)
17 FORMAT(1H0,4X,48H SINGLE SHOT SURVIVAL PROB. WHEN ENGAGED BY SIDE
1          ,19H2 KTH TYPE DEFENDER)
18 FORMAT(1H0,4X,35H SIDE 2 DEFENSE ALLOCATION CONSTANTS)
19 FORMAT(1H0,4X,46H SINGLE SHOT SURVIVAL PROB. OF SIDE 2 MTH TYPE
1          47H RETALIATOR ATTACKED BY SIDE 1 JTH TYPE ATTACKER)
20 FORMAT(1H0,4X,47H NUMBER OF EACH SIDE 1 WEAPON ASSIGNED TO OTHER ,
1          16H MILITARY TARGETS)
21 FORMAT(1H0,4X,6H PREFER,F7.2 ,7H PREFIN,F7.2 ,7H PREINC,F7.2 ,
1          4H PHI,F7.4 ,7H PREBET,F7.2 ,7H TL,F7.2 ,4H EPS,
2F7.4)
23 FORMAT(1H0,4X,32H NO. SIDE 2 OFFS. TYPE I WEAPONS)
24 FORMAT(1H0,4X,40H PFLIABILITY OF KTH TYPE SIDE 2 DEFENDER)
25 FORMAT(1H0,4X,5H NDEFS,I2,9H IP1=,I2,6H NU1=,I2,6H NU3=,I2,6H
1 NU4=,I2)
655 FORMAT (1H1)
660 FORMAT (29X,62H*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM)
1*****,,//45X,34H ALLOCATION OPTIMIZATION MODEL )
91 FORMAT(5E8.0 ,A8)
94 FORMAT(7E8.0 ,A8)
92 FORMAT(1H0,4X,11H SIDE 2 TYPE,I2,22H WEAPON -- NUMBER ,F7.2,14H
1 RELIABILITY,F7.4,16H WARHEAD YIELD,F7.2,9H P.S.I.,F7.2,18H
2 NO. OF WARHEADS,F7.2/ 5X,7H NAME - ,A6)
93 FORMAT(1H0,4X,11H SIDE 1 TYPE,I2,24H WEAPON --NO. OF WEAPONS,F7.2,
114H RELIABILITY,F7.4,34H NO. OF IND. TARGETABLE WARHEADS,F7.2,
216H WARHEAD YIELD,F7.2/5X,7H NAME - ,A6,9H C.E.P.,F7.2,26H NO
3. OF CLUSTER WARHEADS,F7.2,18H NO. OF WARHEADS,F7.2)
803 FORMAT( 1H0,5X,14I5)
9000 FORMAT( //132H *****
1*****
2*****
END

```

SUBROUTINE RESTNT(MT,VAL)

```

C
C ---- THIS SUBROUTINE GIVES THE VALUES OF THE CONSTRAINTS AND OBJECT--
C -----IVE FUNCTION -----
C
COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONE/NI,NJ,NII,NJJ,MM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
1,IEX,IEX1,IEXN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOP8(2),DL(9,7),ENL(10),RB(10),
1EKB(10),TITLE2(10),P(15,7),AB(10,15),E(2,10),DE(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(13,15),AN(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PREFET,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),D(9,7),EN(10),C(9,5),U(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),EETA(6),Y(6),
1RETAB(2),YP(2),BETP,RET
COMMON/SEVEN/CFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETFP(6),BETBPP(2)
COMMON/EIGHT/CSX(5,6),DSD(5,7),DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),CF2D(10,5,7),DYBX(2,5,6),CYBD(2,5,7)
COMMON/NINE/CBBX(5,6),CBBD(5,7)
IF(MT.EQ.1) CALL IDENTV
IF(MT-1)900,1,1
1 IF(I1.EQ.0) GO TO 2
IF(MT-I1)100,100,2
2 IF(I1.EQ.NJ) GO TO 3
IF(MT-I2)200,200,3
3 IF(I2.EQ.NJJ) GO TO 1000
IF(MT-I3)300,300,1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES -----
C
100 J=MT
SUM=0.
DO 110 I=1,NII
110 SUM = SUM + XX(I,J)
IF(J.EQ.1) GO TO 150
IF(ND2.NE.2) GO TO 130
DO 120 I=1,NII
120 SUM = SUM + U(I,J+1) + U(I,J+2)
GO TO 190
130 DO 140 I=1,NII
140 SUM = SUM + U(I,J+ND1-1)
GO TO 190
150 DO 160 I=1,NII
DO 160 K=1,NP1
160 SUM = SUM + U(I,K)
GO TO 190
190 VAL = EM(J) - SUM
GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
200 J=MT
SUM=0.
DO 210 I=1,NII

```

```

210 SUM=SUM+XX(I,J)
   VAL=EM(J)-SUM
   GO TO 1000

```

```

C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C

```

```

300 J=MT
   SUM = 0.
   DO 310 I=NI1,NII
310 SUM=SUM+XX(I,J)
   VAL=EM(J)-SUM
   GO TO 1000

```

```

C
C ----- OBJECTIVE FUNCTION (K1 BETABAR - K2 BETA) -----
C

```

```

900 CALL FRACIS
   VAL = PREFER*BETP-PREBET* BET
1000 RETURN
   END

```

```

      GO TO 1200
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
200 J=MT
   DO 210 I=1,NII
      N=(J-1)*NII+I
210 DEL(N) = -1.
   GO TO 1200
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C
300 J=MT-I2
   DO 310 I=1,NI2
      L=NIIJ+(J-1)*NI2+I
310 DEL(L)=-1.
   GO TO 1200
C
C ----- OBJECTIVE FUNCTION      (K1 BETABAR - K2 BETA) -----
C
900 CALL IDENTV
   CALL FRACTS
   WRITE(6,442)BET,BETB
   CALL DERB
   CALL DERBB
442 FORMAT( /10X,4HBET=,E11.4,8H   BETB=,E11.4)
   IF(NU3.NE.1) GO TO 409
   WRITE(6,438)
438 FORMAT( 30X,11HALLOCATIONS)
   DO 401 I=1,NI
401 WRITE(6,437) ( XX(I,J),J=1,NJ)
   DO 402 I=NI1,NII
402 WRITE(6,437) ( XX(I,J),J=1,NJJ)
   IF(ND.LE.1) GO TO 409
   DO 403 I=1,NII
403 WRITE(6,437) (U(I,K),K=1,ND)
409 DO 410 J=1,NJ
   DO 410 I=1,NI
      N=(J-1)*NII+I
410 DEL(N) = PREFER * DBX(I,J)
   DO 420 I=1,NI2
   DO 420 J=1,NJ
      N=(J-1)*NII+I+NI
420 DEL(N) =-PREBET * DBX(I,J)
   DO 430 J=1,NJ2
      N=NIIJ+(J-1)*NI2+I
430 DEL(N) =-PREBET * DBX(I,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
   IF(ND.LE.0) GO TO 1000
   DO 450 K=1,ND
   DO 440 I=1,NI
      N= IEX + (I-1) * ND + K
440 DEL(N) = PREFER * DBD(I,K) * B1(I,K) * D(I,K)
   DO 450 I=NI1,NII
      N=IEX + (I-1) * ND + K
450 DEL(N) =-PREBET* DBD(I-NI,K) * B1(I,K) * D(I,K)

```


SUBROUTINE GRAD1(MT)

C
C ---- THIS SUBROUTINE CALCULATES THE GRADIENT VECTOR OF THE CONSTRAINTS
C ----- AND OBJECTIVE FUNCTION -----
C

```

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/NI, NJ, NII, NIJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NOEFS, NOOFFS, NA, NU1, NU2, NU3
2, IP1, ND1, NU4, NU5, NU6, NU7, NU8, ND1, ND2
COMMON/TWO/AA(6), AAP(2), FPOP(6), FPOP8(2), OL(9,7), ENL(10), RB(10),
1EKB(10), TITLE2(10), P(15,7), AB(10,15), R(2,10), DB(2,10), FM(15),
2E(15), EK(15), TITLE1(15), PR(10,15), AN(15,7), SS(5,6), LU(15)
COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
COMMON/FIVE/XX(9,15), D(9,7), EN(10), O(9,5), U(9,7)
COMMON/SIX/Z(9,7), ZP(2,10), F(9,15), S(10), FP(2,10), EFTA(6), Y(6),
1BETAB(2), YB(2), BETR, BET
COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), CYX(6,15), DEX(6,15),
1DYD(6,7), DED(6,7), BETBF(2), BETPP(6), BETBPP(2)
COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), CYBC(2,5,7)
COMMON/NINE/DBBX(5,6), DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15), DBXD(90,7), DBDD(30,5)
COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSDO(6,5)
COMMON/FOURTN/DBBXX(30,30), DBBXD(30,35), DBBDD(30,30), D2YB(2)
437 FORMAT( 1,F13.3)
DO 10 I=1,IFC
1 DEL(I)=1.
IF(MT-1)GO TO 1,1
1 IF(I1.EQ.0) GO TO 2
IF(MT-I1)100,100,2
2 IF(I1.EQ.NJ) GO TO 3
IF(MT-I2)200,200,3
3 IF(I2.EQ.NJJ) GO TO 1000
IF(MT-I3)300,300,1000

```

C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES -----
C

```

100 J=MT
DO 110 I=1,NII
L=(J-1)*NII+I
110 DEL(L)=-1.
IF(J.EQ.1) GO TO 150
IF(ND2.NE.2) GO TO 130
DO 120 I=1,NII
DO 120 K=1,ND2
M= IEX + (I-1) * ND + K + J
120 DEL(M) = -1.
GO TO 100
130 DO 140 I=1,NII
M=IEX + (I-1) * ND + J + ND1 - 1
140 DEL(M) = -1.
GO TO 100
150 DO 160 I=1,NII
DO 160 K=1,ND1
M= IEX + (I-1) * ND + K
160 DEL(M) = -1.

```

GO TC 1000
1000 RETURN
END

SUBROUTINE MATRIX(MT,IK)

