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October 1975

ATACM:

ACDA Tactical Air Campaign Model

ACDA/PAB-249

Prepared For

U.S. ARMS CONTROL
AND
DISARMAMENT AGENCY

Prepared By

KETRON, INC.
1400 Wilson Boulevard
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KFR No. 44-75

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John R. Fish

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ABSTRACT

ATACM is a computer model designed and built for the Arms Control and Disarmament Agency for use in analyzing the impact of various force mixes upon a tactical airwar in Europe between NATO and Warsaw Pact forces. ATACM models an air campaign as a zero-sum staged game and employs dynamic programming to solve this game for approximate, optimal MAXMIN/MINMAX aircraft allocation strategies for the opposing sides at each stage of the campaign. The model permits multiple aircraft types with user-assigned missions, numerical and fractional reinforcements as a function of stage, and user selection of the objective function used to generate the optimal strategies.

Descriptions of the problem formulation and the engagement and optimization methodologies used to solve it are presented along with a user's guide and CDC 6600 FORTRAN listings.

ACKNOWLEDGEMENT

Many of the ideas presented here are the result of survey work by Drs. Fred Miercort and Robert Galiano and the author gratefully acknowledges their assistance. In addition, Captain Bernard M. Robinson, USAF, and Dr. George Pitman of ACDA provided helpful guidance during both model development and documentation and their suggestions were appreciatively considered in preparation of this report.

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INTRODUCTION

The ACDA Tactical Air Campaign Model (ATACM) is a computer model designed and built for the Arms Control and Disarmament Agency (ACDA) for use in analyzing the impacts of various Mutual Balanced Force Reduction (MBFR) proposals upon a tactical airwar in Europe between NATO and Warsaw Pact forces. The design of ATACM was based upon the findings of a survey (Reference 1) of existing tactical air models conducted by KETRON to assess the applicability of existing models to ACDA's requirements. Results of the survey indicated the need for a new model incorporating the most desirable features of existing models (e.g., TAC CONTENDER, VECTOR, OPTSA, DYGAM) into a rigorous optimization framework allowing more aircraft types and a wider selection of aircraft missions.

As a realization of the survey's recommendations, ATACM models an air campaign as a zero-sum staged game between opposing forces and employs dynamic programming to solve this game for approximate, optimal aircraft allocation strategies for both sides at each stage of the campaign. Because of the economies associated with the optimization methodology used, ATACM offers many features previously not practical in other optimizing models. Specifically, ATACM permits:

- as many as four user-defined aircraft types per side and as many as eight different missions per aircraft type

- automatic generation of approximate, optimal, enforceable aircraft allocation strategies as a function of stage for any subset of the missions for which user-specified fractions are not supplied. The user may specify all, part, or none of the allocation fractions for a given aircraft type and the model generates optimal values for those fractions not specified.

- calculation of firm upper and lower bounds on the objective function value associated with the enforceable strategies employed

- option to use a weighted sum of three different objective functions as the criterion for generating the optimal strategies

- option to individually weight the Blue and Red contributions to these objective functions as a function of stage

- option to specify fractional or numerical reinforcements for any aircraft type as a function of stage

Following sections present a description of how the problem of tactical air warfare is formulated in ATACM, a description of the attrition relationships used to evaluate the outcomes of air-to-air, air-to-ground, and ground-to-air engagements, and an outline of the optimization methodology used to generate optimal enforceable strategies and objective function bounds. Appendix A is a user's guide for ATACM which describes the model's inputs, outputs, and general operation. Appendix B presents programming documentation and FORTRAN listings coded for the CDC6600.

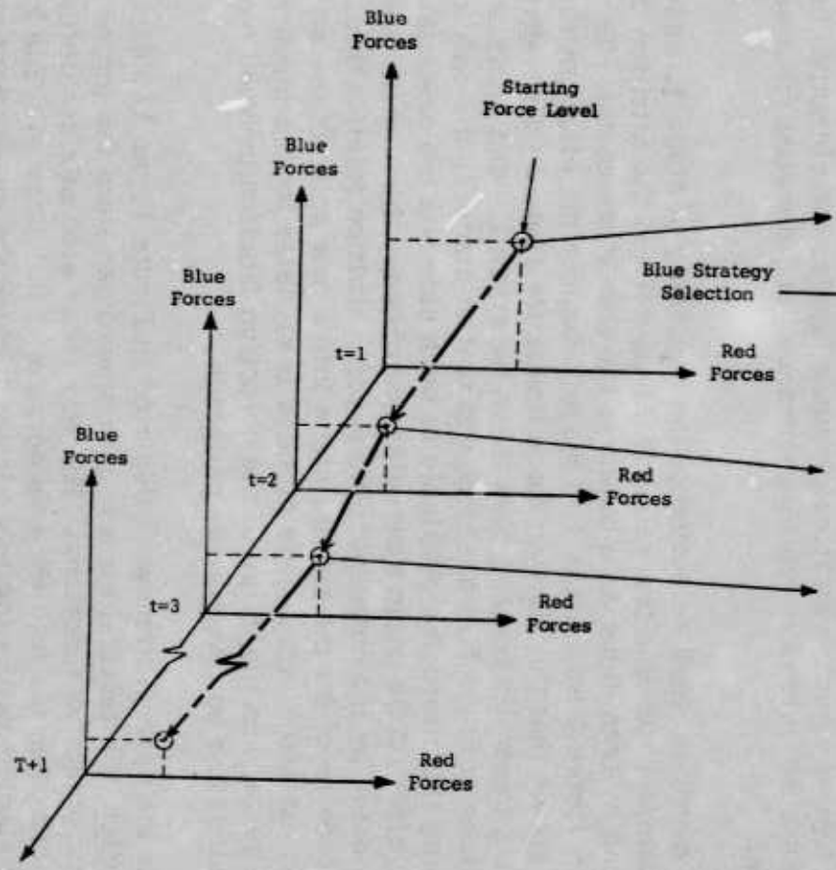
PROBLEM FORMULATION

ATACM formulates a tactical air campaign as a staged game between opposing Blue and Red air and ground forces. It generates for each side, and for each stage of the war, strategies which optimize the utilization of these forces over the length of the campaign. Figure 1 presents a graphical representation of a general staged game which depicts the roles of those essential elements which will be described in detail in following sections.

In Figure 1, for each stage or time period of the campaign, vertical planes represent the state space of possible beginning and ending force levels for the opposing sides. Corresponding to each point in the beginning state space for a given stage, a game matrix can be constructed with m_t and n_t strategies available to Blue and Red respectively. The numbers of strategies, m_t and n_t, are a function of stage, while the one-stage payoffs in the game matrix depend upon the starting resource levels, the objective function chosen as a measure of overall performance, and the strategies selected by both sides.

For a given strategy selection at the beginning of stage 1, assessment relationships determine the value of the payoff and the attrition or losses suffered by both sides as a result of the one-stage battle. The dashed line in Figure 1 from stage 1 to stage 2 depicts the effect of this attrition and shows that the starting force levels for stage 2 will, barring reinforcements, generally be less than those for stage 1. The decision facing both sides at stage 2 is analogous to that at stage 1, the only possible difference being the strategies available to each side and the associated one-stage payoffs. Once again strategies are chosen, the objective function is incremented by the corresponding payoff, attrition relationships map the starting force level for the current stage into a new point in the state space for the next stage, etc. This process is repeated for the number of stages in the game, and the value of the objective function summed over all stages determines the outcome of the campaign.

Within the general framework depicted in Figure 1, the key elements in the formulation of a tactical air war as a staged game are the forces, strategies, and objective functions. The way these elements are defined in ATACM is described in the following paragraphs of this section. The key elements in the solution of a tactical air war include the assessment methodology, used to compute payoffs and attrition, and the optimization methodology used to select optimal strategies at each stage of the campaign. These elements are discussed in following sections.



Red Strategy Selection

Blue Strategy Selection

B \ R	$\bar{S}_1$	$\bar{S}_2$	$\bar{S}_3$	...	$\bar{S}_{n_1}$
S_1	P_{11}	P_{12}	P_{13}	...	P_{1n_1}
S_2	P_{21}	P_{22}	P_{23}	...	P_{2n_1}
⋮	⋮	⋮	⋮		⋮
S_{m_1}	$P_{m_1 1}$	$P_{m_1 2}$	$P_{m_1 3}$	...	$P_{m_1 n_1}$

GAME #1

GAME #2

GAME #3

FIGURE 1

A STAGED GAME

OPPOSING FORCES AND MISSIONS

In the ATACM formulation, opposing forces consist of aircraft, SAMs, and ground divisions deployed in the stylized scenario depicted in Figure 2. A single airbase on each side serves as the staging area for all air missions flown against the opponent's SAMs, ground troops, or airbase. SAMs, which may be interpreted as any type of surface-to-air defense weapons, are segregated into forward and rear components corresponding to the location of the area they defend. Ground troops are defined in terms of homogenous divisions fighting on either side of a single-sector front (FEBA).

Aircraft

As many as four aircraft types can be assigned to either side and each of these types may be assigned as many as eight missions chosen from those listed in Table 1. In the course of a battle, forward and rear SAM suppressors (FSS and RSS) deploy before other aircraft and suppress the enemy's SAM sites. Afterward, aircraft assigned to fly close air support (CAS) attack the enemy's ground troops, reduce their total firepower, and directly influence the movement of the FEBA. Airbase attack (ABA) aircraft attack the opponent's airbase, destroy aircraft parked in shelters or on the open airfield, and thus reduce the enemy's effectiveness later in the war. Close air support and airbase attack escorts (CASE and ABAE) accompany the CAS and ABA aircraft on their attack missions and provide them protection from the opponent's battlefield and airbase defenders (BD and ABD). Finally, aircraft assigned to the Nothing mission remain on the ground during the battle because of the strength of opposing forces, maintenance requirements, unpreparedness due to a surprise attack, etc.

SAMs

The mission of the forward and rear SAMs is to defend the ground troops and airbase by attacking and destroying enemy aircraft. In prosecuting this mission, forward SAMs attack FSS, CAS, and CASE aircraft in direct defense of the ground troops, as well as RSS, ABA, and ABAE aircraft which must fly over the forward SAMs to reach their targets in the rear. Rear SAMs attack only those aircraft flying RSS, ABA, and ABAE missions.

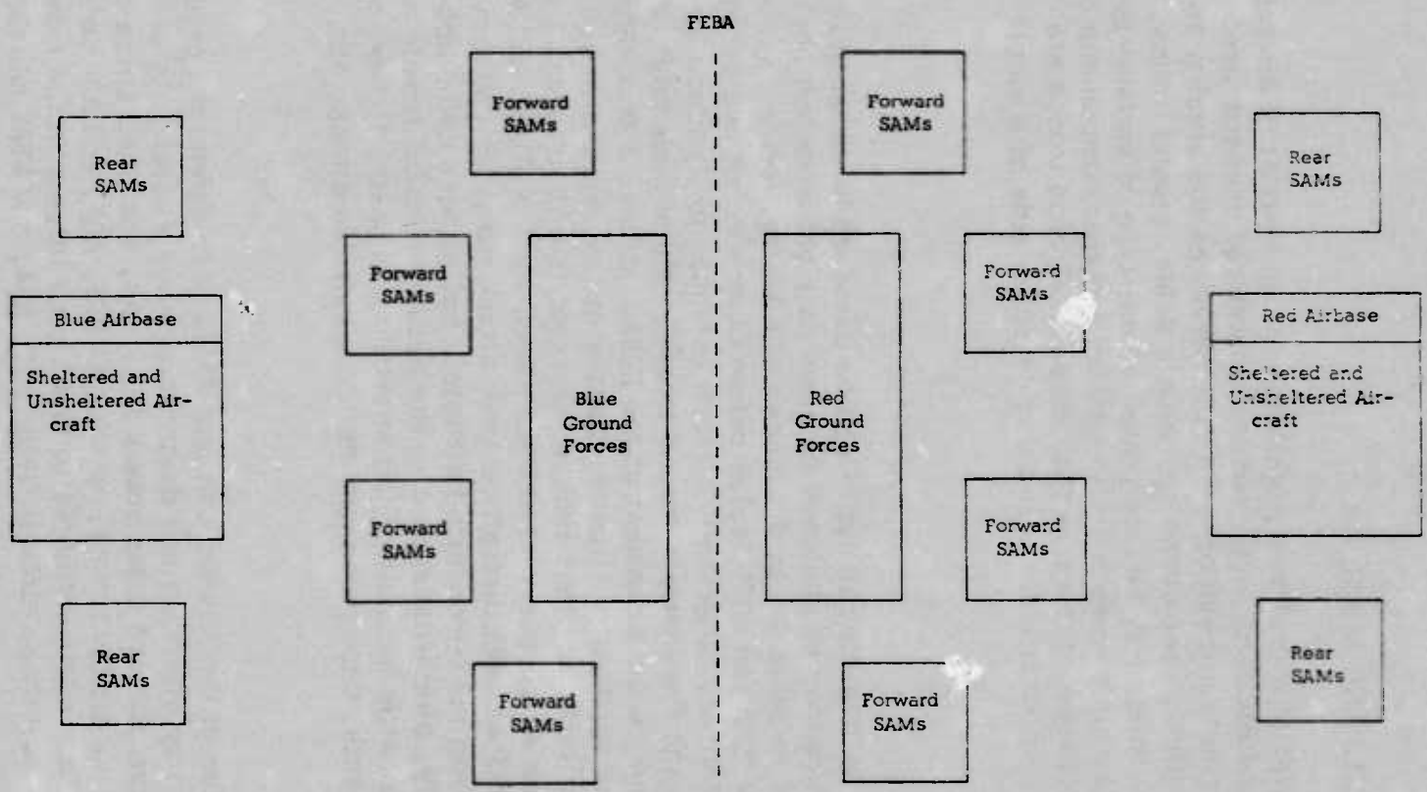


FIGURE 2

ATACM SCENARIO

TABLE 1

AIRCRAFT MISSIONS PERMITTED IN ATACM

Acronym	Mission
CAS	Close Air Support
ABA	Airbase Attack
BD	Battlefield Defense
ABD	Airbase Defense
CASE	Close Air Support Escort
ABAE	Airbase Attack Escort
FSS	Forward SAM Suppression
RSS	Rear SAM Suppression
Nothing	No assigned mission

Ground Troops

Because ATACM was designed as a tool for studying the effects of different numbers and types of aircraft upon the outcome of an air campaign, the ground representation is simplistic and serves primarily as an input to the figure of merit used in the optimization process. Ground troops are segregated into homogeneous divisions with each division assigned a maximum firepower score. Successful CAS sorties flown against the enemy troops reduce this maximum firepower by a specified amount, and FEBA movement is then calculated as a user-specified function of the ratio of the total net firepowers delivered by Blue and Red respectively.

STRATEGIES

Given the forces and missions described above, the strategy a commander uses during a given time period or stage is a fractional allocation of all aircraft to missions. For example, if only one aircraft type is available to the Blue commander, and this aircraft can prosecute four missions selected from Table 1, the set of possible strategies from which he may choose can be characterized as the set of all 4-tuples whose elements are positive fractions which sum to one. Examples include (.5, 0, .5, 0), (.5, 0, .2, .3), (.25, .25, .25, .25), etc. In the general case of s missions, s-tuples representing possible fractional allocations for one aircraft type are called decision vectors.

If the Blue commander has only one aircraft type, the sets of possible decision vectors and strategies are identical. If two aircraft types are available to the Blue side, the set of possible strategies corresponds to the set of all possible decision vector pairs with the first decision vector representing allocations for aircraft type 1, the second allocations for aircraft type 2. An example of a strategy for two aircraft types, each with four possible missions, would be

$$\big((.5, 0, .5, 0), (.5, .2, .2, .1)\big)$$

Analogously, possible strategies for a side with three aircraft types can be represented as decision vector triples, etc.

To limit the number of decision vectors (and thus strategies) from which ATACM must choose an optimal allocation, a parameter called a minimum allocation fraction is specified for each aircraft type. The minimum allocation fraction for an aircraft type is the smallest fractional unit which can be assigned to any mission. In the case of an aircraft type with four

assigned missions, a minimum allocation fraction of .5 limits the set of possible decision vectors to the following ten.

(1, 0, 0, 0)	(0, .5, 0, .5)
(.5, 0, 0, .5)	(0, .5, .5, 0)
(.5, 0, .5, 0)	(0, 0, 1, 0)
(.5, .5, 0, 0)	(0, 0, .5, .5)
(0, 1, 0, 0)	(0, 0, 0, 1)

Correspondingly, the number of strategies available to a side with two, three, or four such aircraft types would be 100, 1000, or 10,000 respectively. In general, the number of possible decision vectors V for an aircraft type with s missions and a minimum allocation fraction equal to 1/t is given by

$$V = \frac{(s + t - 1)!}{(s - 1)!\, t!} \qquad (1)$$

In addition to aircraft types, missions assigned, and minimum allocation fractions, ATACM permits one other important specification which determines the set of strategies available for a particular stage of the conflict. The user is allowed to specify, for any stage, a fixed assignment of aircraft to mission in terms of a multiple of the minimum allocation fraction. Looking at the previous example, the user can force half of the aircraft to prosecute the first mission assigned by specifying the first element in the corresponding decision vector to always equal .5. In that case, the set of possible decision vectors for the specified stage and aircraft type reduces to the following subset of those shown above:

(.5, 0, 0, .5)
(.5, 0, .5, 0)
(.5, .5, 0, 0)

The set of all strategies generated from these three decision vectors will reflect the specified allocation, and the strategy selected from this set by ATACM will optimize remaining allocations over those missions for which fractions are not specified.

As can be seen from this example, as more and more fractions are specified, the number of possible decision vectors and strategies decreases, and the process of strategy selection optimizes over fewer and fewer missions. In the extreme case, where all fractions in all decision vectors are specified, the set of strategies available at each stage reduces to a single strategy. Strategy selection then becomes a vacuous operation, and the net effect is an evaluation of an air campaign using a user-specified strategy at each

stage. Thus, depending upon the number of mission allocations specified, ATACM can be used as an optimization, sub-optimization, or strategy-specified model.

OBJECTIVE FUNCTIONS

ATACM permits the user to select any linear combination of three objective functions to be used as the overall measure of the opposing forces' performance during an air campaign. Specifically, the overall objective function used as the criterion for strategy selection can be expressed as

$$F = w_1 f_1 + w_2 f_2 + w_3 f_3 \tag{2}$$

where f_1 = difference of total Blue minus total Red CAS firepower

f_2 = difference of total Blue minus total Red (CAS firepower + ground firepower)

f_3 = total FEBA movement computed as a user-specified function of the ratio of Blue's total ground firepower to Red's

and w_j = user specified weight on f_j, j = 1, 2, or 3.

By appropriate choice of the w_j, the user can optimize using any one of the f_j, or he can generate hedging strategies -- those not precisely optimal for any single criterion but instead optimal for several criteria at once -- by specifying F to be a combination of the f_j. Regardless of what F is specified, f_1, f_2, and f_3 are also computed and recorded individuaaly making it possible to simultaneously monitor the effects of different optimization criteria on each of the objective functions.

In addition to the weights w_1, w_2, and w_3, ATACM also permits the user to weight the Blue and Red components of f_1, f_2, and f_3 by stage. To illustrate, each f_j can be expanded as follows:

$$f_1 = \sum_{t=1}^{T+1} b_t CAS_{Bt} - r_t CAS_{Rt} \tag{3}$$

$$f_2 = \sum_{t=1}^{T+1} b_t TFP_{Bt} - r_t TFP_{Rt} \tag{4}$$

$$f_3 = \sum_{t=1}^{T+1} \frac{b_t + r_t}{2} \text{FEBA}_t \qquad (5)$$

where T = number of stages in the campaign

CAS_{kt} = { CAS firepower delivered by side k during stage t — for $t \leq T$; residual value of undamaged aircraft on side k at end of war — for $t+T+1$

TFP_{kt} = { total firepower (ground + CAS) delivered by side k during stage t — for $t \leq T$; residual value of undamaged aircraft on side k at end of war — for $t+T+1$

FEBA_t = { FEBA movement during stage t — for $t \leq T$; 0 — for $t=T+1$

b_t = weight on Blue's contribution to the objective function during stage t ($b_{T+1}=1$)

r_t = weight on Red's contribution to the objective function during stage t ($r_{T+1}=1$)

Depending upon the scenario being simulated, the weights b_t and r_t can be used to reflect the various effects of logistics, force readiness, pilot skills, ground terrain, etc., all as a function of stage. For example, in the case of a surprise attack by Red, the amount of firepower Blue can deliver per sortie during early stages of the war might be severely limited by logistics, readiness, etc. To simulate this situation, weights b_t specified for the first few stages of the war would be smaller than those specified for later stages.

ASSESSMENT METHODOLOGY

Returning to the general description of a staged game depicted in Figure 1, the assessment methodology computes the values of the payoffs in each game matrix and the attrition suffered by both sides as a result of each possible one-stage battle. The important considerations in describing this methodology include the types of engagements which may occur between the opposing sides, the sequence in which these engagements occur within each stage, and the relationships used to compute attrition for each type of engagement. An important finding of the survey of existing models was the general lack of agreement concerning the best way to treat each of these facets of the assessment procedure. The assessment methodology described below is a mix of those used in OPTSA and VECTOR (References 2 and 3) and consequently suffers from some of the same limitations cited in Reference 1. In consideration of these limitations, ATACM is purposely structured so that other, alternative assessment methodologies can be implemented with minimal programming effort.

TYPES OF ENGAGEMENTS

In the current version of ATACM the types of engagements permitted can be classified as air-to-air, air-to-ground, and ground-to-air. Air-to-air engagements occur when CAS and CASE aircraft engage battlefield defenders or when ABA and ABAE aircraft engage airbase defenders. Air-to-ground engagements occur when ABA aircraft attack the opponent's airbase, when SAM suppressors attack the opponent's SAMs, or when CAS aircraft deliver ordnance against the opponent's ground troops. Ground-to-air engagements occur between SAMs and opposing aircraft flying SAM suppression, CAS, CASE, ABA, or ABAE missions.

ENGAGEMENT CYCLES

The first event in each stage of the air campaign is the addition of any numerical or fractional aircraft reinforcements specified by the user. Thereafter, attrition and payoffs for each strategy pair are computed and accumulated over a specified number of equal length time periods (e.g. days) called engagement cycles. The first event in each engagement cycle is the assignment of aircraft to missions according to the strategy pair being examined. Then, using specified sortie rates per cycle, these

assignments are converted into sorties which progress en masse through the engagements described below.

FSS and RSS Engagements

FSS and RSS missions depicted in Figure 3 are flown by each side before all other missions in an attempt to clear corridors for subsequent battlefield and airbase attackers. SAMs successfully attacked by suppressors are killed for the duration of the stage in which they are suppressed, but are replaced or restored at the beginning of the next stage. SAM suppressors successfully engaged by SAMs or destroyed by the opponent's airbase attackers are lost for the duration of the campaign.

CAS, CASE, and BD Engagements

The CAS, CASE, and opposing BD missions depicted in Figure 4 are flown after the SAM suppressors. All air-to-air engagements between CAS, CASE, and the opponent's BD sorties are one-on-one encounters. Excess attackers or defenders not engaged in one phase of the engagement cycle proceed unmolested to the next phase. Sorties which are engaged abort their original mission, fight the opposing aircraft, and, if not killed, return to their own airbase. Each successful CAS sortie delivers ordnance on the opponent's ground troops and reduces their total firepower (computed at the beginning of each stage as number of divisions times firepower per division) by a user-specified amount. Thus ground troops, like SAMs, can be thought of as being killed for the duration of the stage in which they are attacked, but replaced at the beginning of the next stage. CAS, CASE, or BD killed in air-to-air engagements or destroyed by the opponent's airbase attackers are lost for the duration of the campaign.

ABA, ABAE, and ABD Engagements

The ABA, ABAE, and opposing ABD missions depicted in Figure 5 are the last missions flown in each engagement cycle. All air-to-air engagements between ABA, ABAE, and the opponent's ABD sorties are one-on-one encounters treated in the same way as those described for CAS, CASE, and BD missions. Each successful ABA sortie delivers ordnance on the opponent's airbase destroying those sheltered and unsheltered aircraft specified as being vulnerable to airbase attack. Shelters are assigned to vulnerable aircraft types in proportion to their relative numbers. Shelters are not destroyed; damaged shelters are

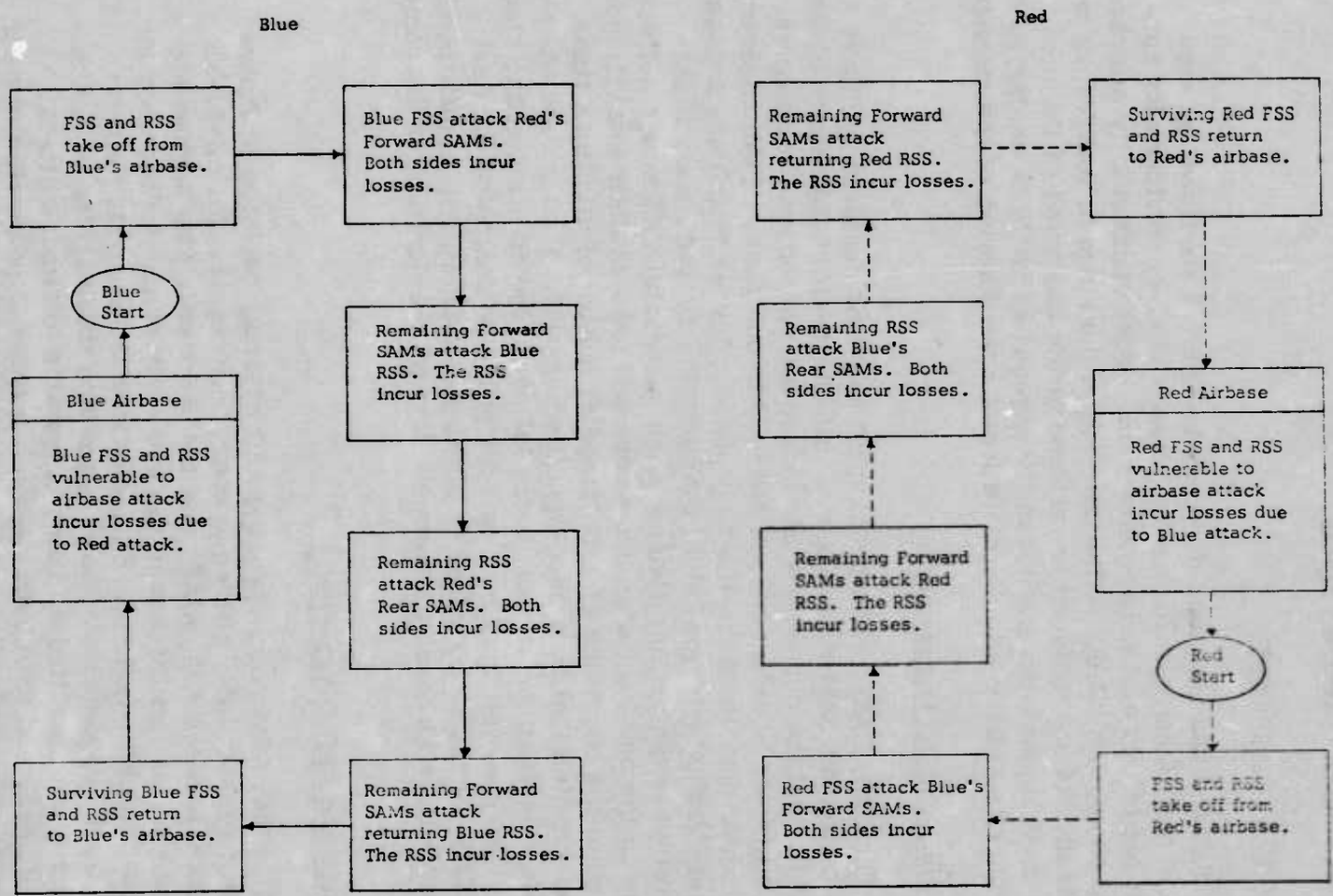


FIGURE 3

FSS AND RSS ENGAGEMENTS DURING AN ENGAGEMENT CYCLE

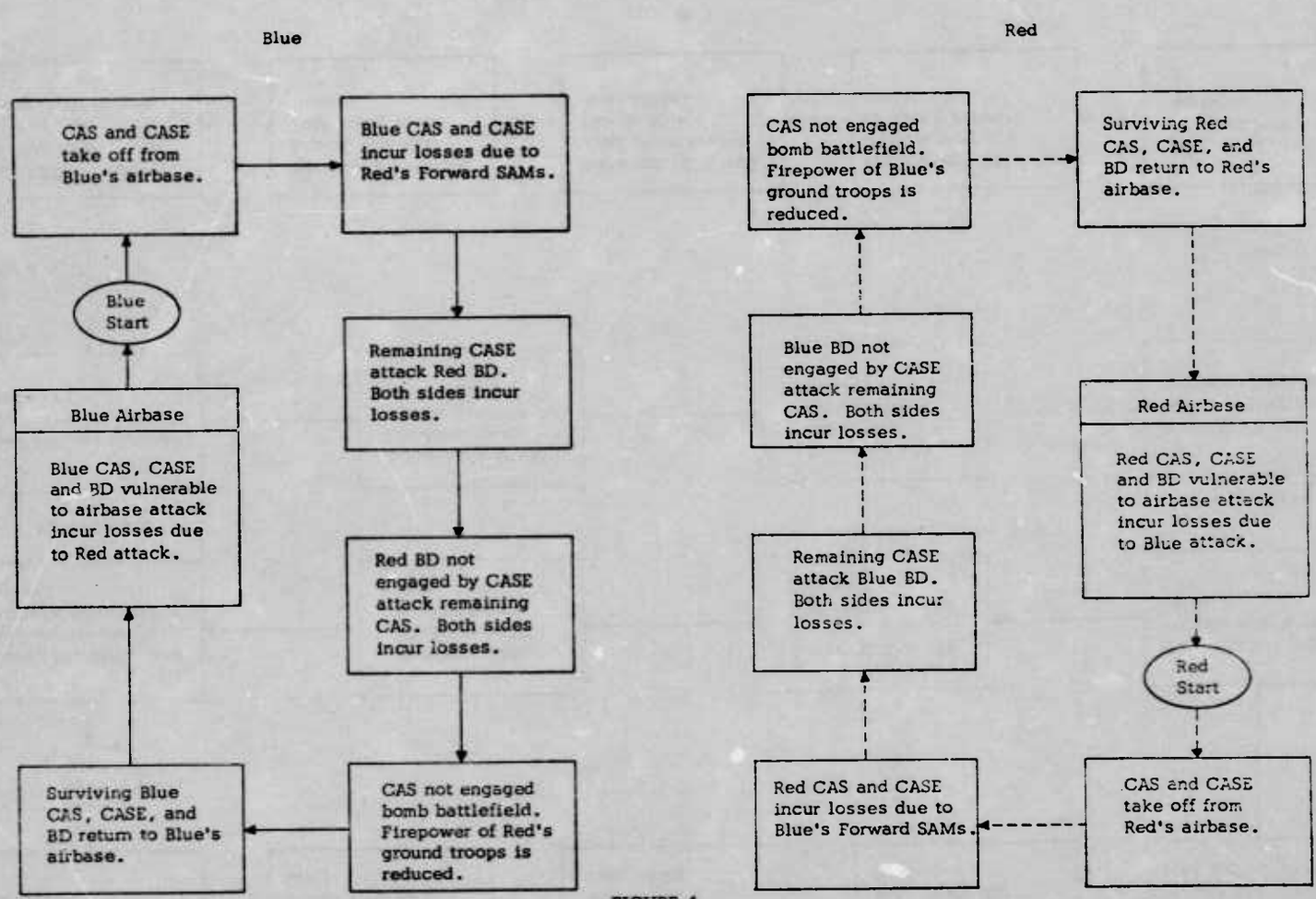


FIGURE 4

CAS, CASE, AND BD ENGAGEMENTS DURING AN ENGAGEMENT CYCLE

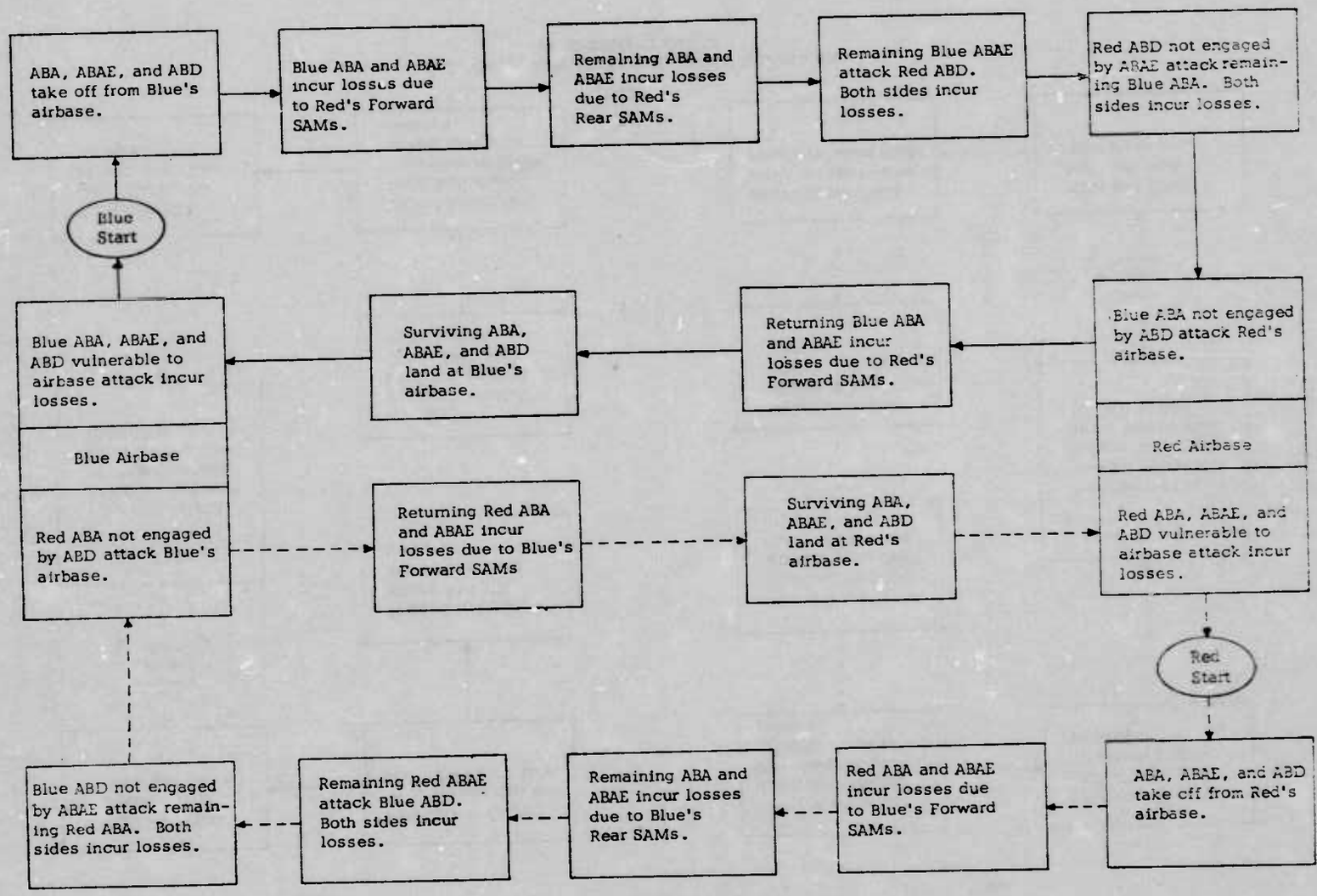


FIGURE 5

ABA, ABAE, AND ABD ENGAGEMENTS DURING AN ENGAGEMENT CYCLE

assumed to be repaired by the beginning of the next cycle. ABA, ABAE, or ABD killed in air-to-air engagements or destroyed by the opponent's airbase attackers are lost for the duration of the campaign.

ATTRITION RELATIONSHIPS

During the course of the engagement cycles just described, all aircraft casualties due to air-to-air and ground-to-air engagements are computed in terms of sorties lost. Surviving sorties, which successfully return to their airbase at the end of each cycle, are converted to aircraft before they are subjected to airbase attack by dividing numbers of surviving sorties by the sortie rates. The mathematical relationships used to evaluate sortie losses as well as the attrition resulting from air-to-ground engagements are described below.

Air-to-Air Engagements

In general, for each possible air-to-air engagement shown in the blocks of Figures 4 and 5, sorties on one side assigned to a generic attack mission, engage, in one-on-one encounters, sorties on the opposing side assigned to a generic defense mission. Excess attack sorties not engaged in one phase of the air-to-air war proceed to the next phase; sorties that are engaged abort their assigned mission, prosecute the air-to-air engagement and, if not killed, return immediately thereafter to their airbase. To describe how sortie attrition on both sides is computed in such an engagement, let

A_i = number of attack sorties in the current engagement flown by aircraft of type i

D_j = number of defense sorties in the current engagement flown by aircraft of type j

A_i^k = number of the A_i killed in the current engagement

D_j^k = number of the D_j killed in the current engagement

p_{ij} = probability an attack sortie of type i is killed by a defense sortie of type j in a one-on-one encounter

q_{ji} = probability a defense sortie of type j is killed by an attack sortie of type i in a one-on-one encounter

To compute A_i^k and D_j^k, the total numbers of attack and defense sorties are first used to compute E, the number of one-on-one encounters, as

$$E = \min \left(\sum_i A_i, \sum_j D_j \right) \tag{6}$$

The allocation of this total to individual aircraft types is then computed proportionally as

$$E_{ij} = E \left(\frac{A_i}{\sum_i A_i} \right) \left(\frac{D_j}{\sum_j D_j} \right) \tag{7}$$

where E_{ij} represents the number of one-on-one encounters between attackers of type i and defenders of type j.

Finally, expected numbers of killed attack and defense sorties flown by aircraft of types i and j respectively are computed as

$$A_i^k = \sum_j E_{ij} \, p_{ij} \tag{8}$$

and

$$D_j^k = \sum_i E_{ij} \, q_{ji} \tag{9}$$

Air-to-Ground Engagements

Of the three types of air-to-ground engagements considered in ATACM, only the SAM suppression and airbase attack missions directly produce losses among the opponent's forces. As described in the discussion of Figure 4, CAS sorties reduce the opponent's ground firepower by a simple subtractive rule which indirectly reflects ground losses. By contrast, SAM and parked aircraft losses are computed using exponential relationships relating the kill probabilities and numbers of attackers (SAM suppressors or ABA) to the number of opponents (SAMs or parked aircraft).

SAM Losses

To derive the expression for SAM losses produced by generic (FSS or RSS) SAM suppression sorties, let

A_i = number of SAM suppression sorties in the current engagement flown by aircraft of type i

D = number of opposing SAMs

D^k = number of D killed in the current engagement

q_i = probability a SAM is killed by a SAM suppressor sortie of type i

To compute D^k, the numbers of SAM suppression sorties flown are used as weights to compute an average probability of kill

$$\bar{q} = \frac{\sum_i A_i q_i}{\sum_i A_i} \tag{10}$$

This probability, along with the numbers of suppression sorties and SAMs, is used to compute D^k as

$$D^k = D\left(1 - \exp\left(-\bar{q}\,\frac{\sum_i A_i}{D}\right)\right) \tag{11}$$

Losses Due to ABA

The attrition relationship for computing the effect of ABA sorties on parked aircraft is analogous to Equation (11), the only difference being the number of opponent types. Specifically, let -

A_i = number of ABA sorties in the current engagement flown by aircraft of type i

D_j = number of parked aircraft of type j vulnerable to airbase attack. Vulnerable aircraft are assigned to shelters in proportion to their relative numbers in the inventory; j=1 corresponds to sheltered aircraft, j=2 to unsheltered.

