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DIFFERENTIAL MODELS OF COMBAT IN CITIES

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The use of models to study combat has an appeal for everyone endowed with natural curiosity. Broadly speaking, a model is that which is analyzed; it comprises the assumptions of the study. Combat models are usually designed to predict battle outcomes and the optimum mix of weapons, and have been developed and used extensively in recent years.

Analytic combat models are abstract models that have received interest in the operations research community. These models are distinguished by the integration of basic combat events into an overall mathematical structure. Analyses of these models are performed by logically consistent mathematical transformations and deductions. Although analytic combat models may be either stochastic or deterministic, they are almost invariably driven by systems of ordinary differential equations. Thus, there has been little or no use made of the other classical differential theories (such as geometry and partial equations) to describe the structure of a battle. In fact, almost all analytic combat models to date are based on Lanchester type equations or small modifications thereof, such as the introduction of time (or range) dependent kill rate coefficients. An interesting feature of this type of formulation is the lack of any space variable in the equation system. The inclusion of space variables could allow the natural use of transformations to describe dispersion, concentration and the non-uniform distribution of targets.

Another feature related to this approach is the treatment of mobility. Generally, straight line segments are used to model advance paths with a record kept of the track of each homogeneous unit. This implies that a Lagrangian, rather than an Eulerian, coordinate system is being employed.* A property of Eulerian systems is that they facilitate the treatment of dispersion, bunching and other geometric aspects.

In order to embrace considerations of spatial distribution of forces the notion of combat unit densities is employed. (hereafter referred to as c.u. density). This consideration, while still taking advantage of the procedures of averaging and estimating of the attrition coefficients, affords a more fundamental approach through the explicit use of personnel densities in both space and time.

A derivation of the mathematical model will demonstrate a natural method for handling c.u. densities. The model is

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* Eulerian coordinates are field coordinates that apply to locations in time and space and do not denote the locations of individual units. Lagrangian coordinates, which are used in rigid body dynamics, denote the position of an individual unit as it moves about.

developed in Eulerian coordinates with each model component being in general a function of space and time.

The first model component represents the flow of units due to random motion. This is a motion in which the center of the density has no velocity -- a diffusion effect encountered in general area combat. Such a flow is described as

$$f_j^{I}(\bar{x}, t) = -D_j \overline{\nabla n_j}(\bar{x}, t),$$

where

D_j = a constant of proportionality $\left(\text{meters}^2/\text{sec}\right)$

n_j = c.u. density of side "n" $\left(\text{c.u.}/\text{meters}^2\right)$

f_j^{I} = flow $\left(\text{c.u.}/\text{sec}\right)$

j denotes a particular homogeneous group of the "n" force.

In this derivation a two dimensional space serves as the battlefield terrain. The derivation is readily extended to a three dimensional space; hence area and linear dimension are completely analagous to the more general notions of volume and area.

The next contribution to the model accounts for a directed flow of c.u. that is non random. This flow is represented as

$$f_j^{II} = n_j \overline{V}_j$$

where $\overline{V}_j = \overline{V}_j(\bar{x}, t)$ is the velocity of flow at the position $\bar{x}$ at time t. The net flow from the random and directed components is taken as

$$\text{(1)} \qquad \bar{f}_j(\bar{x}, t) = -D_j \overline{\nabla n_j}(\bar{x}, t) + n_j(\bar{x}, t)\,\overline{V}_j(\bar{x}, t)$$

The action for a particular area in the absence of attrition and other sink terms can be expressed as the net rate of unit flow out of this area. This must be

$$(2) \qquad \frac{\partial N_j}{\partial t} = \int \bar{f}_j (\bar{x}, t) \cdot d\bar{l}$$

where N_j is the net number of units and $d\bar{l}$ is an element of the boundry of the area being considered. For a three dimensional problem an element of the boundary surface would correspond to the differential length $d\bar{l}$.