```

C
C ---- THIS SUBROUTINE CALCULATES THE MATRIX OF SECOND PARTIAL DERIV-
C ----- ATIVES OF THE CONSTRAINTS AND OBJECTIVE FUNCTION -----
C
COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IEJ,IFN
1,IEX1,IEYEN,I1,I2,I3,I4,I5,I6,I7,NDOFFS,NCOFFS,NA,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),OL(9,7),ENL(10),R9(10),
1EKP(10),TITLE2(10),P(15,7),A3(10,15),B(2,10),DB(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(10,15),AM(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PREFET,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),Q(9,7),EN(10),Q(9,5),U(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
1BETA9(2),YP(2),BETP,BET
COMMON/SEVEN/DFX(9,15,15),DFQ(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
COMMON/EIGHT/DSX(5,6),DSQ(5,7),DF1X(10,5,6),DF2X(10,5,6),
1DF1Q(10,5,7),DF2Q(10,5,7),DYEX(2,5,6),DYBD(2,5,7)
COMMON/NINE/DBX(5,6),DBBD(5,7)
COMMON/ELEVEN/DBXX(9,15),DBXD(9,7),DBDD(30,5)
COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
COMMON/FOURTEEN/DBPXX(30,30),DBRXD(30,35),DBRDD(30,33),D2YB(2)
IF(MT-1)900,1,1
1 IF(I1.EQ.0) GO TO 2
IF(MT-I1)100,100,2
2 IF(I1.EQ.NJ) GO TO 3
IF(MT-I2)200,200,3
3 IF(I2.EQ.NJJ) GO TO 1000
IF(MT-I3)300,300,1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES -----
C
100 IK=1
GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
200 IK=1
GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C
300 IK=1
GO TO 1000
C
C ----- OBJECTIVE FUNCTION (K1 BETABAR - K2 BETA) -----
C
900 CALL IDENTV
CALL FRACFS
CALL DERP
CALL DERBE
CALL DER2E
CALL DER2S
CALL DER2EB

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IF(PREFER.EQ.0) GO TO 915
DO 917 JJ=1,NJ
DO 916 I=1,NI
NN2=(JJ-1)*NI+I
LROW=(JJ-1)*NII+I
DO 917 J=JJ,NJ
DO 913 K=I,NI
M=(J-1) * NI + K
LCOL=(J-1)*NII+K
913 A(LROW,LCOL)= PREFER *DBXX(NN2,M)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 915
DO 916 II=1,NI
DO 916 K=1,ND
NN3=(II-1)*ND + K
LCOL = IFX + NN3
916 A(LROW,LCOL) = PREFER * DBXD(NN2,NN3) * P1(II,K) * C(II,K)
917 CONTINUE
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 915
DO 912 I=1,NI
DO 912 J=1,ND
NN2 = (I-1) * ND + J
LROW = IFX + NN2
DO 912 K=I,NI
DO 912 KR=J,ND
NN3 = (K-1) * ND + KR
LCOL = IFX + NN3
TERM = 0
IF(I.EQ.K.AND.J.EQ.KR) TERM = DBBD(I,J)*P1(I,J)**2*C(I,J)
C
C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-47
C
912 A(LROW,LCOL) = PREFER*(DBDD(NN2,NN3)*D(I,J)*D(K,KR)*B1(I,J)*B1(K,
1KR) + TERM)
915 IF(PREBET.EQ.0) GO TO 1000
DO 925 JJ=1,NJ
DO 925 I=1,NI2
LROW=(JJ-1)*NII+NI+I
NN2=(JJ-1)*NI2+I
DO 917 J=JJ,NJ
LCOL=(J-1)*NII + NI + I
917 A(LROW,LCOL) = - PREBET * DBXX(NN2,J)
DO 919 J=1,NJ2
LCOL = NIIJ + (J-1) * NI2 + I
919 A(LROW,LCOL) = - PREBET * DBXX(NN2,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 925
DO 920 K=1,ND
LCOL = IFX + (NI+I-1) * ND + K
920 A(LROW,LCOL) = -PREBET * DBXD(NN2,K)*B1(NI+I,K)*C(NI+I,K)

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925 CONTINUE
DO 93 JJ=1,NJ2
DO 93 I=1,NI2
LROW=NIIJ+(JJ-1)*NI2+I
NN2=(JJ-1)*NI2+I+NJ
DO 926 J=JJ,NJ2
LCOL=NIIJ+(J-1)*NI2+I
926 A(LROW,LCOL)=-PREBT * DBXX(NN2,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 935
DO 928 K=1,NC
LCOL = IFX + (NI+I-1) * ND + K
928 A(LROW,LCOL) = -PREBT * DBXN(NN2,K) * P1(NI+I,K)*D(NI+I,K)
93 CONTINUE
C
C --- IF NO ATTACK ON DEFENSES RYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 1000
DO 940 I=NI1,NIJ
DO 940 KK=1,NC
LROW = IFX + (I-1) * ND + KK
NN2 = ( I - 1 ) * ND + KK - ND * NI
DO 970 K=KK,NC
LCOL = IFX + (I-1) * ND + K
TERM = 0.
IF(K.EQ.KK) TERM = DBD(I-NI,K) * P1(I,K)**2 * D(I,K)
C
C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CP-43
C
935 A(LROW,LCOL) = - PREBT * (DBD(NN2,K)*D(I,K)*D(I,KK)*B1(I,K)*P1(I,
KK) + TERM)
94 CONTINUE
1000 RETURN
END

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SUBROUTINE IDENTV

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C
C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-9. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C
COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
1,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NK,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWO/AA(6),AA3(2),FPOP(6),FPOP3(2),DL(9,7),ENL(10),RB(10),
1EKR(10),TITLF2(10),D(15,7),AB(10,15),B(2,10),DB(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PRERET,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CB(10,15),FLMS(5,6)
COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
13ETAR(2),YB(2),BETP,BET
COMMON/SEVEN/CFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DEX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETFP(6),BETBFP(2)
COMMON/EIGHT/DSX(5,6),DSO(5,7),DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),DF2D(10,5,7),DYEX(2,5,6),CYBD(2,5,7)
COMMON/NINE/DEEX(5,6),DBBD(5,7)
C **THIS SUBROUTINE IDENTIFIES MODEL VARIABLES WITH SUMT VARIABLES XXX
DO 10 J=1,NJ
JJ=(J-1)*NII
DO 10 I=1,NII
K=JJ+I
10 XX(I,J)=X(K)
DO 20 J=1,NJ2
JJ = NIIJ+(J-1)*NI2
DO 20 I=NI1,NII
K=JJ+I-NI
L=NJ + J
20 XX(I,L)=X(K)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 60
DO 30 I=1,NII
C
C --- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-9.
C
II = (I-1) * ND + IFX
DO 30 K=1,ND
L=II+K
30 U(I,K) = X(L)
60 RETURN
END

```

SUEROUTINE FRACFS

```

C
C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C
COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
1EKB(10),TITLE2(10),P(15,7),AB(10,15),B(2,10),DE(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFFIN,PREINC,PBET,B1(9,5),R1(5)
COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),Q(9,7),EN(10),Q(9,5),U(9,7)
COMMON/SIX/Z(9,7),7B(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
13ETAB(2),YB(2),BETB,BET
COMMON/SEVEN/CFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DEX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
COMMON/EIGHT/CSX(5,6),DSN(5,7), DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),DF2D(10,5,7), DYEX(2,5,6),DYBD(2,5,7)
COMMON/NINE/DEEX(5,6),DBBD(5,7)
C
C** COMPUTE FRACTIONS F,S,AND FBAR ,BETA,BETAPAR, ALSO Z ZEAR Y YBAR
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 7
DO 5 I=1,NII
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CP-43 PART IV-B.
C
DO 5 K=1,ND
5 D(I,K) = DL(I,K) * EXP(B1(I,K)*U(I,K))
7 DO 30 J=1,NJ
DO 30 I=1,NI
SUM=0.
DO 20 K=1,NK
Z(I,K)=0.
DO 10 L=1,NJ
10 Z(I,K)= Z(I,K) + XX(I,L)*AN(L,K)
IF(Z(I,K).LE.0.)Z(I,K)=1.E-100
20 SUM= SUM+ C(J,K)*D(I,K)/Z(I,K)
IF(SUM .LE.-140.)SUM =-140.
IF(SUM .GT.140.)SUM =140.
30 F(I,J)= EXP(SUM)
DO 60 I=NI1,NII
DO 60 J=1,NJJ
SUM=0.
DO 50 K=1,NK
Z(I,K)=0.
DO 40 L=1,NJJ
40 Z(I,K)=Z(I,K)+ XX(I,L)*AN(L,K)
IF(Z(I,K).LE.0.)Z(I,K)=1.E-100
50 SUM=SUM+C(J,K)*D(I,K)/Z(I,K)
IF(SUM .LE.-140.)SUM =-140.
IF(SUM .GT.140.)SUM =140.
60 F(I,J)=EXP(SUM)

```