D_j^k = number of D_j killed in the current engagement.

q_{ji} = probability a vulnerable aircraft of type j is killed by a sortie flown by an ABA aircraft of type i

To determine D_j^k, first E_{ij}, the number of attack sorties of each type i assumed to attack vulnerable aircraft of type j, is computed pro-

portionally as

$$E_{ij} = A_i \frac{D_j}{\sum_j D_j} \tag{12}$$

Using the E_{ij} as weights, an average probability of killing a parked aircraft of type j is computed as

$$\bar{q}_j = \frac{\sum_i E_{ij} q_{ji}}{\sum_i E_{ij}} \tag{13}$$

Finally, D_j^k is computed using the standard exponential expression

$$D_j^k = D_j \left(1 - \exp\left(-\bar{q}_j \frac{\sum_i E_{ij}}{D_j}\right)\right) \tag{14}$$

Ground-to-Air Engagements

In ground-to-air engagements, SAMs attack opposing sorties in one-on-one encounters analogous to one-sided air-to-air engagements. If the number of opposing sorties exceeds the number of SAMs, excessive sorties are not attacked. If the number of SAMs exceeds the number of sorties, excessive SAMs are not launched. To describe the attrition produced by a generic SAM (forward or rear) attack, let

- A = number of SAMs in the current engagement
- D_j = number of target sorties in the current engagement flown by aircraft of type j
- D_j^k = number of D_j killed in the current engagement
- q_j = probability a target sortie flown by an aircraft of type j is killed by a SAM in a one-on-one encounter

To compute D_j^k, the total number of SAMs and opposing aircraft sorties are used to compute E, the number of one-on-one encounters, as

$$E = \min\left(A, \sum_j D_j\right) \tag{15}$$

$$E_j = E \frac{D_j}{\sum_j D_j} \tag{16}$$

where E_j represents the number of one-on-one encounters between SAMs and target sorties of type j.

Finally, the expected number of killed sorties flown by aircraft of type j is computed as

$$D_j^k = E_j q_j \tag{17}$$

OPTIMIZATION METHODOLOGY

The methodology used to select optimal strategies for both sides at each stage of the campaign reflects the recommendations of the survey presented in Reference 1. The basic approach is to select enforceable strategies which individually optimize each side's minimal performance over the length of the campaign. Following paragraphs explain this optimization criterion in detail and describe the dynamic programming methodology used to implement it.

MAXMIN/MINMAX STRATEGIES AND PAYOFFS

In the standard game matrix such as that shown in Figure 1 the possible objective functions used to compute payoffs to Blue are defined such that positive payoffs indicate Blue success. Blue's objective is to choose that strategy which will produce the largest payoff, while Red's objective is to choose that strategy which will produce the smallest payoff. The approach used in ATACM is to assume both Blue and Red act conservatively in choosing their strategies. To illustrate, for a simple case, Figure 6 presents a game matrix for starting force levels in a hypothetical one-stage campaign in which Blue has five possible strategies, Red has four.

One-Stage Game

Since Blue and Red are assumed to be conservative, each chooses that strategy which will produce the most favorable outcome under the worst of circumstances -- i.e. prior knowledge of his selection by his opponent. In the case of Blue, selection of S_1 guarantees a payoff no less than 1 regardless of which strategy Red chooses. Selection of S_2 guarantees a payoff no less than 0, S_3 no less than -1, etc. These minimal payoffs (or row minimums) are shown in Figure 6 for each possible Blue selection. Assuming Red has superior intelligence, Blue would choose that strategy, S_1, which maximizes over the set of minimal payoffs. Thus S_1 is called Blue's MAXMIN strategy, and 1, the minimal payoff associated with S_1, is called the MAXMIN payoff or objective function value. The Red strategy $\bar{S}_2$ which would have to be play against S_1 to yield the MAXMIN payoff is called Red's MAXMIN strategy.

	Red / Blue	$\bar{S}_1$	$\bar{S}_2$	$\bar{S}_3$	$\bar{S}_4$	Row Min
			Red MAXMIN ↓		Red MINMAX ↓	
Blue MAXMIN →	S_1	2	[1]	4	(2)	1
	S_2	3	5	0	0	0
Blue MINMAX →	S_3	6	-1	4	[3]	-1
	S_4	3	1	2	-2	-2
	S_5	0	-3	-5	1	-5
	Col Max	6	5	4	3	

FIGURE 6

ONE-STAGE GAME MATRIX

In the case of Red's selection, choice of $\bar{S}_1$ could result in a payoff as large as 6 if Blue were to play S_3, selection of $\bar{S}_2$ could result in a payoff as large as 5, $\bar{S}_3$ a payoff as large 4, and $\bar{S}_4$ a payoff as large as 3. Assuming Blue has superior intelligence, conservative Red would choose that strategy, $\bar{S}_4$, which minimizes over the set of column maximums shown in Figure 6. Strategy $\bar{S}_4$ is called Red's MINMAX strategy, S_3 is called Blue's MINMAX strategy, and 3, the payoff associated with playing $\bar{S}_4$ against S_3 is called the MINMAX payoff.

If Blue were to play its MAXMIN strategy and Red its MINMAX strategy, the payoff which would result is 2. This MAXMIN vs. MINMAX payoff will always be greater than or equal to the MAXMIN payoff (in this case 1) and less than or equal to the MINMAX payoff (in this case 3).

From this example, it should be clear how the optimization criterion used in ATACM would be applied for a one-stage campaign. Given the starting force levels, strategies, and objective function specification, payoffs in the corresponding game matrix would be computed using the assessment methodology described in the previous section. Blue's MAXMIN strategy and payoff would be computed by maximizing over row minimums while Red's MINMAX strategy and payoff would be computed by minimizing over column maximums. Output would consist of the Blue MAXMIN strategy, the Red MINMAX strategy, the lower and upper MAXMIN/MINMAX objective function bounds, and the actual MAXMIN vs. MINMAX payoff which would result if both sides played their conservative strategies.

Multi-Stage Game

To understand how the MAXMIN/MINMAX strategy selection procedures for a one-stage game extend to a multi-stage game, it is helpful to present an alternative representation of a staged game called an extended game as shown in Figure 7. In an extended game representation of a T-stage air campaign, Blue extended strategies are T-tuples whose t^{th} element is a strategy selected from the set of one-stage strategies $S_1, S_2, \ldots, S_{m_t}$ available to Blue at the t^{th} stage of the campaign. In other words, the first element in an extended strategy for Blue is the strategy Blue would use for stage 1, the 2nd element is Blue's strategy for stage 2, ..., and the T^{th} element is Blue's strategy for the last stage of the campaign. The number of possible extended

FIGURE 7

EXTENDED GAME REPRESENTATION
OF A T-STAGE GAME

Blue \ Red	$\overline{\overline{ES}}_1$	$\overline{\overline{ES}}_2$	...	$\overline{\overline{ES}}_N$
ES_1	TP_{11}	TP_{12}	...	TP_{1N}
ES_2	TP_{21}	TP_{22}	...	TP_{2N}
⋮	⋮	⋮		⋮
ES_M	TP_{M1}	TP_{M2}	...	TP_{MN}

ES_i = Blue Extended Strategy = $(S_{i_1}, S_{i_2}, \ldots, S_{i_T})$

where S_{i_t} = Blue strategy for stage t

$\overline{\overline{ES}}_j$ = Red Extended Strategy = $(\bar{S}_{j_1}, \bar{S}_{j_2}, \ldots, \bar{S}_{j_T})$

where $\bar{S}_{j_t}$ = Red strategy for stage t

$M = m_1 \cdot m_2 \cdot \ldots \cdot m_T$ $\qquad N = n_1 \cdot n_2 \cdot \ldots \cdot n_T$

TP_{ij} = Total Payoff produced by playing ES_i against $\overline{\overline{ES}}_j$

strategies, M, from which Blue may choose is equal to

$$M = m_1 \cdot m_2 \cdot m_3 \cdot \ldots \cdot m_T \qquad (18)$$

where m_t equals the number of possible Blue strategies available for stage t. Extended strategies for Red are analogous.

Payoffs in an extended game are total payoffs over the length of the campaign which result from playing a Blue extended strategy against a Red extended strategy. Looking back at Figure 1, a total payoff in the extended game depends upon the one-stage payoffs and the attrition represented by the dashed line. Each different combination of Blue-Red extended strategies corresponds to a unique attrition path from the state space at the beginning of stage 1 to the state space at the end of stage T.

Theoretically, selection of MAXMIN/MINMAX strategies in a multi-stage campaign, represented in the context of the extended game, is exactly the same as that described for a one-stage game. Indeed, for a one-stage campaign the extended game representation reduces to a one-stage game. Unfortunately, for air campaigns with reasonable numbers of strategies and stages the extended game representation is valuable only as an abstraction because of its prohibitive size. For example, if Blue and Red each had only 20 possible strategies to choose from at each stage of a three stage campaign, the corresponding extended game would be an 8000 by 8000 matrix requiring 64 million three-stage payoff evaluations. Assuming 10^{-3} seconds of computer time was required for each one-stage assessment, evaluation of the payoffs alone would require over 50 hours. Needless to say, a method other than the straightforward solution of the extended game is required to determine MAXMIN/MINMAX strategies for the general multi-stage campaign.

DYNAMIC PROGRAMMING SOLUTION

The reason the extended game representation of modest sized air campaigns becomes untractable is that it treats the problem of strategy selection for all stages as a single step process. An alternative approach, using dynamic programming, is to decompose the problem into a series of one-stage problems, similar in many respects to the way the problem was originally posed in Figure 1. To illustrate the dynamic programming approach, its necessary to define more precisely many of the

concepts first presented there. For purposes of illustration, we will assume Blue and Red each have one aircraft type -- more types simply increase the dimensionality of the state space. For this case, shown in Figure 8, let

X_t = a point, (B_t, R_t), in the state space at the beginning of stage t corresponding to B_t and R_t aircraft available to Blue and Red respectively

$S(X_t)$ = Blue's one-stage MAXMIN strategy selection corresponding to X_t

$\bar{S}(X_t)$ = Red's one-stage MINMAX strategy selection corresponding to X_t

$TP(X_t)$ = the total MAXMIN payoff associated with optimal play by Blue from state X_t at the beginning of stage t to the end of the campaign

$\overline{TP}(X_t)$ = the total MINMAX payoff associated with optimal play by Red from state X_t at the beginning of stage t to the end of the campaign

$P_{ij}(X_t)$ = payoff in the one-stage game matrix corresponding to selection of the i^{th} and j^{th} strategies when in state X_t

$Z_{ij}(X_t)$ = state X_{t+1} into which selection of the i^{th} and j^{th} strategies by Blue and Red maps the state X_t

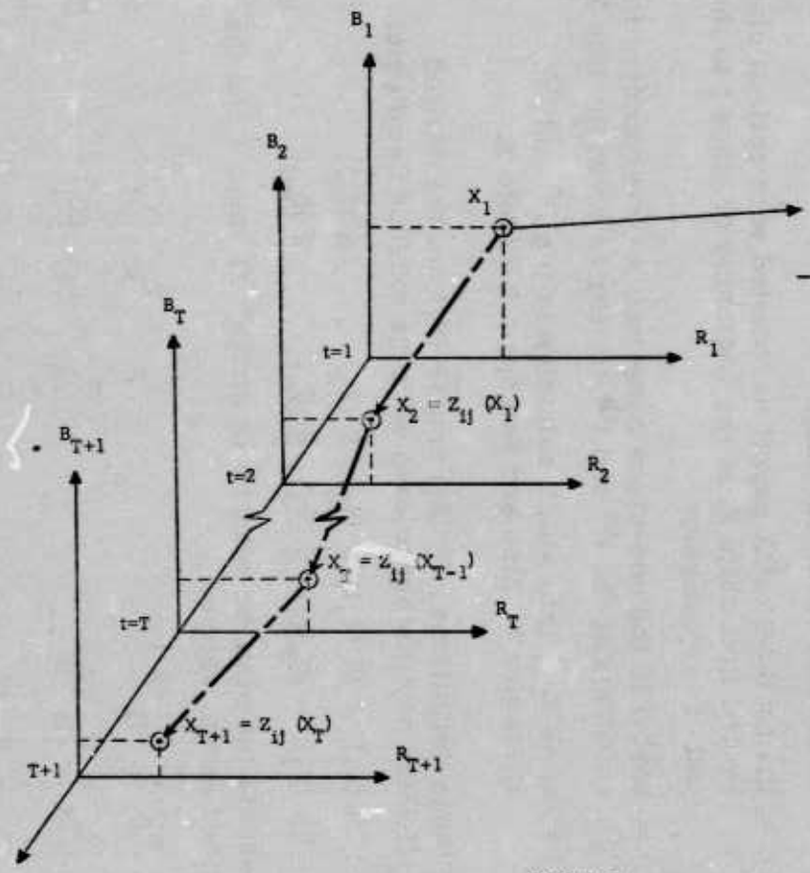
Using these definitions, $TP(X_1)$ and $\overline{TP}(X_1)$ are the desired MAXMIN and MINMAX payoffs associated with the extended strategies

$$ES(X_1) = (S(X_1), S(X_2), S(X_3), \ldots, S(X_T)) \tag{19}$$

$$\overline{ES}(X_1) = (\bar{S}(X_1), \bar{S}(\bar{X}_2), \bar{S}(\bar{X}_3), \ldots, \bar{S}(\bar{X}_T)) \tag{20}$$

where X_1 represents the starting numbers of aircraft at stage 1 and the X_t and $\bar{X}_t$ are defined recursively by

$$\begin{aligned} X_2 &= Z_{ij}(X_1) & \bar{X}_2 &= Z_{k\ell}(X_1) \\ X_3 &= Z_{ij}(X_2) & \bar{X}_3 &= Z_{k\ell}(\bar{X}_2) \\ &\vdots & &\vdots \\ X_T &= Z_{ij}(X_{T-1}) & \bar{X}_T &= Z_{k\ell}(\bar{X}_{T-1}) \end{aligned} \tag{21}$$



B \ R	$\bar{S}_1$	...	$\bar{S}_j$	...	$\bar{S}_{n_1}$
S_1					
⋮					
S_i			P_{ij}		
⋮					
S_{m_1}					

S_i = Blue MAXMIN strategy

$\bar{S}_j$ = Red MAXMIN strategy

$P_{ij} = P_{ij}(X_1) + TP(X_2 = Z_{ij}(X_1))$

$S(X_1) = S_i$

$TP(X_1) = P_{ij}$

FIGURE 8

DYNAMIC PROGRAMMING SOLUTION FOR
MAXMIN STRATEGIES AND BOUNDS

with i = index of Blue's MAXMIN strategy for the current stage
j = index of Red's MAXMIN strategy for the current stage
k = index of Blue's MINMAX strategy for the current stage
ℓ = index of Red's MINMAX strategy for the current stage

The dynamic programming approach for solving for TP (X_1), ES (X_1), $\overline{TP}$ (X_1), and $\overline{ES}$ (X_1) separates the solution for the MAXMIN total payoff and extended strategy from the MINMAX counterparts. Although all descriptions which follow concentrate on the MAXMIN solution, the MINMAX solution technique is exactly analogous.

Idealized Approach

To compute TP (X_1) and ES (X_1) using a general dynamic programming procedure, one begins at the beginning of the last stage of the campaign and computes one-stage MAXMIN payoffs and strategies, TP (X_T) and S (X_T), for all possible states X_T. The i, j^{th} payoff, P_{ij}, in the MAXMIN game matrix for each state X_T is given by

$$P_{ij} = P_{ij}(X_T) + TP(X_{T+1} = Z_{ij}(X_T)) \quad (22)$$

where $P_{ij}(X_T)$ is the one-stage payoff and TP $(X_{T+1} = Z_{ij}(X_T))$ is the contribution of undamaged aircraft at the end of the war, B_{T+1} and R_{T+1}, to the value of the overall objective function (Equation 2).

After TP (X_T) and S (X_T) have been computed for all states X_T, these values are stored and the process moves backward to the beginning of stage T-1. Using the TP (X_T) just computed, the elements in the payoff matrix for each stage X_{T+1} are now given by

$$P_{ij} = P_{ij}(X_{T-1}) + TP(X_T = Z_{ij}(X_{T-1})) \quad (23)$$

where $P_{ij}(X_{T-1})$ is the payoff contribution of the current stage and TP $(X_T = Z_{ij}(X_{T-1}))$ is the MAXMIN payoff associated with optimal play thereafter. Once again, a Blue MAXMIN strategy is computed for each game matrix along with the cumulative MAXMIN payoff TP (X_{T-1}) and each is stored for all possible states X_{T-1}. Processing moves backward to the preceding stage in time, game matrices are generated for all states, etc.

Eventually, through this iterative process, strategies and payoffs can be generated for all stages and states from stage T back to the beginning of stage 1. Since X_1, the hypothesized starting resource level, is

a point in the state space at the beginning of stage 1, the solution is complete. TP (X_1) is available immediately, while the one-stage strategies which compose ES (X_1) can be retrieved from storage by tracing through the states using the attrition map Z_{ij}. Perhaps even more important, as a by-product of the dynamic programming approach, solutions for all other X_t are also available since they have been stored during the processing required to solve for X_1. By simply retrieving the stored results, solutions for all shorter campaigns less than T stages which begin with any number of aircraft on either side can be easily generated.

Problems

Precise implementation of the general dynamic programming algorithm as described above requires evaluation of one-stage game for every possible state of every possible stage. The number of such states in a reasonable sized game is huge, even for the case in which each side has only one aircraft type. For example, each side might reasonably start with 1000 aircraft, making the number of possible (B_t, R_t) pairs more than one million.

Intuitively, one would suspect states which differ by only a few aircraft would produce approximately the same solution. ATACM exploits this intuitive feel by imposing a descrete grid upon the state space at each stage in a manner analogous to that used in DYGAM (Reference 4). If a grid such as that shown in Figure 9 were imposed, a tractable approach would be to explicitly compute one-stage strategies and payoffs for only the discrete grid points using the dynamic programming procedure described above. Unfortunately, as shown in Figure 9, the Z_{ij} (X_t) for a grid point X_t would generally not lie on a grid point in the subsequent stage's state space. Since TP (Z_{ij} (X_t)) is necessary to compute the elements in the one-stage game matrix (Equation (22)), an approximation technique is required for computing payoffs associated with points not on the grid.

Possible Approximations

One possible approximation technique for computing TP (X_{t+1} = Z_{ij} (X_t)) would be to linearly interpolate using the explicit payoffs for grid points adjacent to X_{t+1}. It can be shown that as the grid becomes finer the strategies which would result from using linear interpolation would approach those produced by the idealized dynamic programming solution. Similarly, the payoffs produced would approach the idealized lower bound TP (X_1), but not necessarily from below. In other words, although the

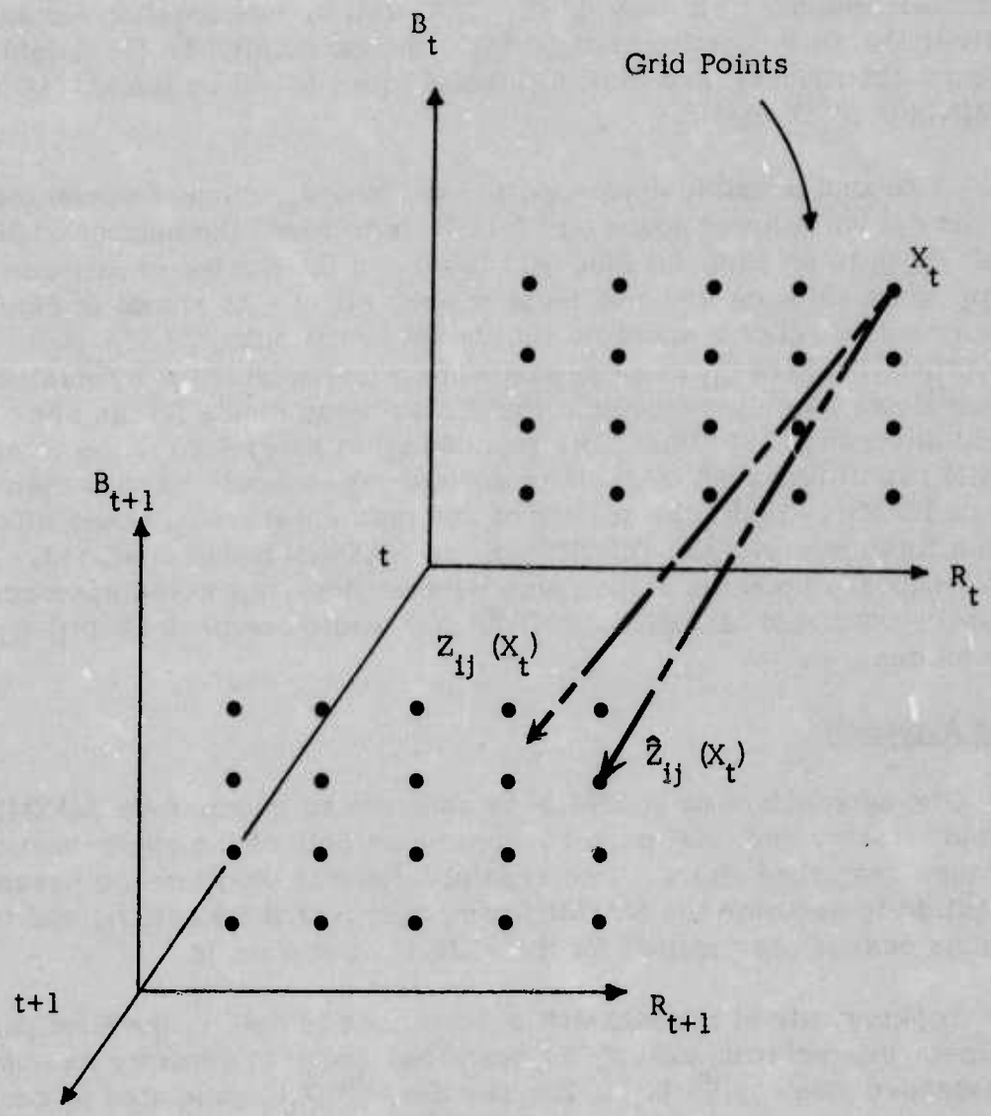


FIGURE 9

DYNAMIC PROGRAMMING
APPROXIMATIONS

approximate extended strategy $\hat{ES}(X_1)$ produced by interpolation would intuitively be a good estimate of $ES(X_1)$, the associated $\hat{TP}(X_1)$ might be greater than $TP(X_1)$ and thus an invalid lower bound on the MAXMIN vs. MINMAX total payoff.

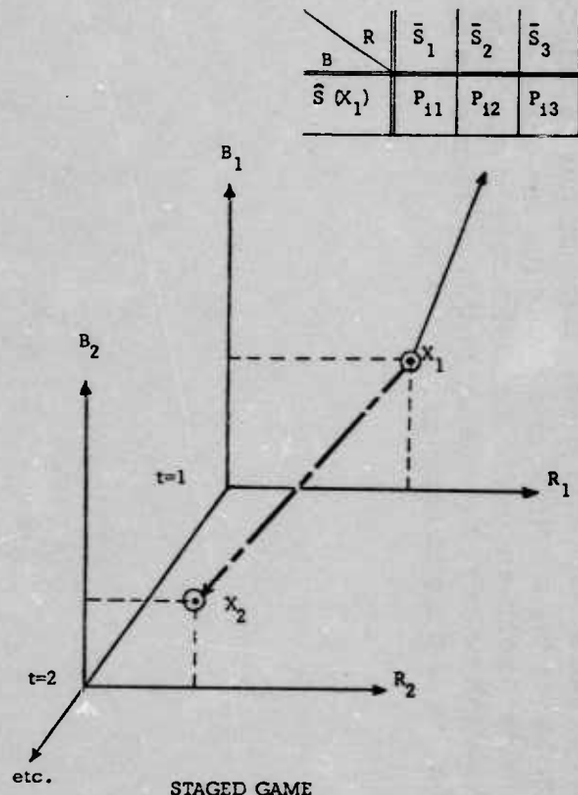
A second possible approximation technique, which is guaranteed to produce a valid lower bound on $TP(X_1)$, is to round the number of Blue aircraft down to an adjacent Blue grid level and the number of Red aircraft up to an adjacent Red grid level at each stage. As shown in Figure 9, such a rounding scheme would be equivalent to replacing $TP(Z_{ij}(X_t))$ by $TP(\hat{Z}_{ij}(X_t))$ where $\hat{Z}_{ij}$ is an approximate mapping which incorporates the Blue-down, Red-up rounding criteria. Because Blue's forces are rounded down and Red's forces are rounded up at every stage, the total MAXMIN payoff produced by such an approximation would be less than or equal to $TP(X_1)$. Thus, the quality of the approximation $\hat{Z}_{ij}$ would affect only the tightness, not the validity, of the MAXMIN bound produced. As the grid imposed upon the state space became finer, $\hat{Z}_{ij}$ would approach Z_{ij} and the computed MAXMIN payoff $\hat{TP}(X_1)$ would approach $TP(X_1)$ from below as desired.

ATACM Approach

The approach used in ATACM to generate an approximate MAXMIN extended strategy and total payoff incorporates both of the approximation techniques described above. Two separate dynamic programming passes are required to generate the MAXMIN components of the solution, and two analogous passes are required for the MINMAX components.

Looking only at the MAXMIN calculations in detail, the first pass uses linear interpolation exactly as described above to generate an approximate extended strategy $\hat{ES}(X_1)$. The payoffs, $\hat{TP}(X_t)$, generated at each stage and state are used only to compute $\hat{ES}(X_1)$ and are discarded after the one-stage strategies are stored.

The second pass, designed to produce a lower bound on the MAXMIN total payoff $TP(X_1)$, uses the $\hat{S}(X_t)$ stored during the first pass as fixed Blue strategies against which Red performs a MINMAX pass using the rounding scheme described above. As shown in Figure 10, in this second pass the game matrix for each stage and state has only one Blue strategy. Column maximums in these one-stage games are the single one-stage payoffs corresponding to each Blue strategy, and the MINMAX pass reduces to the calculation of the minimum payoff Red can achieve against $\hat{ES}(X_1)$.



STAGED GAME

OR

B \ R	$\overline{ES}_1$	$\overline{ES}_2$	$\overline{ES}_3$	...	$\overline{ES}_N$
$\hat{FS}(X_1)$	TP_{i1}	TP_{i2}	TP_{i3}	...	TP_{iN}

EXTENDED GAME

FIGURE 10

ALTERNATIVE REPRESENTATIONS
OF THE SECOND DYNAMIC PROGRAMMING
PASS FOR COMPUTING $\hat{TP}(X_1)$

To see that this second MINMAX pass produces a lower bound on TP (X_1), consider two cases.

- If $\hat{ES}$ (X_1) is the same as ES (X_1), and no Blue-down/Red-up rounding is required, the best Red can do in the MINMAX pass is to generate Red's MAXMIN extended strategy, which, by definition, produces a total payoff exactly equal to TP (X_1). If rounding is required, the total payoff would clearly be less than or equal to TP (X_1).

- If $\hat{ES}$ (X_1) is not equal to ES (X_1), and rounding is not required, the minimum total payoff Red can achieve in the MINMAX pass is the row minimum corresponding to $\hat{ES}$ (X_1) in the extended game of Figure 10. Since TP (X_1) is defined as the maximum over all row minimums, TP (X_1) must be bounded from below by the MINMAX payoff. As before, if rounding is required the value of the MINMAX payoff can only be reduced.

Finally, after two analogous dynamic programming passes for computing estimates of Red's MINMAX extended strategy $\overline{ES}$ (X_1) and the upper objective function bound TP (X_1), the solution is virtually complete. All that remains is the estimation of the MAXMIN vs. MINMAX payoff for starting state X_1 which is accomplished by actually playing the one-stage strategies stored for Blue and Red at each grid point. If during this calculation a Z_{ij} (X_t) does not fall on one of the specified grid points the one-stage strategies stored for the nearest point are used. As in the case of computing the MAXMIN and MINMAX bounds, the quality of this approximation depends upon the coarseness of the grid imposed.

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APPENDIX A

ATACM USER'S GUIDE

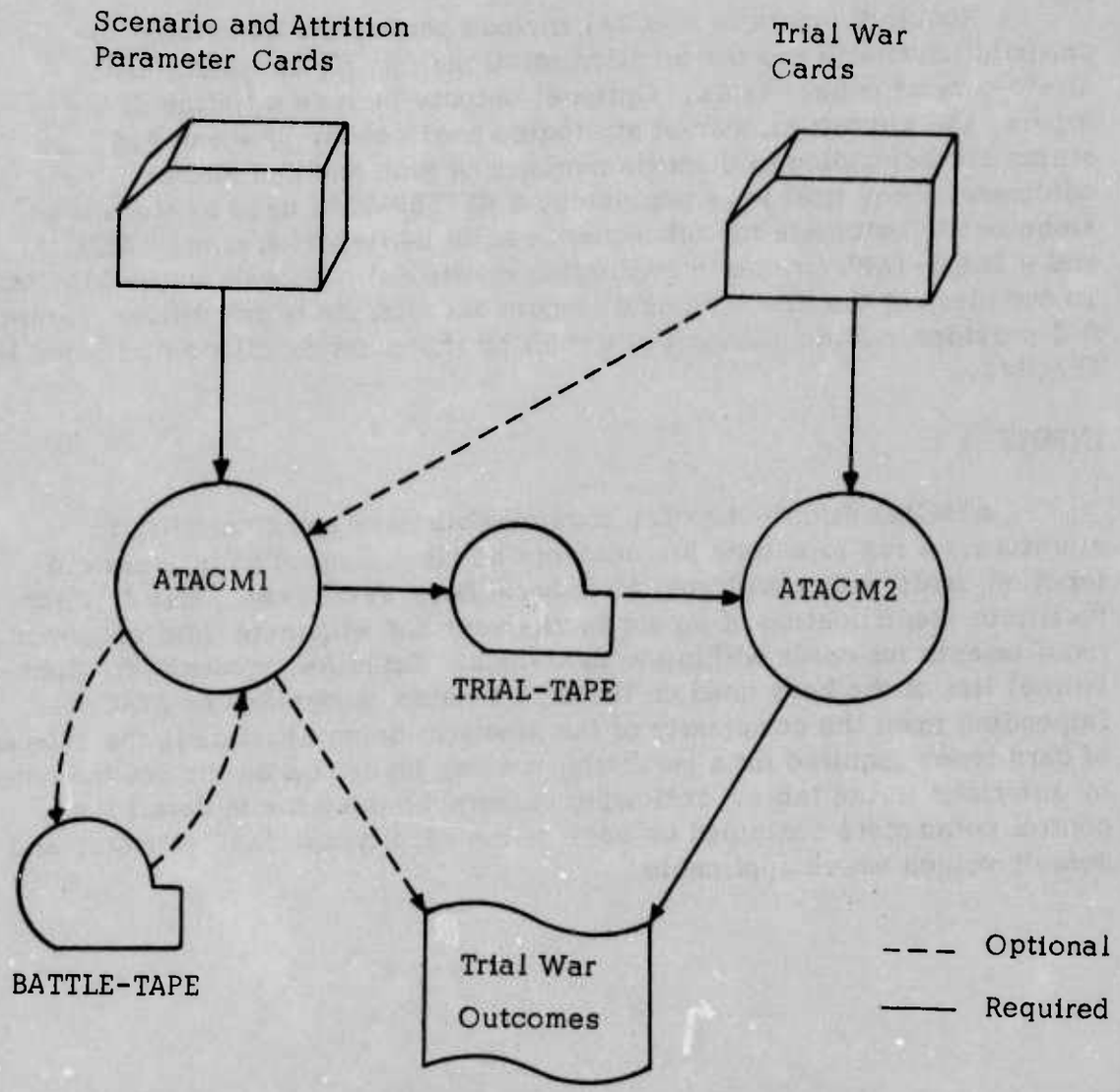
This appendix is a guide to the use of ATACM. Following sections describe the inputs, the operation, and the outputs of the model.

GENERAL OVERVIEW

The computer model ATACM was developed by the Arms Control and Disarmament Agency as a tool for studying the impact of various force postures upon the outcome of a tactical airwar in Europe between NATO and Warsaw Pact forces. ATACM treats an air campaign as a zero-sum staged gamed between opposing forces, Blue and Red, each consisting of air and ground forces. Most of the emphasis in the current version of ATACM is upon air force interactions although a simplistic representation of the ground war is also included. The model uses dynamic programming to generate for each stage and state of the campaign optimal aircraft allocation strategies and associated MAXMIN/MINMAX bounds on a user-specified objective function.

As currently implemented, ATACM consists of two FORTRAN programs, ATACM1 and ATACM2, designed for use on a CDC 6600 computer. ATACM1 generates optimal strategies and associated objective function bounds for each stage and state and uses these values to evaluate the outcomes of trial wars of specified length which are initiated with user-specified numbers of Blue and Red aircraft. In addition to the outcomes of the trial wars, ATACM1 can output to magnetic tape one-stage battle assessments (BATTLE-TAPE) for use in subsequent runs of ATACM1, and optimal strategies and bounds (TRIAL-TAPE) for use in subsequent trial war evaluations using ATACM2. To evaluate additional trial wars, ATACM2 reads the TRIAL-TAPE and uses the information it contains to process trial war requests and produce outputs identical to those which would have been produced if the requests had been evaluated during the execution of ATACM1. Thus, for a given set of scenario and attrition parameters, only a single execution of ATACM1 is necessary regardless of when or how many trial war evaluations are eventually required.

Figure A-1 presents a schematic representation of how ATACM1, ATACM2, the BATTLE-TAPE, and the TRIAL-TAPE interrelate.



AN OVERVIEW OF ATACM'S OPERATION

FIGURE A-1

ATACM1

Required inputs to ATACM1 include parameters describing the campaign scenario and the attrition relationships for air-to-air and air-to-ground engagements. Optional outputs include a listing of the inputs, the aircraft allocation strategies available to Blue and Red, the states corresponding to discrete numbers of Blue and Red aircraft, the outcomes of any trial wars requested, a BATTLE-TAPE used to store one-stage battle outcomes for subsequent use in perturbation runs of ATACM1, and a TRIAL-TAPE for use in evaluating additional trial wars using ATACM2. To complement the discussions of inputs and outputs which follow, Figure A-2 provides a logical flowchart depicting the major functions performed by ATACM1.

INPUTS

ATACM1 affords the user considerable ease and flexibility in sturcturing a run to satisfy his analysis needs. Control parameters are input on cards with identifying alphabetic keys in columns 1 thru 5 which facilitate identification of inputs by the user and eliminate rigid sequence requirements for cards within the data deck. Table A-1 presents an alphabetical list of the keys used on the inputs cards recognized by ATACM1. Depending upon the complexity of the scenario being simulated, the number of card types required for a particular run can be as few as the six indicated by asterisks in the table. Following paragraphs describe in detail the control parameters contained on each of the card types, their formats, and default values where applicable.

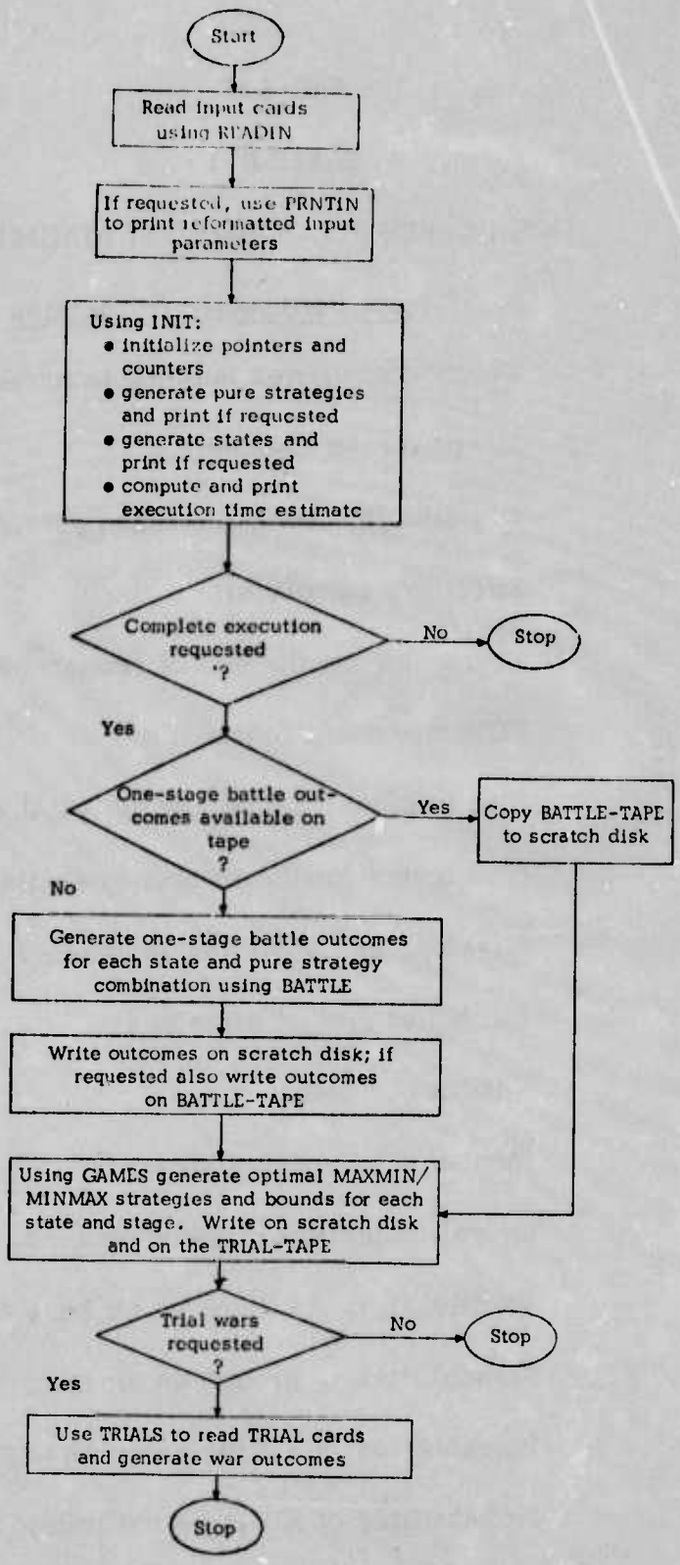


FIGURE A-2
LOGICAL FLOWCHART OF ATACM1

PAB-249

TABLE A-1

INPUT CARDS RECOGNIZED BY ATACM1

Card Key	Input Parameters It Contains
ABAF	Fraction of planes vulnerable to ABA
CASF	Firepower per CAS sortie
DFRC	Division firepower reduction per CAS sortie
DIVF	Firepower per division
END*	Flag to signal the end of scenario and attrition inputs
FEBAM	FEBA movement function
FINIS	Flag to signal the end of the TRIAL cards
GRID**	Grid levels for the number of available planes
MISS**	Missions assigned and associated sortie rates
NDIV	Number of ground divisions
NSAM	Number of SAMs
NSHL	Number of air base shelters
OWGHT	Overall objective function weights
PKAA	Probabilities of killing an air base attacker
PKAD	Probabilities of killing an air base defender
PKAE	Probabilities of killing an air base attacker escort
PKBA	Probabilities of killing a battlefield attacker
PKBD	Probabilities of killing a battlefield defender

TABLE A-1 (Cont'd)

Card Key	Input Parameters It Contains
PKBE	Probabilities of killing a battlefield attacker escort
PKFA	Probabilities of killing a forward SAM attacker
PKFS	Probabilities of killing a forward SAM
PKNS	Probabilities of killing a non-sheltered plane
PKRA	Probabilities of killing a rear SAM attacker
PKRS	Probabilities of killing a rear SAM
PKSH	Probabilities of killing a sheltered plane
REIN	Plane reinforcements by stage
RUN*	Run options and title
STAGE*	Number of stages and engagement cycles per stage
STRT**	Strategy specifications by stage
TRIAL	Initial number of planes and length of a TRIAL war
VALU	Value of an undamaged plane at end of war
WGHT	Objective function weights by stage

* At least one card required for every run.
**At least one card required for each side for every run.