A useful representation for equation (2) can be written with Gauss' theorem,

$$(3) \qquad \int \bar{f}_j (\bar{x}, t) \cdot d\bar{l} = \int \bar{\nabla} \cdot \bar{f}_j (\bar{x}, t) \, ds$$

where ds is a patch of the area under consideration. The net outflow can now be expressed as

$$(4) \qquad - \frac{\partial N_j (\bar{x}, t)}{\partial t} = \int \bar{\nabla} \cdot \left[-D_j \overline{\nabla n_j} (\bar{x}, t) + n_j (\bar{x}, t) \, \bar{V}_j (\bar{x}, t) \right] ds$$

The expression for the rate of change of the c.u.s in terms of the c.u. densities is simply

$$(5) \qquad - \frac{\partial N_j (\bar{x}, t)}{\partial t} = - \int \frac{\partial n_j}{\partial t} (\bar{x}, t) \, ds$$

Direct substitution of equation (5) into (4) yields

$$(6) \qquad \int \left\{ \bar{\nabla} \cdot \left[-D_j \overline{\nabla n_j} (\bar{x}, t) + n_j (\bar{x}, t) \, \bar{V}_j (\bar{x}, t) \right] + \frac{\partial n_j}{\partial t} \right\} ds = 0 \ .$$

This equation holds over the entire area, therefore it follows that

$$(7) \qquad \frac{\partial n_j(x, t)}{\partial t} = \bar{\nabla} \cdot \left[\Gamma_j(\bar{x}, t)\ \bar{\nabla} n_j(\bar{x}, t)\right] - \bar{\nabla} \cdot \left[n_j(\bar{x}, t)\ \bar{V}_j(\bar{x}, t)\right],$$

which holds in the absence of attrition terms.

The remaining model considerations account for the sink terms associated with attrition. Generally, attrition terms are expressed as

$$(8) \qquad S_j(\bar{x}, t) = -\sum_i n_i(\bar{x} + \bar{\delta}_i, t)\ A_{ij}(\bar{x}, t) .$$

In the case of aimed fire

$$A_{ij}(\bar{x}, t) = K_j(\bar{\delta}_i, t)$$

where

$\bar{\delta}_i$ = the range between unit "j" at $\bar{x}$ and attacker "i" at $(\bar{x} + \bar{\delta}_i)$.

$K_j = K_j(\bar{\delta}_i, t)$ = the rate at which a single "j" unit destroys "i" units

For area type fire

$$(9) \qquad A_{ij}(\bar{x}, t) = K_j'(\bar{\delta}_i, t)\ n_j(\bar{x}, t) .$$

Both "K_j" and "K_j'" are referred to as attrition coefficients and are themselves functions of space and time. They are, as one would expect, complex functions of weapon capabilities, target characteristics, allocation procedures for assigning weapons to targets, intelligence, etc.

The attrition terms, when combined with the random motion and the directed flow term, give the general structure of the mathematical model. The total expression is

$$(10)\ \frac{\partial n_j}{\partial t}(\bar{x}, t) = \bar{\nabla}\cdot\left[D_j(\bar{x}, t)\,\bar{\nabla} n_j(\bar{x},t)\right] - \bar{\nabla}\cdot\left[n_j(\bar{x},t)\,\bar{V}_j(\bar{x},t)\right] - S_j(\bar{x}, t)$$

Whereas the solutions to most analytic models are determined by an initial condition for each equation describing the force (the number of units as the battle begins) the solution to the above partial differential equation requires an initial condition in addition to two boundary conditions (BC) in one dimension and four boundary conditions in the two dimensional model. In consonance with other analytic models that describe heterogeneous forces in combat, outcomes are determined from the solution of sets of partial differential equations. Thus, each heterogeneous force is considered to be composed of homogeneous units each of which is described by its own differential equation.