```

      DO 100 I=1,NI
      SUM=0.
      DO 90 J=1,NJ
90  SUM=SUM+XX(I,J)*F(I,J)*ELNS(I,J)
      SUM=SUM/EN(I)
      IF(SUM.LE.-140.)SUM=-140.
      IF(SUM.GT.140.)SUM=140.
100 S(I) = RR(I) * EXP(SUM)
      DO 140 L=1,NL
      DO 140 M=1,NM
      SUM2=0.
      DO 130 N=1,NN
      SUM1=0.
      DO 120 K=1,NM
120 SUM1=SUM1+S(K)*EN(K)*AP(K,N)
      ZR(L,N)= FPOP(L)* SUM1
      IF(ZB(L,N).LE.0.)ZB(L,N)=1.E-100
130 SUM2=SUM2+CB(M,N)*CB(L,N)/ZB(L,N)
      IF(SUM2.LE.-140.)SUM2=-140.
      IF(SUM2.GT.140.)SUM2=140.
140 FB(L,M)=EXP(SUM2)
      BET=0.
      DO 200 I=1,NI2
      Y(I)=0.
      DO 150 J=1,NJJ
150 Y(I)=Y(I)+F(NI+I,J)*XX(NI+I,J)*FK(J)
      IF(Y(I).LE.0.)Y(I)=1.E-100
      TERM=AA(I)*SQRT(Y(I))
      BETA(I)=1.-(1.+TERM)*EXP(-TERM)
200 BET=BET + FPOP(I)*BETA(I)
      BETB=0.
      DO 300 L=1,NL
      YB(L)=0.
      DO 250 M=1,NM
250 YB(L)=YB(L)+ FB(L,M)*S(M)*EN(M)*FKB(M)
      IF(YB(L).LE.0.)YB(L)=1.E-100
      YB(L) = FPOPB(L) * YB(L)
      TERM= AAB(L)*SQRT(YB(L))
      BETAB(L)=1.-(1.+TERM)*EXP(-TERM)
300 BETB=BETB + FPOPB(L)*BETAB(L)
      RETURN
      END

```


SUBROUTINE DERB

C
C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C

```
COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/ NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCCFFS, NN, NU1, NU2, NU3
2, IB1, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
COMMON/TWO/ AA(6), AAB(2), FPOP(6), FPOPR(2), DL(9,7), ENL(10), RB(10),
1EKB(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), LU(15)
COMMON/THREE/ PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
COMMON/FIVE/ XX(9,15), C(9,7), EN(10), O(9,5), L(9,7)
COMMON/SIX/ Z(9,7), ZB(2,10), F(9,15), S(10), FB(2,10), EETA(6), Y(6),
1BETAB(2), YE(2), BETR, BET
COMMON/SEVEN/ DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DBX(5,15),
1DYD(6,7), DBD(6,7), BETBP(2), BETPP(6), BETBPP(2)
COMMON/EIGHT/ DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
COMMON/NINE/ DBBX(5,6), DBRD(5,7)
```

C** COMPUTES FIRST DERIVATIVES OF BETA, ALSO DER. OF F ***

```
DO 30 I=1, NI
DO 30 J=1, NJ
DO 30 L=1, NJ
SUM=0.
DO 20 K=1, NK
20 SUM=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
30 DFX(I,J,L)=-SUM*F(I,J)
DO 60 I=NI1, NII
DO 60 J=1, NJJ
DO 60 L=1, NJJ
SUM=L.
DO 50 K=1, NK
50 SUM=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
60 DFX(I,J,L)=-SUM*F(I,J)
```

C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C

```
IF(ND.LE.0) GO TO 85
DO 70 I=1, NI
```

C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C

```
DO 70 J=1, NJ
DO 70 K=1, ND
70 DFD(I,J,K)=F(I,J)*C(J,K)/Z(I,K)
DO 80 I=NI1, NII
DO 80 J=1, NJJ
DO 80 K=1, ND
80 DFD(I,J,K)=F(I,J)*C(J,K)/Z(I,K)
85 DO 90 I=1, NI2
90 BETP(I)=AA(I)**2*EXP(-AA(I)*SQRT(Y(I)))/2.
DO 120 I=1, NI2
DO 120 J=1, NJJ
SUM=0.
```

```

      DO 110 K=1,NJJ
110  SUM=SUM+XX(NI+I,K)*DFX(NI+I,K,J) * EK(K)
      DYX(I,J)=SUM +F(NI+I,J)*EK(J)
120  DBY(I,J)=FFOP(I)*BETP(I)*DYX(I,J)
C
C --- IF NC ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
      IF(ND.LE.G) GC TO 150
C
C --- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 140 K=1,ND
      DO 140 I=1,NI2
      SUM=0.
      DO 130 J=1,NJJ
130  SUM=SUM+XX(NI+I,J)*CFD(NI+I,J,K) * EK(J)
      DYD(I,K)=SUM
140  DBD(I,K)=FFOP(I)*BETP(I)*DYD(I,K)
150  RETURN
      END

```

SUBROUTINE DFRBB

```

C
C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C
COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/ONF/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NJ2,NIIJ,IEX,IED,IEN
1,IFU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCCFFS,NA,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOP8(2),DL(9,7),ENL(10),RB(10),
1EKB(10),TITLE2(10),P(15,7),AB(10,15),B(2,10),DB(2,10),FM(15),
2F(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PREFT,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CR(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),L(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),EFTA(6),Y(6),
1BFTAB(2),YR(2),PET8,BET
COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),PETF(6),DYX(6,15),DBX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
COMMON/EIGHT/DSX(5,6),DSO(5,7), DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),CF2D(10,5,7), DYBX(2,5,6),DYBD(2,5,7)
COMMON/NINE/DBX(5,6),DBBD(5,7)
DO 80 M=1,NI
DO 20 J=1,NJ
SUM=0.
DO 10 L=1,NJ
10 SUM=SUM+XX(M,L)*DFX(M,L,J)*ELNS(M,L)
SUM=SUM+F(M,J)*ELNS(M,J)
20 DSX(M,J)=S(M)*SUM/EN(M)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.3) GO TO 80
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
DO 40 K=1,ND
SUM=0.
DO 30 L=1,NJ
30 SUM=SUM+XX(M,L)*DFD(M,L,K)*ELNS(M,L)
40 DSO(M,K)=S(M)*SUM/EN(M)
80 CONTINUE
DO 120 L=1,NL
DO 120 M=1,NM
DO 120 I=1,NI
DO 120 J=1,NJ
SUM=0.
DO 110 N=1,NN
110 SUM=SUM+CB(M,N)*CB(L,N)*AB(I,N)/ZB(L,N)**2
SUM=-FPOP8(L)*FB(L,M)*DSX(I,J)*EN(I)*SUM
GO TO(111,112),L
111 DF1X(M,I,J)=SUM
GO TO 120
112 DF2X(M,I,J)=SUM
120 CONTINUE
IF(ND.LE.0) GO TO 195
DO 140 L=1,NL

```

```

      DO 140 M=1,NM
      DO 140 I=1,NI
C
C --- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF PAC-CR-43 PART IV-B.
C
      DO 140 K=1,NO
      SUM=0.
      DO 130 N=1,NN
130 SUM=SUM+CB(M,N)*CB(L,N)*AB(I,N)/ZB(L,N)**2
      SUM=-FPOPP(L)*FB(L,M)*DSO(I,K)*EN(I) * SUM
      GO TO(131,132),L
131 DF1D(M,I,K)=SUM
      GO TO 140
132 DF2D(M,I,K)=SUM
140 CONTINUE
195 DO 230 L=1,NL
      DO 230 I=1,NI
      DO 230 J=1,NJ
      SUM=0.
      DO 220 M=1,NM
      GO TO (211,212),L
211 TEMP=DF1X(M,I,J)
      GO TO 220
212 TEMP=DF2X(M,I,J)
220 SUM=SUM+TEMP*S(M)*EN(M)*EKB(M)
      SUM=SUM+FB(L,I)*DSX(I,J)*EN(I)*EKB(I)
230 DYBX(L,I,J)=FPOPB(L)*SUM
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
      IF(ND.LE.0) GO TO 295
      DO 260 L=1,NL
      DO 260 I=1,NI
      DO 260 K=1,NO
      SUM=0.
      DO 250 M=1,NM
      GO TO (241,242),L
241 TEMP=DF1D(M,I,K)
      GO TO 250
242 TEMP=DF2D(M,I,K)
250 SUM=SUM+TEMP*S(M)*EN(M)*EKB(M)
      SUM=SUM+FB(L,I)*DSO(I,K)*EN(I)*EKB(I)
260 DYBD(L,I,K)=FFOPF(L)*SUM
295 DO 300 L=1,NL
300 BETBP(L)=AAB(L)**2*EXP(-AAB(L)*SORT(YB(L)))/2.
      DO 350 I=1,NI
      DO 350 J=1,NJ
      SUM=0.
      DO 340 L=1,NL
340 SUM=SUM+FFOPB(L)*BETBP(L)*DYBX(L,I,J)
350 DBRX(I,J)=SUM
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
      IF(ND.LE.0) GO TO 1000
      DO 370 I=1,NI
      DO 370 K=1,NO
      SUM=0.

```

```
00 360 L=1,NL
360 SUM=SUM+FPOP8(L)*BETBP(L)*DYBD(L,I,K)
370 DBBD(I,K)=SUM
1000 RETURN
END
```

SUBROUTINE DER2B

C
C
C
C

--- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
--- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----

```

COMMON/SHAPE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/CNE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
1,I EU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NA,NU1,NU2,NU3
2,I B1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
COMMON/TWC/AA(6),AAP(2),FPOF(6),FPOP(2),NL(9,7),ENL(10),RB(17),
1,EKB(10),TITLE2(10),F(15,7),AB(10,15),B(2,10),DB(2,10),EM(15),
2,E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RO(5)
COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),D(9,7),EN(10),G(9,5),U(9,7)
COMMON/SIX/Z(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
1,BETAB(2),YB(2),BETB,BET
COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
1,DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
COMMON/EIGHT/DSX(5,6),DSD(5,7), DF1X(10,5,6),DF2X(10,5,6),
1,DF1D(10,5,7),DF2D(10,5,7), DYEX(2,5,6),DYBD(2,5,7)
COMMON/NINE/DBEX(5,6),DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
COMMON/FOURTEEN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
DO 5 I=1,NI2
TERM = SQRT(Y(I))
IF (TERM) 4,3,4
3 BETPP(I)=-1.E+100
GO TO 5
4 BETPP(I)=-AA(I)*3*EXP(-AA(I)*TERM) / (4.*TERM)
5 CONTINUE
DO 70 I=NI1,NII
DO 50 J=1,NJJ
NN2 = ( J - 1 ) *NI2 + I - NI
DO 30 KR=1,NJJ
SUM=0.
DO 20 K=1,NJ
NN1=(K-1)*NII+I
20 SUM=SUM+DFXX(NN1,J,KR)* XX(I,K) * EK(K)
IF (NJ.EQ.NJJ) GO TO 25
DO 25 K=NJ1,NJJ
NN1=NIIJ+(K-1-NJ)*NI2+I-NI
25 SUM=SUM+DFXX(NN1,J,KR)*XX(I,K)*EK(K)
26 D2YXX=SUM+DFX(I,KR,J)*EK(KR)+DFX(I,J,KR)*EK(J)
III=I-NT
30 DBXX(NN2,KR)=FPOP(III)*(BETPP(III)*DYX(III,J)*DYX(III,KR)+BETP(III
1)*D2YXX)

```

C
C
C
C
C
C

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----

IF(ND.LE.0) GO TO 60

--- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.