ABAF Card

One ABAF card for each aircraft type is used to specify the fraction of the aircraft assigned to each mission which is vulnerable to airbase attack. By specifying different fractions, aircraft flying selected missions can be made invulnerable or partially vulnerable to the opponent's airbase attack. Generally larger fractions are more applicable for aircraft prosecuting missions close to friendly airbases (e.g., ABD, BD, CAS, and forward SAM suppression) than for aircraft flying missions deep in the opponent's territory (e.g., ABA and rear SAM suppression). Aircraft whose fractions are set equal to zero might include planes housed in impenetrable shelters or long-range bombers flying from a sanctuary base.

The ABAF card is read under

FORMAT (A4, A1, I1, 4X, 8F5.0)

and its fields are assigned as follows:

A4 - (1-4) - "ABAF"

A1 - (5) - "B" or "R" to indicate the vulnerability fractions are for either a Blue or Red aircraft type

I1 - (6) - the number of the aircraft type for which the fractions are applicable

8F5.0 - (11-50) - the fraction of the aircraft flying a particular mission which is vulnerable to airbase attack. The fraction specified in columns 11-15 corresponds to the 1st mission assigned on the associated MISS card, columns 16-20 to the 2nd, etc. Default value is 1.

CASF Card

One CASF card for each side is used to specify the firepower delivered per CAS sortie flown. The units used to specify firepower on the CAS card must be consistent with those used on both the DFRC and the DIVF cards. The CASF card is read under

FORMAT (A4, A1, 5X, 4F5.4)

and its fields are defined as follows:

A4 - (1-4) - "CASF"

A1 - (5) - "B" or "R" to indicate the firepower rates are for either the Blue or Red side

4F5.4 - (11-30) - the firepower delivered per CAS sortie by aircraft of types 1 thru 4 respectively. Default value is 0.

DFRC Card

One DFRC card for each side is used to specify the ground division firepower reduction produced by each CAS sortie flown. The units used to specify firepower reduction on the DFRC card must be consistent with those used on both the CASF and the DIVF cards. The DFRC card is read under

FORMAT (A4, A1, 5X, 4F5.4)

and its fields are defined as follows:

A4 - (1-4) - "DFRC"

A1 - (5) - "B" or "R" to indicate the ground division firepower reductions are produced by either a Blue or Red CAS sortie.

4F5.4 - (11-30) - the ground division firepower reduction resulting from a CAS sortie flown by aircraft of types 1 thru 4 respectively. Default value is 0.

DIVF Card

One DIVF card for each side is used to specify the firepower per ground division. The units used to specify firepower on the DIFV card must be consistent with those used on both the CASF and the DFRC card. The DIVF card is read under

FORMAT (A4, A1, 5X, F5.0)

and its fields are assigned as follows:

A4 - (1-4) - "DIVF"

A1 - (5) - "B" or "R" to indicate the firepower is specified for each Blue or Red ground divisions

F5.0 - (11-15) - the firepower per ground division. Default value is 0.

END Card

The END card signals the end of the scenario and attrition parameter cards required by ATACM1 and the beginning of the optional TRIAL cards. The END card is read under

FORMAT (A3)

and its only field contains

A3 - (1-3) - "END"

FEBAM Card

As many as four FEBAM cards may be used to specify the rate of FEBA movement per cycle as a function of the ratio of Blue ground firepower to Red ground firepower. Any functional relationship desired can be input by specifying up to 28 points that lie on the graph of the desired function. The model linearly interpolates between these points to yield a piecewise linear approximation. The quality of the approximation depends upon the shape of the desired graph and the number and location of points chosen. The coordinates of the points are read from the FEBAM card under

FORMAT (A5, I1, 4X, 7(2F5.0))

and the fields are assigned as follows:

A5 - (1-5) - "FEBAM"

I1 - (6) - card sequence number. Seven points (smallest firepower ratio to largest) are input on each card to a maximum of four cards or 28 points. The first card has sequence number 1, the second card (if required) has sequence number 2, etc.

7(2F5.0)-(11-80) - x and y coordinates of the ith point on the graph

x = ratio of Blue ground firepower to Red ground firepower (always positive)

y = FEBA movement per engagement cycle (positive movement corresponds to Blue advance)

Default value for (x,y) is (0,0).

FINIS Card

The FINIS card signals the end of the TRIAL cards and consequently the end of the input data. The FINIS card is read under

FORMAT (A5)

and its only field contains

A5 - (1-5) - "FINIS"

GRID Card

One GRID card for each aircraft type is required to indicate the discrete numbers of aircraft for which optimal plays and associated bounds are explicitly computed. The GRID card is read under

FORMAT (A4, A1, I1, 4X, 11I5)

and its fields are assigned as follows:

A4 - (1-4) - "GRID"

A1 - (5) - "B" or "R" to indicate the grid levels are for either a Blue or Red aircraft type

I1 - (6) - the number of aircraft type for which the grid levels are applicable. Aircraft types are numbered in ascending order from 1 to 4.

11I5 - (11-65) - the discrete numbers of aircraft of the specified type for which optimal plays and bounds are explicitly generated. The first grid level must be 0 followed by remaining grid levels listed in ascending order. The maximum number of grid levels for an aircraft type is 11. The largest grid level should be the upper bound on the initial number of planes of this type plus the total number of reinforcements which can be added during a trial war.

MISS Card

One MISS card is required for each aircraft type to specify its minimum allocation fraction, the missions it can prosecute, and the asso-

ciated sortie rates. Each MISS card is read under

FORMAT (A4, A1, I1, 4X, I2, 1X, 8(2X,I1), 3X, 8F5.2)

and the fields are assigned as follows:

A4 - (1-4) - "MISS"

A1 - (5) - "B" or "R" to indicate the mission information is for either a Blue or Red aircraft type

I1 - (6) - the number of the aircraft type

I2 - (11-12) - the denominator of the minimum allocation fraction for this aircraft type. The minimum allocation fraction is the smallest fraction of the total number of planes which can be assigned to any mission. All fractional assignments are integer multiples of the minimum allocation fraction.

8(2X,I1)-(14-37) - numerical codes (see Table A-2) corresponding to the missions to which planes of the specified type may be assigned. A maximum of eight missions may be specified for an aircraft type.

8F5.2-(41-80) - sortie rates per engagement cycle associated with the missions specified in the preceding columns. The sortie rates must be specified in the same relative order as the mission codes.

TABLE A-2

AIR MISSION CODES

Code	Mission
1	Close air support (CAS)
2	Airbase attack (ABA)
3	Battlefield defense (BD)
4	Airbase defense (ABD)
5	Close air support escort (CASE)
6	Airbase attack escort (ABAE)
7	Forward SAM suppression (FSS)
8	Rear SAM suppression (RSS)
9	No assigned mission

NDIV Card

One NDIV card for each side is used to specify the number of ground divisions available. The NDIV card is read under

FORMAT (A4, A1, 5X, I5)

and its fields are defined as follows:

A-4 - (1-4) - "NDIV"

A1 - (5) - "B" or "R" to indicate the number of divisions correspond to either the Blue or Red side

I5 - (11-15) - the number of ground divisions. Default value is 0.

NSAM Card

One NSAM card for each side is used to specify the number of for-

ward and rear SAMs available. The NSAM card is read under

FORMAT (A4, A1, 5X, 2I5)

and its fields are defined as follows:

A4 - (1-4) - "NSAM"

A1 - (5) - "B" or "R" to indicate the number of SAMs correspond to either the Blue or Red side

I5 - (11-15) - the number of forward SAMs. Default value is 0.

I5 - (16-20) - the number of rear SAMs. Default value is 0.

NSHL Card

One NSHL card for each side is used to specify the number of aircraft shelters available. The NSHL card is read under

FORMAT (A4, A1, 5X, I5)

and its fields are assigned as follows:

A4 - (1-4) - "NSHL"

A1 - (5) - "B" or "R" to indicate the number of shelters correspond to either the Blue or Red side

I5 - (11-15) - the number of aircraft shelters. Default value is 0.

OWGHT Card

The basic form of the overall function used to generate optimal conservative strategies is given by

$$F = w_1 f_1 + w_2 f_2 + w_3 f_3 \qquad \text{(A-1)}$$

where f_1 = difference of total Blue minus total Red CAS firepower

f_2 = difference of total Blue minus total Red (CAS firepower + ground firepower)

and f_3 = total FEBA movement (positive movement corresponds to Blue advance).

One OWGHT card is used to specify the values of the weights, w_1, w_2, and w_3 to be used in computing F. The OWGHT card is read under

FORMAT (A5, 5X, 3F5.0)

and its fields are defined as follows:

A5 - (1-5) - "OWGHT"

F5.0 - (11-15) - the value of w_1. Default value is 1.

F5.0 - (16-20) - the value of w_2. Default value is 0.

F5.0 - (21-25) - the value of w_3. Default value is 0.

PKAA Card

For each aircraft type assigned an airbase attack (ABA) mission, one PKAA card is required to specify the probabilities that such an aircraft is killed by an opposing airbase defender or SAM in a one-on-one engagement. The PKAA card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, 2F5.3)

and its fields are defined as follows:

A4 - (1-4) - "PKAA"

A1 - (5) - "B" or "R" to indicate the ABA aircraft belongs to either the Blue or Red forces

I1 - (6) - the number of the ABA aircraft type

4F5.3-(11-30) - the probability the ABA aircraft is killed by opposing ABD's of types 1 thru 4 respectively. Default value is 0.

F5.3-(36-40) - the probability the ABA aircraft is killed by an opposing forward SAM. Default value is 0.

F5.3 - (41-45) - the probability the ABA aircraft is killed by an opposing rear SAM. Default value is 0.

PKAD Card

For each aircraft type assigned an airbase defense (ABD) mission, one PKAD card is required to specify the probabilities that such an aircraft is killed by an opposing airbase attacker or airbase attack escort in a one-on-one engagement. The PKAD card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, 4F5.3)

and its fields are assigned as follows:

A4 - (1-4)	-	"PKAD"
A1 - (5)	-	"B" or "R" to indicate the ABD aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the ABD aircraft type
4F5.3- (11-30)	-	the probability the ABD aircraft is killed by opposing ABA's of types 1 thru 4 respectively. Default value is 0.
4F5.3- (36-55)	-	the probability the ABD aircraft is killed by opposing ABA escorts of types 1 thru 4 respectively. Default value is 0.

PKAE Card

For each aircraft type assigned an airbase attack escort (ABAE) mission, one PKAE card is required to specify the probabilities that such an aircraft is killed by an opposing airbase defender or SAM in a one-on-one engagement. The PKAE card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, 2F5.3)

and its fields are defined as follows:

A4 - (1-4)	-	"PKAE"
A1 - (5)	-	"B" or "R" to indicate the ABAE aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the ABAE aircraft type
4F5.3- (11-30)	-	the probability the ABAE aircraft is killed by opposing ABD's of types 1 thru 4 respectively. Default value is 0.
F5.3 - (36-40)	-	the probability the ABAE aircraft is killed by an opposing forward SAM. Default value is 0.
F5.3 - (41-45)	-	the probability the ABAE aircraft is killed by an opposing rear SAM. Default value is 0.

PKBA Card

For each aircraft type assigned a battlefield attack (CAS) mission, one PKBA card is required to specify the probabilities that such an aircraft

is killed by an opposing battlefield defender or forward SAM in a one-on-one engagement. The PKBA card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, F5.3)

and its fields are defined as follows:

A4 - (1-4)	-	"PKBA"
A1 - (5)	-	"B" or "R" to indicate the CAS aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the CAS aircraft type
4F5.3- (11-30)	-	the probability the CAS aircraft is killed by opposing BD's of types 1 thru 4 respectively. Default value is 0.
F5.3- (36-40)	-	the probability the CAS aircraft is killed by an opposing forward SAM. Default value is 0.

PKBD Card

For each aircraft type assigned a battlefield defense (BD) mission, one PKBD card is required to specify the probabilities that such an aircraft is killed by an opposing battlefield attacker (CAS) or battlefield attack escort (CASE) in a one-on-one engagement. The PKBD card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, 4F5.3)

and its fields are defined as follows:

A4 - (1-4)	-	"PKBD"
A1 - (5)	-	"B" or "R" to indicate the BD aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the BD aircraft type
4F5.3- (11-30)	-	the probability the BD aircraft is killed by opposing CAS's of types 1 thru 4 respectively. Default value is 0.
4F5.3- (36-55)	-	the probability the BD aircraft is killed by opposing CAS escorts of types 1 thru 4 respectively. Default value is 0.

PKBE Card

For each aircraft type assigned a battlefield attack escort (CASE) mission, one PKBE card is required to specify the probabilities that such an aircraft is killed by an opposing battlefield defender or forward SAM in a one-on-one engagement. The PKBE card is read under

FORMAT (A4, A1, I1, 4X, 4F5.3, 5X, F5.3)

and its fields are defined as follows:

A4 - (1-4)	-	"PKBE"
A1 - (5)	-	"B" or "R" to indicate the CASE aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the CASE aircraft type
4F5.3- (11-30)	-	the probability the CASE aircraft is killed by opposing BD's of types 1 thru 4 respectively. Default value is 0.
F5.3- (36-40)	-	the probability the CASE aircraft is killed by an opposing forward SAM. Default value is 0.

PKFA Card

For each aircraft type assigned a forward SAM suppression (FSS) mission, one PKFA card is required to specify the probability that such an aircraft is killed by an opposing forward SAM in a one-on-one engagement. The PKFA card is read under

FORMAT (A4, A1, I1, 4X, F5.3)

and its fields are defined as follows:

A4 - (1-4)	-	"PKFA"
A1 - (5)	-	"B" or "R" to indicate the FSS aircraft belongs to either the Blue or Red forces
I1 - (6)	-	the number of the FSS aircraft type
F5.3- (11-15)	-	the probability the FSS aircraft is killed by an opposing forward SAM. Default value is 0.

PKFS Card

One PKFS card for each side is used to specify the probabilities that a forward SAM is killed by forward SAM suppressors. The PKFS card is read under

FORMAT (A4, A1, 5X, 4F5.3)

and its fields are defined as follows:

A4 - (1-4)	- "PKFS"
A1 - (5)	- "B" or "R" to indicate the SAM being attacked belongs to either the Blue or Red forces
4F5.3 - (11-30)	- the probability the SAM is killed by opposing FSS's of types 1 thru 4 respectively. Default value is 0.

PKNS Card

One PKNS card for each side is used to specify the probabilities that a non-sheltered aircraft on the airbase is killed by airbase attackers. These kill probabilities are only applicable to the fraction specified as vulnerable to airbase attack on the ABAF card. The PKNS card is read under

FORMAT (A4, A1, 5X, 4F5.3)

and its fields are assigned as follows:

A4 - (1-4)	- "PKNS"
A1 - (5)	- "B" or "R" to indicate the airbase being attacked is either Blue or Red
4F5.3 - (11-30)	- the probability a non-sheltered, vulnerable aircraft on the airbase is killed by opposing ABA's of types 1 thru 4 respectively. Default value is 0.

PKRA Card

For each aircraft type assigned a rear SAM Suppression (RSS) mission, one PKRA card is required to specify the probabilities that such an aircraft is killed by an opposing SAM in a one-on-one engagement. The PKRA card is read under

FORMAT (A4, A1, I1, 4X, 2F5.3)

and its fields are defined as follows:

A4 - (1-4) - "PKRA"

A1 - (5) - "B" or "R" to indicate the RSS aircraft belongs to either the Blue or Red forces

I1 - (6) - the number of the RSS aircraft type

F5.3- (11-15) - the probability the RSS aircraft is killed by an opposing forward SAM. Default value is 0.

F5.3- (16-20) - the probability the RSS aircraft is killed by an opposing rear SAM. Default value is 0.

PKRS Card

One PKRS card for each side is used to specify the probabilities that a rear SAM is killed by rear SAM suppressors. The PKRS card is read under

FORMAT (A4, A1, 5X, 4F5.3)

and its fields are assigned as follows:

A4 - (1-4) - "PKRS"

A1 - (5) - "B" or "R" to indicate the SAM being attacked belongs to either the Blue or Red forces

4F5.3- (11-30) - the probability the SAM is killed by opposing RSS's of types 1 thru 4 respectively. Default value is 0.

PKSH Card

One PKSH card for each side is used to specify the probabilities that a sheltered aircraft on the airbase is killed by airbase attackers.

PKSH card is read under

FORMAT (A4, A1, 5X, 4F5.3)

and its fields are assigned as follows:

A4 - (1-4) - "PKSH"

A1 - (5) - "B" or "R" to indicate the airbase being attacked is either Blue or Red

4F5.3- (11-30) - the probability a sheltered, vulnerable aircraft on the airbase is killed by opposing ABA's of types 1 thru 4 respectively. Default value is 0.

REIN Card

The REIN card is used to specify numerical and/or fractional aircraft reinforcements as a function of stage. The REIN card is read under

FORMAT (A4, A1, 1X, I2, 4F5.0, 5X, 4F5.0)

and its fields are assigned as follows:

A4 - (1-4) - "REIN"

A1 - (5) - "B" or "R" to indicate the specified reinforcements are for either the Blue or Red side

I2 - (7-8) - the number of the stage when the reinforcements arrive. In every case reinforcement occurs at the beginning of the stage before attrition is computed.

4F5.0- (11-30) - the number of aircraft of types 1 thru 4 respectively added (or subtracted if entry is negative) at the beginning of the specified stage. Default value is 0.

4F5.0- (36-55) - the fractional increase (or decrease if entry is negative) in the number of aircraft of types 1 thru 4 respectively at the beginning of the specified stage. If both a fractional and a numerical change are specified for the same stage, the fractional change is applied before the numerical change. Default value for the fractional change is 0.

RUN Card

The RUN card, which must precede all other input cards, contains parameters to control input, execution, and output options. The RUN card is read under

FORMAT (A3, 7X, 8I1, 2X, 6A10)

and its fields are assigned as follows:

A3 - (1-3) - "RUN"

I1 - (11) - print option

if 0 or blank input parameters are printed

if 1 output is suppressed

I1 - (12) - print option

if 0 or blank the sets of pure strategies available to Blue and Red are printed

if 1 output is suppressed

I1 - (13) - print option

if 0 or blank the set of discrete states corresponding to the number of Blue and Red planes available is printed

if 1 output is suppressed

I1 - (14) - abort option

if 0 or blank execution proceeds to normal termination

if 1 execution is terminated immediately after run-time estimates are printed

I1 - (15) - BATTLE-TAPE option

if 0 or blank one-stage battle outcomes for each state and pure strategy combination are not available on tape and must be computed. The computed battle outcomes are <u>not</u> written and stored on the BATTLE-TAPE

if 1 one-stage battle outcomes for each state and pure strategy combination are not available on tape and must be computed. The computed battle outcomes are

written and stored on the BATTLE-TAPE

if 2 one-stage battle outcomes for each state and pure strategy combination are read from the BATTLE-TAPE

I1 - (16) - debug option

if 0 or blank debug output is suppressed

if 1 one-stage battle outcomes for each state and pure strategy combination are printed

I1 - (17) - debug option

if 0 or blank debug output is suppressed

if 1 MAXMIN/MINMAX plays and corresponding bounds are printed for each stage and state

I1 - (18) - debug option

if 0 or blank debug output is suppressed

if 1 beta weights used for linear interpolation are printed each time subroutine BETAS is called

6A10-(21-80) - optional run title

STAGE Card

The STAGE card is used to specify the number of stages in the campaign and the number of engagement cycles per stage. It is read under

FORMAT (A5, 5X, I2, 2X, I2)

and contains the following values:

A5 - (1-5) - "STAGE"

I2 - (11-12) - the number of stages in the campaign for which plays and associated bounds are generated ($\leq$99). Trial wars of longer duration than the number of stages specified can not be evaluated.

I2 - (15-16) - the number of engagement cycles per stage ($\leq$99).

STRT Card

The STRT card is used to specify any, all, or none of the fractional allocations of aircraft to missions as a function of stage. One STRT card is required to specify each time the allocation fractions change for either Blue or Red aircraft types. If no mission allocation fractions are specified for a given stage, ATACM1 optimizes strategy selection from the complete set of possible pure strategies; if the mission allocation fractions are specified for a subset of the missions, the model optimizes strategy selection from the associated subset of possible pure strategies; if allocation fractions are specified for all missions, the set of possible pure strategies consists of a single strategy and optimal selection reduces to the selection of this single specified strategy. Thus by using different combinations of STRT cards, ATACM1 can be used to evaluate the effects of Blue, Red, or both sides using optimal, sub-optimal, or user-specified strategies against its opponent.

The STRT card is read under

FORMAT (A4, A1, 1X, I2, 4 (2X, 8I2))

with the fields defined as follows:

A4 - (1-4) - "STRT"

A1 - (5) - "B" or "R" to indicate the specified allocations are for either the Blue or Red side

I2 - (7-8) - the upper bound on the range of stages over which the allocations specified are in effect. The lower bound is 1 plus the upper bound specified on the preceding STRT card for the same side. The lower bound for the first STRT card for either side is assumed to be 1. The upper bound for the last STRT card for either side must be greater than or equal to the number of stages specified on the STAGE card.

4(2X,8I2)-(9-80) - the fractional assignments of the ith aircraft type ($1 \leq i \leq 4$) to its missions, specified as integer multiples of the corresponding minimum allocation fraction. Columns 9-26 correspond to aircraft type 1, 27-44 to type 2, 45-62 to type 3, 63-80 to type 4. The

integer multiples for the ith aircraft type must be specified in the same order as the missions are assigned on the MISS card. To indicate that the allocation fraction for a mission is unspecified, the corresponding 2 character field must be punched with a right-justified asterisk (" *").

TRIAL Card

One TRIAL card is required for each trial war evaluation desired. If input to ATACM1, the first TRIAL card must follow the END card and the last must be followed by a FINIS card. Each TRIAL card is read under

FORMAT (A5, 5X, I2, 2X, 3I1, 3X, 4F5.0, 5X, 4F5.0)

and its fields are assigned as follows:

A5 - (1-5) - "TRIAL"

I2 - (11-12) - the number of stages in the trial war

I1 - (15) - print option

if 0 or blank the number of planes available and the objective function value are printed for every stage

if 1 output is suppressed

I1 - (16) - print option

if 0 or blank the optimal aircraft allocation strategies for Blue and Red are printed for every stage

if 1 output is suppressed

I1 - (17) - print option

if 0 or blank the values of each of the three objective functions (f_1, f_2, and f_3 as described under the OWGHT card) are printed for every stage

if 1 output is suppressed

4F5.0-(21-40) - the number of Blue aircraft of types 1 thru 4 respectively available at the beginning of the trial war

4F5.0-(46-65) - the number of Red aircraft of types 1 thru 4 respectively available at the beginning of the trial war

VALU Card

One VALU card for each side is used to specify the residual value of an undamaged plane at the end of the war. The units used to specify this residual value should be consistent with those used on the CASF card. The VALU card is read under

FORMAT (A4, A1, 5X, 4F5.0)

and its fields are defined as follows:

A4 - (1-4) - "VALU"

A1 - (5) - "B" or "R" to indicate the values specified apply to either Blue or Red aircraft

4F5.0-(11-30) - the residual value of an undamaged aircraft of types 1 thru 4 respectively. Default value is 0.

WGHT Card

Each component, f_j, of the overall objective function described under the OWGHT card (Equation A-1) can be expanded as

$$f_j = \sum_{t=1}^{T+1} f_{jt} \quad \text{for } j = 1, 2, 3 \tag{A-2}$$

where

$$f_{1t} = \begin{cases} \text{weighted difference of Blue minus Red CAS firepower delivered during stage t} \\ b_t \, CAS_{Bt} - r_t \, CAS_{Rt} \end{cases} \tag{A-3}$$

$$f_{2t} = \begin{cases} \text{weighted difference of Blue minus Red total firepower delivered during stage t} \\ b_t \, TFP_{Bt} - r_t \, TFP_{Rt} \end{cases} \tag{A-4}$$

$$f_{3t} = \begin{cases} \text{weighted FEBA movement during stage t} \\ \dfrac{b_t + r_t}{2} \quad \text{(FEBA movement during stage t)} \end{cases} \tag{A-5}$$

WGHT cards are used to specify the values of the weights b_t and r_t as a function of stage. Each WGHT card is read under

FORMAT (A4, A1, 1X, I2, 2X, F5.0)

and its fields are assigned as follows:

A4 - (1-4) - "WGHT"

A1 - (5) - "B" or "R" to indicate whether the value specified is a Blue or Red weight (b_t or r_t)

I2 - (7-8) - the number of the stage t for which the specified weight is applicable

F5.0 - (11-15) - the value of the weight. Default value is 1.

As an aid to the user, Figure A-3 summarizes the formats of all the input cards described above and the default values used if a card is not supplied. With the exception of the TRIAL card, all cards for which default values are not specified are required for every run.

DATA DECK STRUCTURE

As alluded to in the descriptions of the individual cards, ATACM1 permits considerable freedom in the ordering of cards within a run deck. Table A-3 summarizes the order constraints for those card types subject to special restrictions. The only sequence requirement applicable to cards not listed in the table is that they follow the RUN card and precede the END card. Figure A-4 presents a sample run deck with the input cards in an acceptable order.

OUTPUTS

The possible outputs of ATACM1 include the printed output which details the results of the run, the TRIAL-TAPE which can be used by ATACM2 to evaluate additional trial wars, and a BATTLE-TAPE containing one-stage battle outcomes which can be used to speed the execution of certain subsequent runs of ATACM1. Each of these outputs are described below.

FIGURE A-3

FORMATS AND DEFAULT VALUES FOR INPUTS TO ATACM

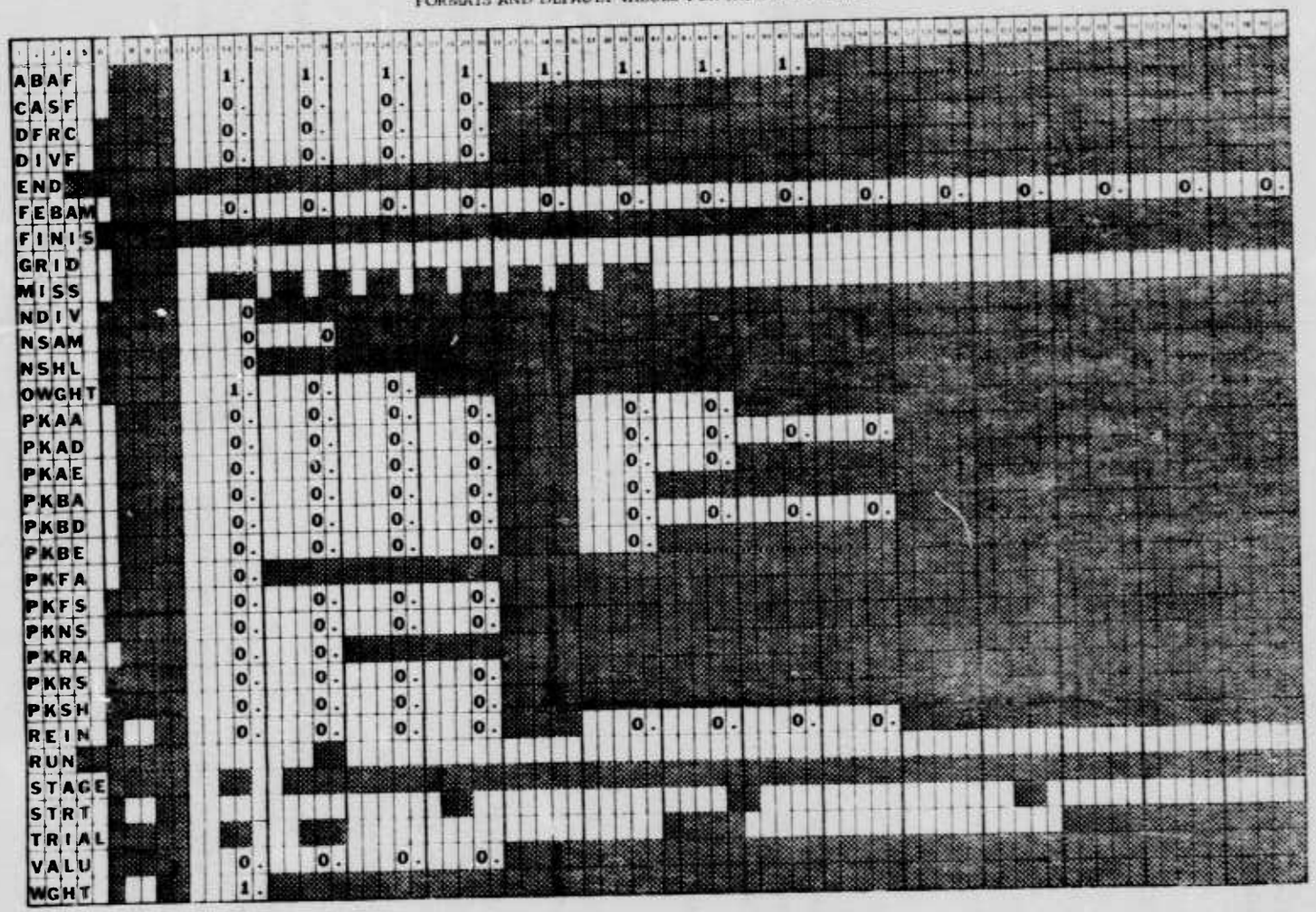


TABLE A-3

SEQUENCE RESTRICTIONS ON INPUT CARDS
TO ATACM1

Card Type	Restriction
RUN	First card in the data deck
STRT	In ascending time sequence (e.g., a STRTB card for stage i must precede a STRTB card for stage j if i<j)
END	Follow scenario and attrition cards/precede the optional TRIAL and FINIS cards
TRIAL	Follow the END card/precede the FINIS card (optional)
FINIS	Follow TRIAL cards/last card in the data deck (optional)

Printed Output

Unless explicitly suppressed by the print options listed in Table A-4, every run of ATACM1 prints:

- both the input deck and the input parameters reformatted for readability
- the numbers of pure strategies available to Blue and Red
- lists of the pure strategies available to Blue and Red
- the number of possible states
- a list of the possible states
- run-time estimates

FIGURE A-4

SAMPLE RUN DECK FOR ATACM1

```
RUN                SAMPLE RUN -- 2 BLUE AIRCRAFT TYPES, 1 RED AIRCRAFT TYPE
STAGE          2   1
ND1VB         10
ND1VR         15
D1VFB          9.
D1VFR          7.
GRIDB1         0  333  667 1000
GRIDB2         0  200  400
GRIDR1         0  400  800 1200
MISSB1         2    1   2   7   8                          2.0  1.0  2.0  1.0
MISSB2         3    3   4   5   6                          2.0  2.0  2.0  1.0
MISSR1         2    1   2   3   4                          2.0  1.0  2.0  2.0
STRTB  2       1    *   *   *                  *   *   1   *
STRTR  1       0    2   0   0
STRTR  2       *    *   *   *                                  .2
REINB  2     100
REINR  2     200
VALUB          8.   0.
VALUR          3.
CASFB          2.
CASFR          3.
OWGHT          0.   1.0   0.
NSHLB        100
NSHLR        300
NSAMB         30   50
NSAMR         20   40
ABAFB1       1.0   .5   1.0   .5
ABAFB2       1.0  1.0   1.0   .5
ABAFR1        .5   .5    .5   .5
WGHTB  1      .5
PKSHB        .20
PKSHR        .25
PKNSB        .35
PKNSR        .50
PKRSR        .06
PKFSR        .08
DFRCB         .5
DFRCR         .8
FEBAM1        0.  -1.  .99  -1. 1.01    1. 200.   1.
PKBAB1       .10                                .16
PKBAR1             .12                          .17
PKAAB1        .09                               .15  .20
PKAAR1             .11                          .14  .21
PKBDB2        .05
PKBDR1        .04                                     .12
PKADB2        .03
PKADR1        .02                                     .03
PKBEB2        .05                                .03
PKAEB2        .07                                .01  .02
PKFAB1        .01
PKRAB1        .01  .03
END
TRIAL          2          400  100                          500
TRIAL          1  11      600  200                          600
TRIAL          2   1     800  300                          800
FINIS
```

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TABLE A-4

RUN CARD
PRINT OPTION CONTROLS

To suppress the print of:	Punch a 1 in RUN card column
Input parameters	11
All possible strategies for Blue and Red	12
All possible states	13

If trial war evaluations are requested during the execution of ATACM1, additional outputs are printed under the control of the print option parameters on the TRIAL card. Specifically, unless explicitly suppressed by the print options listed in Table A-5, every trial war evaluation prints:

- the TRIAL card parameters, the MAXMIN and MINMAX bounds on the objective function, and the value of the objective function produced by playing Blue's MAXMIN strategy against Red's MINMAX strategy

- the number of planes available on both sides and the value of the objective function as a function of stage

- the optimal aircraft allocation strategies as a function of stage

- the individual values of the three objective functions (i.e., Blue-Red CAS Firepower, Blue-Red Total Firepower, and FEBA movement) listed as a function of stage

Figures A-5 and A-6, which were produced by the sample input deck of Figure A-4, illustrate the outputs printed under the control of the RUN and TRIAL cards respectively.

TABLE A-5

TRIAL CARD
PRINT OPTION CONTROLS

To suppress the print (by stage) of:	Punch a 1 in TRIAL card column
Number of planes/objective function value	15
Optimal strategies for Blue and Red	16
All three objective function values	17

BATTLE-TAPE

The BATTLE-TAPE is an optional output of ATACM1 which contains the one-stage battle assessments computed in the initialization phase of the run (see Figure A-2). The BATTLE-TAPE has two potential applications:

- it provides a partial backup/restart capability should an ATACM1 job be terminated abnormally after the battle assessments are computed, and

- it can be used to input rather than recompute battle assessments for perturbation runs of ATACM1 in which those parameters affecting one-stage battle outcomes are unchanged.

The advisability of specifying a BATTLE-TAPE as an output of a long-running ATACM1 job should be obvious. If such a job aborts abnormally after the BATTLE-TAPE is written, a rerun can be made by simply assigning the BATTLE-TAPE as an input, punching a "2" in column 15 of the RUN card, and resubmitting the job. The resubmitted job reads the battle assessments directly from the BATTLE-TAPE, thus saving the time required for their calculation.

In the case of a shorter run, the decision whether to create a BATTLE-TAPE depends upon how applicable the computed battle assessments will be to other related runs of ATACM1. Table A-6 lists those input parameters which can be changed without affecting one-stage battle outcomes and thus defines the set of related runs which may share the

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FIGURE A-5

SAMPLE OUTPUT PRINTED UNDER CONTROL OF RUN CARD

SAMPLE RUN -- 2 BLUE AIRCRAFT TYPES, 1 RED AIRCRAFT TYPE

```
NUMBER OF STAGES =  2
NUMBER OF CYCLES PER STAGE =  1
NUMBER OF BLUE PLANE TYPES = 2
NUMBER OF RED  PLANE TYPES = 1
NUMBER OF BLUE DIVISIONS =    10
NUMBER OF RED  DIVISIONS =    15
FIREPOWER PER BLUE DIVISION =     9.0000
FIREPOWER PER RED  DIVISION =     7.0000
NUMBER OF BLUE SHELTERS =   100
NUMBER OF RED  SHELTERS =   300
NUMBER OF BLUE FORWARD SAMS =    30
NUMBER OF RED  FORWARD SAMS =    20
NUMBER OF BLUE REAR SAMS =    50
NUMBER OF RED  REAR SAMS =    40
OBJECTIVE FUNCTION WEIGHTS = CAS GRD -  0.00   TOTL FP -  1.00   FEBA -  0.00
```

MISSIONS ASSIGNED AND
ASSOCIATED SORTIE RATES

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
1- 2.00	3- 2.00	0- 0.00	0- 0.00	1- 2.00	0- 0.00	0- 0.00	0- 0.00
2- 1.00	4- 2.00	0- 0.00	0- 0.00	2- 1.00	0- 0.00	0- 0.00	0- 0.00
7- 2.00	5- 2.00	0- 0.00	0- 0.00	3- 2.00	0- 0.00	0- 0.00	0- 0.00
8- 1.00	6- 1.00	0- 0.00	0- 0.00	4- 2.00	0- 0.00	0- 0.00	0- 0.00

MINIMUM ALLOCATION FRACTIONS

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
.30	.31	0.00	0.00	.50	0.00	0.00	0.00

GRID POINTS

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
0	0	0	0	0	0	0	0
133	200	0	0	400	0	0	0
667	400	0	0	800	0	0	0
1000	-1	0	0	1200	0	0	0

CAS FIREPOWER PER SORTIE

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
2.0000	-.0000	-.0000	-.0000	3.0000	-.0000	-.0000	-.0000

DIVISION FIREPOWER REDUCTION
PER CAS SORTIE

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
.5000	-.0000	-.0000	-.0000	.8000	-.0000	-.0000	-.0000

RESIDUAL VALUE OF AN
UNDAMAGED PLANE AT END OF THE WAR

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
0.0000	0.0000	-.0000	-.0000	3.0000	-.0000	-.0000	-.0000

FRACTION VULNERABLE TO ABA
BY MISSION

BLUE PLANE TYPE 1	2	3	4	RED PLANE TYPE 1	2	3	4
1-1.000	3-1.000	0-1.000	0-1.000	1- .500	3-1.000	0-1.000	0-1.000
2- .500	4-1.000	0-1.000	0-1.000	2- .500	0-1.000	0-1.000	0-1.000
7-1.000	5-1.000	0-1.000	0-1.000	3- .500	0-1.000	0-1.000	0-1.000
8- .500	6- .500	0-1.000	0-1.000	4- .500	0-1.000	0-1.000	0-1.000

FEBA FUNCTION

F RATIO	0.000	.999	1.010	200.000	-.000	-.000	-.000
MOVEMENT	-1.000	-1.000	1.000	1.000	-.000	-.000	-.000

FIGURE A-5 (cont'd)

STAGE	OBJECTIVE WEIGHTS BLUE	OBJECTIVE WEIGHTS RED	REINFORCEMENTS NUMBER BLUE PLANE TYPE 1	2	3	4	REINFORCEMENTS NUMBER RED PLANE TYPE 1	2	3	4	REINFORCEMENTS FRACTION BLUE PLANE TYPE 1	2	3	4	REINFORCEMENTS FRACTION RED PLANE TYPE 1	2	3	4
1	.50	1.00	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.00	1.00	100	0	0	0	200	0	0	0	0.00	.20	0.00	0.00	0.00	0.00	0.00	0.00

KILL PROBABILITIES

ABA AGAINST NON-SHELTERED AIRCRAFT

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	.500	-.000	-.000	-.000
2	.500	-.000	-.000	-.000
3	.500	-.000	-.000	-.000
4	.500	-.000	-.000	-.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	.350	.350	.350	.350
2	-.000	-.000	-.000	-.000
3	-.000	-.000	-.000	-.000
4	-.000	-.000	-.000	-.000

ABA AGAINST SHELTERED AIRCRAFT

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	.250	-.000	-.000	-.000
2	.250	-.000	-.000	-.000
3	.250	-.000	-.000	-.000
4	.250	-.000	-.000	-.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	.200	.200	.200	.200
2	-.000	-.000	-.000	-.000
3	-.000	-.000	-.000	-.000
4	-.000	-.000	-.000	-.000

FIGURE A-5 (cont'd)

KILL PROBABILITIES

CAS ESCORT AGAINST BD

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	-.000	0.000	0.000	0.000
2	.120	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	-.000	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

BD AGAINST CAS ESCORT

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	.050	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

CAS AGAINST BD

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	.040	0.000	0.000	0.000
2	-.000	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	.050	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

BD AGAINST CAS

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	-.000	0.000	0.000	0.000
2	.120	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	.100	-.000	-.000	-.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

KILL PROBABILITIES

AHA ESCORT AGAINST ABD

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	-.000	0.000	0.000	0.000
2	.030	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	-.000	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

ABD AGAINST AHA ESCORT

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	.070	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

AHA AGAINST AHD

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	.020	0.000	0.000	0.000
2	-.000	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	0.000	0.000	0.000	0.000
2	.030	-.000	-.000	-.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