The system of partial differential equations allows an analyst to specify a highly detailed battle in terms of many combat functions. By the judicious use of proper formulations and the greater number of boundary conditions a flexible model of combat is possible. In particular the boundary conditions can be employed to model some initial placement of personnel at a location on the battlefield, i.e.,

$$n(\bar{x}', t) = g(\bar{x}') \qquad \text{BC}$$

with the function $g(x')$ representing this initial force at location x'.
If an obstacle or barrier were a significant terrain feature then

$$\frac{\partial n(\bar{x}, t)}{\partial x} = f(\bar{x}) \qquad \text{BC}$$

would represent the flow or "leakage" of c.u.s across this obstacle. A perfectly effective minefield could be expressed as

$$f(\bar{x}) = 0$$

implying that no "n" forces are able to penetrate this region of space. In short, the boundary conditions for these models give increased ability to represent tactical situations. Naturally, many other representations for the BCs are possible than the examples cited above.

The net losses in battle are capable of being represented in terms of specific areas for chosen durations. The cost (in c.u. losses) in attacking or defending a specific portion of the battlefield with area σ' in the time interval $\Delta t = (t_2 - t_1)$ is

$$\int_{t_1}^{t_2} \int_{\sigma'} S(\bar{x}, t)\ ds dt$$

Such expressions are useful for formulating and comparing various defensive deployment strategies for ground forces. The trajectory results of the entire action over the complete battlefield are computed by extending the limits of integration,

$$\int_{0}^{\infty} \int_{\sigma} S(\bar{x}, t)\ ds dt$$

The model described here has been used to examine several engagements that are typical of combat in built-up areas. Among these are building assault situations by infantry units and armored attacks from open areas to lines of fortified buildings. The use of variables that describe spatial distribution of forces is particularly appropriate for examining city combat because of the natural canalization of troop movements in urban areas. Specific examples of these engagement models will be discussed at the symposium.

AN OVERVIEW OF THE BATTLE[1] MODEL

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1.0 INTRODUCTION

The purpose of this paper is to present an overview description of the BATTLE model being developed by Vector Research, Incorporated, for the Weapons Systems Evaluation Group (WSEG). The model is intended to describe the joint activities of US Army units and Air Force Tactical Aircraft engaging advancing Soviet forces who are also supported by tactical aircraft. The model is to be used in estimating net assessments and in generating data to make trade-offs among the various forces and systems involved in such an engagement.

Current models such as ATLAS and GACAM which have been used to describe large-scale, joint services, theater-level warfare have been aggregated macroscopic models in that they aggregate individual weapon system effects at the theater level by using a single strength factor (known as the "firepower score") to describe the theater-sized units. Although the existing aggregated "firepower score" models are relatively easy to use, they are known to contain a large number of technical and data problems. In brief, some of the deficiencies are associated with

(a) the use of the "firepower score" force ratio concept as the principal means of driving the attrition process, and
(b) the use of the "firepower score" force ratio concept to determine the rate of FEBA movement.

Two of the most serious problems in the "firepower score" models are

(a) the inability of the models to reflect changes in detailed tactical phenomena (e.g., calls for air support by units engaged at the FEBA), and
(b) the inability of the models to reasonably reflect the significantly different attrition of different weapon systems (which leads to deficiencies in the dynamic modeling of campaigns of any duration, and to problems in producing useful output measures).

The objective of the BATTLE model development is to demonstrate the feasibility of constructing a campaign model which:

(a) does not use the "firepower score" force ratio concept of attrition, but rather models attrition in a way that reflects the internal dynamics of the combat activity and relates to specific weapon system parameters and tactics considered important in small unit engagements,

[1]BAttalion Through Theater Level Engagement

(b) disaggregates the Army by explicitly considering five weapon system types that can individually be attrited in maneuver battalions, as well as artillery, air defense, and helicopter systems, and

(c) drives the FEBA movement activity by other than the "firepower score" force ratio concept.