```

DO 50 KR = 1,ND
SUM=0.

```

```

DO 40 K=1,NJ
NN1=(K-1)*NII+I
40 SUM=SUM+DFXD(NN1,J,KR)*XX(I,K)*EK(K)
IF(NJ.EQ.NJJ) GO TO 46
DO 45 K=NJ1,NJJ
NN1=NIIJ+(K-1-NJ)*NI2+I-NI
45 SUM=SUM+DFXD(NN1,J,KR)*XX(I,K)*EK(K)
46 D2YXD=SUM+DFD(I,J,KR)*EK(J)
K=I-NI
50 DBXD(NN2,KR)=FFOP(K)*(BETPP(K)*DYX(K,J)*DYD(K,KR)+BETP(K)*D2YXD)
60 CONTINUE

```

C
C --- IF NO ATTACK, ON DEFENSES BYPASS THIS SECTION -----
C

```

IF(ND.LE.0) GO TO 70
DO 56 K=1,ND

```

C
C --- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -----
C

```

NN2=(I-1)*NC*K-ND*NI
DO 56 KR=1,ND
SUM=0.
DO 54 J=1,NJ
NN1=(J-1)*NII+I
54 SUM=SUM+DFDC(NN1,K,KR)*XX(I,J)*EK(J)
IF(NJ.EQ.NJJ) GO TO 53
DO 52 J=NJ1,NJJ
NN1=NIIJ+(J-1-NJ)*NI2+I-NI
52 SUM=SUM+DFDC(NN1,K,KR)*XX(I,J)*EK(J)
53 D2YDD=SUM
TII=I-NI
56 DBDD(NN2,KR)=FFOP(III)*(BETPP(III)*DYD(III,K)*DYD(III,KR)+BETP(III)*D2YDD)
70 CONTINUE
RETURN
END

```

SUBROUTINE DER2S

C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C

COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
COMMON/CNE/NI,NJ,NII,NJJ,NM,NK,NL,NII,NJ1,NJ2,NIIJ,TEX,IED,IEN
1,IEU,TEX1,TEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
2,IB1,ND,NU4,NU5,NL6,NU7,NU8,NC1,ND2
COMMON/TWO/AA(6),AAB(2),FOP(6),FOPB(2),OL(9,7),ENL(10),RB(10),
1EKB(10),TITLE2(10),P(15,7),AB(10,15),R(2,10),DE(2,10),EM(15),
2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
COMMON/THREE/PREFER,PREFIN,PREINC,PPEET,B1(9,5),RD(5)
COMMON/FOUR/ C(15,7),CR(10,15),ELNS(5,6)
COMMON/FIVE/XX(9,15),C(9,7),EN(10),G(9,5),U(9,7)
COMMON/SIX/7(9,7),ZB(2,10),F(9,15),S(10),FB(2,10),EETA(6),Y(6),
1BETAB(2),YB(2),BETB,BFT
COMMON/SEVEN/CFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DEX(6,15),
1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
COMMON/FIGHT/CSX(5,6),DSO(5,7), DF1X(10,5,6),DF2X(10,5,6),
1DF1D(10,5,7),DF2D(10,5,7), DYBX(2,5,6),DYBD(2,5,7)
COMMON/NINE/DBPX(5,6),DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
COMMON/FOURTN/DBEXX(30,30),DBBXD(30,35),DBDDC(30,30),D2YB(2)
DO 40 M=1,NI
DO 40 K=1,NJ
NN2=(K-1)*NI+M
DO 40 L=1,NJ
IF(S(M)-C.)20,20,25
20 DSXX(NN2,L)=C.
GO TO 40
25 SUM=C.
DO 30 J=1,NJ
NN1=(J-1)*NII+M
30 SUM=SUM+XX(M,J)*DFXX(NN1,K,L)*ELNS(M,J)
DSXX(NN2,L)=DSX(M,L)*DSX(M,K)/S(M)+S(M)*(DFX(M,K,L)*ELNS(M,K)+
1DFX(M,L,K)*ELNS(M,L)+SUM)/EN(M)
40 CONTINUE

C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C

IF(ND.LE.0) GO TO 100
DO 90 M=1,NI
DO 70 K=1,NJ

C --- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C

NN2=(K-1)*NI+M
DO 70 L=1,ND
IF(S(M)-C.)45,45,50
45 DSXD(NN2,L)=C.
GO TO 70
50 SUM=0.
DO 60 J=1,NJ
NN1=(J-1)*NII+M
60 SUM=SUM+XX(M,J)*DFXD(NN1,K,L)*ELNS(M,J)

DSXD(NN2,L)=DSD(M,L)*DSX(M,K)/S(M)+S(M)*(DFD(M,K,L)*ELNS(M,K)+
1SUM)/EN(M)

70 CONTINUE

C

C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT

C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -----

C

DO 80 K=1,ND

NN2 = (M-1) * ND + K

DO 80 L=1,ND

IF(S(M)-C.)72,72,75

72 DSDD(NN2,L) = C.

GO TO 80

75 SUM = C.

DO 78 J=1,NJ

NN1=(J-1) * NII + M

78 SUM = SUM + XX(M,J) * DFD(NN1,K,L) * ELNS(M,J)

DSDD(NN2,L) = DSD(M,L) * DSD(M,K) / S(M) + S(M) + SUM / EN(M)

80 CONTINUE

90 CONTINUE

100 RETURN

END

SUEROUTINE DER2PP

C

C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART

C --- IV-3. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----

C

COMMON/SHARE/ X(10), DEL(10), A(10,10), NV, MC, MN, NP1, NM1
COMMON/CNE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
1, IEU, IEX1, IFXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCOFFS, NA, NU1, NU2, NU3
2, IRI, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2

COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOP8(2), DL(9,7), ENL(10), RB(10),
1EKB(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), LU(15)

COMMON/THREE/PREFER, PREFER, PREINC, PREDET, B1(9,5), RD(5)

COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)

COMMON/FIVE/XX(9,15), C(9,7), EN(10), O(9,5), U(9,7)

COMMON/SIX/Z(9,7), ZR(2,10), F(9,15), S(10), FB(2,10), BETA(6), Y(6),
1BETAB(2), YB(2), BETB, BET

COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DEX(6,15),
1DYD(6,7), DBD(6,7), BETBP(2), BETPP(6), BETBPP(2)

COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), CYBC(2,5,7)

COMMON/NINE/DBRX(5,6), DBBD(5,7)

COMMON/ELEVEN/CPXX(9,15), DBXD(9,7), DBDD(30,5)

COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSD(6,5)

COMMON/FOURTN/DBPXX(30,30), DBXD(30,35), DBPDC(30,30), D2YB(2)

DO 5 L = 1, NL

TERM = SQRT(YB(L))

IF (TERM - (.) 4, 3, 4

3 BETBPP(L) = -1.E+100

GO TO 5

4 BETBPP(L) = -AAB(L)**3*EXP(-AAB(L)*TERM)/(4.*TERM)

5 CONTINUE

DO 55 I=1, NI

DO 55 J=1, NJ

JN2 = (J-1)*NI + I

DO 57 K=1, NI

DO 31 KR=1, NJ

JN3 = (KR - 1) * NI + K

DO 20 L=1, NL

SUM = 0.

DO 10 M=1, NM

JN1 = (L-1)*NM + M

11 SUM = SUM + DFBXX(NN1, NN2, NN3)*S(M)*EN(M)*EKB(M)

GO TO (12, 14), L

12 TERM1L = DF1X(K, I, J)

TERM2L = DF1X(I, K, KR)

GO TO 15

14 TERM1L = DF2X(K, I, J)

TERM2L = DF2X(I, K, KR)

15 TERM2 = TERM1L*DSX(K, KR)*EN(K)*EKB(K)

TERM3 = TERM2L*DSX(I, J)*EN(I)*EKB(I)

TERM4 = 0.

IF (I.EG.K) TERM4 = FB(L, I)*EN(I)*EKB(I)*DSXX(NN2, KR)

20 D2Y3(L) = FPOP8(L)*(SUM+TERM2+TERM3+TERM4)

SUM = 0.

DO 25 L=1, NL

25 SUM = SUM + FPOP8(L)*(BETBPP(L)*DYBX(L, I, J)*DYBX(L, K, KR) + BETBP(L)*

```

102YB(L))
30 DBBX(NN2,NN3)=SUM
IF(ND.LE.1) GO TO 62
DO 50 KR=1,ND
IN3 = (K-1) * ND + KR
DO 50 L=1,NL
SUM=L.
DO 40 M=1,NM
NN1=(L-1)*NM+M
40 SUM=SUM+DFBXD(NN1,NN2,NN3)*S(M)*EN(M)*EKB(M)
GO TO(42,44),L
42 TERM1L=DF1X(K,I,J)
TERM2L=DF1D(I,K,KR)
GO TO 45
44 TERM1L=DF2X(K,I,J)
TERM2L=DF2D(I,K,KR)
45 TERM2=TERM1L *DSO(K,KR)*EN(K)*EKB(K)
TERM3=TERM2L *CSX(I,J)*EN(I)*EKB(I)
TERM4=L.
IF(I.EQ.K)TERM4=FB(L,I)*EN(I)*EKB(I)*DSXD(NN2,KR)
50 D2YB(L)=FFOPB(L)*(SUM+TERM2+TERM3+TERM4)
SUM=L.
DO 55 L=1,NL
55 SUM=SUM+FFOPB(L)*(BETBPP(L)*DYBX(L,I,J)*DYBD(L,K,KR)+BETBP(L)*
102YB(L))
60 DBBXD(NN2,NN3)=SUM
62 CONTINUE
65 CONTINUE

```