ABD AGAINST AHA

BLUE KILLS RED

	RED TYPE 1	2	3	4
1	-.000	0.000	0.000	0.000
2	.110	0.000	0.000	0.000
3	-.000	0.000	0.000	0.000
4	-.000	0.000	0.000	0.000

RED KILLS BLUE

	RED TYPE 1	2	3	4
1	.090	-.000	-.000	-.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000

FIGURE A-5 (cont'd)

KILL PROBABILITIES

SAM AGAINST CAS

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	.170	0.000	0.000	0.000	.160	0.000	0.000	0.000

SAM AGAINST CAS ESCORT

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	0.000	0.000	0.000	0.000	0.000	.030	0.000	0.000

SAM AGAINST ABA

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	.140	0.000	0.000	0.000	.150	0.000	0.000	0.000
REAR	.210	0.000	0.000	0.000	.200	0.000	0.000	0.000

SAM AGAINST ABA ESCORT

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	0.000	0.000	0.000	0.000	0.000	.010	0.000	0.000
REAR	0.000	0.000	0.000	0.000	0.000	.020	0.000	0.000

KILL PROBABILITIES

FORWARD SAM SUPPRESSOR AGAINST SAM

	BLUE KILLS RED				RED KILLS BLUE			
	BLUE TYPE				RED TYPE			
	1	2	3	4	1	2	3	4
FORWARD	.080	-.000	-.000	-.000	0.000	0.000	0.000	0.000

SAM AGAINST FORWARD SAM SUPPRESSOR

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	0.000	0.000	0.000	0.000	.010	0.000	0.000	0.000

REAR SAM SUPPRESSOR AGAINST SAM

	BLUE KILLS RED				RED KILLS BLUE			
	BLUE TYPE				RED TYPE			
	1	2	3	4	1	2	3	4
REAR	.060	-.000	-.000	-.000	0.000	0.000	0.000	0.000

SAM AGAINST REAR SAM SUPPRESSOR

	BLUE KILLS RED				RED KILLS BLUE			
	RED TYPE				BLUE TYPE			
	1	2	3	4	1	2	3	4
FORWARD	0.000	0.000	0.000	0.000	.010	0.000	0.000	0.000
REAR	0.000	0.000	0.000	0.000	.030	0.000	0.000	0.000

FIGURE A-5 (cont'd)

NUMBER OF BLUE PURE STRATEGIES EQUALS 18

NUMBER OF RED PURE STRATEGIES EQUALS 11

NUMBER OF STATES EQUALS 48

BLUE PURE STRATEGIES

STRAT NUMBER	LAST STAGE	PLANE TYPE/MISSION 1/1	1/2	1/7	1/8	2/3	2/4	2/5	2/6
1	2	.50	0.00	0.00	.50	0.00	0.00	.33	.67
2	2	.50	0.00	0.00	.50	0.00	.33	.33	.33
3	2	.50	0.00	0.00	.50	0.00	.67	.33	0.00
4	2	.50	0.00	0.00	.50	.33	0.00	.33	.33
5	2	.50	0.00	0.00	.50	.33	.33	.33	0.00
6	2	.50	0.00	0.00	.50	.67	0.00	.33	0.00
7	2	.50	0.00	.50	0.00	0.00	0.00	.33	.67
8	2	.50	0.00	.50	0.00	0.00	.33	.33	.33
9	2	.50	0.00	.50	0.00	0.00	.67	.33	0.00
10	2	.50	0.00	.50	0.00	.33	0.00	.33	.33
11	2	.50	0.00	.50	0.00	.33	.33	.33	0.00
12	2	.50	0.00	.50	0.00	.67	0.00	.33	0.00
13	2	.50	.50	0.00	0.00	0.00	0.00	.33	.67
14	2	.50	.50	0.00	0.00	0.00	.33	.33	.33
15	2	.50	.50	0.00	0.00	0.00	.67	.33	0.00
16	2	.50	.50	0.00	0.00	.33	0.00	.33	.33
17	2	.50	.50	0.00	0.00	.33	.33	.33	0.00
18	2	.50	.50	0.00	0.00	.67	0.00	.33	0.00

RED PURE STRATEGIES

STRAT NUMBER	LAST STAGE	PLANE TYPE/MISSION 1/1	1/2	1/3	1/4
1	1	0.00	1.00	0.00	0.00
2	2	0.00	0.00	0.00	1.00
3	2	0.00	0.00	.50	.50
4	2	0.00	0.00	1.00	0.00
5	2	0.00	.50	0.00	.50
6	2	0.00	.50	.50	0.00
7	2	0.00	1.00	0.00	0.00
8	2	.50	0.00	0.00	.50
9	2	.50	0.00	.50	0.00
10	2	.50	.50	0.00	0.00
11	2	1.00	0.00	0.00	0.00

LIST OF ALL POSSIBLE STATES

STATE NUMBER	BLUE 1	2	3	4	RED 1	2	3	4
1	0	0	0	0	0	0	0	0
2	0	0	0	0	400	0	0	0
3	0	0	0	0	800	0	0	0
4	0	0	0	0	1200	0	0	0
5	0	200	0	0	0	0	0	0
6	0	200	0	0	400	0	0	0
7	0	200	0	0	800	0	0	0
8	0	200	0	0	1200	0	0	0
9	0	400	0	0	0	0	0	0
10	0	400	0	0	400	0	0	0
11	0	400	0	0	800	0	0	0
12	0	400	0	0	1200	0	0	0
13	333	0	0	0	0	0	0	0
14	333	0	0	0	400	0	0	0
15	333	0	0	0	800	0	0	0
16	333	0	0	0	1200	0	0	0
17	333	200	0	0	0	0	0	0
18	333	200	0	0	400	0	0	0
19	333	200	0	0	800	0	0	0
20	333	200	0	0	1200	0	0	0
21	333	400	0	0	0	0	0	0
22	333	400	0	0	400	0	0	0
23	333	400	0	0	800	0	0	0
24	333	400	0	0	1200	0	0	0
25	667	0	0	0	0	0	0	0
26	667	0	0	0	400	0	0	0
27	667	0	0	0	800	0	0	0
28	667	0	0	0	1200	0	0	0
29	667	200	0	0	0	0	0	0
30	667	200	0	0	400	0	0	0
31	667	200	0	0	800	0	0	0
32	667	200	0	0	1200	0	0	0
33	667	400	0	0	0	0	0	0
34	667	400	0	0	400	0	0	0
35	667	400	0	0	800	0	0	0
36	667	400	0	0	1200	0	0	0
37	1000	0	0	0	0	0	0	0
38	1000	0	0	0	400	0	0	0
39	1000	0	0	0	800	0	0	0
40	1000	0	0	0	1200	0	0	0
41	1000	200	0	0	0	0	0	0
42	1000	200	0	0	400	0	0	0
43	1000	200	0	0	800	0	0	0
44	1000	200	0	0	1200	0	0	0
45	1000	400	0	0	0	0	0	0
46	1000	400	0	0	400	0	0	0
47	1000	400	0	0	800	0	0	0
48	1000	400	0	0	1200	0	0	0

FIGURE A-5 (cont'd)

CDC 6600 TIME ESTIMATES FOR CURRENT RUN (SECONDS)

FUNCTION	CPU TIME	I/O TIME
SETUP	2.0	2.0
BATTLES	19.0	5.8
GAMES	7.4	11.5
TOTAL	28.4	19.3

FIGURE A-6

SAMPLE OUTPUT PRINTED
UNDER CONTROL OF TRIAL CARDS

TRIAL CARD #1

TRIAL NUMBER	NUMBER OF STAGES	NUMBER OF PLANES AVAILABLE ----- BLUE ----- 1	2	3	4	----- RED ------ 1	2	3	4	BLUE MAXMIN	RED MINMAX	MAXMIN VS MINMAX
1	2	400	100	0	0	500	0	0	0	-10515	9735	-2837

TRIAL NUMBER 1

STAGE NUMBER	NUMBER OF BLUE PLANES AVAILABLE 1	2	3	4	NUMBER OF RED PLANES AVAILABLE 1	2	3	4	MAXMIN VS MINMAX	TOTAL
1	297	77	0	0	481	0	0	0	442	442
2	396	91	0	0	679	0	0	0	-3279	-2837

TRIAL NUMBER 1

PLANE ALLOCATION FRACTIONS FOR BLUE

STAGE NUMBER	PLANE TYPE/MISSION 1/1	1/2	1/7	1/8	2/3	2/4	2/5	2/6
1	.50	0.00	0.00	.50	0.00	0.00	.33	.67
2	.50	0.00	.50	0.00	0.00	0.00	.33	.67

TRIAL NUMBER 1

PLANE ALLOCATION FRACTIONS FOR RED

STAGE NUMBER	PLANE TYPE/MISSION 1/1	1/2	1/3	1/4
1	0.00	1.00	0.00	0.00
2	1.00	0.00	0.00	0.00

FIGURE A-6 (cont'd)

TRIAL CARD #1 (cont'd)

TRIAL NUMBER 1

STAGE NUMBER	BLUE-RED CAS FIREPOWER	TOTAL	BLUE-RED GRND+AIR FIREPOWER	TOTAL	FEBA MOVEMENT	TOTAL
1	397	397	442	442	1	1
2	-3279	-2882	-3279	-2837	0	1

TRIAL CARD #2

TRIAL NUMBER	NUMBER OF STAGES	NUMBER OF PLANES AVAILABLE BLUE 1	BLUE 2	BLUE 3	BLUE 4	RED 1	RED 2	RED 3	RED 4	BLUE MAXMIN	RED MINMAX	MAXMIN VS MINMAX
2	1	600	200	0	0	600	0	0	0	-5721	5321	-15

TRIAL NUMBER 2

STAGE NUMBER	BLUE-RED CAS FIREPOWER	TOTAL	BLUE-RED GRND+AIR FIREPOWER	TOTAL	FEBA MOVEMENT	TOTAL
1	0	0	-15	-15	-1	-1

FIGURE A-6 (cont'd)

TRIAL CARD #3

TRIAL NUMBER	NUMBER OF STAGES	NUMBER OF PLANES AVAILABLE BLUE 1	BLUE 2	BLUE 3	BLUE 4	RED 1	RED 2	RED 3	RED 4	BLUE MAXMIN	RED MINMAX	MAXMIN VS MINMAX
3	2	800	300	0	0	800	0	0	0	-9412	6660	-1909

TRIAL NUMBER 3

STAGE NUMBER	NUMBER OF BLUE PLANES AVAILABLE 1	2	3	4	NUMBER OF RED PLANES AVAILABLE 1	2	3	4	MAXMIN VS MINMAX	TOTAL
1	717	254	0	0	737	0	0	0	842	842
2	816	295	0	0	910	0	0	0	-2751	-1909

TRIAL NUMBER 3

PLANE ALLOCATION FRACTIONS FOR BLUE

STAGE NUMBER	PLANE TYPE/MISSION 1/1	1/2	1/7	1/8	2/3	2/4	2/5	2/6
1	.50	0.00	0.00	.50	0.00	.67	.33	0.00
2	.50	0.00	.50	0.00	.67	0.00	.33	0.00

TRIAL NUMBER 3

PLANE ALLOCATION FRACTIONS FOR RED

STAGE NUMBER	PLANE TYPE/MISSION 1/1	1/2	1/3	1/4
1	0.00	1.00	0.00	0.00
2	1.00	0.00	0.00	0.00

same BATTLE-TAPE. For example, to study the sensitivity of war outcomes to reinforcement policies, numerous runs of ATACM1 would be required in which only the reinforcement parameters on the REIN cards would change. In such a case, since reinforcement parameters are listed in Table A-6, the BATTLE-TAPE produced by the first run of ATACM1 could be used to input, rather than recompute, the one-stage battle outcomes required by the remaining runs. The only changes required in the data deck for one of these perturbation runs would be the changed REIN cards and a modified RUN card with a "2" punched in column 15.

In the CDC 6600 version of ATACM1, the BATTLE-TAPE is assigned the logical file name "TAPE10".

TABLE A-6

INPUT PARAMETERS WHICH DO NOT AFFECT ONE-STAGE BATTLE ASSESSMENTS

Card Type	Parameters	Columns
REIN	Reinforcements	11-30, 36-55
STAGE	Number of stages	11-12
VALU	Residual value of undamaged plane	11-30
WGHT	Objective function weights by stage	11-15

TRIAL-TAPE

The TRIAL-TAPE produced by ATACM1 contains the values of the major COMMON areas assigned during the execution of ATACM1 as well as the optimal strategies and associated bounds generated for each state and stage of the campaign. The tape is used exclusively by ATACM2 to input those parameters required to evaluate trial wars of varying length initiated with differing numbers of aircraft available to the opposing forces.

In the CDC 6600 version of ATACM1, the TRIAL-TAPE is assigned the logical file name "TAPE4".

EXECUTION TIME

One of the most important considerations in the use of ATACM1 is the execution time required to generate the results written on the TRIAL-TAPE. There are three phases of calculation necessary for the generation of this tape:

- SETUP - the generation of strategies and states
- BATTLES - the calculation and output to scratch disk (and BATTLE-TAPE if requested) of one-stage battle assessments for each Blue-Red strategy combination
- GAMES - the calculation of the MAXMIN/MINMAX objective function bounds and plays for each stage and state

The time required for SETUP is usually insignificant (2 seconds) compared to the times for BATTLES and GAMES. Run times for these last two phases can range from a few seconds for a simple scenario to several minutes or even hours for the most ambitious requests.

Time Estimates

The run time associated with BATTLES and GAMES is a relatively complex function of the total number of aircraft types on both sides, the number of Blue and Red pure strategies, the size of the state space, and the number of stages and cycles-per-stage in the air campaign being simulated. To provide the user with estimates of the CPU and IO times required for BATTLES and GAMES, all of these variables were incorporated into empirical formulas derived from numerous test runs made on the CDC 6600. The formulas were coded into the subroutine TIMER which prints time estimates for BATTLE and GAMES before the calculations are performed.

To use the time estimates produced by TIMER to assess the reasonableness of a particular run before it is submitted for complete execution, a preliminary run using the candidate data deck should be submitted with a 1 punched in column 14 of the RUN card. All outputs shown in Figure A-5 through the printing of the time estimates are generated in their normal manner. However, execution is terminated just before the BATTLES and GAMES phases of computation begin. The output which is generated permits verification of the accuracy of the input data and provides a basis

for determining whether the length of time required for a complete run is acceptable. Because of the minimal effort and cost associated with such a data-and-time check, its use is strongly recommended for all but the simplest runs.

Use of the BATTLE-TAPE

Another consideration related to the execution time of ATACM1 is the use of the BATTLE-TAPE. As described under the outputs of ATACM1, use of the BATTLE-TAPE permits the one-stage battle assessments produced during the BATTLES phase of calculation to be written and stored on magnetic tape for use in subsequent related runs of ATACM1. Since the time required for the calculation of these battle assessments is typically a significant fraction of the total execution time, judicious job sequencing which permits the use of a single BATTLE-TAPE for numerous runs of ATACM1 will produce substantial savings in the total computer time used.

DIAGNOSTIC MESSAGES

Diagnostic messages generated by ATACM1 are classified in order of increasing severity as

INFO:	Information only -- anomaly is ignored.
ERROR:	Processing error -- job is aborted at the end of the current subroutine.
ABORT:	Abort -- job is aborted immediately.

Messages which may be produced by ATACM1 are listed and interpreted in Table A-7 in approximately the same order they are encountered during program execution.

TABLE A-7

DIAGNOSTIC MESSAGES GENERATED BY ATACM1

Message	Severity	Interpretation
DATA CARD KEY NOT RECOGNIZED	ERROR	Input card key does not match any of those listed in Table A-1, or a TRIAL or FINIS card precedes the END card.
SMALLEST GRID LEVEL MUST BE ZERO	ERROR	One of the GRID cards does not have a 0 punched in columns 11-15.
SUM OF SPECIFIED ALLOCATIONS EXCEEDS 1.0	ABORT	The sum of the allocations of an aircraft type to its missions, as specified on a STRT card, exceeds the denominator of the minimum allocation fraction for the corresponding aircraft type.
IF ALL ALLOCATIONS ARE SPECIFIED THEY MUST SUM TO 1.0	ABORT	If all the allocations of an aircraft type to its missions are specified on a STRT card, they must sum to the denominator of the minimum allocation fraction for the corresponding aircraft type.
STRATEGIES NOT SPECIFIED THRU THE LAST STAGE OF CAMPAIGN	ABORT	The number in columns 7-8 of last STRT card read for either Blue or Red was less than the total number of stages specified on the STAGE card.

TABLE A-7 (Cont'd)

Message	Severity	Interpretation
TOO MANY PURE STRATEGIES TO BE STORED IN CORE	ABORT	Either the number of pure strategies for one side exceeds 500, the number of decision vectors for a single aircraft type exceeds 200, or the total area required to store the pure strategies for both sides exceeds 25,000 words. Possible remedies include specification of fewer missions, fewer aircraft types, or a larger minimum allocation fraction.
TOO MANY STATES TO STORE VALUES AND PLAYS	ABORT	The total number of states multiplied by 10 plus the dimensioned area used to store the pure strategies exceeds 25,000 words. Either the number of states or the total number of pure strategies must be reduced.
NOT ENOUGH COMMON AREA TO STORE GAME MATRIX	ABORT	Two times the number of elements in the one-stage game matrix, plus 10 times the number of states, plus the dimensioned area used to store the pure strategies exceeds 25,000 words. Either the number of states or the number of pure strategies must be reduced.
BUFFER OUT ERROR TO TAPE9 IN SUBROUTINE READIN	ABORT	System write failure was encountered while writing STRT parameters on scratch disk (TAPE9). Rerun job or consult systems analyst.

TABLE A-7 (Cont'd)

Message	Severity	Interpretation
BUFFER IN ERROR FROM TAPE9 IN SUBROUTINE INIT	ABORT	Either a parity error or system read failure was encountered while reading STRT parameters from scratch disk (TAPE9). Rerun job or consult systems analyst.
USER REQUESTED ONLY A DATA CHECK AND TIME ESTIMATE	ABORT	A 1 was punched in column 14 of the RUN card. Execution is terminated immediately after run-time estimates are printed.
I/O ERROR ON TAPE10 IN SUBROUTINE INIT	ABORT	Either a read parity error or a system I/O failure was encountered on the BATTLE-TAPE (TAPE10). Rerun job or consult systems analyst.
BUFFER OUT ERROR TO TAPE1 IN SUBROUTINE INIT	ABORT	System write failure was encountered while writing battle assessments on scratch disk (TAPE1). Rerun job or consult systems analyst.
BUFFER IN ERROR FROM TAPE1 IN SUBROUTINE GAMES	ABORT	Either a parity error or system read failure was encountered while reading battle assessments from scratch disk (TAPE1). Rerun job or consult systems analyst.
BUFFER OUT ERROR TO TAPE4 IN MAIN PROGRAM	ABORT	System write failure was encountered while writing TRIAL-TAPE (TAPE4). Rerun job or consult systems analyst.

TABLE A-7 (Cont'd)

Message	Severity	Interpretation
BUFFER OUT ERROR TO TAPE7 IN MAIN PROGRAM	ABORT	System write failure was encountered while writing MAXMIN/MINMAX objective function values on scratch disk (TAPE7). Rerun job or consult systems analyst.
BUFFER IN ERROR FROM TAPE7 IN SUBROUTINE TRIALS	ABORT	Parity error or system read failure was encountered while reading MAXMIN/MINMAX objective function values from scratch disk (TAPE7). Rerun job or consult systems analyst.
BUFFER OUT ERROR TO TAPE8 IN MAIN PROGRAM	ABORT	System write failure was encountered while writing MAXMIN/MINMAX plays on scratch disk (TAPE8). Rerun job or consult systems analyst.
BUFFER IN ERROR FROM TAPE8 IN SUBROUTINE TRIALS	ABORT	Parity error or system read failure was encountered while reading MAXMIN/MINMAX plays from scratch disk (TAPE8). Rerun job or consult systems analyst.
DISK I/O ERROR ON TAPE9 IN SUBROUTINE TRIALS	ABORT	A system I/O failure was encountered on scratch disk (TAPE9) used to store available planes and objective function values as a function of stage. Rerun job or consult systems analyst.

TABLE A-7 (Cont'd)

Message	Severity	Interpretation
TRIAL CARD IGNORED -- INCORRECT FORMAT	INFO	The key on one of the TRIAL cards is mis-punched. Columns 1-5 should contain "TRIAL".
TRIAL CARD IGNORED -- TOO MANY STAGES REQUESTED	INFO	The number of stages requested for a trial war exceeds the number of stages specified in the original run of ATACM1.
TRIAL CARD IGNORED -- TOO MANY PLANES OF ONE TYPE SPECIFIED	INFO	The initial number of planes specifed on a TRIAL card for one of the aircraft types exceeds the maximum grid level specified for that aircraft type in the original run of ATACM1.
RUN ABORTED DUE TO FATAL ERRORS	ABORT	Indicates previously diagnosed ERRORS necessitate job abortion.

ATACM2

As depicted in the logical flowchart of Figure A-7, the required inputs to ATACM2 are a TRIAL-TAPE written by a previous run of ATACM1 and the TRIAL cards requesting war evaluations. In addition to the outcomes of the requested trial wars, ATACM2 can print the inputs, the strategies, and the states used in the original run of ATACM1 to generate the TRIAL-TAPE being read.

INPUTS

The TRIAL-TAPE is the primary input to ATACM2 and is assigned the logical file name "TAPE4". The input deck to ATACM2 consists of three card types described previously under the discussion of ATACM1's inputs. The first card in the input deck must be a RUN card, the last card must be a FINIS card, and the remaining cards must be TRIAL cards. The formats of all three cards are identical to those shown in Figure A-3 with the exception that RUN card parameters in columns 14-80 are ignored by ATACM2. Figure A-8 presents a sample input deck for ATACM2.

OUTPUTS

The outputs produced by ATACM2 are a subset of those produced by ATACM1. By specifying the print parameters described in Table A-3, the user can elect to print any or all of the following outputs under control of the RUN card:

- the input parameters to the original run of ATACM1 which generated the TRIAL-TAPE
- lists of the pure strategies available to Blue and Red in the original run of ATACM1
- a list of the possible states generated in the original run of ATACM1

In addition, for each trial war evaluation requested, ATACM2 produces outputs identical to those described under the outputs of ATACM1 which are controlled by the print options of Table A-4 and displayed in the sample output of Figure A-6.

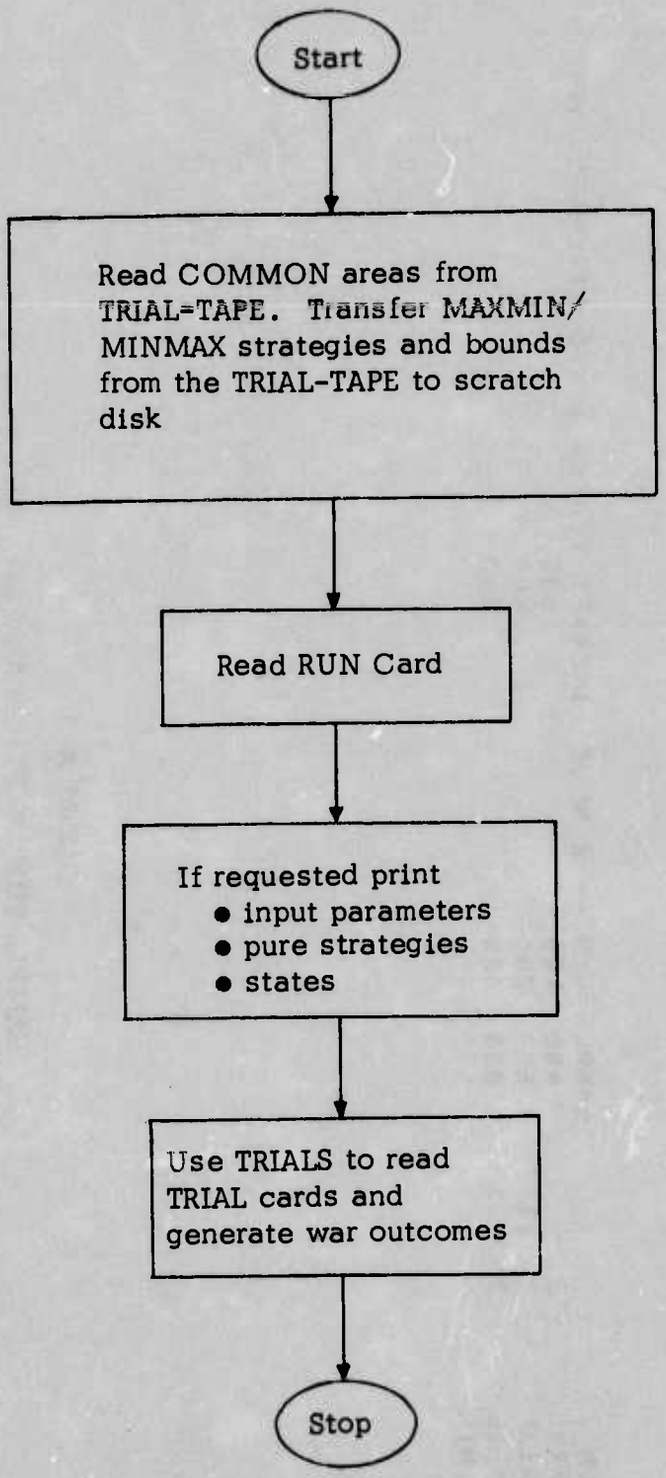

FIGURE A-7

LOGICAL FLOWCHART OF ATACM2

```
RUN                          SAMPLE RUN -- 2 BLUE AIRCRAFT TYPES, 1 RED AIRCRAFT TYPE
TRIAL      2                   400  100                        500
TRIAL      1  11               600  200                        600
TRIAL      2     1             800  300                        800
FINIS
```


FIGURE A-8

SAMPLE RUN DECK FOR ATACM2

EXECUTION TIME

The execution time required for ATACM2 is insignificant relative to that required for ATACM1. A typical run requesting the evaluation of 10 trial wars of 10 stages each will generally take less than one minute.

DIAGNOSTIC MESSAGES

Diagnostic messages generated by ATACM2 are classified according to the same scheme described under ATACM1. Table A-8 lists and interprets those messages applicable to ATACM2.

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TABLE A-8

DIAGNOSTIC MESSAGES GENERATED BY ATACM2

Message	Severity	Interpretation
RUN CARD MUST PRECEDE TRIAL CARDS	ABORT	The first card in the input deck was not a RUN card.
BUFFER IN ERROR FROM TAPE4 IN MAIN PROGRAM	ABORT	Parity error or system read failure was encountered while reading the TRIAL-TAPE (TAPE4). Rerun job or consult systems analyst.
BUFFER OUT ERROR TO TAPE7 IN MAIN PROGRAM	ABORT	System write failure was encountered while writing MAXMIN/MINMAX objective function values on scratch disk (TAPE7). Rerun job or consult systems analyst.
BUFFER IN ERROR FROM TAPE7 IN SUBROUTINE TRIALS	ABORT	Parity error or system read failure was encountered while reading MAXMIN/MINMAX objective function values from scratch disk (TAPE7). Rerun job or consult systems analyst.
BUFFER OUT ERROR TO TAPE8 IN MAIN PROGRAM	ABORT	System write failure was encountered while writing MAXMIN/MINMAX plays on scratch disk (TAPE8). Rerun job or consult systems analyst.
BUFFER IN ERROR FROM TAPE8 IN MAIN PROGRAM	ABORT	Parity error or system read failure was encountered while reading MAXMIN/MINMAX plays on scratch disk (TAPE8). Rerun job or consult systems analyst.

TABLE A-8 (Cont'd)

Message	Severity	Interpretation
DISK I/O ERROR ON TAPE9 IN SUBROUTINE TRIALS	ABORT	A system I/O failure was encountered on scratch disk (TAPE9) used to store available planes and objective function values as a function of stage. Rerun job or consult systems analyst.
TRIAL CARD IGNORED -- INCORRECT FORMAT	INFO	The key on one of the TRIAL cards is mis-punched. Columns 1-5 should contain "TRIAL".
TRIAL CARD IGNORED -- TOO MANY STAGES REQUESTED	INFO	The number of stages requested for a trial war exceeds the number of stages specified in the original run of ATACM1.
TRIAL CARD IGNORED -- TOO MANY PLANES OF ONE TYPE SPECIFIED	INFO	The initial number of planes specified on a TRIAL card for one of the aircraft types exceeds the maximum grid level specified for that aircraft type in the original run of ATACM1.

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APPENDIX B

PROGRAMMING DOCUMENTATION

This appendix presents programming documentation for ATACM1 and ATACM2. Following sections describe the storage requirements for the two programs and potential problems associated with converting them to a computer system different from the current CDC6600. In addition, FORTRAN listings and definitions of the most frequently used variable names are provided.

STORAGE REQUIREMENTS

In its current form ATACM1 requires approximately 54,000 words of core storage, of which about 14,000 are used for program instructions and 40,000 are used for array storage. In addition, approximately 2,000,000 words of scratch disk storage, as described in Table B-1, are required for a representative run of the model.

ATACM2 requires approximately 40,000 words of core storage, of which about 8,000 are used for program instructions and 32,000 are used for array storage. Scratch disk requirements for ATACM2 include those shown for files TAPE7, TAPE8, and TAPE9 in Table B-1 -- approximately 16,000 words for a representative run.

CONVERSION TO A DIFFERENT COMPUTER

Both ATACM1 and ATACM2 are coded in CDC 6600 FORTRAN EXTENDED which is generally compatible with FORTRAN compilers available on other major computer systems. Use of those capabilities of the CDC FORTRAN which are unique or less standard was purposely avoided to minimize the problem of program conversions. Subroutine and variable names are limited to six characters, the standard H specification is used in FORMAT statements for the output of Hollerith strings, multiple assignment statements are not used, etc. ENCODE and DECODE statements are used extensively in the subroutine READIN but, if required, they could be eliminated by imposing more strict rules upon the order of the cards in the input deck.

Assuming the problem of FORTRAN compatibility can be resolved, the only remaining obstacles to conversion are the core and disk storage

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TABLE B-1

SCRATCH DISK STORAGE REQUIREMENTS FOR ATACM1

Logical File Name	Access Mode	Number of Records	Number of Words per Record	Total Number of Words Required**
TAPE1	Sequential	NSTATE*	2·NRST·NRST	2,000,000
TAPE2	Random	NSTAGE	2·NSTATE	8,000
TAPE3	Random	NSTAGE	2·NSTATE	8,000
TAPE7	Sequential	NSTAGE	2·NSTATE	8,000
TAPE8	Sequential	NSTAGE	2·NSTATE	8,000
TAPE9	Sequential	NSTAGE	10	100

*Mnemonic variables are defined below:

NSTAGE = number of stages
NSTATE = number of states
NBST = number of Blue strategies
NRST = number of Red strategies

**Representative value computed with:

NSTAGE = 10
NSTATE = 400
NBST = 50
NRST = 50

requirements described above. Unfortunately, these requirements will probably increase rather than decrease in a conversion to another machine because of the large 60-bit word used in the CDC6600. The number of words required for program instructions after conversion to a 32 or 36-bit word machine (e.g. IBM or UNIVAC) could be as many as twice (60/32 or 60/36) the number currently required. Most array and disk storage requirements would be unaffected by a smaller word, the one notable exception being the storage used for battle assessments. In the current versions of ATACM1 and ATACM2 ten integer values are required to characterize the results of each one-stage battle assessment and these are packed into two words. Eight unsigned integer values are stored in one word (7 bits each), and the remaining two signed values are stored in the other word (30 bits each). The most natural allocation of these values on machines with 32 or 36-bit words would require four words -- two for the eight values and one word each for the other two. In a representative run such as that described in Table B-1, the one-stage battle assessments for a single state which currently occupy 5,000 words would require 10,000 words in the converted programs. Analogcusly, the total amount of scratch disk required to store the one-stage battle assessments for all states on TAPE1 (see Table B-1) would increase from 2 to 4 million words. To illustrate the impact of smaller words, Table B-2 summarizes current and estimated storage requirements for both ATACM1 and ATACM2 before and after conversion.

One final consideration in the conversion problem is the possibility of reducing the size or complexity of the air campaign which can be simulated in order to fit the model to the storage available. The major array used for variable storage in both ATACM1 and ATACM2 is a singly dimensioned vector called XARRAY. The location of values in XARRAY are assigned dynamically depending upon the number of strategies, number of missions, and number of states addressed in the scenario being simulated. The total number of words in XARRAY which are required for a particular run is generated by

$$\text{Total Words Required in XARRAY} = NBST \cdot NBM + NRST \cdot NRM + 2 \cdot NBST \cdot NRST + 10 \cdot NSTATE \quad \text{(B-1)}$$

where

NBST = number of Blue strategies

NRST = number of Red strategies

NBM = number of Blue missions per strategy

NRM = number of Red missions per strategy

NSTATE = number of states

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TABLE B-2

CURRENT VS. ESTIMATED STORAGE
REQUIREMENTS AFTER CONVERSION TO A 32-BIT WORD COMPUTER*

	ATACM1		ATACM2	
	Before	After	Before	After
Core Storage				
Instructions	14K	28K	8K	16K
Data Arrays	40K	45K	32K	37K
Total	54K	73K	40K	53K
Scratch Disk				
TAPE1	2,000K	4,000K	**	**
TAPE2	8K	8K	**	**
TAPE3	8K	8K	**	**
TAPE7	8K	8K	8K	8K
TAPE8	8K	8K	8K	8K
TAPE9	.1K	.1K	.1K	.1K
Total	2,032K	4,032K	16K	16K

*Based upon the same representative run used in Table B-1.

**Not used by ATACM2.

In the current versions XARRAY is dimensioned to be 25,000 words long, the value of NWORK. If calculations using Equation B-1 indicate fewer than 25,000 words are adequate for the type of runs which will be made on a different computer, both NWORK and the size of XARRAY can be reduced to a more compatible value*. The result would be a commensurate reduction in the data array storage requirements shown in Table B-2. Although additional reductions beyond those possible by changing NWORK can be achieved by reducing other array dimensions, such changes require a more detailed understanding of the program structure and would yield considerably smaller savings relative to the effort required.

FORTRAN LISTINGS

Figures B-1 and B-2 present FORTRAN listings of ATACM1 and ATACM2 as written for the CDC6600 system. Comment cards in the listings describe the functions of the various subroutine while Table B-3 lists and defines the variable names used most frequently in the two programs.

*The only restriction is that NWORK can not be reduced below 6600 -- the length of NALOCS in READIN.