A first version of the BATTLE model was delivered to the WSEG in May and some initial development tests performed during June and July. Although the BATTLE model will eliminate some of the deficiencies in existing models, it is important to recognize that the model delivered to the WSEG this past summer is a prototype which contains some purposeful simplifications to complete its initial development by that time. It has, however, been structured so that some of the recognized simplified assumptions can be removed and replaced by more realistic ones at a later date. The next section of this overview describes what is contained in the BATTLE model.

2.0 THEATER BATTLEFIELD REPRESENTED

2.1 Geometry: The FEBA in the BATTLE model is divided into parallel segments so that the FEBA is considered piecewise linear over the total theater. Maneuver forces at the FEBA are associated with these segments. Each segment is assumed to be of such a length that it will accommodate a battalion-sized maneuver force (i.e., 2000-8000 meters) and accordingly, the area about each segment is referred to as a "battalion area." The total theater battlefield is divided into sectors to provide for better representation of the spatial allocation of forces. The sectors are parallel areas that run from the FEBA all the way back to the rear area. The model contains ten of these sectors; and accordingly, they may be thought of as areas that might accommodate from Corps to Field Army sized forces.[1] Reserves for maneuver forces at the FEBA (referred to as maneuver forces in reserve) are associated with each of the sectors, as are all rear area forces (artillery, air defense artillery, tactical aircraft, etc.).

2.2 BATTLE Time: Model time is discrete (integer valued) measuring model time periods. These may, but need not, correspond to days (e.g., they may be considered six-hour time periods). Model data must be consistent with the period definition used.

2.3 Forces Represented: The BATTLE model considers maneuver forces at the FEBA (one Blue battalion task force in each battalion area and appropriate Red units allocated to face it), maneuver forces in reserve, artillery forces, attack helicopters, air defense artillery, tactical fixed-wing air forces, and service support forces. Maneuver forces (both at

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[1]The initial development tests were conducted with a one-sector version, i.e., the theater was treated as one large sector.

the FEBA and in reserve) can contain armor (tank) systems, antitank systems, infantry with rifles or infantry in armored personnel carriers, infantry with automatic weapons, infantry with area fire weapons, and personnel associated with the different weapon systems. Artillery forces can contain one weapon system class and personnel associated with that system; attack helicopters can contain one weapon system class and personnel associated with it. Air defense artillery forces can contain short-range air defense systems, long-range air defense systems, and personnel associated with these. The tactical air forces are comprised of a number of user selected (input) types of fixed wing aircraft and personnel associated with them. Service support forces are made up of personnel. The model continually keeps track of the number of weapon systems by type and personnel in each of the Red and Blue maneuver forces at the FEBA and the maneuver forces in reserve in each sector. Additionally, the numbers of weapon systems are separately retained for artillery forces, attack helicopter forces, air defense artillery forces, tactical air forces, and service support forces for each of the sectors.

2.4 Supplies Represented: Supplies of the following kinds are separately represented in the model: ammunition for each army weapon system type, ordnance (in user specified categories) for aircraft, aviation gasoline and associated POL (for fixed wing aircraft and attack helicopters), POL for ground systems, and other supplies. Ammunition is assigned to (and separately kept track of by type at each place) individual battalion area maneuver forces, individual artillery forces, individual attack helicopter forces, individual air defense artillery forces, individual tactical air forces, sector stores,[1] and theater stores.[1] POL is assigned to individual battalion-area maneuver forces, sector air forces, sector stores,[1] and theater stores.[1] Finally, the "other" supply category is assigned to sector stores and theater stores.

2.5 Plans and Intentions: For each time period in BATTLE, each maneuver force at the FEBA has a plan which currently may take one of the following values: move forward; hold; hold, delay if moved on; and hold, withdraw if moved on. The list of plans can be expanded to include additional instructions such as: "If successful when moving forward, do not move more than 10 kilometers." Each side has an intention in each sector which currently may be to attack or defend.