```

C
C --- IF NO ATTACK CN DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 100
C
C --- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43
C

```

```

DO 90 I=1,NI
DO 90 J=1,NJ
NN2 = (I-1) * ND + J
DO 90 KR=1,ND
IN3 = (K-1) * ND + KR
DO 80 L=1,NL
SUM=L.
DO 70 M=1,NM
NN1=(L-1)*NM+M
70 SUM=SUM+DFBXD(NN1,NN2,NN3)*S(M)*EN(M)*EKB(M)
GO TO(72,74),L
72 TERM1L=DF1D(K,I,J)
TERM2L = DF1D(I,K,KR)
GO TO 75
74 TERM1L=DF2D(K,I,J)
TERM2L=DF2D(I,K,KR)
75 TERM2=TERM1L *DSO(K,KR)*EN(K)*EKB(K)
TERM3=TERM2L *DSO(I,J)*EN(I)*EKB(I)
TERM4=L.
IF(I.EQ.K)TERM4=FB(L,I)*EN(I)*EKB(I)*DSOD(NN2,KR)
80 D2YB(L)=FFOPB(L)*(SUM+TERM2+TERM3+TERM4)

```

```

SUM=1.
DO 85 L=1,NL
85 SUM=SUM+FFCFB(L)*(BETBPP(L)*DYBD(L,I,J)*DYBD(L,K,KR)+BET9F(L)*
102Y9(L))
9J DBBTD(NN2,NN3)=SUM
100 RETURN
END

```

FUNCTION DFXD(NN1,L,KS)

C
C --- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----
C

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCOFFS, NN, NU1, NU2, NU3
2, IB1, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOP8(2), OL(9,7), ENL(10), RR(10),
1EKR(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), LU(15)
COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
COMMON/FOUR/ C(15,7), CB(10,15), FLNS(5,6)
COMMON/FIVE/XX(9,15), D(9,7), EN(10), G(9,5), U(9,7)
COMMON/SIX/Z(9,7), Z9(2,10), F(9,15), S(10), FR(2,10), BETA(6), Y(6),
1BETAB(2), YE(2), BETB, BET
COMMON/SEVEN/DFX(9,15,15), DFO(9,15,7), BETP(6), DYX(6,15), DBX(6,15),
1DYD(6,7), DBD(6,7), BETBP(2), BETPP(6), BETBPP(2)
COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
COMMON/NINE/DBBX(5,6), DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15), DEXD(90,7), DBDD(30,5)
COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSDD(6,5)
COMMON/FCURTN/DBEXX(30,30), DBBXD(30,35), DBBDC(30,30), D2YB(2)

C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C

IF(ND.LE.0) GO TO 100
IF(NN1-NIIJ) 8,8,7
7 J=NJ + (NN1-NIIJ-1)/NI2 + 1
I=NI + (NN1-NIIJ) - (J-NJ-1)*NI2
GO TO 9
8 J=(NN1-1)/NII+1
I=NN1-(J-1)*NII
9 SUP=0.
DO 70 K=1,NK
70 SUP=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
DFXD=-DFD(I,J,KS)*SUM-F(I,J)*C(J,KS)*AN(L,KS)/Z(I,KS)**2
100 RETURN
END

FUNCTION CFDD(NN1,L,KS)

C
C --- THESE ARE SECCND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -----
C

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IEO, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NOEFS, NCOFFS, NA, NU1, NU2, NU3
2, I81, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOP8(2), DL(9,7), ENL(10), RB(10),
1EK2(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), UU(15)
COMMON/THREE/PREFER, PREFIN, PREINC, PRERET, B1(9,5), RD(5)
COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
COMMON/FIVE/XX(9,15), O(9,7), EN(10), Q(9,5), U(9,7)
COMMON/SIX/Z(9,7), 7B(2,10), F(9,15), S(10), FB(2,10), BETA(6), Y(6),
1BETA9(2), YB(2), BETB, RET
COMMON/SEVEN/CFX(9,15,15), DFD(9,15,7), BETP(6), OYX(6,15), DBX(6,15),
1DYD(6,7), DBD(6,7), BETBP(2), BETPP(6), BETBPP(2)
COMMON/EIGHT/CSX(5,6), OSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
COMMON/NINE/DBBX(5,6), DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15), DBXD(90,7), DBDD(30,5)
COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSDD(6,5)
COMMON/FOURTN/DBPXX(30,30), DBBXD(30,35), DBBD0(30,30), D2YB(2)

C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C

IF(ND.LE.0) GO TO 100
IF(NN1-NIIJ)8,8,7
7 J=NJ + (NN1-NIIJ-1)/NI2 + 1
I=NI + (NN1-NIIJ) - (J-NJ-1)*NI2
GO TO 9
8 J=(NN1-1)/NII+1
I=NN1-(J-1)*NII
9 DFDD = F(I,J)*C(I,J,L)*C(J,KS) / (Z(I,L)*Z(I,KS))
100 RETURN
END

FUNCTION DFBXX(NN1,NN2,NN3)

C
C
C
C

--- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
--- IV-9. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----

```

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCOFFS, NA, NU1, NU2, NU3
2, IB1, ND, NU4, NU5, NU6, NU7, NU8, NC1, NO?
COMMON/TWC/AA(6), AAB(2), FPOP(6), FPOPB(2), OL(9,7), ENL(10), RB(10),
1EKB(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), LU(15)
COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), R0(5)
COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
COMMON/FIVE/XX(9,15), D(9,7), EN(10), O(9,5), U(9,7)
COMMON/SIX/Z(9,7), ZB(2,10), F(9,15), S(10), FB(2,10), EETA(6), Y(6),
19ETAB(2), YB(2), BETB, BET
COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DBX(6,15),
10YD(6,7), DBD(6,7), BETBP(2), BETPP(6), BETBPP(2)
COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
10F1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
COMMON/NINE/DPBX(5,6), DBBD(5,7)
COMMON/ELEVEN/DBXX(90,15), DBXD(90,7), DBDD(30,5)
COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSDD(6,5)
COMMON/FOURTN/DBBXX(30,30), DBBXD(30,35), DBBDD(30,30), D2YB(2)
L=(NN1-1)/NM+1
M=NN1-(L-1)*NM
J=(NN2-1)/NI+1
I=NN2-(J-1)*NI
KR=(NN3-1)/NI+1
K=NN3-(KR-1)*NI
SUM1=0.
SUM2=0.
DO 10 N=1,NN
TERM=CB(M,N)*DB(L,N)*AB(I,N)
SUM1=SUM1+TERM/ZB(L,N)**2
10 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3
TERML=DF1X(M,K,KR)
IF(L.EQ.2)TERML=DF2X(M,K,KR)
TERM1=-TERML*DSX(I,J)*EN(I)*SUM1
TERM2=0.
IF(I.EQ.K)TERM2=-FB(L,M)*DSXX(NN2,KR)*EN(I)*SUM1
TERM3=2.*FPOPB(L)*EN(I)*EN(K)*DSX(I,J)*DSX(K,KR)*FB(L,M)*SUM2
DFBXX=FPCFB(L)*(TERM1+TERM2+TERM3)
RETURN
END

```

FUNCTION DFBX0(NN1,NN2,NN3)

--- THESE COMPUTATIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
 --- IV-B. WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -----

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
 COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
 1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCOFFS, NA, NU1, NU2, NU3
 2, I21, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
 COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOP8(2), DL(9,7), ENL(10), RB(10),
 1FKB(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DB(2,10), EM(15),
 2E(15), FK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), UU(15)
 COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
 COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
 COMMON/FIVE/XX(9,15), D(9,7), EN(10), O(9,5), U(9,7)
 COMMON/SIX/Z(9,7), ZB(2,10), F(9,15), S(10), FB(2,10), BETA(6), Y(6),
 1BETAB(2), YB(2), BETB, BET
 COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), RETP(6), DYX(6,15), DBX(6,15),
 1DYD(6,7), DBD(6,7), RETBP(2), BETPP(6), BETBPP(2)
 COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
 1DF1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
 COMMON/NINE/DBPX(5,6), DBBD(5,7)
 COMMON/ELEVEN/CBXX(90,15), DBXD(90,7), DBDD(30,5)
 COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSDD(6,5)
 COMMON/FOURTN/DBBXX(30,30), DBBXD(30,35), DBBDD(30,30), D2YB(2)

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----

IF(NC.LE.0) GO TO 100
 L=(NN1-1)/NM+1
 M=NN1-(L-1)*NM
 J=(NN2-1)/NI+1
 I=NN2-(J-1)*NI

--- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.

K= (NN3 - 1) / ND + 1

--- NO REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.

KR = NN3 - (K-1) * ND

SUM1=0.

SUM2=0.

DO 70 N=1,NN

TERM=CB(M,N)*DE(L,N)*AP(I,N)

SUM1=SUM1+TERM/ZB(L,N)**2

30 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3

TERML=DF1D(M,K,KR)

IF(L.EQ.2)TERML=DF2D(M,K,KR)

TERM1=TERML*DSX(I,J)*EN(I)*SUM1

TERM2=0.

IF(I.EQ.K)TERM2=FB(L,M)*DSXD(NN2,KR)*EN(I)*SUM1

TERM3=-2.*FB(L,M)*EN(I)*EN(K)*DSX(I,J)*DSD(K,KR)*FPOP8(L)*SUM2

DFBXC=-FPOP8(L)*(TERM1+TERM2+TERM3)

100 RETURN

END

FUNCTION DF800(NN1,NN2,NN3)

--- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
 --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -----

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
 COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IED, IEN
 1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NCOFFS, NN, NU1, NU2, NU3
 2, IB1, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
 COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOPB(2), DL(9,7), ENL(10), RB(10),
 1EKR(10), TITLE2(10), P(15,7), AB(10,15), R(2,10), DE(2,10), EM(15),
 2E(15), EK(15), TITLE1(15), PB(10,15), AN(15,7), SS(5,6), UU(15)
 COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
 COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
 COMMON/FIVE/XX(9,15), D(9,7), EN(10), C(9,5), U(9,7)
 COMMON/SIX/Z(9,7), ZB(2,10), F(9,15), S(10), FB(2,10), BETA(6), Y(6),
 1BETAB(2), YB(2), BETE, BET
 COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DBX(6,15),
 10YD(6,7), DBD(6,7), BETRP(2), BETPP(6), BETBPP(2)
 COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
 10F1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), CYBD(2,5,7)
 COMMON/NINE/CBBX(5,6), DBBD(5,7)
 COMMON/ELEVEN/DBXX(90,15), DBXD(90,7), DBDD(30,5)
 COMMON/TWELVE/DSXX(30,6), DSXD(30,7), DSD(6,5)
 COMMON/FOURTH/DBBXX(30,30), CBBXD(30,35), DBEDC(30,30), D2YB(2)

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----

IF(ND.LE.C) GO TO 100
 L=(NN1-1)/NM+1
 M=NN1-(L-1)*NM
 I = (NN2 - 1) / ND + 1
 J = NN2 - (I - 1) * ND
 K = (NN3 - 1) / ND + 1
 KR = NN3 - (K-1) * ND
 SUM1=0.
 SUM2=0.
 DO 30 N=1,NN
 TERM=CB(M,N)*DB(L,N)*AB(I,N)
 SUM1=SUM1+TERM/ZB(L,N)**2
 30 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3
 TERML=DF1D(M,K,KR)
 IF(L.EC.2)TERML=DF2D(M,K,KR)
 TERM1=TERML*DSD(I,J)*EN(I)*SUM1
 TERM2=0.
 IF(I.EQ.K)TERM2=FB(L,M)*DSD(NN2,KR)*EN(I)*SUM1
 TERM3=-2.*FB(L,M)*EN(I)*EN(K)*DSD(I,J)*DSD(K,KR)*FPOPB(L)*SUM2
 DF800=-FPOPB(L)*(TERM1+TERM2+TERM3)
 100 RETURN
 END

SUBROUTINE STARTP