FIGURE B-1

ATACM1 LISTING

```
      PROGRAM ATACM1 (OUTPUT,TAPE1=65,TAPE2,TAPE3,TAPE4=65,                00110
     1TAPE5,TAPE6=OUTPUT,TAPE7=65,TAPE8=65,TAPE9=65,TAPE10=65)             00120
C                                                                          00130
C                                                                          00140
C                                ATACM1                                    00150
C                                                                          00160
C           VERSION 1.0                      MAY, 1975                     00170
C                                                                          00180
C                                                                          00190
C     /ATACM1/ IS THE MAIN PROGRAM OF THE ACDA TACTICAL AIR                00200
C     CAMPAIGN MODEL WRITTEN BY KETRON, INC. FOR THE US ARMS               00210
C     CONTROL AND DISARMAMENT AGENCY.  /ATACM1/ CALLS THE                  00220
C     SUBROUTINES USED TO PRODUCE OPTIMAL CONSERVATIVE PLAYS               00230
C     AND ASSOCIATED MAXMIN/MINMAX OBJECTIVE FUNCTION VALUES               00240
C     FOR ALL STAGES AND STATES OF THE CAMPAIGN.                           00250
C                                                                          00260
      COMMON /INPUT/ 1MISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),          00270
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),1PRINT(8),                00280
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),         00290
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                   00300
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),       00310
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),         00320
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),                00330
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),         00340
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),          00350
     1REINF(4,2,100)                                                       00360
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),             00370
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),            00380
     11TPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,           00390
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                   00400
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,          00410
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                    00420
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,             00430
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                          00440
      COMMON /WORK/ XARRAY(25000)                                          00450
      COMMON /ERROR/ IERR                                                  00460
      DIMENSION INPUTZ(2680),WORKNZ(1640),WORKLZ(1024),WORKZ(25000)        00470
      DIMENSION IARRAY(1)                                                  00480
      DIMENSION NAMES(6)                                                   00490
      EQUIVALENCE (IMISS,INPUTZ),(NTYPE,WORKNZ),(LOCST,WORKLZ)             00500
      EQUIVALENCE (XARRAY,IARRAY,WORKZ)                                    00510
      DATA((NAMES(I),I=1,5)=5HSTART,6HREADIN,6HPRNTIN,6HBATTLE,5HGAMES)    00520
      DATA(NAMES(6)=6HTRIALS)                                              00530
      DATA(IERR=0)                                                         00540
      CALL SECOND(T)                                                       00550
      WRITE(LUNO,100) T,NAMES(1)                                           00560
  100 FORMAT(/1X,F9.3,24H CPU SECONDS USED AFTER ,A10)                     00570
      T=TIOCALL(X)                                                         00580
      WRITE(LUNO,110) T,NAMES(1)                                           00590
  110 FORMAT(1X,F9.3,24H I/O SECONDS USED AFTER ,A10/)                     00600
      IERR=0                                                               00610
      CALL READIN                                                          00620
      CALL SECOND(T)                                                       00630
      WRITE(LUNO,100) T,NAMES(2)                                           00640
      T=TIOCALL(X)                                                         00650
      WRITE(LUNO,110) T,NAMES(2)                                           00660
      IF(IERR .EQ. 1) CALL ERR(1)                                          00670
      IF(IPRINT(1) .EQ. 0) CALL PRNTIN                                     00680
      CALL SECOND(T)                                                       00690
```

FIGURE B-1 (cont'd)

```
      WRITE(LUNO,100) T,NAMES(3)                                        00700
      T=TIOCALL(X)                                                      00710
      WRITE(LUNO,110) T,NAMES(3)                                        00720
      CALL INIT                                                         00730
      CALL SECOND(T)                                                    00740
      WRITE(LUNO,100) T,NAMES(4)                                        00750
      T=TIOCALL(X)                                                      00760
      WRITE(LUNO,110) T,NAMES(4)                                        00770
      IF(IERR .EQ. 1) CALL ERR(1)                                       00780
      CALL GAMES                                                        00790
      CALL SECOND(T)                                                    00800
      WRITE(LUNO,100) T,NAMES(5)                                        00810
      T=TIOCALL(X)                                                      00820
      WRITE(LUNO,110) T,NAMES(5)                                        00830
      IF(IERR .EQ. 1) CALL ERR(1)                                       00840
C                                                                       00850
C     WRITE COMMON BLOCKS TO THE TRIAL-TAPE TO BE USED FOR              00860
C     SUBSEQUENT SENSITIVITY ANALYSES                                   00870
C                                                                       00880
      BUFFER OUT (4,1) (INPUTZ,INPUTZ(2680))                            00890
      IF(UNIT(4)) 200,150,150                                           00900
  150 CALL ERR(11)                                                      00910
  200 BUFFER OUT (4,1) (WORKNZ,WORKNZ(1640))                            00920
      IF(UNIT(4)) 300,150,150                                           00930
  300 BUFFER OUT (4,1) (WORKLZ,WORKLZ(1024))                            00940
      IF(UNIT(4)) 400,150,150                                           00950
  400 BUFFER OUT (4,1) (WORKZ,WORKZ(NWORK))                             00960
      IF(UNIT(4)) 500,150,150                                           00970
C                                                                       00980
C     WRITE VALUE AND PLAY OUTCOMES FOR EACH STAGE AND                  00990
C     STATE ON THE TRIAL-TAPE AND ON SCRATCH DISK                       01000
C                                                                       01010
C                                                                       01020
  500 DO 600 I=1,NSTAGE                                                 01030
      CALL READMS(2,IARRAY(LOCBV8),NSTAT2,I)                            01040
      BUFFER OUT (4,1) (IARRAY(LOCBV8),IARRAY(LOCEVR))                  01050
      IF(UNIT(4)) 520,150,150                                           01060
  520 CALL READMS(3,IARRAY(LOCBPB),NSTAT2,I)                            01070
      BUFFER OUT (4,1) (IARRAY(LOCBPB),IARRAY(LOCEPR))                  01080
      IF(UNIT(4)) 530,150,150                                           01090
  530 BUFFER OUT (7,1) (IARRAY(LOCBV8),IARRAY(LOCEVR))                  01100
      IF(UNIT(7)) 550,540,540                                           01110
  540 CALL ERR(12)                                                      01120
  550 BUFFER OUT (8,1) (IARRAY(LOCBP8),IARRAY(LOCEPR))                  01130
      IF(UNIT(8)) 600,560,560                                           01140
  560 CALL ERR(13)                                                      01150
  600 CONTINUE                                                          01160
      CALL TRIALS                                                       01170
      CALL SECOND(T)                                                    01180
      WRITE(LUNO,100) T,NAMES(6)                                        01190
      T=TIOCALL(X)                                                      01200
      WRITE(LUNO,110) T,NAMES(6)                                        01210
      END
```

FIGURE B-1 (cont'd)

```
      SUBROUTINE BATTLE                                                 00110
                                                                        00120
C                                                                       00130
C     /BATTLE/ COMPUTES THE RESULTS OF A ONE-STAGE ENGAGEMENT           00140
C     BETWEEN SPECIFIED NUMBERS OF BLUE AND RED GROUND AND AIR          00150
C     FORCES ALLOCATED TO MISSIONS ACCORDING TO SPECIFIED               00160
C     STRATEGIES.                                                       00170
C                                                                       00180
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00190
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),             00200
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00210
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00220
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00230
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00240
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),             00250
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00260
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00270
     1REINF(4,2,100)                                                    00280
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00290
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00300
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00310
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                00320
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00330
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00340
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00350
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                       00360
C                                                                       00370
C                                                                       00380
C               CODES FOR AIR MISSIONS                                  00390
C                                                                       00400
C               1 - CAS                                                 00410
C               2 - ABA                                                 00420
C               3 - BD                                                  00430
C               4 - ABD                                                 00440
C               5 - CAS ESCORT                                          00450
C               6 - ABA ESCORT                                          00460
C               7 - FORWARD DEFENSE SUPPRESSION                         00470
C               8 - REAR DEFENSE SUPPRESSION                            00480
C               9 - NOTHING                                             00490
C                                                                       00500
C                                                                       00510
      COMMON /WORK/ XARRAY(25000)                                       00520
      DIMENSION IARRAY(1)                                               00530
      EQUIVALENCE (XARRAY,IARRAY)                                       00540
      COMMON /BPARM/ CNP(4,2),IBR(2),XNP(9,4,2),OBJEC(2,5)              00550
      DIMENSION TNP(9,2),REMP(4,2),TCASO(2),TOTFP(2),RFSAM(2),RRSAM(2)  00560
      DIMENSION YNP(9,4,2),TFIRE(2),CASO(2),CNPV(4)                     00570
      DATA(XNP=72(0.)),(YNP=72(0.))                                     00580
      TMOVE=0.                                                          00590
      DO 50 K=1,2                                                       00600
      TCASO(K)=0.                                                       00610
      TOTFP(K)=0.                                                       00620
      RFSAM(K)=NFSAM(K)                                                 00630
      RRSAM(K)=NRSAM(K)                                                 00640
50    CONTINUE                                                          00650
      DO 900 N=1,NDAPST                                                 00660
      XMOVE=0.                                                          00670
      DO 100 M=1,9                                                      00680
      DO 100 K=1,2                                                      00690
      TNP(M,K)=0.
```

FIGURE B-1 (cont'd)

```
  100   CONTINUE                                                          00700
                                                                          00710
C                                                                         00720
C          DETERMINE NUMBER OF SORTIES ALLOCATED TO EACH MISSION          00730
C                                                                         00740
        DO 110 K=1,2                                                      00750
        CASO(K)=0.                                                        00760
        TFIRE(K)=NDIV(K)*DIVFP(K)                                         00770
        IUP=NMISST(K)                                                     00780
        IST=IBR(K)                                                        00790
        IST=LOCST(IST,K)-1                                                00800
        DO 110 I=1,IUP                                                    00810
        IST=IST+1                                                         00820
        L=INPNT(I,K)                                                      00830
        M=IMPNT(I,K)                                                      00840
        J=ITPNT(I,K)                                                      00850
        XNP(M,J,K)=XARRAY(IST)*CNP(J,K)*XSORT(L,J,K)                      00860
        YNP(M,J,K)=XNP(M,J,K)                                             00870
        TNP(M,K)=TNP(M,K)+XNP(M,J,K)                                      00880
  110   CONTINUE                                                          00890
C                                                                         00900
C                                                                         00910
C          BATTLE ASSESSMENT                                              00920
C                                                                         00930
C                                                                         00940
        DO 200 K=1,2                                                      00950
        L=3-K                                                             00960
        XFSAM=RFSAM(L)                                                    00970
        XRSAM=RRSAM(L)                                                    00980
        IHI1=NTYPE(K)                                                     00990
C                                                                         01000
C          FORWARD SAM SUPPRESSORS VS FORWARD SAMS                        01010
C                                                                         01020
        IF(XFSAM .EQ. 0.) GO TO 125                                       01030
        SUMS=0.                                                           01040
        DO 115 I=1,IHI1                                                   01050
        SUMS=SUMS+XNP(7,I,K)*PKFS(I,L)                                    01060
  115   CONTINUE                                                          01070
        RFSAM(L)=XFSAM*EXP(-SUMS/XFSAM)                                   01080
C                                                                         01090
C          FORWARD SAMS VS FORWARD SAM SUPPRESSORS                        01100
C                                                                         01110
        XOPP=TNP(7,K)                                                     01120
        IF(XOPP .EQ. 0.) GO TO 125                                        01130
        XNENG=AMIN1(XOPP,XFSAM)                                           01140
        RO=XNENG/XOPP                                                     01150
        DO 120 I=1,IHI1                                                   01160
        XNPS=XNP(7,I,K)                                                   01170
        XN=RO*XNPS*PKFAFS(I,K)                                            01180
        XNP(7,I,K)=XNP(7,I,K)-XN                                          01190
  120   CONTINUE                                                          01200
C                                                                         01210
C          REMAINING FORWARD SAMS VS REAR SAM SUPPRESSORS                 01220
C                                                                         01230
  125   XOPP=TNP(8,K)                                                     01240
        IF(XOPP .EQ. 0.) GO TO 200                                        01250
        XFSAM=RFSAM(L)                                                    01260
        IF(XFSAM .EQ. 0.) GO TO 140                                       01270
        XNENG=AMIN1(XOPP,XFSAM)                                           01280
        RO=XNENG/XOPP
```

FIGURE B-1 (cont'd)

```
                                                                    01290
      DO 130 I=I,IHII                                               01300
      XNPS=XNP(8,I,K)                                               01310
      XN=RO*XNPS*PKRAFS(I,K)                                        01320
      XNP(8,I,K)=XNPS-XN                                            01330
      XOPP=XOPP-XN                                                  01340
130   CONTINUE                                                      01350
C                                                                   01360
C         REMAINING REAR SAM SUPPRESSORS VS REAR SAMS               01370
C                                                                   01380
      IF(XOPP .LE. 0.) GO TO 200                                    01390
140   IF(XRSAM .EQ. 0.) GO TO 155                                   01400
      SUMS=0.                                                       01410
      DO 145 I=1,IHI1                                               01420
      SUMS=SUMS+XNP(8,I,K)*PKRS(I,L)                                01430
145   CONTINUE                                                      01440
      RRSAM(L)=XRSAM*EXP(-SUMS/XRSAM)                               01450
C                                                                   01460
C         REAR SAMS VS REMAINING REAR SAM SUPPRESSORS               01470
C                                                                   01480
      XNENG=AMIN1(XOPP,XRSAM)                                       01490
      RO=XNENG/XOPP                                                 01500
      DO 150 I=1,IHI1                                               01510
      XNPS=XNP(8,I,K)                                               01520
      XN=RO*XNPS*PKRARS(I,K)                                        01530
      XNP(8,I,K)=XNPS-XN                                            01540
      XOPP=XOPP-XN                                                  01550
150   CONTINUE                                                      01560
C                                                                   01570
C         FORWARD SAMS VS RETURNING REAR SAM SUPPRESSORS            01580
C                                                                   01590
      IF(XOPP .LE. 0.) GO TO 200                                    01600
155   IF(XFSAM .EQ. 0.) GO TO 200                                   01610
      XNENG=AMIN1(XOPP,XFSAM)                                       01620
      RO=XNENG/XOPP                                                 01630
      DO 160 I=I,IHII                                               01640
      XNPS=XNP(8,I,K)                                               01650
      XN=RO*XNPS*PKRAFS(I,K)                                        01660
      XNP(8,I,K)=XNPS-XN                                            01670
160   CONTINUE                                                      01680
200   CONTINUE                                                      01690
C                                                                   01700
      DO 700 K=1,2                                                  01710
      L=3-K                                                         01720
      IHI1=NTYPE(K)                                                 01730
      IHI2=NTYPE(L)                                                 01740
      XFSAM=RFSAM(L)                                                01750
      XRSAM=RRSAM(L)                                                01760
C                                                                   01770
C         FORWARD SAMS VS CAS ESCORTS                               01780
C                                                                   01790
      RO1=I.                                                        01800
      XATT=TNP(5,K)                                                 01810
      XOPP=TNP(3,L)                                                 01820
      IF(XATT .EQ. 0.) GO TO 310                                    01830
      IF(XFSAM .EQ. 0.) GO TO 250                                   01840
      XNENG=AMIN1(XATT,XFSAM)                                       01850
      RO=XNENG/XATT                                                 01860
      DO 225 I=1,IHI1                                               01870
      XNPS=XNP(5,I,K)
```

FIGURE B-1 (cont'd)

```
      XN=RO*XNPS*PKBEFS(I,K)                                            01880
      XNP(5,I,K)=XNPS-XN                                                01890
      XATT=XATT-XN                                                      01900
  225 CONTINUE                                                          01910
C                                                                       01920
C         CAS ESCORTS VS BD                                             01930
C                                                                       01940
      IF(XATT .LE. 0.) GO TO 310                                        01950
  250 IF(XOPP .EQ. 0.) GO TO 310                                        01960
      XNENG=AMIN1(XATT,XOPP)                                            01970
      RO=XNENG/XOPP                                                     01980
      ROA=RO/XATT                                                       01990
      RO1=1.-RO                                                         02000
      DO 300 I=1,IHI1                                                   02010
      DO 300 J=1,IHI2                                                   02020
      XNPSB=XNP(5,I,K)                                                  02030
      XNPSR=XNP(3,J,L)                                                  02040
      XN=XNPSB*XNPSR*ROA                                                02050
      XNP(5,I,K)=XNPSB-PKESBO(J,I,K)*XN                                 02060
      XNP(3,J,L)=XNPSR-PKBOES(I,J,L)*XN                                 02070
  300 CONTINUE                                                          02080
  310 DO 350 J=1,IHI2                                                   02090
      REMP(J,L)=YNP(3,J,L)*RO1                                          02100
  350 CONTINUE                                                          02110
C                                                                       02120
C         FORWARD SAMS VS CAS                                           02130
C                                                                       02140
      XATT=XOPP*RO1                                                     02150
      XOPP=TNP(1,K)                                                     02160
      RO1=1.                                                            02170
      IF(XOPP .EQ. 0.) GO TO 410                                        02180
      IF(XFSAM .EQ. 0.) GO TO 370                                       02190
      XNENG=AMINI(XOPP,XFSAM)                                           02200
      RO=XNENG/XOPP                                                     02210
      DO 360 I=1,IHI1                                                   02220
      XNPS=XNP(1,I,K)                                                   02230
      XN=RO*XNPS*PKBAFS(I,K)                                            02240
      XNP(1,I,K)=XNPS-XN                                                02250
      YNP(1,I,K)=XNP(1,I,K)                                             02260
      XOPP=XOPP-XN                                                      02270
  360 CONTINUE                                                          02280
C                                                                       02290
C         BD NOT ENGAGED VS CAS                                         02300
C                                                                       02310
      IF(XOPP .LE. 0.) GO TO 410                                        02320
  370 IF(XATT .EQ. 0.) GO TO 410                                        02330
      XNENG=AMIN1(XATT,XOPP)                                            02340
      RO=XNENG/XOPP                                                     02350
      ROA=RO/XATT                                                       02360
      RO1=1.-RO                                                         02370
      DO 400 I=1,IHI1                                                   02380
      DO 400 J=1,IHI2                                                   02390
      XNPS=XNP(1,I,K)                                                   02400
      XN=REMP(J,L)*XNPS*ROA                                             02410
      XNP(3,J,L)=XNP(3,J,L)-PKBD(I,J,L)*XN                              02420
      XNP(1,I,K)=XNPS-PKBA(J,I,K)*XN                                    02430
  400 CONTINUE                                                          02440
C                                                                       02450
C         ACCUMULATE CAS ORONANCE DELIVERED BY CAS NOT ENGAGED          02460
```

FIGURE B-1 (cont'd)

```
C                                                                       02470
C                                                                       02480
410   DO 420 I=1,IHI1                                                   02490
      XNPC=YNP(1,I,K)*RO1                                               02500
      CASO(K)=CASO(K)+XNPC*CASF(I,K)                                    02510
      TFIRE(L)=TFIRE(L)-XNPC*DFPRED(I,K)                                02520
420   CONTINUE                                                          02530
C                                                                       02540
C          FORWARD SAMS VS ABA ESCORTS                                  02550
C                                                                       02560
      RO1=1.                                                            02570
      XATT=TNP(6,K)                                                     02580
      XOPP=TNP(4,L)                                                     02590
      IF(XATT .EQ. 0.) GO TO 540                                        02600
      IF(XFSAM .EQ. 0.) GO TO 470                                       02610
      XNENG=AMIN1(XATT,XFSAM)                                           02620
      RO=XNENG/XATT                                                     02630
      DO 460 I=1,IHI1                                                   02640
      XNPS=XNP(6,I,K)                                                   02650
      XN=RO*XNPS*PKAEFS(I,K)                                            02660
      XNP(6,I,K)=XNPS-XN                                                02670
      XATT=XATT-XN                                                      02680
460   CONTINUE                                                          02690
C                                                                       02700
C          REAR SAMS VS ABA ESCORTS                                     02710
C                                                                       02720
470   IF(XATT .LE. 0.) GO TO 540                                        02730
      IF(XRSAM .EQ. 0.) GO TO 490                                       02740
      XNENG=AMIN1(XATT,XRSAM)                                           02750
      RO=XNENG/XATT                                                     02760
      DO 480 I=1,IHI1                                                   02770
      XNPS=XNP(6,I,K)                                                   02780
      XN=RO*XNPS*PKAERS(I,K)                                            02790
      XNP(6,I,K)=XNPS-XN                                                02800
      XATT=XATT-XN                                                      02810
480   CONTINUE                                                          02820
C                                                                       02830
C          ABA ESCORTS VS ABD                                           02840
C                                                                       02850
      IF(XATT .LE. 0.) GO TO 540                                        02860
490   IF(XOPP .EQ. 0.) GO TO 510                                        02870
      XNENG=AMIN1(XATT,XOPP)                                            02880
      RO=XNENG/XOPP                                                     02890
      ROA=RO/XATT                                                       02900
      RO1=1.-RO                                                         02910
      DO 500 I=1,IHI1                                                   02920
      DO 500 J=1,IHI2                                                   02930
      XNPSB=XNP(6,I,K)                                                  02940
      XNPSR=XNP(4,J,L)                                                  02950
      XN=XNPSB*XNPSR*ROA                                                02960
      XNN=PKESAD(J,I,K)*XN                                              02970
      XNP(6,I,K)=XNPSB-XNN                                              02980
      XATT=XATT-XNN                                                     02990
      XNP(4,J,L)=XNPSR-PKADES(I,J,L)*XN                                 03000
500   CONTINUE                                                          03010
C                                                                       03020
C          FORWARD SAMS VS RETURNING ABA ESCORTS                        03030
C                                                                       03040
510   IF(XATT .LE. 0.) GO TO 540                                        03050
      IF(XFSAM .EQ. 0.) GO TO 540
```

FIGURE B-1 (cont'd)

```
      XNENG=AMIN1(XATT,XFSAM)                                          03060
      RO=XNENG/XATT                                                    03070
      DO 520 I=1,IHI1                                                  03080
      XNPS=XNP(6,I,K)                                                  03090
      XNP(6,I,K)=XNPS-XNPS*RO*PKAEFS(I,K)                              03100
520   CONTINUE                                                         03110
540   DO 550 J=1,IHI2                                                  03120
      REMP(J,L)=YNP(4,J,L)*ROI                                         03130
550   CONTINUE                                                         03140
C                                                                      03150
C          FORWARD SAMS VS ABA                                         03160
C                                                                      03170
      XATT=XOPP*ROI                                                    03180
      XOPP=TNP(2,K)                                                    03190
      ROI=1.                                                           03200
      IF(XOPP .EQ. 0.) GO TO 640                                       03210
      IF(XFSAM .EQ. 0.) GO TO 570                                      03220
      XNENG=AMINI(XOPP,XFSAM)                                          03230
      RO=XNENG/XOPP                                                    03240
      DO 560 I=1,IHI1                                                  03250
      XNPS=XNP(2,I,K)                                                  03260
      XN=RO*XNPS*PKAAFS(I,K)                                           03270
      XNP(2,I,K)=XNPS-XN                                               03280
      YNP(2,I,K)=XNP(2,I,K)                                            03290
      XOPP=XOPP-XN                                                     03300
560   CONTINUE                                                         03310
C                                                                      03320
C          REAR SAMS VS ABA                                            03330
C                                                                      03340
      IF(XOPP .LE. 0.) GO TO 640                                       03350
570   IF(XRSAM .EQ. 0.) GO TO 590                                      03360
      XNENG=AMINI(XOPP,XRSAM)                                          03370
      RO=XNENG/XOPP                                                    03380
      DO 580 I=1,IHI1                                                  03390
      XNPS=XNP(2,I,K)                                                  03400
      XN=RO*XNPS*PKAARS(I,K)                                           03410
      XNP(2,I,K)=XNPS-XN                                               03420
      YNP(2,I,K)=XNP(2,I,K)                                            03430
      XOPP=XOPP-XN                                                     03440
580   CONTINUE                                                         03450
C                                                                      03460
C          ABD NOT ENGAGED VS ABA                                      03470
C                                                                      03480
      IF(XOPP .LE. 0.) GO TO 640                                       03490
590   IF(XATT .EQ. 0.) GO TO 610                                       03500
      XNENG=AMIN1(XATT,XOPP)                                           03510
      RO=XNENG/XOPP                                                    03520
      ROA=RO/XATT                                                      03530
      ROI=1.-RO                                                        03540
      DO 600 I=1,IHI1                                                  03550
      DO 600 J=1,IHI2                                                  03560
      XNPS=XNP(2,I,K)                                                  03570
      XN=REMP(J,L)*XNPS*ROA                                            03580
      XNN=PKAA(J,1,K)*XN                                               03590
      XNP(2,1,K)=XNPS-XNN                                              03600
      XNP(4,J,L)=XNP(4,J,L)-PKAD(I,J,L)*XN                             03610
      XOPP=XOPP-XNN                                                    03620
600   CONTINUE                                                         03630
C                                                                      03640
```

FIGURE B-1 (cont'd)

```
C          FORWARD SAMS VS RETURNING ABA                                03650
C                                                                       03660
C                                                                       03670
610     IF(XOPP .LE. 0.) GO TO 640                                      03680
        IF(XFSAM .LE. 0.) GO TO 640                                     03690
        XNENG=AMIN1(XOPP,XFSAM)                                         03700
        RO=XNENG/XOPP                                                   03710
        DO 620 I=1,IHI1                                                 03720
        XNPS=XNP(2,I,K)                                                 03730
        XNP(2,I,K)=XNPS-XNPS*RO*PKAAFS(I,K)                             03740
620     CONTINUE                                                        03750
640     DO 650 I=1,IHI1                                                 03760
        REMP(I,K)=YNP(2,I,K)*RO1                                        03770
650     CONTINUE                                                        03780
700     CONTINUE                                                        03790
C                                                                       03800
C          COMPUTE AIRCRAFT ON GROUND KILLED BY ABA NOT ENGAGED         03810
C                                                                       03820
        DO 800 K=1,2                                                    03830
        L=3-K                                                           03840
        IHI1=NTYPE(K)                                                   03850
        IHI2=NTYPE(L)                                                   03860
        ATTK=0.                                                         03870
        TARG=0.                                                         03880
        SUMS=0.                                                         03890
        SUMN=0.                                                         03900
        DO 715 J=1,IHI2                                                 03910
        IUP=NMISS(J,L)                                                  03920
        CNP(J,L)=0.                                                     03930
        CNPV(J)=0.                                                      03940
        DO 710 M=1,IUP                                                  03950
        IM=IMISS(M,J,L)                                                 03960
        CP=XNP(IM,J,L)/XSORT(M,J,L)                                     03970
        CNP(J,L)=CNP(J,L)+CP                                            03980
        CNPV(J)=CNPV(J)+CP*ABAF(M,J,L)                                  03990
710     CONTINUE                                                        04000
        TARG=TARG+CNPV(J)                                               04010
715     CONTINUE                                                        04020
        IF(TARG .EQ. 0.) GO TO 800                                      04030
        NTARG=TARG                                                      04040
        TARGS=AMIN0(NSHL(L),NTARG)                                      04050
        TARGN=NTARG-TARGS                                               04060
        RS=TARGS/TARG                                                   04070
        RN=1.-RS                                                        04080
        DO 720 I=1,IHI1                                                 04090
        CP=REMP(I,K)                                                    04100
        ATTK=ATTK+CP                                                    04110
        SUMS=SUMS+CP*RS*PKSH(I,L)                                       04120
        SUMN=SUMN+CP*RN*PKNS(I,L)                                       04130
720     CONTINUE                                                        04140
        IF(ATTK .EQ. 0.) GO TO 800                                      04150
        TSNK=0.                                                         04160
        IF(TARGS .EQ. 0.) GO TO 730                                     04170
        TSNK=TARGS*EXP(-SUMS/TARGS)                                     04180
730     TNNK=0.                                                         04190
        IF(TARGN .EQ. 0.) GO TO 740                                     04200
        TNNK=TARGN*EXP(-SUMN/TARGN)                                     04210
740     FR=1.-(TSNK+TNNK)/TARG                                          04220
        DO 750 J=1,IHI2                                                 04230
        CNP(J,L)=CNP(J,L)-CNPV(J)*FR                                    04240
750     CONTINUE
```

FIGURE B-1 (cont'd)

```
  800   CONTINUE                                                          04250
        DO 805 K=1,2                                                      04260
        TCASO(K)=TCASO(K)+CASO(K)                                         04270
  805   CONTINUE                                                          04280
        BTFP=AMAX1(0.,TFIRE(1))                                           04290
        RTFP=AMAX1(0.,TFIRE(2))                                           04300
        TOTFP(1)=TOTFP(1)+BTFP*CASO(1)                                    04310
        TOTFP(2)=TOTFP(2)+RTFP*CASO(2)                                    04320
        IF(FEBA(1,1) .EQ. -1.) GO TO 900                                  04330
        FRATIO=100.                                                       04340
        IF(RTFP .EQ. 0.) GO TO 810                                        04350
        FRATIO=BTFP/RTFP                                                  04360
        IF(FRATIO .GT. 100.) FRATIO=100.                                  04370
        GO TO 815                                                         04380
  810   IF(BTFP .EQ. 0.) FRATIO=1.0                                       04390
  815   DO 820 I=2,28                                                     04400
        IF(FRATIO .LE. FEBA(1,I)) GO TO 830                               04410
  820   CONTINUE                                                          04420
        GO TO 850                                                         04430
  830   XMOVE=FEBA(2,I-1)+(FRATIO-FEBA(1,I-1))*(FEBA(2,I)-FEBA(2,I-1))/   04440
       1(FEBA(1,I)-FEBA(1,I-1))                                           04450
  850   TMOVE=TMOVE+XMOVE                                                 04460
  900   CONTINUE                                                          04470
        C                                                                 04480
        C     ASSIGN OBJECTIVE FUNCTION VALUES                            04490
        C                                                                 04500
        DO 920 K=1,2                                                      04510
        OBJEC(K,1)=TCASO(K)                                               04520
        OBJEC(K,2)=TOTFP(K)                                               04530
  920   CONTINUE                                                          04540
        OBJEC(1,3)=TMOVE/2.                                               04550
        OBJEC(2,3)=-OBJEC(1,3)                                            04560
        RETURN                                                            04570
        END                                                               04580
```

```
        SUBROUTINE BETAS                                                  00110
                                                                          00120
        C                                                                 00130
        C     /BETAS/ COMPUTES THE WEIGHTS USED FOR LINEAR INTERPOLATION  00140
        C     BETWEEN GRID POINTS IN THE STATE SPACE.                     00150
        C                                                                 00160
        COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00170
       1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),             00180
       1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00190
       1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00200
       1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00210
       1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00220
       1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),             00230
       1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00240
       1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00250
       1REINF(4,2,100)                                                    00260
        COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00270
       1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00280
       1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00290
       1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)
```

FIGURE B-1 (cont'd)

```
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,      00300
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                00310
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,         00320
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                      00330
      COMMON /BPARM/ CNP(8),I8,IR,XNP(9,4,2),OBJEC(2,5)                00340
      COMMON /INTERP/ BETA(2,8),IBETA(2,8),NDEX(8),IHI(8)              00350
      DIMENSION YGRID(11,8)                                            00360
      EQUIVALENCE (XGRID,YGRID)                                        00370
      DO 200 K=1,8                                                     00380
      DO 100 M=2,11                                                    00390
      IF(CNP(K)-YGRID(M,K)) 150,150,100                                00400
  100 CONTINUE                                                         00410
      M=11                                                             00420
  150 N=M-1                                                            00430
      IBETA(1,K)=N-1                                                   00440
      IBETA(2,K)=M-1                                                   00450
      DIF=YGRID(M,K)-YGRID(N,K)                                        00460
      IF(DIF .EQ. 0.) GO TO 175                                        00470
      BETA(1,K)=(YGRID(M,K)-CNP(K))/DIF                                00480
      GO TO 190                                                        00490
  175 BETA(1,K)=1.                                                     00500
      IBETA(2,K)=0                                                     00510
  190 BETA(2,K)=1.-BETA(1,K)                                           00520
  200 CONTINUE                                                         00530
      IF(IPRINT(8) .EQ. 0) RETURN                                      00540
      WRITE(LUNO,900) IBETA                                            00550
  900 FORMAT(/,8H IBETAS=,2(8I5/8X))                                   00560
      WRITE(LUNO,910) BETA                                             00570
  910 FORMAT(7H BETAS=,2(8F5.2/7X))                                    00580
      RETURN                                                           00590
      END                                                              00600
```

```
      SUBROUTINE ERR(K)                                                00110
                                                                       00120
C                                                                      00130
C         /ERR/ IS CALLED TO PRINT A DIAGNOSTIC OR ERROR MESSAGE.      00140
C                                                                      00150
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),      00160
     1NFRAC(4,2),NSHL(2),NSTAGE,NUAPST,CASF(4,2),IPRINT(8),            00170
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),     00180
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),               00190
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),   00200
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),     00210
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),            00220
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),     00230
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),OFPRED(4,2),FEBA(2,28),      00240
     1REINF(4,2,100)                                                   00250
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),         00260
     1I8LURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),        00270
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,       00280
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)               00290
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,      00300
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                00310
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,         00320
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                      00330
      COMMON /ERROR/ IERR                                              00340
```

FIGURE B-1 (cont'd)

```
      DIMENSION 1MESSG(6,30),IERROR(3),IETYPE(30)                          00340
                                                                           00350
      DATA(IMESSG=180(1H ))                                                00360
      DATA(IERROR=10H***INFO***,10H***ERROR**,10H***ABORT**)               00370
      DATA(1MESSG(1,1)=31HRUN ABORTED DUE TO FATAL ERRORS)                 00380
      DATA(1MESSG(1,2)=28HDATA CARD KEY NOT RECOGNIZED)                    00390
      DATA(IMESSG(1,3)=45HTOO MANY PURE STRATEGIES TO BE STORED IN CORE)   00400
      DATA(IMESSG(1,4)=41HTOO MANY STATES TO STORE VALUES AND PLAYS)       00410
      DATA(IMESSG(1,5)=43HNOT ENOUGH COMMON AREA TO STORE GAME MATRIX)     00420
      DATA(IMESSG(1,6)=44HBUFFER OUT ERROR TO TAPE1 IN SUBROUTINE INIT)    00430
      DATA(IMESSG(1,7)=40HUSER REQUESTED ONLY A DATA CHECK AND TIM)        00440
      DATA(IMESSG(5,7)=10HE ESTIMATE)                                      00450
      DATA(IMESSG(1,8)=40HSUM OF SPECIFIED ALLOCATIONS EXCEEDS 1.0)        00460
      DATA(IMESSG(1,9)=32HSMALLEST GRID LEVEL MUST BE ZERO)                00470
      DATA(IMESSG(1,10)=40HBUFFER IN ERROR FROM TAPE1 IN SUBRDUTINE)       00480
      DATA(1MESSG(5,10)=6H GAMES)                                          00490
      DATA(IMESSG(1,11)=41HBUFFER OUT ERROR TO TAPE4 IN MAIN PROGRAM)      00500
      DATA(IMESSG(1,12)=41HBUFFER OUT ERROR TO TAPE7 IN MAIN PROGRAM)      00510
      DATA(IMESSG(1,13)=41HBUFFER OUT ERROR TO TAPE8 IN MAIN PROGRAM)      00520
      DATA(IMESSG(1,14)=40HBUFFER IN ERROR FROM TAPE7 IN SUBROUTINE)       00530
      DATA(IMESSG(5,14)=7H TRIALS)                                         00540
      DATA(IMESSG(1,15)=40HBUFFER IN ERROR FROM TAPE8 IN SUBROUTINE)       00550
      DATA(IMESSG(5,15)=7H TRIALS)                                         00560
      DATA(IMESSG(1,16)=33HRUN CARD MUST PRECEDE TRIAL CARDS)              00570
      DATA(IMESSG(1,17)=38HTRIAL CARD IGNORED -- INCORRECT FORMAT)         00580
      DATA(IMESSG(1,18)=40HTRIAL CARD IGNORED -- TOO MANY STAGES RE)       00590
      DATA(IMESSG(5,18)=7HQUESTED)                                         00600
      DATA(IMESSG(1,19)=40HTRIAL CARD IGNORED -- TOO MANY PLANES OF)       00610
      DATA(IMESSG(5,19)=19H ONE TYPE SPECIFIED)                            00620
      DATA(IMESSG(1,20)=40HDISK I/O ERROR ON TAPE9 IN SUBRDUTINE TR)       00630
      DATA(1MESSG(5,20)=4HIALS)                                            00640
      DATA(IMESSG(1,21)=40HBUFFER OUT ERROR ON TAPE9 IN SUBROUTINE )       00650
      DATA(1MESSG(5,21)=6HREADIN)                                          00660
      DATA(IMESSG(1,22)=42HBUFFER IN ERROR FROM TAPE4 IN MAIN PROGRAM)     00670
      DATA(IMESSG(1,23)=40H1F ALL ALLOCATIONS ARE SPECIFIED THEY MU)       00680
      DATA(IMESSG(5,23)=13HST SUM TO 1.0)                                  00690
      DATA(IMESSG(1,24)=38H1/O ERROR ON TAPE10 IN SUBROUTINE INIT)         00700
      DATA(IMESSG(1,25)=40HSTRATEGIES NOT SPECIFIED THRU THE LAST S)       00710
      DATA(1MESSG(5,25)=16HTAGE OF CAMPAIGN)                               00720
      DATA(IMESSG(1,26)=40HBUFFER IN ERROR ON TAPE9 IN SUBROUTINE 1)       00730
      DATA(IMESSG(5,26)=3HN1T)                                             00740
      DATA(IETYPE=3,2,6(3),2,7(3),3(1),4(3),7(3))                          00750
      IDERR=IETYPE(K)                                                      00760
      WRITE(LUNO,100) 1ERROR(IDERR),(IMESSG(I,K),I=1,6)                    00770
  100 FORMAT(/,1X,A10,1X,6A10,/)                                           00780
      IF(IDERR .EQ. 3) STOP                                                00790
      IF(IDERR .EQ. 1) RETURN                                              00800
      IERR=1                                                               00810
      RETURN                                                               00820
      END


      SUBROUTINE GAMES                                                     00110
C                                                                          00120
C     /GAMES/ PERFORMS A DYNAMIC PROGRAMMING BACKWARD PASS                 00130
C     COMPUTING FOR EACH STAGE AND STATE THE MAXMIN AND MINMAX             00140
C     STRATEGIES AND ASSOCIATED OBJECTIVE FUNCTION VALUES FOR              00150
C     BOTH BLUE AND RED.                                                   00160
```

FIGURE B-1 (cont'd)

```
C                                                                       00170
      COMMON /1NPUT/ IM1SS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00180
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPR1NT(8),             00190
     11ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),     00200
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00210
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,4,2),PKNS(4,2),REIN(4,2,100),  00220
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00230
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),D1VFP(2),PKBAFS(4,2),             00240
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00250
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00260
     1REINF(4,2,100)                                                    00270
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00280
     11BLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,N1NGAM,1MPNT(32,2),         00290
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00300
     1NWORK,NSTAT2,ISINT(500,2),1D1NT(100,2),INPNT(32,2)                00310
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00320
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00330
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00340
     11OCBVB,1OCEVB,IOCBVR,IOCEVR                                       00350
      COMMON /1NTERP/ BETA(2,8),1BETA(2,8),J1,J2,J3,J4,J5,J6,J7,J8,     00360
     1JH11,JH12,JH13,JH14,JH15,JH16,JH17,JH18                           00370
      COMMON /1PARM/ DELTA(8),JBETA(2,8,128),XBETA(2,8,128),IBIT(8)     00380
      COMMON /ROUND/ JDEX(4,2,2)                                        00390
      DIMENSION MVEC(8),NVEC(8)                                         00400
      EQUIVALENCE(MVEC,JDEX(1,1,1)),(NVEC,JDEX(1,1,2))                  00410
      COMMON /WORK/ XARRAY(25000)                                       00420
      DIMENSION JHI(8),JVEC(8),NDEX(8),BMIN(500),RMAX(500),1ARRAY(1)    00430
      DIMENSION 1VERT(8,256),IBSINT(500),IRSINT(500)                    00440
      EQUIVALENCE (ISINT(1,1),IBSINT),(ISINT(1,2),IRSINT)               00450
      EQUIVALENCE(XARRAY,1ARRAY),(NDEX,J1),(JH1,JH11)                   00460
      DIMENSION SEIN(8,100),SEINF(8,100)                                00470
      EQUIVALENCE (REIN,SEIN),(REINF,SEINF)                             00480
      COMMON /TEMP/ IPPNT(8),TEIN(8),TE1NF(8),NPTT                      00490
      DATA(JDEX=16(0)),(JVEC=8(0)),(JH1=8(1)),(1VERT=2048(1))           00500
      NPTT=NTYPE(1)+NTYPE(2)                                            00510
      MPTT=NPTT                                                         00520
      M=4-NTYPE(1)                                                      00530
      DO 25 NN=1,NPTT                                                   00540
      JHI(NN)=2                                                         00550
      N=NN                                                              00560
      IF(N .GT. NTYPE(1)) N=N+M                                         00570
      IPPNT(NN)=N                                                       00580
25    CONTINUE                                                          00590
      IF(1PPNT(NPTT) .EQ. 8) MPTT=MPTT-1                                00600
      ICNT=0                                                            00610
      DO 50 J8=1,JH18                                                   00620
      DO 50 J7=1,JH17                                                   00630
      DO 50 J6=1,JH16                                                   00640
      DO 50 J5=1,JH15                                                   00650
      DO 50 J4=1,JH14                                                   00660
      DO 50 J3=1,JH13                                                   00670
      DO 50 J2=1,JH12                                                   00680
      DO 50 J1=1,JH11                                                   00690
      ICNT=ICNT+1                                                       00700
      DO 50 NN=1,NPTT                                                   00710
      1VERT(NN,1CNT)=NDEX(NN)                                           00720
50    CONTINUE                                                          00730
      LPTT=ICNT                                                         00740
      IH11=NFULST(2)                                                    00750
```

FIGURE B-1 (cont'd)

```
      IHI2=IHI1-1                                                       00760
      IHI3=NFULST(1)                                                    00770
      LVB=LOCBVB-1                                                      00780
      LVR=LOCBVR-1                                                      00790
      LPB=LOCBPB-1                                                      00800
      LPR=LOCBPR-1                                                      00810
      KVB=KOCBVB-1                                                      00820
      KVR=KOCBVR-1                                                      00830
      JVB=JOCBVB-1                                                      00840
      JVR=JOCBVR-1                                                      00850
      IVB=IOCBVB-1                                                      00860
      IVR=IOCBVR-1                                                      00870
      DO 900 I=1,NSTAGE                                                 00880
      MSLOC=NSTAGE-I+1                                                  00890
      NSLOC=MSLOC+1                                                     00900
      IDINTB=IDINT(MSLOC,1)                                             00910
      IDINTR=IDINT(MSLOC,2)                                             00920
      WGHTB=WGHT(MSLOC,1)                                               00930
      WGHTR=WGHT(MSLOC,2)                                               00940
      DO 75 NN=1,NPTT                                                   00950
      N=IPPNT(NN)                                                       00960
      TEINF(N)=SEINF(N,NSLOC)                                           00970
      TEIN(N)=SEIN(N,NSLOC)/DELTA(N)+1.5                                00980
75    CONTINUE                                                          00990
      REWIND 1                                                          01000
      DO 800 J=1,NSTAT                                                  01010
      IF(IPRINT(7) .NE. 0) WRITE(LUNO,80) MSLOC,J                       01020
80    FORMAT(/,7H STAGE=,I3,3X,6HSTATE=,I3)                             01030
      BUFFER IN (1,1) (IARRAY(LOCBG),IARRAY(KOCEG))                     01040
      IF(UNIT(1)) 200,100,100                                           01050
100   CALL ERR(10)                                                      01060
C                                                                       01070
C          COMPUTE INTERPOLATED VALUES AND PLAYS FOR EACH STATE         01080
C                                                                       01090
200   DO 210 K=1,IHI3                                                   01100
      BMIN(K)=1.E10                                                     01110
210   CONTINUE                                                          01120
      DO 220 K=1,IHI1                                                   01130
      RMAX(K)=-1.E10                                                    01140
220   CONTINUE                                                          01150
      ICNT=0                                                            01160
      DO 400 K=LOCBG,LOCEG,IHI1                                         01170
      ICNT=ICNT+1                                                       01180
      IF(IBSINT(ICNT) .EQ. IDINTB) GO TO 300                            01190
      BMIN(ICNT)=-1.E10                                                 01200
      GO TO 400                                                         01210
300   IHI=K+IHI2                                                        01220
      JCNT=0                                                            01230
      DO 390 L=K,IHI                                                    01240
      JCNT=JCNT+1                                                       01250
      IF(IRSINT(JCNT) .EQ. IDINTR) GO TO 305                            01260
      RMAX(JCNT)=1.E10                                                  01270
      GO TO 390                                                         01280
305   IWORD=IARRAY(L)                                                   01290
      JWORD=IARRAY(L+NINGAM)                                            01300
      DO 310 NN=1,NPTT                                                  01310
      N=IPPNT(NN)                                                       01320
      LEVEL=LBYT(IBIT(N),7,JWORD)                                       01330
```