2.6 Activities Represented: The model separately represents activities for each of the forces. Maneuver forces at the FEBA can be engaged in either a Blue assault (Red hasty defense), a Blue advance (Red delay), a Blue pursuit (Red withdrawal), relative inaction, Red assault (Blue hasty defense), Red advance (Blue delay), and a Red pursuit (Blue withdrawal). Artillery forces can simultaneously be engaged in (by percent allocation) counter-battery fire, direct support of engaged forces (preparatory fire, counter-preparatory fire, calls for additional fire to battalion area units, and final protective fire), and other fires for attrition[2] on other targets

[1] These are intended to simulate physically removed supplies which the tactical decision rules may not make immediately available.

[2] Artillery systems do not fire smoke or other non-explosive projectiles.

such as reserves, etc. Attack helicopters engage in support of engaged forces (either in delay, withdrawal, or assaults), and air defense artillery engage in air defense fires. The tactical air forces can simultaneously engage in the following activities: air base attack; combat air support (against FEBA maneuver forces, reserve maneuver forces, artillery, and air defense artillery); suppression of air defense artillery; interdiction against convoys, depots, etc.; escort of the above missions; and air defense. The service support forces perform the transfer of supplies (and also serve as targets).

In this section we have discussed what is represented in the model in terms of time, forces (type, composition, and location), supply types and levels, plans and intentions, and activities. Each of these are variables in the model which may change from time period to time period. At the end of each BATTLE time period we can look at values of these variables and think of them as representing a complete description of the battle at that point in time; i.e., a snapshot of the battle at that time. Thus, the values of these variables describe the "state" of the model battle at some point in time and are thus referred to as "state" variables. The processes which cause changes in these state variables are discussed in the following section of this overview.

3.0 PROCESSES FOR DYNAMIC CHANGES IN STATE VARIABLES

A number of processes are modeled in BATTLE which cause dynamic changes in values of the state variables. These are firepower processes; FEBA movement processes; supply consumption processes; weapon system, personnel, and supply replacement processes; reserve utilization processes; and tactical decision processes. A number of processes can occur within an activity. Descriptions of these processes are essentially a description of how an activity is performed. This section describes which processes are contained in the model (with principal emphasis on the firepower processes) and lists their outputs.

3.1 Firepower Delivery Processes: The firepower processes describe different mechanisms of delivering firepower and their effects which cause changes in force composition values and supply levels. These processes may be grouped into four categories: air-to-air, ground-to-air, air-to-ground, and ground-to-ground. Descriptions of the processes in each of these categories are contained in BATTLE as submodels based on specific assumptions about the process being described. Inputs to each of these models are either directly measurable quantities or can be estimated from systems engineering models or more detailed combat process models.

The air-to-air firepower processes separately describe the interactions of the escort versus the interceptor duel and the interceptor versus the attack aircraft duel. Outputs of these submodels consist of the escorts continuing their mission, escorts killed, escorts who return without engaging interceptors, interceptors killed by escorts, interceptors killed by attackers, attackers killed by interceptors, attackers aborting missions, and attackers who continue on to perform their mission. These results are produced both by mission and aircraft type.

The ground-to-air firepower processes describe the interactions of air defense artillery against aircraft on missions to attack ground targets other than air defense sites,[1] air defense artillery versus aircraft on missions to suppress long-range air defense artillery, and the duel between attack helicopters and ground maneuver forces. The first two firepower processes consider the effects on the aircraft during the flight to its target, while in its target's area, and the return flight; and generate the fraction of aircraft surviving to perform their mission, the fraction of aircraft that perform their mission which survive the return flight, and the fraction of long-range air defense sites suppressed. The model for the maneuver force-attack helicopter duels generates estimates of the number of maneuver force weapons attritted, by type, and attack helicopter attrition while supporting its ground forces.

The air-to-ground firepower processes separately describe the effect of attack aircraft against maneuver units at the FEBA and attack aircraft against other targets such as reserves, supplies, aircraft at air bases, etc. The model describing the firepower process against maneuver forces at the FEBA generates estimates of surviving numbers of weapon systems (by type) in the maneuver force while the model describing firepower effects against other ground targets generates estimates for the remaining number of elements in the target.