```

C
C *** THIS SUBROUTINE SELECTS A STARTING FEASIBLE POINT. CALLED IF NU1=1
C
COMMON/SHAPE/ X(100), DEL(100), A(100,100), NV, MC, MN, NP1, NM1
COMMON/ONE/NT, NJ, NII, NUJ, NM, NK, NL, NI1, NJ1, NI2, NU2, NIIJ, IEX, IED, IEN
1. IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NDEFS, NOOFFS, NN, NU1, NU2, NU3
2. IR1, NO, NU4, NU5, NU6, NU7, NUR, ND1, ND2
COMMON/TWO/AA(6), AAB(2), FPOP(5), FPOP8(2), DL(9,7), ENL(10), PP(10),
1FKD(10), TITLF2(10), P(15,7), AB(10,15), R(2,10), DR(2,10), EM(15),
2E(15), EK(15), TITL1(15), PB(10,15), AN(15,7), SS(5,6), UU(15)
COMMON/THREE/PREFPR, PREFTN, PREINC, PREBET, B1(9,5), PD(5)
COMMON/FOUR/ C(15,7), CB(10,15), ELNS(5,6)
COMMON/FIVE/XX(9,15), D(9,7), FN(10), Q(9,5), U(9,7)
COMMON/SIX/Z(9,7), ZR(2,10), F(9,15), S(10), FB(2,10), BETA(6), Y(6),
1RETAP(2), YR(2), BETR, RET
COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DBX(6,15),
1DYD(6,7), DDD(6,7), RETPD(2), RETPD(6), RETPD(2)
COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
1DF1D(10,5,7), DF2D(10,5,7), DYRX(2,5,6), DYBD(2,5,7)
COMMON/NINE/DBBX(5,6), DBBD(5,7)
COMMON/TEN/RRP(20), ZN1(20), ZN2(20), RAT(10)
COMMON/EQUAL/ H, H1, M7
DIMENSION ALL(10)
CV = PREBET/(PREFPR + PREBET)
CF = 1. - CV
SMALL=.01
FL1 = FLOAT(NII)/FLOAT(NII+1)
FL2 = FLOAT(NI2) / FLOAT(NI2 + 1)
DO 10 J=1, NJ
11 ALL(J) = FL1 * EM(J)
DO 20 I=NI1, NII
DO 20 J=NU1, NUJ
20 XX(I,J) = FN(J) * FL2 * FPOP(I-NI) + SMALL
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----
C
IF(ND.LE.0) GO TO 500
IF(ND2.EQ.2) GO TO 200
GO TO (30,40,50,60), ND1
31 SUM=0.0
DO 36 K=1, NO
ALL(K) = ALL(K) / 2.0
DO 32 I=1, NI
32 U(I,K) = CF * ALL(K) / FLOAT(NT) + SMALL
DO 34 I=NI1, NII
34 U(I,K) = CV * ALL(K) * FPOP(I-NI) + SMALL
35 CONTINUE
GO TO 500
40 ALL(1) = ALL(1) / 3.0
ALL(2) = ALL(2) / 2.0
ALL(3) = ALL(3) / 2.0
DO 46 J=1, 2
DO 42 I=1, NI
42 U(I,J) = ALL(1) * CF / FLOAT(NI) + SMALL
DO 44 I=NI1, NII
44 U(I,J) = ALL(1) * CV * FPOP(I-NI)

```

```

46 CONTINUE
  DO 47 I=1,NI
    U(I,3) = ALL(2) * CF / FLOAT(NI) + SMALL
47 U(I,4) = ALL(3) * CF / FLOAT(NI) + SMALL
  DO 48 I=NI1,NII
    U(I,3) = ALL(2) * CV * FPOP(I-NI) + SMALL
48 U(I,4) = ALL(3) * CV * FPOP(I-NI) + SMALL
  GO TO 500
50 ALL(1) = ALL(1) / 4.0
  ALL(2) = ALL(2) / 2.0
  DO 51 J=1,3
  DO 52 I=1,NT
52 U(I,J) = ALL(1) * CF / FLOAT(NI) + SMALL
  DO 54 I=NI1,NII
54 U(I,J) = ALL(1) * CV * FPOP(I-NI) + SMALL
56 CONTINUE
  DO 57 I=1,NT
57 U(I,4) = ALL(2) * CF / FLOAT(NI) + SMALL
  DO 58 I=NI1,NII
58 U(I,4) = ALL(2) * CV * FPOP(I-NI) + SMALL
  GO TO 500
59 ALL(1) = ALL(1) / 5.0
  DO 60 J=1,N0
  DO 62 I=1,NT
62 U(I,J) = ALL(1) * CF / FLOAT(NI) + SMALL
  DO 64 I=NI1,NII
64 U(I,J) = ALL(1) * CV * FPOP(I-NI) + SMALL
66 CONTINUE
  GO TO 500
200 ALL(1) = ALL(1) / 3.0
  ALL(2) = ALL(2) / 3.0
  K=1
  DO 201 J=1,4
  IF(J.GT.2) K=2
  DO 202 I=1,NT
202 U(I,J) = ALL(K) * CF / FLOAT(NI) + SMALL
  DO 204 I=NI1,NII
204 U(I,J) = ALL(K) * CV * FPOP(I-NI) + SMALL
210 CONTINUE
500 DO 501 J= 1,NJ
  DO 525 I= 1,NT
525 XX(I,J) = CF * ALL(J) / FLOAT(NI) + SMALL
  DO 550 I=NI1,NII
550 XX(I,J) = CV * ALL(J) * FPOP(I-NI) + SMALL
500 CONTINUE
  DO 700 I=1,NII
  DO 701 J=1,NJ
  N=(J-1)*NII + J
700 X(N) = XX(I,J)
  DO 710 J=1,NJ2
  DO 711 I=1,NI2
  N= NI1J + (J-1)* NI2 + I
710 X(N) = XX(NI1I,NJ+J)

```

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200

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----

```

  IF(NP.LE.0.0) GO TO 1000
  DO 720 I=1,NII

```

```
DO 720 K=1,N0  
N=TFX + (T-1)*M0 + K  
720 X(N)=U(T,X)  
1000 RETURN  
END
```

--- THIS SUBROUTINE SUMMARIZES THE RESULTS OF AN EXCHANGE -----