FIGURE B-1 (cont'd)

```
                                                                    01340
      LEVEL=TEINF(N)*LEVEL+TEIN(N)                                  01350
      IF(LEVEL .LT. 1) LEVEL=1                                      01360
      IF(LEVEL .GT. 128) LEVEL=128                                  01370
      DO 310 M=1,2                                                  01380
      IBETA(M,N)=JBETA(M,N,LEVEL)                                   01390
      BETA(M,N)=XBETA(M,N,LEVEL)                                    01400
310   CONTINUE                                                      01410
      IOBJ=LBYT(31,29,IWORD)                                        01420
      JOBJ=LBYT(1,29,IWORD)                                         01430
      IF(LBYT(60,1,IWORD) .EQ. 1) IOBJ=-IOBJ                        01440
      IF(LBYT(30,1,IWORD) .EQ. 1) JOBJ=-JOBJ                        01450
      CHECKB=IOBJ*WGHTB-JOBJ*WGHTR                                  01460
      CHECKR=CHECKB                                                 01470
      DO 340 LL=1,LPTT                                              01480
      ALPHA=1.                                                      01490
      DO 320 NN=1,NPTT                                              01500
      N=IPPNT(NN)                                                   01510
      M=IVERT(NN,LL)                                                01520
      JVEC(N)=IBETA(M,N)                                            01530
      ALPHA=ALPHA*BETA(M,N)                                         01540
320   CONTINUE                                                      01550
      IF(ALPHA .EQ. 0.) GO TO 340                                   01560
      ISTAT=JVEC(8)+I                                               01570
      DO 330 NN=1,MPTT                                              01580
      N=IPPNT(NN)                                                   01590
      ISTAT=ISTAT+JVEC(N)*IDEM(N)                                   01600
330   CONTINUE                                                      01610
      CHECKB=CHECKB+ALPHA*XARRAY(LVB+ISTAT)                         01620
      CHECKR=CHECKR+ALPHA*XARRAY(LVR+ISTAT)                         01630
340   CONTINUE                                                      01640
      IF(CHECKB .GE. BMIN(ICNT)) GO TO 350                          01650
      BMIN(ICNT)=CHECKB                                             01660
350   IF(CHECKR .LE. RMAX(JCNT)) GO TO 390                          01670
      RMAX(JCNT)=CHECKR                                             01680
390   CONTINUE                                                      01690
400   CONTINUE                                                      01700
C                                                                   01710
C     STORE BLUES MAXMIN PLAY                                       01720
C                                                                   01730
      XMAX=-1.E10                                                   01740
      DO 410 N=1,IHI3                                               01750
      IF(XMAX .GE. BMIN(N)) GO TO 410                               01760
      XMAX=BMIN(N)                                                  01770
      IBPLAY=N                                                      01780
410   CONTINUE                                                      01790
      XARRAY(KVB+J)=XMAX                                            01800
      IARRAY(LPB+J)=IBPLAY                                          01810
C                                                                   01820
C     STORE REDS MINMAX PLAY                                        01830
C                                                                   01840
      XMIN=1.E10                                                    01850
      DO 420 N=1,IHI1                                               01860
      IF(XMIN .LE. RMAX(N)) GO TO 420                               01870
      XMIN=RMAX(N)                                                  01880
      IRPLAY=N                                                      01890
420   CONTINUE                                                      01900
      XARRAY(KVR+J)=XMIN                                            01910
      IARRAY(LPR+J)=IRPLAY                                          01920
C
```

FIGURE B-1 (cont'd)

```
C          COMPUTE AND STORE MAXMIN FOR BLUE                          01930
C                                                                     01940
      ILO=LOCBG+IHII*(IBPLAY-1)                                       01950
      IHI=ILO+IHII-1                                                  01960
      JCNT=0                                                          01970
      XMIN=1.E10                                                      01980
      DO 600 K=ILO,IHI                                                01990
      JCNT=JCNT+I                                                     02000
      IF(IRSINT(JCNT) .NE. IDINTR) GO TO 600                          02010
      IWORD=IARRAY(K)                                                 02020
      JWORD=IARRAY(K+NINGAM)                                          02030
      IOBJ=LBYT(31,29,IWORD)                                          02040
      JOBJ=LBYT(1,29,IWORD)                                           02050
      IF(LBYT(60,1,IWORD) .EQ. 1) IOBJ=-IOBJ                          02060
      IF(LBYT(30,1,IWORD) .EQ. 1) JOBJ=-JOBJ                          02070
      DO 510 NN=1,NPTT                                                02080
      N=IPPNT(NN)                                                     02090
      M=(N-1)/4+1                                                     02100
      LEVEL=LBYT(IBIT(N),7,JWORD)                                     02110
      LEVEL=TEINF(N)*LEVEL+TEIN(N)                                    02120
      IF(LEVEL .LT. 1) LEVEL=1                                        02130
      IF(LEVEL .GT. 128) LEVEL=128                                    02140
      MVEC(N)=JBETA(M,N,LEVEL)                                        02150
  510 CONTINUE                                                        02160
      IS=ISTATE(MVEC)                                                 02170
      CHECK=IOBJ*WGHTB-JOBJ*WGHTR+XARRAY(JVB+IS)                      02180
      IF(CHECK .GE. XMIN) GO TO 600                                   02190
      XMIN=CHECK                                                      02200
  600 CONTINUE                                                        02210
      XARRAY(IVB+J)=XMIN                                              02220
      IF(IPRINT(7) .NE. 0) WRITE(LUNO,605) XMIN,IBPLAY                02230
  605 FORMAT(8H MAXMIN=,F10.0,2X,5HPLAY=,I3)                          02240
C                                                                     02250
C          COMPUTE AND STORE MINMAX FOR RED                           02260
C                                                                     02270
      ILO=LOCBG+IRPLAY-1                                              02280
      IHI=ILO+(IHI3-1)*IHI1                                           02290
      ICNT=0                                                          02300
      XMAX=-1.E10                                                     02310
      DO 700 K=ILO,IHI,IHI1                                           02320
      ICNT=ICNT+1                                                     02330
      IF(IBSINT(ICNT) .NE. IOINTB) GO TO 700                          02340
      IWORD=IARRAY(K)                                                 02350
      JWORD=IARRAY(K+NINGAM)                                          02360
      IOBJ=LBYT(31,29,IWORD)                                          02370
      JOBJ=LBYT(1,29,IWORD)                                           02380
      IF(LBYT(60,1,IWORD) .EQ. 1) IOBJ=-IOBJ                          02390
      IF(LBYT(30,1,IWORD) .EQ. 1) JOBJ=-JOBJ                          02400
      DO 610 NN=1,NPTT                                                02410
      N=IPPNT(NN)                                                     02420
      MM=2-(N-1)/4                                                    02430
      LEVEL=LBYT(IBIT(N),7,JWORD)                                     02440
      LEVEL=TEINF(N)*LEVEL+TEIN(N)                                    02450
      IF(LEVEL .LT. 1) LEVEL=1                                        02460
      IF(LEVEL .GT. 128) LEVEL=128                                    02470
      NVEC(N)=JBETA(MM,N,LEVEL)                                       02480
  610 CONTINUE                                                        02490
      IS=ISTATE(NVEC)                                                 02500
      CHECK=IOBJ*WGHTB-JOBJ*WGHTR+XARRAY(JVR+IS)                      02510
```

FIGURE B-1 (cont'd)

```
      IF(CHECK .LE. XMAX) GO TO 700                                      02520
      XMAX=CHECK                                                         02530
  700 CONTINUE                                                           02540
      XARRAY(IVR+J)=XMAX                                                 02550
      IF(IPRINT(7) .NE. 0) WRITE(LUNO,705) XMAX,IRPLAY                   02560
  705 FORMAT(8H MINMAX=,F10.0,2X,5HPLAY=,I3)                             02570
  800 CONTINUE                                                           02580
C                                                                        02590
C         WRITE PLAYS AND VALUES ON RA MASS STORAGE                      02600
C                                                                        02610
      CALL WRITMS(3,IARRAY(LOCBPB),NSTAT2,MSLOC)                         02620
      CALL WRITMS(2,IARRAY(IOCBVB),NSTAT2,MSLOC)                         02630
      DO 850 J=1,NSTAT2                                                  02640
      IARRAY(LVB+J)=IARRAY(KVB+J)                                        02650
      IARRAY(JVB+J)=IARRAY(IVB+J)                                        02660
  850 CONTINUE                                                           02670
  900 CONTINUE                                                           02680
      RETURN                                                             02690
      END                                                                02700
```

```
      SUBROUTINE INIT                                                    00110
C                                                                        00120
C         /INIT/ ASSIGNS COUNTERS AND POINTERS, COMPUTES THE PURE        00130
C         STRATEGIES AND THE NUMBER OF STATES, AND COMPUTES AND STORES   00140
C         ON MASS STORAGE THE BATTLE ASSESSMENTS FOR EACH STATE AND      00150
C         PURE STRATEGY COMBINATION.                                     00160
C                                                                        00170
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),        00180
     1NFRAC(4,2),NSHL(2),NSTAGE,NOAPST,CASF(4,2),IPRINT(8),              00190
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),       00200
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                 00210
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),     00220
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),       00230
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),              00240
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),       00250
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),        00260
     1REINF(4,2,100)                                                     00270
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),           00280
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),          00290
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,         00300
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                 00310
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,        00320
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                  00330
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,           00340
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                        00350
      COMMON /WORK/ XARRAY(25000)                                        00360
      DIMENSION IARRAY(I)                                                00370
      DIMENSION KEVEL(8)                                                 00380
      EQUIVALENCE (XARRAY,IARRAY)                                        00390
      DIMENSION STRATS(8,200,4),JGRID(11,8),YGRID(11,8)                  00400
      EQUIVALENCE (XARRAY(18601),STRATS)                                 00410
      EQUIVALENCE (IGRID,JGRID),(XGRID,YGRID)                            00420
      COMMON /SPARM/ MFRAC,MMISS,IBR,ITYPE,NSTOR(8),IPNT(8)              00430
      COMMON /BPARM/ CNP(4,2),IB,IR,XNP(9,4,2),OBJEC(2,5)                00440
      COMMON /IPARM/ DELTA(4,2),JBETA(2,8,128),XBETA(2,8,128),IBIT(8)    00450
```

FIGURE B-1 (cont'd)

```
      COMMON /INTERP/ BETA(2,8),IBETA(2,8),NDEX(8),IH1(8)                00460
      COMMON /SINTVL/ IRLO(500),IRH1(500)                                00470
      DIMENSION ISTOR(4)                                                 00480
      DATA(NWORK=25000)                                                  00490
      DATA(IBIT=50,43,36,29,22,15,8,1)                                   00500
      DATA(NSTRAT=8(0)),(NM1SS=8(0)),(XNP=72(0.))                        00510
C                                                                        00520
      DO 100 I=1,NWORK                                                   00530
      1ARRAY(1)=0                                                        00540
100   CONTINUE                                                           00550
      DO 110 K=1,2                                                       00560
      DO 110 J=1,4                                                       00570
      DO 110 I=1,11                                                      00580
      XGRID(I,J,K)=IGRID(I,J,K)                                          00590
110   CONTINUE                                                           00600
C                                                                        00610
C          ASSIGN COUNTERS AND POINTERS                                  00620
C                                                                        00630
      DO 140 K=1,2                                                       00640
      L=0                                                                00650
      DO 135 J=1,4                                                       00660
      DO 115 I=1,8                                                       00670
      IF(1MISS(I,J,K) .EQ. 0) GO TO 120                                  00680
      L=L+1                                                              00690
      1NPNT(L,K)=1                                                       00700
      IMPNT(L,K)=IMISS(I,J,K)                                            00710
      ITPNT(L,K)=J                                                       00720
115   CONTINUE                                                           00730
120   NMISS(J,K)=I-1                                                     00740
      DO 125 I=2,11                                                      00750
      IF(IGRID(I,J,K) .EQ. 0) GO TO 130                                  00760
125   CONTINUE                                                           00770
130   NGRID(J,K)=I-1                                                     00780
      DELTA(J,K)=XGRID(I-1,J,K)/127.                                     00790
135   CONTINUE                                                           00800
      NM1SST(K)=L                                                        00810
140   CONTINUE                                                           00820
C                                                                        00830
C          COMPUTE INTERPOLATION PARAMETERS                              00840
C                                                                        00850
      DO 160 I=1,128                                                     00860
      L=I-1                                                              00870
      DO 150 K=1,2                                                       00880
      DO 150 J=1,4                                                       00890
      CNP(J,K)=L*DELTA(J,K)                                              00900
150   CONTINUE                                                           00910
      CALL BETAS                                                         00920
      DO 160 K=1,2                                                       00930
      DO 160 J=1,8                                                       00940
      JBETA(K,J,1)=1BETA(K,J)                                            00950
      XBETA(K,J,I)=BETA(K,J)                                             00960
160   CONTINUE                                                           00970
      DO 165 K=1,2                                                       00980
      DO 165 J=1,4                                                       00990
      IF(DELTA(J,K) .EQ. 0.) DELTA(J,K)=1.                               01000
165   CONTINUE                                                           01010
      CALL OPENMS(2,IRA,100,0)                                           01020
      CALL OPENMS(3,JRA,100,0)                                           01030
C                                                                        01040
```

FIGURE B-1 (cont'd)

```
      C       GENERATE PURE STRATEGIES FOR BLUE AND RED                  01050
      C                                                                  01060
            ILOC=1                                                       01070
            REWIND 9                                                     01080
            DO 400 K=1,2                                                 01090
            IBR=K                                                        01100
            IUP1=NTYPE(K)                                                01110
            IUP3=NSTRTC(K)                                               01120
            JCNT=0                                                       01130
            KASTP=1                                                      01140
            DO 360 II=1,IUP3                                             01150
            BUFFER IN (9,1) (LASTP,NALOC(8,4))                           01160
            IF(UNIT(9)) 175,170,170                                      01170
      170   CALL ERR(26)                                                 01180
      175   DO 180 J=KASTP,LASTP                                         01190
            IDINT(J,K)=LASTP                                             01200
      180   CONTINUE                                                     01210
            KASTP=LASTP+1                                                01220
            DO 300 J=1,IUP1                                              01230
            ITYPE=J                                                      01240
            MMISS=NMISS(J,K)                                             01250
            MFRAC=NFRAC(J,K)                                             01260
            IHI2=MMISS                                                   01270
            ICNT=0                                                       01280
            DO 200 I=1,IHI2                                              01290
            IPNT(I)=0                                                    01300
            IF(NALOC(I,J) .EQ. -1) GO TO 190                             01310
            MMISS=MMISS-1                                                01320
            MFRAC=MFRAC-NALOC(I,J)                                       01330
            IF(MFRAC .LT. 0) CALL ERR(8)                                 01340
            NSTOR(1)=NALOC(I,J)                                          01350
            GO TO 200                                                    01360
      190   ICNT=ICNT+1                                                  01370
            IPNT(ICNT)=I                                                 01380
      200   CONTINUE                                                     01390
            IF(MMISS .EQ. 0 .AND. MFRAC .GT. 0) CALL ERR(23)             01400
            CALL STRAT                                                   01410
      300   CONTINUE                                                     01420
            IHI1=NSTRAT(1,K)                                             01430
            IHI2=NSTRAT(2,K)                                             01440
            IHI3=NSTRAT(3,K)                                             01450
            IHI4=NSTRAT(4,K)                                             01460
            IF(IHI1 .EQ. 0) IHI1=1                                       01470
            IF(IHI2 .EQ. 0) IHI2=1                                       01480
            IF(IHI3 .EQ. 0) IHI3=1                                       01490
            IF(IHI4 .EQ. 0) IHI4=1                                       01500
            DO 360 I=1,IHI1                                              01510
            DO 360 J=1,IHI2                                              01520
            DO 360 L=1,IHI3                                              01530
            DO 360 M=1,IHI4                                              01540
            JCNT=JCNT+1                                                  01550
            LOCST(JCNT,K)=ILOC                                           01560
            ISINT(JCNT,K)=LASTP                                          01570
            ISTOR(1)=I                                                   01580
            ISTOR(2)=J                                                   01590
            ISTOR(3)=L                                                   01600
            ISTOR(4)=M                                                   01610
            DO 360 II=1,IUP1                                             01620
            IDEX=ISTOR(II)                                               01630
```

FIGURE B-1 (cont'd)

```
      IUP2=NMISS(I1,K)                                                  01640
      DO 360 N=1,IUP2                                                   01650
      XARRAY(ILOC)=STRATS(N,IDEX,I1)                                    01660
      ILOC=ILOC+1                                                       01670
360   CONTINUE                                                          01680
      NFULST(K)=JCNT                                                    01690
      IF(JCNT .GT. 500) CALL ERR(3)                                     01700
      IF(K .EQ. I .AND. ILOC .GT. NWORK-6400) CALL ERR(3)               01710
      IF(LASTP .LT. NSTAGE) CALL ERR(25)                                01720
400   CONTINUE                                                          01730
      WRITE(LUNO,410)                                                   01740
410   FORMAT(1HI)                                                       01750
      WRITE(LUNO,420) (IBLURD(K),NFULST(K),K=I,2)                       01760
420   FORMAT(//11H NUMBER OF ,A4,24H PURE STRATEGIES EQUALS ,I5)        01770
      IF(ILOC .GT. NWORK) CALL ERR(3)                                   01780
C                                                                       01790
C     SET POINTERS FOR EACH BLUE STRATEGY TO INDICATE THE RED           01800
C     STRATEGIES WHICH CAN BE PLAYED AGAINST IT                         01810
C                                                                       01820
      IHI1=NFULST(1)                                                    01830
      IHI2=NFULST(2)                                                    01840
      ILOB=0                                                            01850
      DO 428 I=I,IHI1                                                   01860
      IF(ISINT(I,1) .EQ. ILOB) GO TO 426                                01870
      IRL=0                                                             01880
      IBL=ILOB+1                                                        01890
      IBH=ISINT(I,1)                                                    01900
      DO 424 K=IBL,IBH                                                  01910
      DO 422 J=I,IHI2                                                   01920
      IF(ISINT(J,2) .NE. IDINT(K,2)) GO TO 422                          01930
      IF(IRL .EQ. 0) IRL=J                                              01940
      IRH=J                                                             01950
422   CONTINUE                                                          01960
424   CONTINUE                                                          01970
      ILOB=IBH                                                          01980
426   IRLO(I)=IRL                                                       01990
      IRHI(I)=IRH                                                       02000
428   CONTINUE                                                          02010
C                                                                       02020
C     PRINT STRATEGIES UNLESS SUPPRESSED                                02030
C                                                                       02040
      IF(IPRINT(2) .NE. 0) GO TO 500                                    02050
      DO 460 K=1,2                                                      02060
      IHI3=NMISST(K)                                                    02070
      IHI1=NFULST(K)                                                    02080
      DO 460 I=I,IHI1                                                   02090
      ILO2=LOCST(I,K)                                                   02100
      IHI2=ILO2+NMISST(K)-I                                             02110
      IF((I-1)/50*50 .NE. I-1) GO TO 438                                02120
      WRITE(LUNO,430) IBLURD(K),(ITPNT(J,K),IMPNT(J,K),J=1,IHI3)        02130
430   FORMAT(1HI///,17X,A5,15HPURE STRATEGIES//,6H STRAT,4X,4HLAST,     02140
     1I2X,18HPLANE TYPE/MISSION/,/H NUMBER,3X,5HSTAGE,5X,               02150
     I4(10(I1,1H/,I1,2X)/20X))                                          02160
      WRITE(LUNO,435)                                                   02170
435   FORMAT(1H )                                                       02180
438   WRITE(LUNO,440) I,ISINT(I,K),(XARRAY(J),J=ILO2,IHI2)              02190
440   FORMAT(1X,I5,5X,I3,4X,4(10F5.2,/,18X))                            02200
460   CONTINUE                                                          02210
C                                                                       02220
```

FIGURE B-1 (cont'd)

```
C      ---- COMPUTE TOTAL NUMBER OF STATES                              02230
C                                                                       02240
500    NSTAT=I                                                          02250
       ICNT=9                                                           02260
       DO 510 K=1,2                                                     02270
       DO 510 J=1,4                                                     02280
       L=3-K                                                            02290
       M=5-J                                                            02300
       ICNT=ICNT-1                                                      02310
       IDEM(ICNT)=NSTAT                                                 02320
       NSTAT=NSTAT*NGRID(M,L)                                           02330
510    CONTINUE                                                         02340
       NSTAT2=2*NSTAT                                                   02350
       WRITE(LUNO,520) NSTAT                                            02360
520    FORMAT(1H1,//25H NUMBER OF STATES EQUALS ,I7)                    02370
       IF(ILOC+5*NSTAT2 .GT. NWORK) CALL ERR(4)                         02380
       NG1=NGRID(1,1)                                                   02390
       NG2=NGRID(2,1)                                                   02400
       NG3=NGRID(3,1)                                                   02410
       NG4=NGRID(4,1)                                                   02420
       NG5=NGRID(1,2)                                                   02430
       NG6=NGRID(2,2)                                                   02440
       NG7=NGRID(3,2)                                                   02450
       NG8=NGRID(4,2)                                                   02460
C                                                                       02470
C      ;    PRINT STATES UNLESS SUPPRESSED                              02480
C                                                                       02490
       IF(IPRINT(3) .NE. 0) GO TO 635                                   02500
       ICNT=0                                                           02510
       DO 630 I1=1,NG1                                                  02520
       DO 630 I2=1,NG2                                                  02530
       DO 630 I3=1,NG3                                                  02540
       DO 630 I4=1,NG4                                                  02550
       DO 630 I5=1,NG5                                                  02560
       DO 630 I6=1,NG6                                                  02570
       DO 630 I7=1,NG7                                                  02580
       DO 630 I8=1,NG8                                                  02590
       ICNT=ICNT+1                                                      02600
       IF((ICNT-1)/50*50 .EQ. ICNT-1) WRITE(LUNO,610)                   02610
610    FORMAT(1H1,//18X,27HLIST OF ALL POSSIBLE STATES,//6H STATE,      02620
      115X,4HBLUE,27X,3HRED,/7H NUMBER,7X,2(19H1    2    3    4,       02630
      111X)/)                                                           02640
       WRITE(LUNO,620) ICNT,JGRID(I1,1),JGRID(I2,2),JGRID(I3,3),        02650
      1JGRID(I4,4),JGRID(I5,5),JGRID(I6,6),JGRID(I7,7),JGRID(I8,8)      02660
620    FORMAT(1X,I5,4X,2(4I6,6X))                                       02670
630    CONTINUE                                                         02680
635    CALL TIMER                                                       02690
C                                                                       02700
C      ---- TERMINATE EXECUTION IF ABORT OPTION IS SPECIFIED            02710
C                                                                       02720
       IF(IPRINT(4) .EQ. 1) CALL ERR(7)                                 02730
       JLOCI=ILOC                                                       02740
C                                                                       02750
C      COMPUTE FINAL PAYOFFS FOR EACH STATE AND STORE IN                02760
C      NEXT-STAGE-ARRAYS                                                02770
C                                                                       02780
       DO 645 I1=1,NG1                                                  02790
       DO 645 I2=1,NG2                                                  02800
       DO 645 I3=1,NG3                                                  02810
```

FIGURE B-1 (cont'd)

```
      DO 645 I4=1,NG4                                                    02820
      DO 645 I5=1,NG5                                                    02830
      DO 645 I6=1,NG6                                                    02840
      DO 645 I7=1,NG7                                                    02850
      DO 645 I8=1,NG8                                                    02860
      XARRAY(ILOC)=YGRID(II,I)*VALU(1,1)+YGRID(12,2)*VALU(2,1)+          02870
     1YGRID(13,3)*VALU(3,1)+YGRID(14,4)*VALU(4,1)-                       02880
     1YGRID(15,5)*VALU(1,2)-YGRID(16,6)*VALU(2,2)-                       02890
     1YGRID(17,7)*VALU(3,2)-YGRID(18,8)*VALU(4,2)                        02900
      XARRAY(ILOC)=XARRAY(ILOC)*(OWGHT(1)+OWGHT(2))                      02910
      ILOC=ILOC+1                                                        02920
  645 CONTINUE                                                           02930
      JLOC2=ILOC-1                                                       02940
      LOCBVB=JLOC1                                                       02950
      LOCEVB=JLOC2                                                       02960
      DO 648 I=JLOC1,JLOC2                                               02970
      XARRAY(ILOC)=XARRAY(I)                                             02980
      ILOC=ILOC+1                                                        02990
  648 CONTINUE                                                           03000
      LOCBVR=JLOC2+1                                                     03010
      LOCEVR=ILOC-1                                                      03020
      KOCBVB=LOCEVR+1                                                    03030
      KOCEVB=LOCEVR+NSTAT                                                03040
      KOCBVR=KOCEVB+1                                                    03050
      KOCEVR=KOCEVB+NSTAT                                                03060
      JOCBVB=KOCEVR+1                                                    03070
      JOCEVB=KOCEVR+NSTAT                                                03080
      JOCBVR=JOCEVB+1                                                    03090
      JOCEVR=JOCEVB+NSTAT                                                03100
      IOCBVB=JOCEVR+1                                                    03110
      IOCEVB=JOCEVR+NSTAT                                                03120
      IOCBVR=IOCEVB+1                                                    03130
      IOCEVR=IOCEVB+NSTAT                                                03140
      LOCBPB=IOCEVR+1                                                    03150
      LOCEPB=IOCEVR+NSTAT                                                03160
      LOCBPR=LOCEPB+1                                                    03170
      LOCEPR=LOCEPB+NSTAT                                                03180
      DO 650 I=1,NSTAT2                                                  03190
      J=I-1                                                              03200
      XARRAY(JOCBVB+J)=XARRAY(LOCBVB+J)                                  03210
  650 CONTINUE                                                           03220
C                                                                        03230
C         READ OR COMPUTE BATTLE ASSESSMENTS FOR EACH STATE AND          03240
C         PURE STRATEGY COMBINATION AND STORE ON SCRATCH DISK            03250
C                                                                        03260
      IHI1=NFULST(1)                                                     03270
      IHI2=NFULST(2)                                                     03280
      NINGAM=IHI1*IHI2                                                   03290
      LOCBG=LOCEPR+1                                                     03300
      LOCEG=LOCEPR+NINGAM                                                03310
      KOCBG=LOCEG+1                                                      03320
      KOCEG=LOCEG+NINGAM                                                 03330
      IF(KOCEG .GT. NWORK) CALL ERR(5)                                   03340
      CALL SECOND(T)                                                     03350
      WRITE(LUNO,651) T                                                  03360
  651 FORMAT(/////1X,F9.3,25H CPU SECONDS USED IN INIT/)                  03370
      IF(IPRINT(5) .LT. 2) GO TO 665                                     03380
C                                                                        03390
C         IF AVAILABLE READ BATTLE ASSESSMENTS FROM BATTLE-TAPE          03400
C                                                                        03410
```

FIGURE B-1 (cont'd)

```
      DO 660 I=I,NSTAT                                                  03420
      BUFFER IN (I0,1) (IARRAY(LOCBG),IARRAY(KOCEG))                    03430
      IF(UNIT(I0)) 655,653,653                                          03440
653   CALL ERR(24)                                                      03450
655   BUFFER OUT (I,1) (IARRAY(LOCBG),IARRAY(KOCEG))                    03460
      IF(UNIT(I)) 660,658,658                                           03470
658   CALL ERR(6)                                                       03480
660   CONTINUE                                                          03490
      RETURN                                                            03500
C                                                                       03510
C         IF BATTLE-TAPE IS NOT AVAILABLE, COMPUTE ASSESSMENTS          03520
C         USING SUBROUTINE /BATTLE/                                     03530
C                                                                       03540
665   DO 900 II=I,NGI                                                   03550
      DO 900 I2=I,NG2                                                   03560
      DO 900 I3=I,NG3                                                   03570
      DO 900 I4=I,NG4                                                   03580
      DO 900 I5=I,NG5                                                   03590
      DO 900 I6=I,NG6                                                   03600
      DO 900 I7=I,NG7                                                   03610
      DO 900 I8=I,NG8                                                   03620
      LOCWD=LOCBG-1                                                     03630
      DO 800 IB=I,IHII                                                  03640
      DO 800 IR=I,IHI2                                                  03650
      IWORD=0                                                           03660
      JWORD=0                                                           03670
      IF(IR .LT. IRLO(IB) .OR. IR .GT. IRHI(IB)) GO TO 780              03680
      CNP(1,1)=YGRID(II,I)                                              03690
      CNP(2,I)=YGRID(I2,2)                                              03700
      CNP(3,I)=YGRID(I3,3)                                              03710
      CNP(4,I)=YGRID(I4,4)                                              03720
      CNP(1,2)=YGRID(I5,5)                                              03730
      CNP(2,2)=YGRID(I6,6)                                              03740
      CNP(3,2)=YGRID(I7,7)                                              03750
      CNP(4,2)=YGRID(I8,8)                                              03760
      IF(IPRINT(6) .EQ. 0) GO TO 680                                    03770
      WRITE(LUNO,670) IB,IR                                             03780
670   FORMAT(/,4H IB=,I3,2X,3HIR=,I3)                                   03790
      WRITE(LUNO,675) CNP                                               03800
675   FORMAT(/,4H CNP,6F9.2)                                            03810
680   CALL BATTLE                                                       03820
      LOCLEV=0                                                          03830
      DO 700 K=I,2                                                      03840
      DO 700 J=I,4                                                      03850
      LEVEL=CNP(J,K)/DELTA(J,K)+.5                                      03860
      LOCLEV=LOCLEV+1                                                   03870
      KEVEL(LOCLEV)=LEVEL                                               03880
      CALL SBYT(IBIT(LOCLEV),7,JWORD,LEVEL)                             03890
700   CONTINUE                                                          03900
      BOBJ=0.                                                           03910
      ROBJ=0.                                                           03920
      DO 720 J=I,3                                                      03930
      BOBJ=BOBJ+OBJEC(I,J)*OWGHT(J)                                     03940
      ROBJ=ROBJ+OBJEC(2,J)*OWGHT(J)                                     03950
720   CONTINUE                                                          03960
      IOBJ=BOBJ+SIGN(.5,BOBJ)                                           03970
      JOBJ=ROBJ+SIGN(.5,ROBJ)                                           03980
      IF(IPRINT(6) .EQ. 0) GO TO 780                                    03990
      WRITE(LUNO,775) CNP,IOBJ,JOBJ,KEVEL                               04000
```

FIGURE B-1 (cont'd)

```
 775  FORMAT(4H CNP,8F9.2/6H IOBJ=,I10,5X,5HJOBJ=,I10,5X,7HLEVELS=,814)
 780  IF(IOBJ .GE. 0) GO TO 785
      IOBJ=-IOBJ
      CALL SBYT(60,I,IWORD,1)
 785  CALL SBYT(31,29,IWORD,IOBJ)
      IF(JOBJ .GE. 0) GO TO 790
      JOBJ=-JOBJ
      CALL SBYT(30,1,IWORD,1)
 790  CALL SBYT(I,29,IWORD,JOBJ)
      LOCWD=LOCWO+I
      IARRAY(LOCWD)=IWORD
      IARRAY(LOCWO+NINGAM)=JWORD
 800  CONTINUE
      BUFFER OUT (I,1) (IARRAY(LOCBG),IARRAY(KOCEG))
      IF(UNIT(1)) 875,850,850
 850  CALL ERR(6)
 875  IF(IPRINT(5) .EQ. 0) GO TO 900
C
C          WRITE BATTLE ASSESSMENTS ON BATTLE-TAPE IF REQUESTED
C
      BUFFER OUT (10,1) (IARRAY(LOCBG),IARRAY(KOCEG))
      IF(UNIT(10)) 900,880,880
 880  CALL ERR(24)
 900  CONTINUE
      RETURN
      END
```

```
      FUNCTION ISTATE(IV)
C
C          /ISTATE/ COMPUTES THE INDEX OF THE STATE CORRESPONDING
C          TO A SPECIFIED COMBINATION OF GRID POINTS.
C
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),
     INFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),
     1ITITLE(6),VALU(4,2),PKBO(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),
     1PKESBO(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),OFPREU(4,2),FEBA(2,28),
     1REINF(4,2,100)
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),
     1IBLURO(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR
      DIMENSION IV(1)
      ISTATE=IV(8)+1
      DO 100 I=1,7
      ISTATE=ISTATE+IV(I)*IDEM(I)
 100  CONTINUE
      RETURN
      END
```

FIGURE B-1 (cont'd)

```
      SUBROUTINE PRNTIN                                                 00110
C                                                                       00120
C     /PRNTIN/ PRINTS THE INPUT PARAMETERS.                             00130
C                                                                       00140
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00150
     1INFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),            00160
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00170
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00180
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00190
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00200
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKAAFS(4,2),             00210
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00220
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00230
     1REINF(4,2,100)                                                    00240
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00250
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00260
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUN1,LUNO,        00270
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                00280
      COMMON /WORKL/ LDCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00290
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00300
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00310
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                       00320
      DIMENSION IHEAD(4,25),IM(4,2),XF(4,2),PKS(4,4,2)                  00330
      DATA(IHEAD(1, 1)=40H      CAS ESCORT AGAINST BD                   )00340
      DATA(IHEAD(1, 2)=40H      BD AGAINST CAS ESCORT                   )00350
      DATA(IHEAD(1, 3)=40H           CAS AGAINST BD                     )00360
      DATA(IHEAD(1, 4)=40H           BD AGAINST CAS                     )00370
      DATA(IHEAD(1, 5)=40H      ABA ESCORT AGAINST ABD                  )00380
      DATA(IHEAD(1, 6)=40H      ABD AGAINST ABA ESCORT                  )00390
      DATA(IHEAD(1, 7)=40H         ABA AGAINST ABD                      )00400
      DATA(IHEAD(1, 8)=40H         ABD AGAINST ABA                      )00410
      DATA(IHEAD(1, 9)=40H ABA AGAINST NON-SHELTERED AIRCRAFT           )00420
      DATA(IHEAD(1,10)=40H   ABA AGAINST SHELTERED AIRCRAFT             )00430
      DATA(IHEAD(1,11)=40H FORWARD SAM SUPPRESSOR AGAINST SAM           )00440
      DATA(IHEAD(1,12)=40H SAM AGAINST FORWARD SAM SUPPRESSOR           )00450
      DATA(IHEAD(1,13)=40H   REAR SAM SUPPRESSOR AGAINST SAM            )00460
      DATA(IHEAD(1,14)=40H   SAM AGAINST REAR SAM SUPPRESSOR            )00470
      DATA(IHEAD(1,15)=40H         SAM AGAINST CAS                      )00480
      DATA(IHEAD(1,16)=40H      SAM AGAINST CAS ESCORT                  )00490
      DATA(IHEAD(1,17)=40H         SAM AGAINST ABA                      )00500
      DATA(IHEAD(1,18)=40H      SAM AGAINST ABA ESCORT                  )00510
      WRITE(LUNO,100) (ITITLE(I),I=1,6)                                 00520
  100 FORMAT(1H1,1X,6A10/)                                              00530
      WRITE(LUNO,102) NSTAGE                                            00540
  102 FORMAT(1X,18HNUMBER OF STAGES =,I3)                               00550
      WRITE(LUNO,104) NDAPST                                            00560
  104 FORMAT(1X,28HNUMBER OF CYCLES PER STAGE =,I3)                     00570
      WRITE(LUNO,110) (IBLURD(K),NTYPE(K),K=1,2)                        00580
  110 FORMAT(1X,10HNUMBER OF ,A4,14H PLANE TYPES =,I2)                  00590
      WRITE(LUNO,120) (IBLURD(K),NDIV(K),K=1,2)                         00600
  120 FORMAT(1X,10HNUMBER OF ,A4,12H DIVISIONS =,I6)                    00610
      WRITE(LUNO,125) (IBLURD(K),DIVFP(K),K=1,2)                        00620
  125 FORMAT(1X,14HFIREPOWER PER ,A4,11H DIVISION =,F10.4)              00630
      WRITE(LUNO,130) (IBLURD(K),NSHL(K),K=1,2)                         00640
  130 FORMAT(1X,10HNUMBER OF ,A4,11H SHELTERS =,I6)                     00650
      WRITE(LUNO,140) (IBLURD(K),NFSAM(K),K=1,2)                        00660
  140 FORMAT(1X,10HNUMBER OF ,A4,15H FORWARD SAMS =,I6)                 00670
      WRITE(LUNO,150) (IBLURD(K),NRSAM(K),K=1,2)                        00680
  150 FORMAT(1X,10HNUMBER OF ,A4,12H REAR SAMS =,I6)                    00690
```

FIGURE B-1 (cont'd)

```
      WRITE(LUNO,160) (OWGHT(I),I=1,3)                                  00700
  160 FORMAT(1X,29HOBJECTIVE FUNCTION WEIGHTS = ,9HCAS ORD -,F6.2,      00710
     13X,9HTOTL FP -,F6.2,3X,6HFEBA -,F6.2)                             00720
      WRITE(LUNO,200)                                                   00730
  200 FORMAT(/// ,29X,21HMISSIONS ASSIGNED AND/,28X,                    00740
     123HASSOCIATED SORTIE RATES//)                                     00750
      WRITE(LUNO,210)                                                   00760
  210 FORMAT(15X,15HBLUE PLANE TYPE,21X,14HRED PLANE TYPE/              00770
     12(10X,25H1        2        3        4)/)                         00780
      DO 300 I=1,8                                                      00790
      DO 240 K=1,2                                                      00800
      DO 240 J=1,4                                                      00810
      IF(IMISS(I,J,K) .NE. 0) GO TO 250                                 00820
  240 CONTINUE                                                          00830
      GO TO 310                                                         00840
  250 DO 260 K=1,2                                                      00850
      DO 260 J=1,4                                                      00860
      IM(J,K)=0                                                         00870
      XF(J,K)=0.                                                        00880
      IF(IMISS(I,J,K) .NE. 0) IM(J,K)=IMISS(I,J,K)                      00890
      IF(XSORT(I,J,K) .NE. 0.) XF(J,K)=XSORT(I,J,K)                     00900
  260 CONTINUE                                                          00910
      WRITE(LUNO,280) ((IM(J,K),XF(J,K),J=1,4),K=1,2)                   00920
  280 FORMAT(4X,2(3X,4(I1,1H-,F5.2,1X)))                                00930
  300 CONTINUE                                                          00940
  310 WRITE(LUNO,312)                                                   00950
  312 FORMAT(/// ,26X,28HMINIMUM ALLOCATION FRACTIONS//)                00960
      WRITE(LUNO,210)                                                   00970
      DO 315 K=1,2                                                      00980
      DO 315 J=1,4                                                      00990
      XF(J,K)=0.                                                        01000
      IF(NFRAC(J,K) .EQ. 0) GO TO 315                                   01010
      XF(J,K)=1./NFRAC(J,K)                                             01020
  315 CONTINUE                                                          01030
      WRITE(LUNO,318) ((XF(J,K),J=1,4),K=1,2)                           01040
  318 FORMAT(2X,2(3X,4(F7.2,1X)))                                       01050
      WRITE(LUNO,320)                                                   01060
  320 FORMAT(/// ,35X,11HGRID POINTS//)                                 01070
      WRITE(LUNO,210)                                                   01080
      DO 370 I=1,11                                                     01090
      DO 330 K=1,2                                                      01100
      DO 330 J=1,4                                                      01110
      IF(IGRID(I,J,K) .NE. 0 .OR. 1 .EQ. 1) GO TO 340                   01120
  330 CONTINUE                                                          01130
      GO TO 400                                                         01140
  340 WRITE(LUNO,360) ((IGRID(I,J,K),J=1,4),K=1,2)                      01150
  360 FORMAT(3X,2(3X,4(I6,2X)))                                         01160
  370 CONTINUE                                                          01170
  400 WRITE(LUNO,410)                                                   01180
  410 FORMAT(1H1//,28X,24HCAS FIREPOWER PER SORTIE//)                   01190
      WRITE(LUNO,210)                                                   01200
      WRITE(LUNO,420) ((CASF(J,K),J=1,4),K=1,2)                         01210
  420 FORMAT(3X,2(3X,4(F7.4,1X)))                                       01220
      WRITE(LUNO,422)                                                   01230
  422 FORMAT(/// ,26X,28HDIVISION FIREPOWER REDUCTION,/                 01240
     134X,14HPER CAS SORTIE//)                                          01250
      WRITE(LUNO,210)                                                   01260
      WRITE(LUNO,420) ((DFPRED(J,K),J=1,4),K=1,2)                       01270
      WRITE(LUNO,423)                                                   01280
```