The ground-to-ground firepower processes include artillery against maneuver forces at the FEBA, artillery against other targets (other artillery, etc.), maneuver force delays and withdrawals, and maneuver force assault activities. The model describing artillery effects against maneuver forces at the FEBA generates estimates for the expected fraction of surviving forces in a battalion-sized maneuver force (by weapon system type and personnel in that unit), and the model describing artillery effects against other targets generates estimates of the expected fraction of the target and associated personnel surviving. Results of ground-to-ground firepower processes in delay and withdrawal activities are determined outside the model and used as look-up tables for each activity in the model.

The firepower (and other) processes in the assault activity between maneuver forces at the FEBA are computed internally, using VRI's differential models of combat. These models attempt to describe the dynamics of small unit firefights at the FEBA. The models explicitly consider different weapon system types on each side (tanks, anti-tank systems, mounted infantry, etc.), characteristics of these weapon systems (their firing rates, accuracy of fire, projectile flight times, lethality of the projectile), vulnerability of the target by type, firing doctrine of the weapon system (single rounds, burst fire, volley), probabilistic acquisition of targets in the firefight, allocation priorities of weapon systems to targets, maneuver capability of the weapon systems, and the effects of terrain line of sight on acquisition and fire capabilities. Four types of assault scenarios (two for Blue and two for Red) are possible in the BATTLE model, one representing tank heavy assault with mounted infantry and the other a dismounted, infantry heavy, battalion task force. The model computes attrition

[1]By aircraft type and mission.

of weapon systems by type and personnel for the opposing units at different range steps as the assaulting unit closes to the objective. Based on tactical decision rules, the assaulting force may break off the assault or may stop and call for fixed wing air, artillery, or attack helicopter fire support. Output of this model is a complete description of the surviving weapons systems by type and personnel at the end of the assault activity.

3.2 FEBA Movement Process: The FEBA movement process is considered in two parts: the decision for a maneuver force at the FEBA to move and the movement rate, given a decision to move has been made. A decision to move is based on a tactical decision rule which can be dependent upon many state variables. Given the decision to move, movement is computed by looking up an appropriate movement rate from the twelve movement rates accepted as input to the model. These movement rates are different, depending upon the activity being performed (advance, pursuit, successful assault, etc.) for each of the maneuver forces at the FEBA.

3.3 Supply Consumption Process: Consumption of supplies occurs as a result of combat activity and as a result of the passage of time. Consumption during combat is computed separately for the assault activity and other combat activities. Consumption during the assault activity of a maneuver force at the FEBA is computed at each range step in the differential models of combat based on the expected number of rounds fired to achieve the expected attrition calculated in that model. In other combat activities, expenditure of supplies is computed on the same basis as its associated firepower process model. For example, if the firepower model gives effects on a per sortie basis, parallel data items give ammunition and POL expenditure per sortie. Consumption of supplies based simply on the passage of time is intended to simulate combat activities that are not included in the model. This type of consumption for units is in direct proportion to its personnel and weapons system strengths.

3.4 Replacement of Weapon Systems, Personnel, and Supplies: Available weapons systems, personnel, and supplies are bookkept with weapons systems and personnel in the sector reserve forces and they are used as replacements for battalion maneuver forces at the FEBA. This is accomplished by tactical decision rules in any of five ways. In each method, the rules first determine directly the available replacement weapons for each type of battalion for the period. Then, the rules may call for (1) direct replacements to individual battalion areas, (2) averaging the number of weapons and personnel among all "battalions" of the same type in the same sector, (3) assignment of the replacement in proportion to the difference of the present level in a "battalion" from its TO&E level, (4) assignment of the replacement in proportion to another rule determined measure of the "battalions" required replacements (e.g., 90% of TO&E level), and (5) assignment of replacements which approximate the results of assigning replacements to "battalions" so that no "battalion" loses weapons and all "battalions" are brought as close to a constant number of weapons (of the type concerned) as possible. Replacement of weapon systems, personnel, and supplies to the sector stores from the theater stores are modeled by similar tactical decision rules.