```

COMMON/SHARE/ X(100), DEL(100), A(100,100), NV, MC, PN, NP1, NP1
COMMON/ONE/NI, NJ, NII, NJJ, NM, NK, NL, NI1, NJ1, NI2, NJ2, NIIJ, IEX, IEO, IEN
1, IEU, IEX1, IEXEN, I1, I2, I3, I4, I5, I6, I7, NOEFS, NOOFFS, NA, NU1, NU2, NU3
2, IB1, ND, NU4, NU5, NU6, NU7, NU8, ND1, ND2
COMMON/TWO/AA(6), AAB(2), FPOP(6), FPOP8(2), DL(9,7), ENL(10), RB(10),
1EKB(10), TITLE2(10), P(15,7), AB(10,15), B(2,10), DE(2,10), EM(15),
2E(15), EK(15), TITLE1(15), PB(15,15), AN(15,7), SS(5,6), LU(15)
COMMON/THREE/PREFER, PREFIN, PREINC, PREBET, B1(9,5), RD(5)
COMMON/FOUR/ C(15,7), CB(10,15), FLNS(5,6)
COMMON/FIVE/XX(9,15), D(9,7), FN(10), Q(9,5), U(9,7)
COMMON/SIX/Z(9,7), ZB(2,10), F(9,15), S(10), FB(2,10), EETA(6), Y(6),
1BETAB(2), YP(2), BETB, BET
COMMON/SEVEN/DFX(9,15,15), DFD(9,15,7), BETP(6), DYX(6,15), DBX(6,15),
10YD(5,7), DBD(6,7), BETBP(2), PETPP(6), BETPPP(2)
COMMON/EIGHT/DSX(5,6), DSD(5,7), DF1X(10,5,6), DF2X(10,5,6),
10F1D(10,5,7), DF2D(10,5,7), DYBX(2,5,6), DYBD(2,5,7)
COMMON/NINE/DBRX(5,6), DBBD(5,7)
COMMON/OUTIN/ RBB(20), ZN1(20), ZN2(20), RAT(10)
DIMENSION X1(20), X2(20), X3(20), X4(20), X5(20), X6(20)
WRITE (6,655)
WRITE (6,660)
CALL IDENTV
CALL FRACTS
95J FORMAT( //10X, 30H***** DAMAGE TO SIDE ONE ***** ,F5.3)
955 FORMAT( //10X, 30H***** DAMAGE TO SIDE TWO ***** ,F5.3)
WRITE (6,425)
WRITE(6,950)BETB
WRITE(6,955)PET
WRITE (6,410)
WRITE (6,490)
WRITE(6,825)(TITLE1(J),J=1,NJ)
DO 855 I=1,NI
DO 840 J=1,NJ
X1(J) = XY(I,J) / RBB(J)
X2(J) = XX(I,J)
X3(J) = Y2(J) * ZN1(J)
X4(J) = X3(J) * F(I,J)
X5(J) = X4(J) / EN(I)
IF(X5(J).GT.140.) X5(J)=140.
84J X6(J) = SS(I,J) ** X5(J)
WRITE(6,805)(X1(J),J=1,NJ)
WRITE(6,810)(X2(J),J=1,NJ)
WRITE(6,815)TITLE2(I),(X3(J),J=1,NJ)
WRITE(6,810)(X4(J),J=1,NJ)
WRITE(6,820)(X5(J),J=1,NJ)
WRITE(6,820)(X6(J),J=1,NJ)
855 CONTINUE
WRITE(6,655)
WRITE (6,540)
IF(NJJ.LE.12) M1 = NJJ
IF(NJJ.GT.12) M1 = 12
WRITE(6,800)(TITLE1(J),J=1,M1)
DO 896 I=1,NI2

```

15400

15405

15905

16195

```

II= NI + I
DO 885 J=1,M1
X1(J) = XX(II,J) / RBB(J)
X2(J) = XX(II,J)
X3(J) = XX(II,J)*F(II,J)
885 X4(J) = X3(J) *EK(J)
WRITE(6,830) (X1(J),J=1,M1)
WRITE(6,895) I, (X2(J),J=1,M1)
WRITE(6,810) (X3(J),J=1,M1)
WRITE(6,810) (X4(J),J=1,M1)
896 CONTINUE
IF(NJJ.LE.12) GO TO 905
WRITE(6,825) (TITLE1(J),J=13,NJJ)
DO 900 I=1,NI2
DO 889 J=13,NJJ
II = NI + I
X1(J) = XX(II,J) / RBB(J)
X2(J) = XX(II,J)
X3(J) = XX(II,J)*F(II,J)
889 X4(J) = X3(J) *EK(J)
WRITE(6,830) (X1(J),J=13,NJJ)
WRITE(6,895) I, (X2(J),J=13,NJJ)
WRITE(6,810) (X3(J),J=13,NJJ)
WRITE(6,810) (X4(J),J=13,NJJ)
900 CONTINUE
905 CONTINUE
WRITE(6,655)

```

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION -----

```

IF(ND.LE.0) GO TO 787
WRITE(6,575)
WRITE(6,835) (K,K=1,ND)
DO 780 I=1,NII
DO 770 M=1,ND
X1(M) = U(I,M) / RBB(M)
X3(M) = DL(I,M)/RD(M)
X4(M) = C(I,M)/RD(M)
770 X2(M) = U(I,M)
WRITE(6,830) (X1(M),M=1,ND)
WRITE(6,895) I, (X2(M),M=1,ND)
WRITE(6,810) (X3(M),M=1,ND)
WRITE(6,810) (X4(M),M=1,ND)
780 CONTINUE
787 CONTINUE
WRITE(6,655)
WRITE (6,545)
DO 760 L=1,NL
DO 750 M=1,NM
X1(M) = EN(M)
X2(M) = EN(M)* S(M) / RP(M)
X3(M) = X2(M) * RB(M)
X4(M) = X3(M) * FB(L,M)
750 X5(M) = X4(M) * FKB(M)
WRITE(6,825) (TITLE2(M),M=1,NM)
WRITE(6,830) (X1(M),M=1,NM)
WRITE(6,895) L, (X2(M),M=1,NM)
WRITE(6,810) (X3(M),M=1,NM)

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162450

```

WRITE(6,810)(X4(M),M=1,NM)
WRITE(6,810)(X5(M),M=1,NM)
760 CONTINUE
NU8 = NU8 + 1
IF(NU8.GT.NU4) KT = 2
IF(NU8.GT.NU4) RETURN
IF(RAT(NU8).GT.1.E+7) PREBET=100.
IF(RAT(NU8).GT.1.E+7) PREFER=0.
IF(RAT(NU8).GT.1.E+7) GO TO 1000
PREFER = 100.
PREBET = PREFER * RAT(NU8)
.85  FORMAT (47X,30HSTRATEGIC ANALYSIS OF EXCHANGE)
.11  FORMAT (/50X,30HNEW SIDE CNE ARSENAL )
.35  FORMAT( //10X,12(4X,I2,4X))
575  FORMAT( 35X, 47H SIDE CNE COUNTER DEFENSE STRIKE CHARACTERISTICS/
1 23X, 90H SIDE ONE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROW
2S) DEFENDED BY DEFOR. TYPE (COLS.)/29X,10H (ARRIVALS)/20X,
3 90H SIDE TWO ( ORIG. NO. ) OF DEFORS. OF RESOURCE TYPE (ROW
4S) ATTACKED BY OFFS. /20X
5 90H SIDE TWO ( SURV. NO. ) OF DEFORS. OF RESOURCE TYPE (ROW
6S) ATTACKED BY OFFS. )
50  FORMAT (/35X,57H AGGREGATE COUNTERVALUE DAMAGE CHARACTERISTICS OF E 168350
1XCHANGE//45X,50H TOTAL NUMBER OF ALLOCATED (COLUMN) ON (ROW) CITIES 168400
2/10X,18H INTERPRETATION OF ,17X,44H NUMBER OF ARRIVING (COLUMN) ON ( 168450
3ROW) CITIES /10X,20H EACH SET OF ENTRIES ,15X,38H NUMBER OF IMPACT IN 168500
4G (COLUMN) ON (ROW) /45X,58H NUMBER OF 1 MT. EQUIVALENTS ON (ROW) C 168550
5ITIES FROM (COLUMN) ) 168600
.55  FORMAT (/20X,8H MISSILES,20X,7H BOMBERS,20X,5H SLAMS,20X,11H PERCENTAG 168650
1E /75X,13H SIDE TWO ONLY,12X,6H DAMAGE) 168700
.90  FORMAT (45X,46H SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS //30X 169050
1,56H MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)/30X,5 169100
22H MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW) /5X,18H INTER 169150
3PRETATION OF ,7X,55H WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVE 169200
4R TARGET /5X,20H EACH SET OF ENTRIES ,5X,60H WARHEADS OF MISSILE TYP 169250
5E (COLUMN) IMPACTING ON TARGET (ROW) /30X,66H WARHEADS OF MISSILE T 169300
6YPE (COLUMN) IMPACTING ON EACH MISSILE (ROW) /30X,73H SURVIVAL PROB 169350
7. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)) 169400
.35  FORMAT (/25X,67H NUMBER OF EACH SIDE TWO MISSILE TYPE SURVIVING CO 169850
1UNTERFORCE STRIKE ) 169900
.340  FORMAT (40X,46H SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS //30X 169950
1,61H WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW) / 170000
26X,18H INTERPRETATION OF ,6X,56H WEAPONS OF TYPE (COLUMN) ARRIVING O 170050
3VER CITY CLASS (ROW) /6X,20H EACH SET OF ENTRIES ,4X,48H WEAPONS OF T 170100
4YPE (COLUMN) IMPACTING ON CITY CLASS /30X,74H NO. OF 1 MT. EQS. FRO 170150
5M WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW) ) 170200
.345  FORMAT (41X,39H SIDE TWO SECOND STRIKE CHARACTERISTICS /30X,68H NO. 170250
1OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE /3 170300
20X,71H NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFO 170350
3RCE STRIKE /6X,18H INTERPRETATION OF ,6X,62H NO. OF SIDE TWO WEAPONS 170400
4 OF TYPE (COLUMN) ARRIVING OVER CITIES /6X,20H EACH SET OF ENTRIES 170450
5,4X,71H NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE 170500
6ONE CITIES /30X,70H NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN 170550
7) IMPACTING ON CITIES ) 170600
.655  FORMAT (1H1)
.66  FORMAT (29X,62H*****STRATEGIC WEAPONS EXCHANGE MODELS (SWEM)
1*****//45X,34H ALLOCATION OPTIMIZATION MODEL )
.800  FORMAT (/1X,4HCITY,5X,12(4X,A6)/1X,5HCLASS)
.805  FORMAT (/10X,12(2X,F6.1,2X))

```

810 FORMAT (10X,12(2X,F6.1,2X))
815 FORMAT (2X,A6,2X,12(2X,F6.1,2X))
820 FORMAT (10X,12(2X,F6.3,2X))
825 FORMAT (//1X,12(4X,A6))
830 FORMAT (//10X,12(2X,F6.1,2X))
895 FORMAT (4X,I2,4X,12(2X,F6.1,2X))
1000 IF (NU1.EQ.1) CALL STARTB
RETURN
END

170650

Appendix C

D CROSS D SECOND PARTIAL DERIVATIVES

Appendix C

D CROSS D SECOND PARTIAL DERIVATIVES

These derivatives are used in the allocation model for attacks on defenses and were not documented in RAC-CR-43.