FIGURE B-1 (cont'd)

```
  423   FORMAT(/// ,30X,20HRESIDUAL VALUE OF AN/                          01290
       123X,33HUNDAMAGED PLANE AT END OF THE WAR//)                       01300
        WRITE(LUNO,210)                                                   01310
        WRITE(LUNO,420) ((VALU(J,K),J=1,4),K=1,2)                         01320
        WRITE(LUNO,424)                                                   01330
  424   FORMAT(/// ,27X,26HFRACTION VULNERABLE TO ABA/,35X,               01340
       110HBY MISSION//)                                                  01350
        WRITE(LUNO,210)                                                   01360
        DO 430 I=1,8                                                      01370
        DO 425 K=1,2                                                      01380
        DO 425 J=1,4                                                      01390
        IF(IMISS(I,J,K) .NE. 0) GO TO 426                                 01400
  425   CONTINUE                                                          01410
        GO TO 431                                                         01420
  426   DO 427 K=1,2                                                      01430
        DO 427 J=1,4                                                      01440
        IM(J,K)=0                                                         01450
        XF(J,K)=0.                                                        01460
        IF(IMISS(I,J,K) .NE. 0) IM(J,K)=IMISS(I,J,K)                      01470
        IF(ABAF(I,J,K) .NE. 0.) XF(J,K)=ABAF(I,J,K)                       01480
  427   CONTINUE                                                          01490
        WRITE(LUNO,428) ((IM(J,K),XF(J,K),J=1,4),K=1,2)                   01500
  428   FORMAT(4X,2(3X,4(I1,1H-,F5.3,1X)))                                01510
  430   CONTINUE                                                          01520
  431   IF(FEBA(I,1) .EQ. -1.) GO TO 439                                  01530
        WRITE(LUNO,433)                                                   01540
  433   FORMAT(1H1///,33X,13HFEBA FUNCTION//)                             01550
        DO 434 I=2,28                                                     01560
        IF(FEBA(I,1) .EQ. 0.) GO TO 435                                   01570
  434   CONTINUE                                                          01580
  435   I=I-1                                                             01590
        DO 438 K=1,I,7                                                    01600
        L=K+6                                                             01610
        WRITE(LUNO,436) (FEBA(I,J),J=K,L)                                 01620
  436   FORMAT(/1X,7HF RATIO,6X,7F9.3)                                    01630
        WRITE(LUNO,437) (FEBA(2,J),J=K,L)                                 01640
  437   FORMAT(1X,8HMOVEMENT,5X,7F9.3)                                    01650
  438   CONTINUE                                                          01660
  439   DO 470 I=1,NSTAGE                                                 01670
        IF((I-1)/50*50 .NE. I-1) GO TO 445                                01680
        WRITE(LUNO,440)                                                   01690
  440   FORMAT(1H1//12X,9HOBJECTIVE,2(24X,14HREINFORCEMENTS,17X)/13X,     01700
       17HWEIGHTS,29X,6HNUMBER,48X,8HFRACTION/18X,                        01710
       12(13X,15HBLUE PLANE TYPE,12X,14HRED PLANE TYPE,1X)/1X,5HSTAGE,    01720
       14X,4HBLUE,5X,3HRED,2(7X,19H1     2     3     4,1X),1X,           01730
       12(7X,19H1     2     3     4,1X)/)                                01740
  445   DO 450 K=1,2                                                      01750
        DO 450 J=1,4                                                      01760
        IM(J,K)=REIN(J,K,I)                                               01770
        XF(J,K)=REINF(J,K,1)-1.                                           01780
  450   CONTINUE                                                          01790
        WRITE(LUNO,460) I,(WGHT(I,K),K=1,2),((IM(J,K),J=1,4),K=1,2),      01800
       1((XF(J,K),J=1,4),K=1,2)                                           01810
  460   FORMAT(3X,I2,1X,2F8.2,2(3X,4I6),1X,2(3X,4F6.2))                   01820
  470   CONTINUE                                                          01830
        WRITE(LUNO,500)                                                   01840
  500   FORMAT(1H1,/31X,18HKILL PROBABILITIES/)                           01850
        CALL PKILLS(IHEAD(1,1),PKBOES,0.,0.)                              01860
        CALL PKILLS(IHEAD(1,2),PKESBO,0.,0.)                              01870
```

FIGURE B-1 (cont'd)

```
      CALL PKILLS(IHEAD(1,3),PKBD,0.,0.)                                01880
      CALL PKILLS(IHEAD(1,4),PKBA,0.,0.)                                01890
      WRITE(LUNO,500)                                                   01900
      CALL PKILLS(IHEAD(1,5),PKADES,0.,0.)                              01910
      CALL PKILLS(IHEAD(1,6),PKESAD,0.,0.)                              01920
      CALL PKILLS(IHEAD(1,7),PKAD,0.,0.)                                01930
      CALL PKILLS(IHEAD(1,8),PKAA,0.,0.)                                01940
      WRITE(LUNO,500)                                                   01950
      DO 600 I=1,4                                                      01960
      DO 600 J=1,4                                                      01970
      DO 600 K=1,2                                                      01980
      PKS(I,J,K)=PKNS(J,K)                                              01990
600   CONTINUE                                                          02000
      CALL PKILLS(IHEAD(1,9),PKS,0.,0.)                                 02010
      DO 700 I=1,4                                                      02020
      DO 700 J=1,4                                                      02030
      DO 700 K=1,2                                                      02040
      PKS(I,J,K)=PKSH(J,K)                                              02050
700   CONTINUE                                                          02060
      CALL PKILLS(IHEAD(1,10),PKS,0.,0.)                                02070
      WRITE(LUNO,500)                                                   02080
      CALL SAMS(IHEAD(1,11),1.,PKFS,-2.)                                02090
      CALL SAMS(IHEAD(1,12),1.,PKFAFS,-1.)                              02100
      CALL SAMS(IHEAD(1,13),1.,-2.,PKRS)                                02110
      CALL SAMS(IHEAD(1,14),1.,PKRAFS,PKRARS)                           02120
      WRITE(LUNO,500)                                                   02130
      CALL SAMS(IHEAD(1,15),1.,PKBAFS,-1.)                              02140
      CALL SAMS(IHEAD(1,16),1.,PKBEFS,-1.)                              02150
      CALL SAMS(IHEAD(1,17),1.,PKAAFS,PKAARS)                           02160
      CALL SAMS(IHEAD(1,18),1.,PKAEFS,PKAERS)                           02170
      END                                                               02180


      SUBROUTINE PKILLS (LABL,PK,PKF,PKR)                               02190
C                                                                       02200
C        /PKILLS/ AND /SAMS/ ARE PRINT SUBROUTINES USED IN              02210
C        CONJUNCTION WITH /PRNTIN/.                                     02220
C                                                                       02230
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          02240
     1IBLURO(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         02250
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        02260
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                02270
      DIMENSION LABL(1),PK(4,4,2),PKF(4,2),PKR(4,2)                     02280
      WRITE(LUNO,100) (LABL(I),I=1,4)                                   02290
100   FORMAT(3(/),20X,4A10,///,16X,14HBLUE KILLS RED,20X,               02300
     114HRED KILLS BLUE,//,19X,8HRED TYPE,26X,8HRED TYPE/              02310
     12(12X,22H1       2       3       4))                             02320
      WRITE(LUNO,200) (PK(1,I,2),I=1,4),(PK(I,1,1),I=1,4)               02330
200   FORMAT(7X,1H1,4(2X,F5.3),6X,4(2X,F5.3))                           02340
      WRITE(LUNO,300) (PK(2,I,2),I=1,4),(PK(I,2,1),I=1,4)               02350
300   FORMAT(7X,1H2,4(2X,F5.3),6X,4(2X,F5.3))                           02360
      WRITE(LUNO,400) (PK(3,I,2),I=1,4),(PK(I,3,1),I=1,4)               02370
400   FORMAT(7X,1H3,4(2X,F5.3),6X,4(2X,F5.3))                           02380
      WRITE(LUNO,500) (PK(4,I,2),I=1,4),(PK(I,4,1),I=1,4)               02390
500   FORMAT(7X,1H4,4(2X,F5.3),6X,4(2X,F5.3))                           02400
      RETURN                                                            02410
```

FIGURE B-1 (cont'd)

```
      ENTRY SAMS                                                        02420
      WRITE(LUNO,600) (LABL(I),I=1,4)                                   02430
  600 FORMAT(3(/),20X,4A10,///,16X,14HBLUE KILLS RED,20X,               02440
     1 14HRED KILLS BLUE/)                                              02450
      IF(PKF(1,1) .EQ. -2. .OR. PKR(1,1) .EQ. -2.) GO TO 650            02460
      WRITE(LUNO,610)                                                   02470
  610 FORMAT(19X,8HRED TYPE,25X,9HBLUE TYPE)                            02480
      GO TO 670                                                         02490
  650 WRITE(LUNO,660)                                                   02500
  660 FORMAT(18X,9HBLUE TYPE,26X,8HRED TYPE)                            02510
  670 WRITE(LUNO,680)                                                   02520
  680 FORMAT(2(12X,22HI      2      3      4))                         02530
      IF(PKF(1,1) .LT. 0.) GO TO 750                                    02540
      WRITE(LUNO,700) (PKF(J,2),J=1,4),(PKF(J,1),J=1,4)                 02550
  700 FORMAT(1X,7HFORWARD,4(2X,F5.3),6X,4(2X,F5.3))                     02560
      IF(PKR(1,1) .LT. 0.) RETURN                                       02570
  750 WRITE(LUNO,800) (PKR(J,2),J=1,4),(PKR(J,1),J=1,4)                 02580
  800 FORMAT(2X,4HREAR,2X,4(2X,F5.3),6X,4(2X,F5.3))                     02590
      RETURN                                                            02600
      END                                                               02610
```

```
      SUBROUTINE READIN                                                 00110
C                                                                       00120
C         /READIN/ READS THE INPUT PARAMETER CARDS.                     00130
C                                                                       00140
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00150
     1NFRAC(4,2),NSHL(2),NSTAGE,NOAPST,CASF(4,2),IPRINT(8),             00160
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00170
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00180
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00190
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00200
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),             00210
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00220
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00230
     1REINF(4,2,100)                                                    00240
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00250
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00260
     1ITPNT(32,2),IDEN(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00270
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                00280
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00290
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00300
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00310
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                       00320
      COMMON /WORK/ IARRAY(25000)                                       00330
      DIMENSION IDUMMY(8),KEY(35),NALOCS(33,100,2),MALOC(33)            00340
      EQUIVALENCE (IARRAY,NALOCS),(MALOC,LASTP)                         00350
      DATA(NKEYS=30)                                                    00360
      DATA(IBLURD=4HBLUE,3HRED)                                         00370
      DATA(LUNI=5),(LUNO=6)                                             00380
      DATA(KEY=3HRUN,4HMISS,4HGRID,4HPKBD,4HPKAD,4HPKBA,                00390
     14HPKAA,4HCASF,4HVALU,4HSTAG,4HPKBE,4HPKAE,4HNSHL,4HPKSH,          00400
     14HPKNS,4HSTRT,4HWGHT,4HREIN,4HCWGH,4HNDIV,4HDIVF,4HDFRC,          00410
     14HNSAM,4HPKFS,4HPKRS,4HFEBA,4HABAF,4HPKFA,4HPKRA,3HEND,5(1H ))    00420
      DATA(REIN=800(0.)),(REINF=800(1.)),(WGHT=200(1.))                 00430
      DATA(PKBD=32(0.)),(PKBDES=32(0.)),(PKAD=32(0.)),(PKADES=32(0.))   00440
```

FIGURE B-1 (cont'd)

```
      DATA(PKBA=32(0.)),(PKAA=32(0.)),(PKESBD=32(0.)),(PKESAD=32(0.))      00450
      DATA(PKSH=8(0.)),(PKNS=8(0.))                                        00460
      DATA(CASF=8(0.)),(VALU=8(0.)),(NSHL=2(0)),(NFRAC=8(0))               00470
      DATA(NTYPE=2(0)),(NSTRTC=2(0)),(IGRID=88(0)),(IMISS=64(0))           00480
      DATA(XSORT=64(0.)),(OWGHT=1.,4(0.)),(NDIV=2(0)),(NRSAM=2(0))         00490
      DATA(NFSAM=2(0)),(PKRS=8(0.)),(PKFS=8(0.)),(ABAF=64(1.))             00500
      DATA(DIVFP=2(0.)),(PKBAFS=8(0.)),(PKAAFS=8(0.)),(PKAARS=8(0.))       00510
      DATA(PKAEFS=8(0.)),(PKAERS=8(0.)),(PKBEFS=8(0.)),(DFPRED=8(0.))      00520
      DATA(FEBA=-1.,55(0.)),(PKFAFS=8(0.)),(PKRAFS=8(0.)),(PKRARS=8(0.))   00530
      DATA(IPRINT(1)=0)                                                    00540
      WRITE(LUNO,70)                                                       00550
   70 FORMAT(IH1)                                                          00560
C                                                                          00570
C        READ DATA CARD                                                    00580
C                                                                          00590
  100 READ(LUN1,110) 1KEY,JBR,JTP,(IDUMMY(I),I=1,8)                        00600
  110 FORMAT(A4,2A1,7A10,A4)                                               00610
      IF(IPRINT(1) .EQ. 0) WRITE(LUNO,120) 1KEY,JBR,JTP,                   00620
     1(IDUMMY(I),I=1,8)                                                    00630
  120 FORMAT(1X,A4,2A1,7A10,A4)                                            00640
      DO 150 I=1,NKEYS                                                     00650
      IF(IKEY .EQ. KEY(I)) GO TO 200                                       00660
  150 CONTINUE                                                             00670
      CALL ERR(2)                                                          00680
      GO TO 100                                                            00690
  200 IBR=1                                                                00700
      IF(JBR .EQ. 1HR) IBR=2                                               00710
      DECODE(1,210,JTP) ITP                                                00720
  210 FORMAT(I1)                                                           00730
      GO TO (300,320,340,360,380,400,420,440,460,480,500,510,              00740
     1520,540,560,580,600,620,630,640,650,660,670,680,690,700,             00750
     1710,720,730,800) I                                                   00760
C                                                                          00770
C        RUN CARD                                                          00780
C                                                                          00790
  300 DECODE(74,301,IDUMMY) (IPRINT(I),I=1,8),(ITITLE(I),I=1,6)            00800
  301 FORMAT(4X,8I1,2X,6A10)                                               00810
      GO TO 100                                                            00820
C                                                                          00830
C        MISS CARD                                                         00840
C                                                                          00850
  320 DECODE(74,321,IDUMMY) NFRAC(ITP,IBR),(IMISS(I,ITP,IBR),             00860
     1I=1,8),(XSORT(I,ITP,IBR),I=1,8)                                      00870
  321 FORMAT(4X,I2,1X,8(1X,I2),3X,8F5.2)                                   00880
      GO TO 100                                                            00890
C                                                                          00900
C        GRID CARD                                                         00910
C                                                                          00920
  340 DECODE(59,341,IDUMMY) (IGRID(I,ITP,IBR),I=1,11)                      00930
  341 FORMAT(4X,11I5)                                                      00940
      IF(IGRID(1,ITP,IBR) .NE. 0) CALL ERR(9)                              00950
      IF(NTYPE(IBR) .LT. ITP) NTYPE(IBR)=ITP                               00960
      GO TO 100                                                            00970
C                                                                          00980
C        PKBD CARD                                                         00990
C                                                                          01000
  360 DECODE(49,361,IDUMMY) (PKBD(I,ITP,IBR),I=1,4),                       01010
     1(PKBDES(I,ITP,IBR),I=1,4)                                            01020
  361 FORMAT(4X,4F5.3,5X,4F5.3)                                            01030
```

FIGURE B-1 (cont'd)

```
      GO TO 100                                                          01040
C                                                                        01050
C          PKAD CARD                                                     01060
C                                                                        01070
380   DECODE(49,361,IDUMMY) (PKAD(I,ITP,IBR),I=1,4),                     01080
     1(PKADES(I,ITP,IBR),I=1,4)                                         01090
      GO TO 100                                                          01100
C                                                                        01110
C          PKBA CARD                                                     01120
C                                                                        01130
400   DECODE(34,401,IDUMMY) (PKBA(I,ITP,IBR),I=1,4),PKBAFS(ITP,IBR)     01140
401   FORMAT(4X,4F5.3,5X,F5.3)                                           01150
      GO TO 100                                                          01160
C                                                                        01170
C          PKAA CARD                                                     01180
C                                                                        01190
420   DECODE(39,421,IDUMMY) (PKAA(I,ITP,IBR),I=1,4),PKAAFS(ITP,IBR),     01200
     1PKAARS(ITP,IBR)                                                   01210
421   FORMAT(4X,4F5.3,5X,4F5.3)                                          01220
      GO TO 100                                                          01230
C                                                                        01240
C          CASF CARD                                                     01250
C                                                                        01260
440   DECODE(24,441,IOUMMY) (CASF(I,IBR),I=1,4)                          01270
441   FORMAT(4X,4F5.4)                                                   01280
      GO TO 100                                                          01290
C                                                                        01300
C          VALU CARD                                                     01310
C                                                                        01320
460   DECODE(24,461,IDUMMY) (VALU(I,IBR),I=1,4)                          01330
461   FORMAT(4X,4F5.0)                                                   01340
      GO TO 100                                                          01350
C                                                                        01360
C          STAG CARD                                                     01370
C                                                                        01380
480   DECODE(10,481,IDUMMY) NSTAGE,NDAPST                                01390
481   FORMAT(2X,2(2X,I2))                                                01400
      GO TO 100                                                          01410
C                                                                        01420
C          PKBE CARD                                                     01430
C                                                                        01440
500   DECODE(34,401,IDUMMY) (PKESBD(I,ITP,IBR),I=1,4),PKBEFS(ITP,IBR)    01450
      GO TO 100                                                          01460
C                                                                        01470
C          PKAE CARD                                                     01480
C                                                                        01490
510   DECODE(39,421,IOUMMY) (PKESAO(I,ITP,IBR),I=1,4),PKAEFS(ITP,IBR),   01500
     1PKAERS(ITP,IBR)                                                   01510
      GO TO 100                                                          01520
C                                                                        01530
C          NSHL CARD                                                     01540
C                                                                        01550
520   DECODE( 9,521,IOUMMY) NSHL(IBR)                                    01560
521   FORMAT(4X,I5)                                                      01570
      GO TO 100                                                          01580
C                                                                        01590
C          PKSH CARD                                                     01600
C                                                                        01610
540   DECODE(24,541,IDUMMY) (PKSH(I,IBR),I=1,4)                          01620
541   FORMAT(4X,4F5.3)                                                   01630
```

FIGURE B-1 (cont'd)

```
      GO TO 100                                                          01640
                                                                         01650
C                                                                        01660
C        PKNS CARD                                                       01670
C                                                                        01680
560   DECODE(24,541,IDUMMY) (PKNS(I,IBR),I=1,4)                          01690
      GO TO 100                                                          01700
C                                                                        01710
C        STRT CARD                                                       01720
C                                                                        01730
580   DECODE(74,581,IDUMMY) (MALOC(I),I=1,33)                            01740
581   FORMAT(I2,4(2X,8A2))                                               01750
      NSTRTC(IBR)=NSTRTC(IBR)+1                                          01760
      DO 583 I=2,33                                                      01770
      IF(MALOC(I) .EQ. 2H * .OR. MALOC(I) .EQ. 2H**) MALOC(I)=2H-1       01780
      DECODE(2,582,MALOC(I)) IHOLD                                       01790
582   FORMAT(I2)                                                         01800
      MALOC(I)=IHOLD                                                     01810
583   CONTINUE                                                           01820
      J=NSTRTC(IBR)                                                      01830
      DO 584 I=1,33                                                      01840
      NALOCS(I,J,IBR)=MALOC(I)                                           01850
584   CONTINUE                                                           01860
      GO TO 100                                                          01870
C                                                                        01880
C        WGHT CARD                                                       01890
C                                                                        01900
600   DECODE(9,601,IDUMMY) J,WGHT(J,IBR)                                 01910
601   FORMAT(I2,2X,F5.0)                                                 01920
      GO TO 100                                                          01930
C                                                                        01940
C        REIN CARD                                                       01950
C                                                                        01960
620   DECODE(49,621,IDUMMY) J,(REIN(I,IBR,J),I=1,4),                     01970
     1(REINF(I,IBR,J),I=1,4)                                             01980
621   FORMAT(I2,2X,4F5.0,5X,4F5.0)                                       01990
      DO 625 I=1,4                                                       02000
      REINF(I,IBR,J)=REINF(I,IBR,J)+1.                                   02010
625   CONTINUE                                                           02020
      GO TO 100                                                          02030
C                                                                        02040
C        OWGHT CARD                                                      02050
C                                                                        02060
630   DECODE(29,631,IDUMMY) (OWGHT(I),I=1,5)                             02070
631   FORMAT(4X,5F5.0)                                                   02080
      GO TO 100                                                          02090
C                                                                        02100
C        NDIV CARD                                                       02110
C                                                                        02120
640   DECODE(9,521,IDUMMY) NDIV(IBR)                                     02130
      GO TO 100                                                          02140
C                                                                        02150
C        DIVF CARD                                                       02160
C                                                                        02170
650   DECODE(9,651,IDUMMY) DIVFP(IBR)                                    02180
651   FORMAT(4X,F5.0)                                                    02190
      GO TO 100                                                          02200
C                                                                        02210
C        DFRC CARD                                                       02220
C
```

FIGURE B-1 (cont'd)

```
  660   DECODE(24,441,IDUMMY) (DFPRED(I,IBR),I=1,4)                    02230
        GO TO 100                                                       02240
C                                                                       02250
C           NSAM CARD                                                   02260
C                                                                       02270
  670   DECODE(14,671,IDUMMY) NFSAM(IBR),NRSAM(IBR)                     02280
  671   FORMAT(4X,2I5)                                                  02290
        GO TO 100                                                       02300
C                                                                       02310
C           PKFS CARD                                                   02320
C                                                                       02330
  680   DECODE(24,541,IDUMMY) (PKFS(I,IBR),I=1,4)                       02340
        GO TO 100                                                       02350
C                                                                       02360
C           PKRS CARD                                                   02370
C                                                                       02380
  690   DECODE(24,541,IDUMMY) (PKRS(I,IBR),I=1,4)                       02390
        GO TO 100                                                       02400
C                                                                       02410
C           FEBAM CARD                                                  02420
C                                                                       02430
  700   ILO=(ITP-1)*7+1                                                 02440
        IHI=ILO+6                                                       02450
        DECODE(74,701,IDUMMY) ((FEBA(I,J),I=1,2),J=ILO,IHI)             02460
  701   FORMAT(4X,14F5.0)                                               02470
        GO TO 100                                                       02480
C                                                                       02490
C           ABAF CARD                                                   02500
C                                                                       02510
  710   DECODE(44,711,IDUMMY) (ABAF(I,ITP,IBR),I=1,8)                   02520
  711   FORMAT(4X,8F5.0)                                                02530
        GO TO 100                                                       02540
C                                                                       02550
C           PKFA CARD                                                   02560
C                                                                       02570
  720   DECODE(9,721,IDUMMY) PKFAFS(ITP,IBR)                            02580
  721   FORMAT(4X,F5.3)                                                 02590
        GO TO 100                                                       02600
C                                                                       02610
C           PKRA CARD                                                   02620
C                                                                       02630
  730   DECODE(14,731,IDUMMY) PKRAFS(ITP,IBR),PKRARS(ITP,IBR)           02640
  731   FORMAT(4X,2F5.3)                                                02650
        GO TO 100                                                       02660
C                                                                       02670
C           END CARD                                                    02680
C                                                                       02690
  800   DO 810 K=1,2                                                    02700
        J=NSTRTC(K)                                                     02710
        DO 810 I=1,J                                                    02720
        BUFFER OUT (9,1) (NALOCS(1,I,K),NALOCS(33,I,K))                 02730
        IF(UNIT(9)) 810,807,807                                         02740
  807   CALL ERR(21)                                                    02750
  810   CONTINUE                                                        02760
        RETURN                                                          02770
        END                                                             02780
```

FIGURE B-1 (cont'd)

```
      SUBROUTINE STRAT                                                  00110
                                                                        00120
C                                                                       00130
C         /STRAT/ GENERATES THE PURE STRATEGIES FOR A PARTICULAR PLANE  00140
C         TYPE RESULTING FROM A SPECIFIED ALLOCATION OF A MINIMUM       00150
C         ALLOCATION FRACTION TO MISSIONS.                              00160
C                                                                       00170
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00180
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),             00190
     11TITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00200
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00210
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00220
     1WGHT(100,2),XSORT(8,4,2),ND1V(2),OWGHT(5),NRSAM(2),NFSAM(2),      00230
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),D1VFP(2),PKBAFS(4,2),             00240
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00250
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00260
     1REINF(4,2,100)                                                    00270
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NM1SST(2),NGRID(4,2),          00280
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,N1NGAM,IMPNT(32,2),         00290
     11TPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00300
     1NWORK,NSTAT2,1S1NT(500,2),1DINT(100,2),INPNT(32,2)                00310
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00320
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00330
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00340
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                       00350
      COMMON /WORK/ SPACER(18600),STRATS(8,200,4)                       00360
C-----                                                                  00370
C         IF NWORK IS CHANGED IN INIT, THE LENGTH OF SPACER MUST        00380
C         BE SET EQUAL TO NWORK-6400.                                   00390
C                                                                       00400
      COMMON /SPARM/ MFRAC,MMISS,IBR,ITYPE,NSTOR(8),IPNT(8)             00410
      DIMENSION MSTOR(8)                                                00420
      NSTRAT(ITYPE,IBR)=0                                               00430
      MISSN=NMISS(ITYPE,IBR)                                            00440
      FRACN=NFRAC(ITYPE,IBR)                                            00450
      IF(MMISS .NE. 0) GO TO 200                                        00460
      DO 100 I=1,MISSN                                                  00470
      STRATS(I,1,ITYPE)=NSTOR(I)/FRACN                                  00480
  100 CONTINUE                                                          00490
      NSTRAT(ITYPE,IBR)=1                                               00500
      RETURN                                                            00510
  200 IHI1=MFRAC+I                                                      00520
      ILO1=1                                                            00530
      IF(MMISS .EQ. 1) ILO1=IHI1                                        00540
      DO 400 I1=ILO1,IHI1                                               00550
      MSTOR(1)=I1-I                                                     00560
      IHI2=IHI1-MSTOR(1)                                                00570
      ILO2=I                                                            00580
      IF(MMISS .EQ. 2) ILO2=IHI2                                        00590
      DO 400 I2=ILO2,IHI2                                               00600
      MSTOR(2)=I2-1                                                     00610
      IHI3=IHI2-MSTOR(2)                                                00620
      ILO3=1                                                            00630
      IF(MMISS .EQ. 3) ILO3=IHI3                                        00640
      DO 400 I3=ILO3,IHI3                                               00650
      MSTOR(3)=I3-I                                                     00660
      IHI4=IHI3-MSTOR(3)                                                00670
      ILO4=1                                                            00680
      IF(MMISS .EQ. 4) ILO4=IHI4                                        00690
      DO 400 I4=ILO4,IHI4
```

FIGURE B-1 (cont'd)

```
      MSTOR(4)=I4-1                                                     00700
      IHI5=IHI4-MSTOR(4)                                                00710
      IL05=1                                                            00720
      IF(MMISS .EQ. 5) IL05=IHI5                                        00730
      DO 400 I5=IL05,IHI5                                               00740
      MSTOR(5)=I5-1                                                     00750
      IHI6=IHI5-MSTOR(5)                                                00760
      IL06=1                                                            00770
      IF(MMISS .EQ. 6) IL06=IHI6                                        00780
      DO 400 I6=IL06,IHI6                                               00790
      MSTOR(6)=I6-1                                                     00800
      IHI7=IHI6-MSTOR(6)                                                00810
      IL07=1                                                            00820
      IF(MMISS .EQ. 7) IL07=IHI7                                        00830
      DO 400 I7=IL07,IHI7                                               00840
      MSTOR(7)=I7-1                                                     00850
      IHI8=IHI7-MSTOR(7)                                                00860
      IL08=1                                                            00870
      IF(MMISS .EQ. 8) IL08=IHI8                                        00880
      DO 400 I8=IL08,IHI8                                               00890
      MSTOR(8)=I8-1                                                     00900
      NSTRAT(ITYPE,IBR)=NSTRAT(ITYPE,IBR)+1                             00910
      DO 300 I=1,MMISS                                                  00920
      J=IPNT(I)                                                         00930
      NSTOR(J)=MSTOR(I)                                                 00940
  300 CONTINUE                                                          00950
      J=NSTRAT(ITYPE,IBR)                                               00960
      DO 350 I=1,MISSN                                                  00970
      STRATS(I,J,ITYPE)=NSTOR(I)/FRACN                                  00980
  350 CONTINUE                                                          00990
  400 CONTINUE                                                          01000
      IF(NSTRAT(ITYPE,IBR) .GT. 200) CALL ERR(3)                        01010
      RETURN                                                            01020
      END                                                               01030
```

```
      SUBROUTINE TIMER                                                  00110
C                                                                       00120
C     /TIMER/ USES AN EMPIRICAL FORMULA TO ESTIMATE THE                 00130
C       EXECUTION TIME REQUIRED FOR THE CURRENT RUN.                    00140
C                                                                       00150
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00160
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),             00170
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),      00180
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00190
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00200
     1WGHT(100,2),XSORT(8,4,2),NDIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00210
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),             00220
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00230
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00240
     1REINF(4,2,100)                                                    00250
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00260
     1IBLURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00270
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUN1,LUNO,        00280
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                00290
```

FIGURE B-1 (cont'd)

```
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,          00300
     ILOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                    00310
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,             00320
     IIOCBVB,IOCEVB,IOCBVR,IOCEVR                                          00330
      COMMON /SINTVL/ IRLO(500),IRHI(500)                                  00340
      DIMENSION IFUNC(4),TIMEC(4),TIMEI(4)                                 00350
      DATA(V=.12),(W=2.0E-3),(X=1.2E-5),(Y=4.4E-4),(Z=2.0E-4)              00360
      DATA(IFUNC=5HSETUP,7HBATTLES,5HGAMES,5HTOTAL)                        00370
      IHI1=NFULST(1)                                                       00380
      IHI2=NFULST(2)                                                       00390
      TIMEC(1)=2.0                                                         00400
      TIMEI(1)=2.0                                                         00410
      NTP=NTYPE(1)*NTYPE(2)                                                00420
      NPNTS=1                                                              00430
      DO 100 I=1,NTP                                                       00440
      NPNTS=NPNTS*2                                                        00450
  100 CONTINUE                                                             00460
      NBATLS=0                                                             00470
      TIMEC(3)=0.                                                          00480
      DO 200 I=1,IHI1                                                      00490
      NBATLS=NBATLS+IRHI(I)-IRLO(I)+1                                      00500
  200 CONTINUE                                                             00510
      TIMEC(2)=NSTAT*NDAPST*NBATLS*W                                       00520
      TIMEI(2)=NSTAT*V                                                     00530
      DO 500 I=1,NSTAGE                                                    00540
      ICNT=0                                                               00550
      DO 300 J=1,IHI1                                                      00560
      IF(ISINT(J,1) .NE. IDINT(I,1)) GO TO 300                             00570
      ICNT=ICNT+1                                                          00580
  300 CONTINUE                                                             00590
      JCNT=0                                                               00600
      DO 400 J=1,IHI2                                                      00610
      IF(ISINT(J,2) .NE. IDINT(I,2)) GO TO 400                             00620
      JCNT=JCNT+1                                                          00630
  400 CONTINUE                                                             00640
      TIMEC(3)=TIMEC(3)+ICNT*JCNT*(Y+NTP*X*NPNTS)+Z*(ICNT+JCNT)            00650
  500 CONTINUE                                                             00660
      TIMEC(3)=NSTAT*TIMEC(3)                                              00670
      TIMEI(3)=NSTAGE*NSTAT*V                                              00680
      IF(IPRINT(4) .EQ. 1) TIMEI(2)=2.*TIMEI(2)                            00690
      IF(IPRINT(4) .EQ. 2) TIMEC(2)=0.                                     00700
      TIMEC(4)=TIMEC(1)+TIMEC(2)+TIMEC(3)                                  00710
      TIMEI(4)=TIMEI(1)+TIMEI(2)+TIMEI(3)                                  00720
      WRITE(LUNO,600)                                                      00730
  600 FORMAT(1H1///10X,40HCDC 6600 TIME ESTIMATES FOR CURRENT RUN ,        00740
     19H(SECONDS)//16X,8HFUNCTION,8X,8HCPU TIME,3X,8HI/O TIME/)            00750
      DO 700 I=1,3                                                         00760
      WRITE(LUNO,650) IFUNC(I),TIMEC(I),TIMEI(I)                           00770
  650 FORMAT(16X,A7,9X,F8.1,3X,F8.1)                                       00780
  700 CONTINUE                                                             00790
      WRITE(LUNO,750) IFUNC(4),TIMEC(4),TIMEI(4)                           00800
  750 FORMAT(/16X,A7,9X,F8.1,3X,F8.1///)                                   00810
      RETURN                                                               00820
      END                                                                  00830
```

FIGURE B-1 (cont'd)

```
      SUBROUTINE TRIALS                                                 00110
C                                                                       00120
C         /TRIALS/ COMPUTES THE MAXMIN AND MINMAX BOUNDS AND PERFORMS   00130
C         THE FORWARD EVALUATION FOR A TRIAL AIRWAR OF SPECIFIED        00140
C         LENGTH BEGINNING WITH A SPECIFIED NUMBER OF BLUE AND RED      00150
C         PLANES.  /TRIALS/ COMPUTES THESE VALUES USING THE OPTIMAL     00160
C         STRATEGIES AND VALUES PREVIOUSLY DETERMINED BY /GAMES/.       00170
C                                                                       00180
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),       00190
     1NFRAC(4,2),NSHL(2),NSTAGE,NDAPST,CASF(4,2),IPRINT(8),             00200
     1ITITLE(6),VALU(4,2),PKBO(4,4,2),PKBOES(4,4,2),XGRID(11,4,2),      00210
     1PKAD(4,4,2),PKAOES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                00220
     1PKESBD(4,4,2),PKESAO(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),    00230
     1WGHT(100,2),XSORT(8,4,2),NOIV(2),OWGHT(5),NRSAM(2),NFSAM(2),      00240
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),             00250
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),      00260
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),       00270
     1REINF(4,2,100)                                                    00280
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),          00290
     1IBLURO(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),         00300
     1ITPNT(32,2),IDEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,        00310
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                00320
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,       00330
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                 00340
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,          00350
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                       00360
      COMMON /BPARM/ CNP(4,2),IB,IR,XNP(9,4,2),OBJEC(2,5)               00370
      COMMON /INTERP/ BETA(2,8),IBETA(2,8),I1,I2,I3,I4,I5,I6,I7,I8,     00380
     1IHI1,IHI2,IHI3,IHI4,IHI5,IHI6,IHI7,IHI8                           00390
      COMMON /WORK/ XARRAY(25000)                                       00400
      DIMENSION IOPTN(5),IOUT(10),JOUT(4,2),JOPTN(5),IARRAY(1)          00410
      DIMENSION IPLAL(100,2),XOBJF(3,100),TXOBJF(3)                     00420
      EQUIVALENCE (XARRAY,IARRAY)                                       00430
      COMMON /ROUND/ JDEX(4,2,2)                                        00440
      DIMENSION MVEC(1),NVEC(1)                                         00450
      EQUIVALENCE (MVEC,JDEX(1,1,1)),(NVEC,JOEX(1,1,2))                00460
      DATA(JOPTN=5(0))                                                  00470
      NTRIAL=0                                                          00480
  100 READ(LUNI,110) KEY,MSTAGE,(IOPTN(I),I=1,5),((CNP(I,K),I=1,4),     00490
     1K=1,2)                                                            00500
  110 FORMAT(A5,5X,I2,2X,5I1,1X,2(4F5.0,5X))                            00510
      IF(EOF(LUNI)) 990,120                                             00520
  120 IF(KEY .EQ. 5HTRIAL) GO TO 200                                    00530
      IF(KEY .EQ. 5HFINIS) GO TO 990                                    00540
      CALL ERR(17)                                                      00550
      GO TO 100                                                         00560
  200 IF(MSTAGE .LE. NSTAGE) GO TO 240                                  00570
      CALL ERR(18)                                                      00580
      GO TO 100                                                         00590
  240 DO 250 K=1,2                                                      00600
      DO 250 I=1,4                                                      00610
      IUP=NGRID(I,K)                                                    00620
      IF(CNP(I,K) .GT. XGRID(IUP,I,K)) GO TO 270                        00630
  250 CONTINUE                                                          00640
      GO TO 300                                                         00650
  270 CALL ERR(19)                                                      00660
      GO TO 100                                                         00670
  300 REWIND 7                                                          00680
```

FIGURE B-1 (cont'd)

```
      REWIND 8                                                          00690
      REWIND 9                                                          00700
      TOBJF=0.                                                          00710
      DO 305 K=1,2                                                      00720
      DO 305 I=1,4                                                      00730
      JOUT(I,K)=CNP(I,K)+.5                                             00740
  305 CONTINUE                                                          00750
      NTRIAL=NTRIAL+1                                                   00760
      NSKIP=NSTAGE-MSTAGE                                               00770
      IF(NSKIP .EQ. 0) GO TO 400                                        00780
      DO 350 I=1,NSKIP                                                  00790
      BUFFER IN (7,1) (IARRAY(LOCBVB),IARRAY(LOCBVB))                   00800
      IF(UNIT(7)) 320,310,310                                           00810
  310 CALL ERR(14)                                                      00820
  320 BUFFER IN (8,1) (IARRAY(LOCBPB),IARRAY(LOCBPB))                   00830
      IF(UNIT(8)) 350,340,340                                           00840
  340 CALL ERR(15)                                                      00850
  350 CONTINUE                                                          00860
  400 BUFFER IN (7,1) (IARRAY(LOCBVB),IARRAY(LOCEVR))                   00870
      IF(UNIT(7)) 410,405,405                                           00880
  405 CALL ERR(14)                                                      00890
C                                                                       00900
C          COMPUTE MAXMIN AND MINMAX                                    00910
C                                                                       00920
  410 DO 420 K=1,16                                                     00930
      MVEC(K)=0                                                         00940
  420 CONTINUE                                                          00950
      DO 460 K=1,2                                                      00960
      L=3-K                                                             00970
      IUP=NTYPE(L)                                                      00980
      DO 460 J=1,IUP                                                    00990
      N=1                                                               01000
      DO 440 M=1,11                                                     01010
      IF(CNP(J,L)-XGRID(M,J,L)) 450,445,440                             01020
  440 CONTINUE                                                          01030
      M=11                                                              01040
  445 N=0                                                               01050
  450 M=M-1                                                             01060
      JDEX(J,L,K)=M                                                     01070
      JDEX(J,L,L)=M-N                                                   01080
  460 CONTINUE                                                          01090
      IBS=ISTATE(MVEC)-1                                                01100
      IRS=ISTATE(NVEC)-1                                                01110
      XMIN=XARRAY(LOCBVB+IBS)                                           01120
      XMAX=XARRAY(LOCBVR+IRS)                                           01130
C                                                                       01140
C          PERFORM FORWARD EVALUATION FOR SPECIFIED TRIAL               01150
C                                                                       01160
C                                                                       01170
      DO 700 M=1,MSTAGE                                                 01180
      MSLOC=M+NSKIP                                                     01190
      NSLOC=MSLOC+1                                                     01200
      BUFFER IN (8,1) (IARRAY(LOCBPB),IARRAY(LOCEPR))                   01210
      IF(UNIT(8)) 510,505,505                                           01220
  505 CALL ERR(15)                                                      01230
  510 CALL BETAS                                                        01240
      DO 600 N=1,8                                                      01250
      MVEC(N)=IBETA(1,N)                                                01260
      IF(BETA(1,N) .LT. BETA(2,N)) MVEC(N)=IBETA(2,N)                   01270
  600 CONTINUE
```