3.5 Reserve Utilization Process: Tactical rules determine the retirement of maneuver forces at the FEBA into the reserve and the commitment of reserves or new units to the FEBA. When as a result of retirement or commitment of a maneuver force at the FEBA, the model finds a maneuver force at the FEBA temporarily without an opponent, the Red forces are redistributed into one more or one fewer of its allocated units. A force is distributed only into forces of the same type (there are up to ten types of Red and Blue units in a sector). In creating a new composite force, every force of the same type in the same sector loses a constant fraction of its weapons and personnel in such a way that the new "battalion has the mean strength of all forces in the sector. In redistributing an excess Red "battalion" equal fractions of it are distributed to each other Red force of the same type in the same sector.

3.6 Tactical Decision Processes: The model contains a number of tactical decision rules which attempt to describe the behavioral tactical decision processes which are an integral part of any military activity. Recognizing that little is known regarding how military commanders actually make tactical decisions, the model provides the user with a lot of flexibility to specify realistic tactical decision rules for use in the model. A tactical decision rule is a rule that associates a decision (a choice among alternative courses of action) with joint comparisons between ratios of linear sums of the state variables to comparison thresholds. The user has complete flexibility to specify which state variables are to be considered in the rule, the importance or weighting of each of the variables, and the comparison thresholds' values. Essentially, the user can set the value of any state variable as a function of the values of any other state variables contained in the model. Tactical decision rules in BATTLE are used to allocate forces and supplies to sectors; determine which maneuver forces at the FEBA will retire to the reserves; determine how many maneuver forces in reserve will go to the FEBA; govern the assignment of weapons and personnel to maneuver forces at the FEBA as replacements; assign theater intentions and plans for maneuver forces at the FEBA; determine activities of maneuver forces at the FEBA; determine fixed wing tactical air, artillery, and attack helicopter assignments to missions; determine whether forces engaged in an assault (fixed defense) will call for support and when they will break off; and control the FEBA shape.

4.0 MODEL INPUT, OUTPUT, REVIEW PROCEDURE, AND STATUS

4.1 Model Input and Output: Categories of inputs to the BATTLE model are weapon performance data, tactical rule data, and initial force inventory and deployment data. Outputs provided in the current version of the model include:

(1) Daily and cumulative weapon system losses by weapon type.

(2) Daily and cumulative casualties.

(3) Supply totals by type of supply.

(4) Total weapon system survivors by weapon type.

(5) Total personnel survivors in maneuver units.

(6) Total rear area personnel survivors.

(7) Numbers of task forces, weapons, and personnel in reserves.

(8) Numbers of sorties flown on each mission by each aircraft type.

(9) For each battalion area maneuver unit (daily):

Number of weapon systems (by type), personnel, and supplies
FEBA position
Activity

(10) Casualties (by location) and weapon system (by type) losses by system type which inflicts the attrition

4.2 Human Review Procedure: Recognizing that the tactical decision rules may at times result in some anomalies during the course of a 180-day war, or that the user may wish to change a particular decision during the course of a large-scale battle, a human review procedure allows the user a capability to replay a campaign with modifications. The user can direct that any state variable be set to a new value at a prespecified time during a war. This might, for example, be used to change an originally specified allocation variable or an inappropriate theater intention.

4.3 Model Status: The prototype version of the BATTLE model has been developed, programmed in ANSI FORTRAN, debugged, and is operating on both VRI's computer (360/67) and WSEG's CDC 6400. A data base has been formulated for the development testing which involves analysis of parametric variations in force inventory, tactical rules, and weapon performance data. The purpose of the development tests is to determine if (a) one can trace the cause-effect relationship between input variations and output results, and (b) given the input, the output results are consistent with military intuition and/or serve as a basis for changing that intuition. Some results of these development tests will be presented at the symposium.