$$\frac{\partial^2 F_{ij}}{\partial d_{ir} \partial d_{ik}} = F_{ij} \frac{C_{jr}}{Z_{ir}} \frac{C_{jk}}{Z_{ik}} \quad \begin{matrix} (j = 1, \dots, II) \\ (k = 1, \dots, D) \end{matrix} \quad \begin{matrix} (i = 1, \dots, D) \\ (n = 1, \dots, D) \end{matrix}$$

$$\frac{\partial^2 \beta}{\partial d_{I+1r} \partial d_{I+1k}} = P_I \left(\frac{\partial^2 \beta_I}{\partial y_I^2} \frac{\partial y_I}{\partial d_{I+1r}} \frac{\partial y_I}{\partial d_{I+1k}} + \frac{\partial \beta_I}{\partial y_I} \frac{\partial^2 y_I}{\partial d_{I+1r} \partial d_{I+1k}} \right)$$

where

$$\frac{\partial^2 y_I}{\partial d_{I+1r} \partial d_{I+1k}} = \sum_{j=1}^{JJ} \left(\frac{\partial^2 F_{I+1j}}{\partial d_{I+1r} \partial d_{I+1k}} x_{I+1j} k_j \right)$$

$$\frac{\partial^2 S_n}{\partial d_{nr} \partial d_{nk}} = \begin{cases} \frac{\partial S_n}{\partial d_{nr}} \frac{1}{S_n} \frac{\partial S_n}{\partial d_{nk}} + \frac{S_n}{n_n} \left(\sum_{j=1}^J x_{nj} \frac{\partial^2 F_{nj}}{\partial d_{nr} \partial d_{nk}} e_{jn} S_{nj} \right) & \text{if } S_n \neq 0 \\ 0 & \text{if } S_n = 0 \end{cases}$$

0 if $S_n = 0$

$$\frac{\partial^2 \bar{F}_{ln}}{\partial d_{rs} \partial d_{ik}} = -\bar{P}(l) \left\{ \begin{aligned} & \frac{\partial \bar{F}_{ln}}{\partial d_{rs}} \frac{\partial S_l}{\partial d_{ik}} n_l \left(\sum_{n=1}^N \frac{\bar{c}_{nn} \bar{d}_{ln} \bar{a}_{ln}}{\bar{Z}_{ln}^2} \right) \\ & + \bar{F}_{ln} \frac{\partial^2 S_l}{\partial d_{rs} \partial d_{ik}} n_l \quad (\text{sum above}) \\ & + \bar{F}_{ln} \frac{\partial S_l}{\partial d_{ik}} n_l \left(\sum_{n=1}^N \frac{\bar{c}_{nn} \bar{d}_{ln} \bar{a}_{ln} \bar{a}_{rn}}{\bar{Z}_{ln}^3} \right) \left(-2\bar{P}(l) \frac{\partial S_r}{\partial d_{rs}} n_r \right) \end{aligned} \right.$$

(RAC)

$$\frac{\partial^2 \bar{p}}{\partial d_{rs} \partial d_{ik}} = \sum_{\ell=1}^L \bar{p}(\ell) \left(\frac{\partial^2 \bar{p}_\ell}{\partial y_\ell^2} \frac{\partial \bar{y}_\ell}{\partial d_{rs}} \frac{\partial \bar{y}_\ell}{\partial d_{ik}} + \frac{\partial \bar{p}_\ell}{\partial y_\ell} \frac{\partial^2 \bar{y}_\ell}{\partial d_{rs} \partial d_{ik}} \right)$$

where

$$\frac{\partial^2 \bar{y}_\ell}{\partial d_{rs} \partial d_{ik}} = \bar{p}(\ell) \left\{ \sum_{m=1}^M \left(\frac{\partial \bar{F}_{\ell m}}{\partial d_{rs} \partial d_{ik}} S_m n_m \bar{K}_m \right) + \frac{\partial \bar{F}_{\ell r}}{\partial d_{ik}} \frac{\partial S_r}{\partial d_{rs}} n_r \bar{K}_r \right. \\ \left. + \frac{\partial \bar{F}_{\ell i}}{\partial d_{rs}} \frac{\partial S_i}{\partial d_{ik}} n_i \bar{K}_i + \bar{F}_{\ell i} \frac{\partial^2 S_i}{\partial d_{rs} \partial d_{ik}} n_i \bar{K}_i \delta_{ir} \right\}$$

Appendix D

PARTIAL GLOSSARY OF MODEL NOTATION AND FORTRAN NOTATION

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Independent Variables and Computed Functions

MODEL NOTATION

FORTRAN NOTATION

x_{ij}	XX(I,J)
u_{ik}	U(I,K)
d_{ik}	D(I,K)
d'_{ik}	DL(I,K)
n_i	EN(I)
F_{ij}	F(I,J)
z_{ik}	Z(I,K)
s_i	S(I)
$\bar{z}_L$	ZB(L,N)
$\bar{F}_L$	FB(L,M)
y_i	Y(I)
θ_i	BETA(I)
θ	BET
$\bar{y}_L$	YB(L)
$\bar{\theta}_L$	BETAB(L)
$\bar{\theta}$	BETB
p_i	FPOP(I)
$\bar{p}_L$	FPOPB(L)

MODEL NOTATION

$$\frac{\partial \bar{y}_l}{\partial d_{ik}}$$

$$\frac{d \bar{\beta}_l}{d \bar{v}_l}$$

$$\frac{\partial \bar{\beta}}{\partial X_{1j}}$$

$$\frac{\partial \bar{\beta}}{\partial d_{ik}}$$

$$\frac{\partial^2 F_{1j}}{\partial X_{1i} \partial X_{1l}}$$

$$\frac{\partial^2 F_{1j}}{\partial d_{1i} \partial X_{1l}}$$

$$\frac{\partial^2 \beta}{\partial X_{1+i, r} \partial X_{1+i, j}}$$

$$\frac{\partial^2 \beta}{\partial d_{1+i, r} \partial X_{1+i, j}}$$

$$\frac{\partial^2 S_n}{\partial X_{n, l} \partial X_{n, k}}$$

$$\frac{\partial^2 S_n}{\partial d_{n, l} \partial X_{n, k}}$$

$$\frac{\partial F_{1j}}{\partial X_{1l}}$$

$$\frac{\partial F_{1j}}{\partial d_{1k}}$$

FORTTRAN NOTATION

DYBD(L,I,K)

BETBP(L)

DBBX(I,J)

DBBD(I,K)

DFXX(NN1,L,KS)

NN1 depends on i and j

DFXD(NN1,L,KS)

NN1 depends on i and j

DBXX(NN2,KR)

NN2 depends on i and j

DBXD(NN2,KR)

NN2 depends on i and j

DSXX(NN2,L)

NN2 depends on m and k

DSXD(NN2,L)

NN2 depends on m and k

DFX(I,J,L)

DFD(I,J,K)

MODEL NOTATION

$$\frac{\partial \beta}{\partial x_{i+1,j}}$$

$$\frac{\partial y_i}{\partial x_{i+1,j}}$$

$$\frac{\partial \beta}{\partial d_{i+1,k}}$$

$$\frac{\partial y_i}{\partial d_{i+1,k}}$$

$$\frac{\partial S}{\partial x_{i,j}}$$

$$\frac{\partial S}{\partial d_{i,k}}$$

$$\frac{d\beta_i}{dy_i}$$

$$\frac{\partial \bar{F}_{l,j}}{\partial x_{i,j}}$$

$$\frac{\partial \bar{F}_{l,k}}{\partial d_{i,k}}$$

$$\frac{\partial \bar{y}_l}{\partial x_{i,j}}$$

$$\frac{\partial^2 \bar{F}_{l,j}}{\partial x_{i,r} \partial x_{i,j}}$$

FORTRAN NOTATION

DBX(I,J)

DYX(I,J)

DBD(I,K)

DYD(I,K)

DSX(M,J)

DSD(M,K)

BETP(I)

{ DF1X(M,I,J) if l=1
DF2X(M,I,J) if l=2

{ DF1D(M,I,K) if l=1
DF2D(M,I,K) if l=2

DYBX(L,I,J)

DFBX(NN1,NN2,NN3)

NN1 depends on l and m

NN2 depends on i and j

NN3 depends on k and r

MODEL NOTATION

$$\frac{\partial^2 \bar{F}_{l,n}}{\partial a_{kr} \partial x_{ij}}$$

$$\frac{\partial^2 \bar{\beta}}{\partial x_{kr} \partial x_{ij}}$$

$$\frac{\partial^2 \bar{\beta}}{\partial a_{kr} \partial x_{ij}}$$

$$\frac{\partial^2 F_{ij}}{\partial d_{is} \partial d_{it}}$$

$$\frac{\partial^2 \beta}{\partial d_{I+ir} \partial d_{I+ij}}$$

$$\frac{\partial^2 S_n}{\partial d_{n,i} \partial d_{n,k}}$$

$$\frac{\partial^2 \bar{F}_{l,n}}{\partial d_{kr} \partial d_{ij}}$$

$$\frac{\partial^2 \bar{\beta}}{\partial d_{kr} \partial d_{ij}}$$

FORTTRAN NOTATION

DFBXD(NN1,NN2,NN3)

NN1 depends on l and m

NN2 depends on i and j

NN3 depends on k and r

DBBXI(NN1,NN2)

NN1 depends on i and j

NN2 depends on k and r

DBBXD(NN1,NN2)

NN1 depends on i and j

NN2 depends on k and r

DFDD (NN1,L,KS)

NN1 depends on i and j

DBDD (NN2,KR)

NN2 depends on i and j

DSDD (NN2,L)

NN2 depends on m and k

DFBDD (NN1, NN2, NN3)

NN1 depends on l and m

NN2 depends on i and j

NN3 depends on k and r

DBBDD (NN1, NN2)

NN1 depends on l and m

NN2 depends on k and r