FIGURE B-1 (cont'd)

```
      IS=ISTATE(MVEC)-1                                                    01280
      IB=IARRAY(LOCBPB+IS)                                                 01290
      IR=IARRAY(LOCBPR+IS)                                                 01300
      IPLAL(M,1)=LOCST(IB,1)                                               01310
      IPLAL(M,2)=LOCST(IR,2)                                               01320
      CALL BATTLE                                                          01330
      BOBJ=0.                                                              01340
      ROBJ=0.                                                              01350
      DO 605 I=1,3                                                         01360
      BOBJ=BOBJ+OBJEC(1,I)*OWGHT(I)                                        01370
      ROBJ=ROBJ+OBJEC(2,I)*OWGHT(I)                                        01380
  605 CONTINUE                                                             01390
      OBJF=BOBJ*WGHT(MSLOC,I)-ROBJ*WGHT(MSLOC,2)                           01400
      TOBJF=TOBJF+OBJF                                                     01410
      IF(IOPTN(I) .NE. 0) GO TO 630                                        01420
      ICNT=0                                                               01430
      DO 610 K=1,2                                                         01440
      DO 610 I=1,4                                                         01450
      ICNT=ICNT+1                                                          01460
      IOUT(ICNT)=CNP(I,K)+.5                                               01470
      CNP(I,K)=REINF(I,K,NSLOC)*CNP(I,K)+REIN(I,K,NSLOC)                   01480
  610 CONTINUE                                                             01490
      IOUT(9)=OBJF+SIGN(.5,OBJF)                                           01500
      IOUT(10)=TOBJF+SIGN(.5,TOBJF)                                        01510
      BUFFER OUT (9,1) (IOUT,IOUT(10))                                     01520
      IF(UNIT(9)) 630,620,620                                              01530
  620 CALL ERR(20)                                                         01540
  630 IF(IOPTN(3) .NE. 0) GO TO 700                                        01550
      DO 640 I=1,3                                                         01560
      XOBJF(I,M)=OBJEC(1,I)*WGHT(MSLOC,1)-OBJEC(2,I)*WGHT(MSLOC,2)         01570
  640 CONTINUE                                                             01580
  700 CONTINUE                                                             01590
C                                                                          01600
C          WRITE DESIGNATED OUTPUT FOR CURRENT TRIAL                       01610
C                                                                          01620
      IF((NTRIAL-1)/25*25 .EQ. NTRIAL-1) GO TO 720                         01630
      DO 710 I=1,3                                                         01640
      IF(JOPTN(I) .EQ. 0) GO TO 720                                        01650
  710 CONTINUE                                                             01660
      GO TO 730                                                            01670
  720 WRITE(LUNO,725)                                                      01680
  725 FORMAT(1H1,//8X,6HNUMBER,7X,26HNUMBER OF PLANES AVAILABLE,27X        01690
     1,6HMAXMIN/,1X,5HTRIAL,4X,2HOF,5X,16H----- BLUE -----,4X,             01700
     116H----- RED ------,4X,4HBLUE,5X,3HRED,7X,2HVS,/,1X,                 01710
     113HNUMBER STAGES,3X,I6HI    2    3    4,4X,                         01720
     116H1    2    3    4,3X,6HMAXMIN,3X,6HMINMAX,3X,6HMINMAX)             01730
  730 IMIN=XMIN+SIGN(.5,XMIN)                                              01740
      IMAX=XMAX+SIGN(.5,XMAX)                                              01750
      IOBJF=TOBJF+SIGN(.5,TOBJF)                                           01760
      DO 735 I=1,5                                                         01770
      JOPTN(I)=IOPTN(I)                                                    01780
  735 CONTINUE                                                             01790
      WRITE(LUNO,740) NTRIAL,MSTAGE,((JOUT(I,K),I=1,4),K=1,2),IMIN,        01800
     1IMAX,IOBJF                                                           01810
  740 FORMAT(/2X,I3,5X,I2,2X,8I5,2(I8,1X),I8)                              01820
      IF(IOPTN(1) .NE. 0) GO TO 850                                        01830
      REWIND 9                                                             01840
      DO 840 I=1,MSTAGE                                                    01850
      IF((I-1)/50*50-.EQ. I-1) WRITE(LUNO,800) NTRIAL                      01860
```

FIGURE B-1 (cont'd)

```
  800   FORMAT(1H1,//21X,12HTRIAL NUMBER,I5//12X,14HNUMBER OF BLUE,7X,      01870
       113HNUMBER OF RED,8X,6HMAXMIN,/,1X,5HSTAGE,5X,                      01880
       12(16HPLANES AVAILABLE,5X),3X,2HVS,/,1X,6HNUMBER,4X,                01890
       12(16H1     2     3     4,5X),1X,6HMINMAX,4X,5HTOTAL/)              01900
        BUFFER IN (9,1) (IOUT,IOUT(10))                                    01910
        IF(UNIT(9)) 810,805,805                                            01920
  805   CALL ERR(20)                                                       01930
  810   WRITE(LUNO,820) I,(IOUT(J),J=1,10)                                 01940
  820   FORMAT(1X,I4,2X,2(1X,4I5),2X,2I9)                                  01950
  840   CONTINUE                                                           01960
  850   IF(IOPTN(2) .NE. 0) GO TO 900                                      01970
        DO 890 K=1,2                                                       01980
        IUP=NMISST(K)                                                      01990
        DO 890 I=1,MSTAGE                                                  02000
        IF((I-1)/50*50 .NE. I-1) GO TO 865                                 02010
        WRITE(LUNO,860) NTRIAL,IBLURD(K),                                  02020
       1(ITPNT(J,K),IMPNT(J,K),J=1,IUP)                                    02030
  860   FORMAT(1HI,//21X,12HTRIAL NUMBER,I5,//13X,                         02040
       131HPLANE ALLOCATION FRACTIONS FOR ,A4,//,1X,5HSTAGE,16X,           02050
       118HPLANE TYPE/MISSION,/,1X,6HNUMBER,5X,                            02060
       13(I2(I1,1H/,I1,2X)/12X))                                           02070
        WRITE(LUNO,862)                                                    02080
  862   FORMAT(1H )                                                        02090
  865   ILO=IPLAL(I,K)                                                     02100
        ITP=ILO+IUP-1                                                      02110
        WRITE(LUNO,880) I,(XARRAY(J),J=ILO,ITP)                            02120
  880   FORMAT(1X,I4,5X,3(12F5.2,/,10X))                                   02130
  890   CONTINUE                                                           02140
  900   IF(IOPTN(3) .NE. 0) GO TO 100                                      02150
        DO 905 I=1,3                                                       02160
        TXOBJF(I)=0.                                                       02170
  905   CONTINUE                                                           02180
        DO 930 I=1,MSTAGE                                                  02190
        IF((I-1)/50*50 .EQ. I-1) WRITE(LUNO,910) NTRIAL                    02200
  910   FORMAT(1H1//21X,12HTRIAL NUMBER,I5,//12X,8HBLUE-RED,15X,           02210
       18HBLUE-RED/1X,5HSTAGE,8X,3HCAS,18X,8HGRND-AIR,17X,4HFEBA/         02220
       11X,6HNUMBER,5X,9HFIREPOWER,4X,5HTOTAL,5X,9HFIREPOWER,4X,          02230
       15HTOTAL,5X,8HMOVEMENT,5X,5HTOTAL/)                                 02240
        DO 915 J=1,3                                                       02250
        TXOBJF(J)=TXOBJF(J)+XOBJF(J,I)                                     02260
        K=2*J                                                              02270
        IOUT(K-1)=XOBJF(J,I)+SIGN(.5,XOBJF(J,I))                           02280
        IOUT(K)=TXOBJF(J)+SIGN(.5,TXOBJF(J))                               02290
  915   CONTINUE                                                           02300
        WRITE(LUNO,920) I,(IOUT(J),J=1,6)                                  02310
  920   FORMAT(1X,I4,2X,3(3X,2I10))                                        02320
  930   CONTINUE                                                           02330
        GO TO 100                                                          02340
  990   RETURN                                                             02350
        END                                                                02360
```

FIGURE B-2

ATACM2 LISTING

```
      PROGRAM ATACM2 (OUTPUT,TAPE4=65,TAPE5,TAPE6=OUTPUT,TAPE7=65,          00110
     1TAPE8=65,TAPE9=65)                                                    00120
                                                                            00130
C                                                                           00140
C         /ATACM2/ AND ASSOCIATED SUBROUTINES ARE USED TO EVALUATE          00150
C         TRIAL AIRWARS USING THE OPTIMAL STRATEGIES AND GAME VALUES        00160
C         INPUT FROM A TRIAL-TAPE WRITTEN DURING A PREVIOUS RUN             00170
C         OF /ATACM1/.                                                      00180
C                                                                           00190
      COMMON /INPUT/ IMISS(8,4,2),IGRID(11,4,2),LASTP,NALOC(8,4),           00200
     1NFRAC(4,2),NSHL(2),NSTAGE,NUAPST,CASF(4,2),IPRINT(8),                 00210
     1ITITLE(6),VALU(4,2),PKBD(4,4,2),PKBDES(4,4,2),XGRID(11,4,2),          00220
     1PKAD(4,4,2),PKADES(4,4,2),PKBA(4,4,2),PKAA(4,4,2),                    00230
     1PKESBD(4,4,2),PKESAD(4,4,2),PKSH(4,2),PKNS(4,2),REIN(4,2,100),        00240
     1WGHT(100,2),XSORT(8,4,2),NOIV(2),OWGHT(5),NRSAM(2),NFSAM(2),          00250
     1PKRS(4,2),PKFS(4,2),ABAF(8,4,2),DIVFP(2),PKBAFS(4,2),                 00260
     1PKAAFS(4,2),PKAARS(4,2),PKAEFS(4,2),PKAERS(4,2),PKBEFS(4,2),          00270
     1PKFAFS(4,2),PKRAFS(4,2),PKRARS(4,2),DFPRED(4,2),FEBA(2,28),           00280
     1REINF(4,2,100)                                                        00290
      COMMON /WORKN/ NTYPE(2),NMISS(4,2),NMISST(2),NGRID(4,2),              00300
     118LURD(2),NSTRAT(4,2),NFULST(2),NSTAT,NINGAM,IMPNT(32,2),             00310
     1ITPNT(32,2),IOEM(8),NSTRTC(2),IRA(100),JRA(100),LUNI,LUNO,            00320
     1NWORK,NSTAT2,ISINT(500,2),IDINT(100,2),INPNT(32,2)                    00330
      COMMON /WORKL/ LOCST(500,2),LOCBG,LOCEG,KOCBG,KOCEG,LOCBVR,           00340
     1LOCBVB,LOCEVR,LOCEVB,LOCBPR,LOCBPB,LOCEPR,LOCEPB,                     00350
     1KOCBVB,KOCEVB,KOCBVR,KOCEVR,JOCBVB,JOCEVB,JOCBVR,JOCEVR,              00360
     1IOCBVB,IOCEVB,IOCBVR,IOCEVR                                           00370
      COMMON /WORK/ XARRAY(25000)                                           00380
      COMMON /ERROR/ IERR                                                   00390
      DIMENSION INPUTZ(2680),WORKNZ(1640),WORKLZ(1024),WORKZ(25000)         00400
      DIMENSION IARRAY(10000)                                               00410
      DIMENSION JGRID(11,8),JPRINT(8)                                       00420
      EQUIVALENCE (IMISS,INPUTZ),(NTYPE,WORKNZ),(LOCST,WORKLZ)              00430
      EQUIVALENCE (IGRID,JGRID)                                             00440
      EQUIVALENCE (XARRAY,IARRAY,WORKZ)                                     00450
      BUFFER IN (4,1) (INPUTZ,INPUTZ(2680))                                 00460
      IF(UNIT(4)) 200,150,150                                               00470
  150 CALL ERR(22)                                                          00480
  200 BUFFER IN (4,1) (WORKNZ,WORKNZ(1640))                                 00490
      IF(UNIT(4)) 300,150,150                                               00500
  300 BUFFER IN (4,1) (WORKLZ,WORKLZ(1024))                                 00510
      IF(UNIT(4)) 400,150,150                                               00520
  400 BUFFER IN (4,1) (WORKZ,WORKZ(NWORK))                                  00530
      IF(UNIT(4)) 410,150,150                                               00540
  410 DO 480 I=1,NSTAGE                                                     00550
      BUFFER IN (4,1) (IARRAY(LOCBVB),IARRAY(LOCEVR))                       00560
      IF(UNIT(4)) 415,450,450                                               00570
  415 BUFFER OUT (7,1) (IARRAY(LOCBVB),IARRAY(LOCEVR))                      00580
      IF(UNIT(7)) 420,460,460                                               00590
  420 BUFFER IN (4,1) (IARRAY(LOCBPB),IARRAY(LOCEPR))                       00600
      IF(UNIT(4)) 425,450,450                                               00610
  425 BUFFER OUT (8,1) (IARRAY(LOCBPB),IARRAY(LOCEPR))                      00620
      IF(UNIT(8)) 480,470,470                                               00630
  450 CALL ERR(22)                                                          00640
  460 CALL ERR(12)                                                          00650
  470 CALL ERR(13)                                                          00660
  480 CONTINUE                                                              00670
      READ(LUNI,490) IKEY,(JPRINT(I),I=1,8)                                 00680
  490 FORMAT(A3,7X,8I1)                                                     00690
      IF(IKEY .NE. 3HRUN) CALL ERR(16)
```

FIGURE B-2 (cont'd)

```
  500   IF(JPRINT(1) .EQ. 0) CALL PRNTIN                                      00700
        IF(JPRINT(2) .NE. 0) GO TO 700                                        00710
        DO 560 K=1,2                                                          00720
        IHI3=NMISST(K)                                                        00730
        IHI1=NFULST(K)                                                        00740
        DO 560 I=1,IHI1                                                       00750
        ILO2=LOCST(I,K)                                                       00760
        IHI2=ILO2+NMISST(K)-1                                                 00770
        IF((I-1)/50*50 .NE. I-1) GO TO 538                                    00780
        WRITE(LUNO,530) IBLURD(K),(ITENT(J,K),IMPNT(J,K),J=1,IHI3)            00790
  530   FORMAT(1H1///,17X,A5,15HPURE STRATEGIES//,6H STRAT,4X,4HLAST,         00800
       1I2X,18HPLANE TYPE/MISSION/,7H NUMBER,3X,5HSTAGE,5X,                   00810
       I4(10(I1,1H/,I1,2X)/20X))                                              00820
        WRITE(LUNO,535)                                                       00830
  535   FORMAT(1H )                                                           00840
  538   WRITE(LUNO,540) I,ISINT(I,K),(XARRAY(J),J=ILO2,IHI2)                  00850
  540   FORMAT(1X,I5,5X,I3,4X,4(10F5.2,/,18X))                                00860
  560   CONTINUE                                                              00870
  700   IF(JPRINT(3) .NE. 0) GO TO 800                                        00880
        ICNT=0                                                                00890
        NG1=NGRID(1,1)                                                        00900
        NG2=NGRID(2,1)                                                        00910
        NG3=NGRID(3,1)                                                        00920
        NG4=NGRID(4,1)                                                        00930
        NG5=NGRID(1,2)                                                        00940
        NG6=NGRID(2,2)                                                        00950
        NG7=NGRID(3,2)                                                        00960
        NG8=NGRID(4,2)                                                        00970
        DO 730 I1=1,NG1                                                       00980
        DO 730 I2=1,NG2                                                       00990
        DO 730 I3=1,NG3                                                       01000
        DO 730 I4=1,NG4                                                       01010
        DO 730 I5=1,NG5                                                       01020
        DO 730 I6=1,NG6                                                       01030
        DO 730 I7=1,NG7                                                       01040
        DO 730 I8=1,NG8                                                       01050
        ICNT=ICNT+1                                                           01060
        IF((ICNT-1)/50*50 .EQ. ICNT-1) WRITE(LUNO,710)                        01070
  710   FORMAT(1H1,//18X,27HLIST OF ALL POSSIBLE STATES,//6H STATE,           01080
       1I5X,4HBLUE,27X,3HRED,/7H NUMBER,7X,2(19H1     2     3     4,         01090
       111X)/)                                                                01100
        WRITE(LUNO,720) ICNT,JGRID(I1,1),JGRID(I2,2),JGRID(I3,3),             01110
       1JGRID(I4,4),JGRID(I5,5),JGRID(I6,6),JGRID(I7,7),JGRID(I8,8)           01120
  720   FORMAT(1X,I5,4X,2(4I6,6X))                                            01130
  730   CONTINUE                                                              01140
  800   CALL TRIALS                                                           01150
        END                                                                   01160
```

In addition, ATACM2 uses subroutines

BATTLE
BETAS
ERR
ISTATE
PRNTIN
TRIALS
PKILLS

all of which are listed under ATACM1.

TABLE B-3

VARIABLES MOST FREQUENTLY USED
IN ATACM1 AND ATACM2

Variable	Subroutine or COMMON	Description
ABAF(i,j,k)	INPUT	Fraction of type j aircraft on side k assigned to the ith mission which is vulnerable to airbase attack.
ALPHA	GAMES	Coefficient used in the linear interpolation algorithm to weight the objective function value corresponding to that point in the state space currently being examined.
ATTK	BATTLE	Number of ABA sorties flown against the opponent's airbase during the current one-cycle battle.
BETA(·,j)	INTERP	Weights used to linearly interpolate an objective function value for a point lying between two adjacent grid levels in dimension j. BETA(1,j) is the weight for the value corresponding to the lower level; BETA(2,j) the weight for the higher level.
BMIN(i)	GAMES	Minimum value in the ith row of the game matrix for the current state.
BOBJ	INIT TRIALS	Value of Blue's contribution to the objective function.
BTFP	BATTLE	Total ground firepower delivered by Blue during the current one-cycle battle.
CASF(j,k)	INPUT	Firepower per CAS sortie for an aircraft of type j on side k.
CASO(k)	BATTLE	Total CAS firepower delivered by side k during the current one-cycle battle.
CHECK	GAMES	Objective function value resulting from using specified Blue/Red strategies for one stage followed by the use of optimal conservative strategies by both sides for all subsequent stages. Used to compute MAXMIN/MINMAX bounds.
CHECKB	GAMES	Analogous to CHECK. Used to compute Blue's optimal MAXMIN play.
CHECKR	GAMES	Analogous to CHECK. Used to compute Red's optimal MINMAX play.
CNP(j,k)	BPARM	Current number of planes of type j on side k.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
CNPV(j)	BATTLE	Current number of planes of type j vulnerable to the opponent's airbase attackers.
DELTA(j)	IPARM	Distance between adjacent "fine" grid levels in dimension j.
DFPRED(j,k)	INPUT	Division firepower reduction produced by a CAS sortie flown by aircraft type j on side k.
DIVFP(k)	INPUT	Firepower produced by a ground division of type k.
FEBA(i,j)	INPUT	ith coordinate of the jth point in the set of points which define FEBA movement as a function of Blue/Red force ratios.
FRACN	STRAT	Denominator of the minimum allocation fraction for the current aircraft type.
FRATIO	BATTLE	Ratio of Blue ground firepower to Red ground firepower for the current one-cycle battle.
IARRAY(·)	WORK	Work array used to store strategies, battle assessments, and MAXMIN/MINMAX plays and objective function values. EQUIVALENCED to XARRAY.
IB	BPARM	Index of the strategy employed by Blue in the current one-stage battle.
IBETA(·,j)	INTERP	Indices of grid levels lying on either side of an interpolation point in dimension j. IBETA(1,j) is one less than the subscript corresponding to the lower grid level; IBETA(2,j) is one less than the subscript corresponding to the higher.
IBH	INIT	High bound on the range of stages over which the current Blue strategy can be played.
IBIT(i)	IPARM	Rightmost bit in the ith 7-bit byte of the word used to store the results of a one-stage battle assessment. From left to right, bytes 1-4 are used to store levels of Blue aircraft of types 1-4; bytes 5-8 levels of Red aircraft of types 1-4.
IBL	INIT	Low bound on the range of stages over which the current Blue strategy can be played.
IBLURD(k)	WORKN	Hollerith constant equal to "BLUE" if k=1 or "RED" if k=2.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
IBPLAY	GAMES	Index of Blue's optimal MAXMIN strategy.
IBR(k)	BPARM	Index of the strategy employed by side k in the current one-stage battle.
IDEM(·)	WORKN	Array of constants used to compute the number of the state corresponding to a set of grid-level indices. Constants are assigned in INIT.
IDINT(t,k)	WORKN	Latest stage for which the set of strategies available to side k during stage t are applicable.
IDUMMY(·)	READIN	Array used for temporary storage of input parameters prior to their being decoded.
IERR	ERROR	Flag indicating the severity of the last diagnostic message printed.
IETYPE(i)	ERR	Severity code associated with diagnostic i. Codes 1,2, and 3 correspond to "INFO", "ERROR", and "ABORT" respectively.
IGRID(i,j,k)	INPUT	ith grid level assigned to aircraft type j on side k.
IHEAD(·,·)	PRNTIN	Array of explanatory titles used to print input parameters in an easy-to-read format.
IKEY	READIN	Card key on the current input card.
IMAX	TRIALS	Rounded MINMAX bound on the value of the objective function for the current trial.
IMESSG(·,i)	ERR	Diagnostic message associated with error code i.
IMIN	TRIALS	Rounded MAXMIN bound on the value of the objective function for the current trial.
IMISS(i,j,k)	INPUT	Code of the ith mission assigned to aircraft type j on side k.
IMPNT(i,k)	WORKN	ith mission code assigned to aircraft types on side k.
INPNT(i,k)	WORKN	Index, within an aircraft type, of the ith mission code assigned to all aircraft types on side k.
INPUTZ(·)	INPUT	Single array EQUIVALENCED to COMMON block INPUT.
IOBJ	GAMES INIT	Blue's contribution to the value of the objective function resulting from a one-stage battle.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
IOBJF	TRIALS	Rounded cumulative value of the objective function produced by playing optimal MAXMIN strategies against optimal MINMAX strategies during the current trial.
IOCBVB	WORKL	Beginning location of the area used in XARRAY to store current-stage MAXMIN values for Blue.
IOCBVR	WORKL	Beginning location of the area used in XARRAY to store current-stage MINMAX values for Red.
IOCEVB	WORKL	End location of the area used in XARRAY to store current-stage MAXMIN values for Blue.
IOCEVR	WORKL	End location of the area used in XARRAY to store current-stage MINMAX values for Red.
IOPTN(i)	TRIALS	Value of the ith print option specified on the current TRIAL card.
IPLAL(t,k)	TRIALS	Beginning location in XARRAY of the optimal allocation fractions used by side k during stage t of the current trial war.
IPNT(i)	SPARM	Index of the ith strategy for which an allocation fraction is not specified.
IPPNT(i)	TEMP	Pointer indicating the dimension in the state space which corresponds to the ith aircraft type assigned.
IPRINT(i)	INPUT	Value of the control parameter specified for the ith print option on the RUN card.
IR	BPARM	Index of the strategy employed by Red in the current one-stage battle.
IRA(·)	WORKN	Array of indices used in conjuction with the random access file TAPE2.
IRHI(i)	SINTVL	High bound on the range of Red strategies which can be played against the ith strategy of Blue.
IRLO(i)	SINTVL	Low bound on the range of Red strategies which can be played against the ith strategy of Blue.
IRPLAY	GAMES	Index of Red's optimal MINMAX strategy.
ISINT(i,k)	WORKN	Latest stage for which the ith strategy available to side k is applicable.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
ISTAT	GAMES	Number of the state corresponding to a set of grid levels.
ITITLE(·)	INPUT	Array used to store the run title as specified on the RUN card.
ITP	READIN	Flag to indicate whether the parameters on the current card are for Blue or Red. ITP=1 corresponds to Blue, ITP=2 to Red.
ITPNT(i,k)	WORKN	Aircraft type to which the ith mission on side k is assigned.
ITYPE	SPARM	Aircraft type for which the current strategies are being generated.
IVERT(·,j)	GAMES	An NPTT-tuple of 1's and 2's representing the jth vertex of a "cube" in the state space. The number of possible tuples equals LPTT.
IWORD	GAMES INIT	Word containing both Blue and Red contributions to the value of the objective function resulting from a one-stage battle. Blue's contribution is packed into the leftmost 30 bits, Red's in the rightmost 30 bits.
JBETA(·,j,k)	IPARM	Indices of grid levels lying on either side of the kth "fine" grid level in dimension j. JBETA(1,j,k) is one less than the subscript corresponding to the lower grid level; JBETA(2,j,k) is one less than the subscript corresponding to the higher.
JDEX(·,·,k)	ROUND	Array of grid-level indices used to compute the state resulting from rounding the numbers of aircraft on side k down and the numbers opposing side k up.
JOBJ	GAMES INIT	Red's contribution to the value of the objective function resulting from a one-stage battle.
JOCBVB	WORKL	Beginning location of the area used in XARRAY to store next-stage MAXMIN values for Blue.
JOCBVR	WORKL	Beginning location of the area used in XARRAY to store next-stage MINMAX values for Red.
JOCEVB	WORKL	End location of the area used in XARRAY to store next-stage MAXMIN values for Blue.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
JOCEVR	WORKL	End location of the area used in XARRAY to store next-stage MINMAX values for Red.
JOPTN(i)	TRIALS	Value of the ith print option specified on the previous TRIAL card.
JPRINT(i)	ATACM2	Value of the control parameter specified for the ith print option on the RUN card.
JRA(·)	WORKN	Array of indices used in conjunction with the random access file TAPE3.
JWORD	GAMES INIT	Word containing "fine" grid-level indices indicating the numbers of planes remaining after a one-stage battle.
KEVEL(·)	INIT	Array of "fine" grid-level indices indicating the numbers of planes remaining after a one-stage battle.
KEY(·)	READIN	Array of valid card keys recognized by READIN.
KOCBG	WORKL	Beginning location of the area used in IARRAY to store numbers of planes available after one-stage battle assessments.
KOCBVB	WORKL	Beginning location of the area used in XARRAY to store interpolated current-stage MAXMIN values for Blue.
KOCBVR	WORKL	Beginning location of the area used in XARRAY to store interpolated current-stage MINMAX values for Red.
KOCEG	WORKL	End location of the area used in IARRAY to store numbers of planes available after one-stage battle assessments.
KOCEVB	WORKL	End location of the area used in XARRAY to store interpolated current-stage MAXMIN values for Blue.
KOCEVR	WORKL	End location of the area used in XARRAY to store interpolated current-stage MINMAX values for Red.
LASTP	INPUT	Last stage thru which the current STRT card is applicable.
LEVEL	GAMES INIT	Index of the "fine" grid-level corresponding to the numbers of planes remaining after a one-stage battle.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
LOCBG	WORKL	Beginning location of the area used in IARRAY to store objective function values resulting from one-stage battle assessments.
LOCBPB	WORKL	Beginning location of the area used in IARRAY to store the indices of optimal MAXMIN plays for Blue.
LOCBPR	WORKL	Beginning location of the area used in IARRAY to store the indices of optimal MINMAX plays for Red.
LOCBVB	WORKL	Beginning location of the area used in XARRAY to store interpolated next-stage MAXMIN values for Blue.
LOCBVR	WORKL	Beginning location of the area used in XARRAY to store interpolated next-stage MINMAX values for Red.
LOCEG	WORKL	End location of the area used in IARRAY to store objective function values resulting from one-stage battle assessments.
LOCEPB	WORKL	End location of the area used in IARRAY to store the indices of optimal MAXMIN plays for Blue.
LOCEPR	WORKL	End location of the area used in IARRAY to store indices of optimal MINMAX plays for Red.
LOCEVB	WORKL	End location of the area used in XARRAY to store interpolated next-stage MAXMIN values for Blue.
LOCEVR	WORKL	End location of the area used in XARRAY to store interpolated next-stage MINMAX values for Red.
LOCST(i,k)	WORKL	Beginning location in XARRAY of the allocation fractions which define the ith strategy of side k.
LOCWD	INIT	Location within IARRAY where the results of the next one-stage battle will be stored.
LPTT	GAMES	Total number of vertices on a "cube" in the state space. Equals 2 raised to the NPTT power.
LUNI	WORKN	Logical unit number of the primary input device (card reader). In the current version LUNI=5.
LUNO	WORKN	Logical unit number of the primary output device (line printer). In the current version LUNO=6.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
MALOC(·)	INPUT	Input array used for temporary storage of STRT card parameters.
MFRAC	SPARM	Numerator of the fraction of aircraft unspecified on the current STRT card for the current aircraft type.
MISSN	STRAT	Number of missions assigned to the current aircraft type.
MMISS	SPARM	Number of missions assigned to the current aircraft type for which allocation fractions are not specified.
MSLOC	GAMES TRIALS	Number of the stage for which current calculations are being made.
MSTAGE	TRIALS	Number of stages specified on the current TRIAL card.
MSTOR(i)	STRAT	Numerator of the allocation fraction for the ith mission assigned to the current aircraft type.
MVEC(·)	ROUND	Array of grid-level indices used to compute the number of the corresponding state.
NALOC(i,j)	INPUT	Numerator of the allocation fraction specified on the current STRT card for the ith mission assigned to aircraft type j.
NBATLS	TIMER	Total number of battle evaluations required for each stage, state, and cycle.
NDAPST	INPUT	Number of cycles per stage.
NDIV(k)	INPUT	Number of ground divisions specified for side k.
NFRAC(j,k)	INPUT	Denominator of the minimum allocation fraction specified for aircraft type j on side k.
NFSAM(k)	INPUT	Number of forward SAMs specified for side k.
NFULST(k)	WORKN	Total number of strategies available to side k.
NGRID(j,k)	WORKN	Number of grid-levels specified for aircraft type j on side k.
NINGAM	WORKN GAMES	Number of elements in each one-stage/one-state game matrix.
NKEYS	READIN	Number of valid card keys recognized by READIN.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
NMISS(j,k)	WORKN	Number of missions assigned to aircraft type j on side k.
NMISST(k)	WORKN	Total number of missions assigned to all aircraft types on side k.
NPNTS	TIMER	Total number of vertices on a "cube" in the state space. Equals 2 raised to the NTP power.
NPTT	GAMES	Total number of aircraft types assigned to Blue and Red.
NRSAM(k)	INPUT	Number of rear SAMs specified for side k.
NSHL(k)	INPUT	Number of aircraft shelters assigned to side k.
NSKIP	TRIALS	Number of records to be skipped on TAPE7 and TAPE8 before reading optimal plays and values for the first stage of the current trial war.
NSLOC	GAMES TRIALS	Number of the next stage for which calculations will be made. Equals MSLOC + 1.
NSTAGE	INPUT	Number of stages in the campaign.
NSTAT	WORKN	Total number of states for which optimal plays and objective function values are explicitly computed.
NSTOR(i)	SPARM	Numerator of the allocation fraction specified for the ith mission assigned to the current aircraft type.
NSTRAT(k)	WORKN	Total number of strategies available to side k.
NSTRTC(k)	WORKN	Number of STRT cards submitted for side k.
NTARG	BATTLE	Total number of planes vulnerable to the opponent's airbase attackers during the current one-cycle battle.
NTP	TIMER	Total number of aircraft types assigned to Blue and Red.
NTRIAL	TRIALS	Number of the current trial.
NTYPE(k)	WORKN	Number of aircraft types specified for side k.
NVEC(·)	ROUND	Array of grid-level indices used to compute the number of the corresponding state.
NWORK	WORKN	Length, in words, of the array XARRAY.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
OBJEC(k,i)	BPARM	Contribution of side k to the value of the ith objective function f_i (see Equation A-1).
OBJF	TRIALS	Value of the objective function for the current stage produced by playing the optimal MAXMIN strategy against the optimal MINMAX strategy.
OWGHT(i)	INPUT	Weight w_i specified on the OWGHT card to be used as a multiplier on f_i (see Equation A-1).
PKAA(i,j,k)	INPUT	Probability an airbase attacker of type j on side k is killed by an opposing airbase defender of type i.
PKAAFS(j,k)	INPUT	Probability an airbase attacker of type j on side k is killed by an opposing forward SAM.
PKAARS(j,k)	INPUT	Probability an airbase attacker of type j on side k is killed by an opposing rear SAM.
PKAD(i,j,k)	INPUT	Probability an airbase defender of type j on side k is killed by an opposing airbase attacker of type i.
PKADES(i,j,k)	INPUT	Probability an airbase defender of type j on side k is killed by an opposing airbase attack escort of type i.
PKAEFS(j,k)	INPUT	Probability an airbase attack escort of type j on side k is killed by an opposing forward SAM.
PKAERS(j,k)	INPUT	Probability an airbase attack escort of type j on side k is killed by an opposing rear SAM.
PKBA(i,j,k)	INPUT	Probability a battlefield attacker of type j on side k is killed by an opposing battlefield defender of type i.
PKBAFS(j,k)	INPUT	Probability a battlefield attacker of type j on side k is killed by an opposing forward SAM.
PKBD(i,j,k)	INPUT	Probability a battlefield defender of type j on side k is killed by an opposing battlefield attacker of type i.
PKBDES(i,j,k)	INPUT	Probability a battlefield defender of type j on side k is killed by an opposing battlefield attack escort of type i.
PKBEFS(j,k)	INPUT	Probability a battlefield attack escort of type j on side k is killed by an opposing forward SAM.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
PKESAD(i,j,k)	INPUT	Probability an airbase attack escort of type j on side k is killed by an opposing airbase defender of type i.
PKESBD(i,j,k)	INPUT	Probability a battlefield attack escort of type j on side k is killed by an opposing battlefield defender of type i.
PKFAFS(j,k)	INPUT	Probability a forward SAM attacker of type j on side k is killed by an opposing forward SAM.
PKFS(i,k)	INPUT	Probability a forward SAM on side k is killed by an opposing forward SAM attacker of type i.
PKNS(i,k)	INPUT	Probability a vulnerable, non-sheltered aircraft on side k is killed by an opposing airbase attacker of type i.
PKRAFS(j,k)	INPUT	Probability a rear SAM attacker of type j on side k is killed by an opposing forward SAM.
PKRARS(j,k)	INPUT	Probability a rear SAM attacker of type j on side k is killed by an opposing rear SAM.
PKRS(i,k)	INPUT	Probability a rear SAM on side k is killed by an opposing rear SAM attacker of type i.
PKSH(i,k)	INPUT	Probability a vulnerable, sheltered aircraft on side k is killed by an opposing airbase attacker of type i.
REIN(j,k,t)	INPUT	Number of reinforcement planes of type j on side k introduced at the beginning of stage t.
REINF(j,k,t)	INPUT	1.0 plus the fraction of reinforcement planes of type j on side k introduced at the beginning of stage t.
REMP(j,k)	BATTLE	Number of remaining planes of type j on side k after attrition.
RFSAM(k)	BATTLE	Number of undamaged forward SAMs on side k during the current one-cycle battle.
RMAX(j)	GAMES	Maximum value in the jth column of the game matrix for the current state.
ROBJ	INIT TRIALS	Value of Red's contribution to the objective function.
RRSAM(k)	BATTLE	Number of undamaged rear SAMs on side k during the current one-cycle battle.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
RTFP	BATTLE	Total ground firepower delivered by Red during the current one-cycle battle.
STRATS(i,k,j)	WORK	Allocation fraction in strategy k for the ith mission assigned to aircraft type j. STRATS makes temporary use of part of the area occupied by XARRAY.
TARG	BATTLE	Total number of planes vulnerable to the opponent's airbase attackers during the current one-cycle battle.
TARGN	BATTLE	Number of unsheltered planes vulnerable to the opponent's airbase attackers during the current one-cycle battle.
TARGS	BATTLE	Number of sheltered planes vulnerable to the opponent's airbase attackers during the current one-cycle battle.
TCASO(k)	BATTLE	Total CAS firepower delivered by side k during the current one-stage battle.
TFIRE(k)	BATTLE	Total ground firepower delivered by side k during the current one-cycle battle.
TIMEC(k)	TIMER	Estimated CPU time required for the ith phase of calculations performed by ATACM1. Phases 1,2, and 3 are SETUP, BATTLES, and GAMES respectively.
TIMEI(i)	TIMER	Estimated I/O time required for the ith phase of calculations performed by ATACM1. Phases 1,2, and 3 are SETUP, BATTLES, and GAMES respectively.
TMOVE	BATTLE	Total FEBA movement during the current one-stage battle.
TNNK	BATTLE	Total number of unsheltered aircraft not killed by opposing airbase attackers during the current one-cycle battle.
TNP(i,k)	BATTLE	Total number of sorties assigned to be flown by planes prosecuting mission i for side k during the one-cycle battle.
TOBJF	TRIALS	Cumulative value of the objective function produced by playing optimal MAXMIN strategies against optimal MINMAX strategies during the current trial.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
TOTFP(k)	BATTLE	Total firepower delivered by side k during the current one-stage battle.
TSNK	BATTLE	Total number of sheltered aircraft not killed by opposing airbase attackers during the current one-cycle battle.
TXOBJF(i)	TRIALS	Cumulative value of objective function i produced by playing the optimal MAXMIN strategy against the optimal MINMAX strategy during the current trial.
VALU(j,k)	INPUT	Residual value of an undamaged plane of type j available to side k at the end of the war.
WGHT(t,k)	INPUT	Value of weight b_t if k=1 or r_t if k=2 as specified on the WGHT card (see Equations A-3 thru A-5).
WORKLZ(·)	WORKL	Single array EQUIVALENCED to COMMON block WORKL.
WORKNZ(·)	WORKN	Single array EQUIVALENCED to COMMON block WORKN.
WORKZ(·)	WORK	Single array EQUIVALENCED to COMMON block WORK.
XARRAY(·)	WORK	Work array used to store strategies, battle assessments, and MAXMIN/MINMAX plays and objective function values. EQUIVALENCED to IARRAY.
XATT	BATTLE	Number of attack sorties during the current phase of the one-cycle battle.
XBETA(·,j,k)	IPARM	Weights used to linearly interpolate an objective function value for the kth "fine" grid-level lying between two adjacent grid-levels in dimension j. XBETA(1,j,k) is the weight for the value corresponding to the lower level, XBETA(2,j,k) the weight for the higher level.
XFSAM	BATTLE	Number of forward SAMs available to the defending side during the current one-cycle battle.
XGRID(i,j,k)	INPUT	ith grid-level assigned to aircraft type j on side k.
XMOVE	BATTLE	FEBA movement during the current one-cycle battle.

TABLE B-3 (Cont'd)

Variable	Subroutine or COMMON	Description
XNENG	BATTLE	Number of one-on-one engagements between attackers and opponents during the current phase of a one-cycle battle.
XNP(i,j,k)	BPARM	Number of successful sorties flown by planes of type j prosecuting mission i for side k during the current one-cycle battle.
XOBJF(i,t)	TRIALS	Value of objective function i produced by playing the optimal MAXMIN strategy against the optimal MINMAX strategy during stage t.
XOPP	BATTLE	Number of sorties opposing the attackers during the current phase of the one-cycle battle.
XRSAM	BATTLE	Number of rear SAMs available to the defending side during the current one-cycle battle.
XSORT(i,j,k)	INPUT	Sortie rate for aircraft of type j on side k assigned to the ith mission.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

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

ATACM is a computer model designed and built for the Arms Control and Disarmament Agency for use in analyzing the impact of various force mixes upon a tactical airwar in Europe between NATO and Warsaw Pact forces. ATACM models an air campaign as a zero-sum staged game and employs dynamic programming to solve this game for approximate, optimal MAXMIN/MINMAX aircraft allocation strategies for the opposing sides at each stage of the

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campaign. The model permits multiple aircraft types with user-assigned missions, numerical and fractional reinforcements as a function of stage, and user seiection of the objective function used to generate the optimal strategies.

Descriptions of the problem formulation and the engagement and optimization methodologies used to solve it are presented along with a user's guide and CDC 6600 FORTRAN listings.