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THE FIRE-FIGHT ASSESSMENT IN THE GROUND COMBAT CONFRONTATION (GCC) MODEL

Harlan W. Loomis

U.S. NAVAL WEAPONS LABORATORY
DAHLGREN, VIRGINIA

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Dahlgren, Virginia
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Commander

Bernard Smith
Technical Director

NWL Technical Report
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THE FIRE-FIGHT ASSESSMENT IN THE GROUND COMBAT CONFRONTATION (GCC) MODEL

by

Harlan W. Loomis
Computation and Analysis Laboratory

17 April 1968

FOREWORD

The Warfare Analysis Division of the U. S. Naval Weapons Laboratory, Dahlgren, Virginia, is responsible for the formulation of computerized simulations to support military operations research in the area of amphibious warfare. This work is directed by the Assistant for War Gaming Matters, Office of the Chief of Naval Operations (Op-06C) and is funded under Task Assignment AIR50300/291-1/F0180501.

The development of the Ground Combat Confrontation (GCC) Model was begun in February, 1965, with the support of Computer Applications, Incorporated, Silver Spring, Maryland. The model was designed to treat the post landing phase of the amphibious operation.

This report is intended to serve as a user-oriented description as well as documentation of the fire-fight assessment in the GCC Model. The content of this report has been reviewed for technical accuracy by O. F. Braxton, E. L. Miller, and MAJ H. C. Cooper (USMC), all of the Warfare Analysis Division.

RELEASED BY:

Ralph A. Niemann

RALPH A. NIEMANN
Director
Computation and Analysis Laboratory

ABSTRACT

The Ground Combat Confrontation (GCC) Model is a computerized simulation of selected aspects of ground combat and is coded in STRAP for the IBM 7030 (STRETCH) computer. The purpose of this report is to document the assessment techniques employed in the fire-fight portion of the GCC Model, which is called the Fire-Fight Submodel.

The Fire-Fight Submodel is a tool of military operations analysis designed to assess the results of close combat between opposing forces of mixed infantry and mechanized units. The forces are considered to be composed of "fire units", such as a USMC fire team or a single tank, elements of the forces which have their target acquisition, fire and movement internally coordinated. Detailed round-by-round assessments are given to the fires of individual, crew served, tank and antitank weapons possessed by a fire unit. The lethal and suppressive effects of individual projectiles are considered in terms of the activity and presentation of the target fire unit.

Possible applications of the Fire-Fight Submodel to problems of military operations analysis are: (1) applications within the context of the GCC Model as a whole; (2) research in the determination of optimal Table of Organization and Equipment structure and specifically in the selection of mixes of individual and crew-served infantry weapons; (3) application as a fire-fight assessment tool in support of manual war gaming; (4) application as an aid to junior officer training.

PREFACE

The Ground Combat Confrontation (GCC) Model is a computerized simulation of selected aspects of ground combat. The model was designed to treat the post landing phase of operations of a Marine Division/Marine Air Wing against an appropriate size enemy force. Detailed assessments are given for the close combat engagement of infantry and armor units and the appropriate supporting arms (air, artillery, naval gunfire). The model also assesses selected aspects of command, control, and communications, unit movement, intelligence acquisition and processing, engineer and logistics support. The GCC Model is coded in STRAP, the machine language for the IBM 7030 (STRETCH) computer.

The purpose of this report is to document those portions of the GCC Model which perform the assessment of the close combat engagement or the fire-fight. The assessments of certain aspects of command, control, and movement of units, although not explicitly a part of the fire-fight assessment, are also documented here because they determine the circumstances under which the fire-fight begins and terminates. As the goal of this report is thus a limited one, to provide a description and critique only of those aspects of the GCC Model which deal with the fire-fight, this is not a description of the GCC Model as a whole.

In Chapters I through III, a general description of these assessments is given in terms of the underlying assumptions on which the assessments are based and the data which the assessments require. In Appendices I through III, a more detailed documentation is given of topics discussed in Chapter III.

The portion of the GCC Model which performs the fire-fight assessment can, in principle, be used as an assessment tool independent of the balance of the GCC Model. This portion of the GCC Model is called the Fire-Fight Submodel, and its use as an independent tool of military operations research is discussed in Appendix IV.

It is to be noted that although the GCC Model was designed to treat the post landing operations of a Marine Division, the Fire-Fight Submodel has no built-in restrictions which would narrow its range of applicability to the assessment of fire-fights involving only U. S. Marine Corps forces. That is, the Fire-Fight Submodel is suitably generalized to assess the engagement between two forces each having an arbitrary organization with respect to the number of personnel and the number and type of weapons.

The list of references given in Appendix V includes those unclassified documents pertaining to war gaming and ground combat which the author has found serve as basic sources of input data for the Fire-Fight

Submodel. Included also are documents which are of importance through their instructive value as descriptions of military concepts, philosophy, and doctrine.

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CHAPTER I - RESOLUTION OF THE GAME

A. INTRODUCTION

The concept of the resolution of a war game is a necessary starting point in a discussion of the Ground Combat Confrontation (GCC) Model, as this determines the framework within which the activities associated with ground combat are described. The concept of resolution has application not only to the GCC Model or other computerized games but to any war game. The concept is now discussed in this broader context.

A war game is often characterized in terms of the degree of resolution it gives to military units and their activities on the battlefield. The term resolution refers to the degree of detail in which a military unit is described, the list of weapons, equipments and personnel it possesses together with the location and function of these within the unit. Further, the term resolution refers to the degree of detail in which the characteristic activities of a military unit are described.

The selection of a degree of resolution when developing a war game is largely determined by three factors. The first of these is the type and quantity of data which must be produced by the game. This factor is determined by the data requirements of possible studies or investigations in which the war game will be employed. The second factor is the availability of data, whether derived from operational or theoretical sources, on which to base the descriptions of military units, their activities, and the results of those activities, all of which are required inputs to a war game. The incorporation of this data into the required descriptions also implies that the dependence of the outcomes of activities upon the data is sufficiently well known and understood. Finally, the third factor is the human labor required to execute the game at a given level of resolution. These three factors determine the resolution of a war game, either manual or computerized, although the factors exert differing constraints on each type of war game.

The degree of resolution attained in a particular war game can influence in a striking manner the usefulness of the game in applications. A specification of the degree of resolution of a war game is thus important to an understanding of the capabilities of the game. Ideally, a war game used in a particular application or study should have a resolution comparable in depth to the degree of detailed output required by the study. Use of a war game having resolution in excess of that required by a study can only result in a waste of human effort, from the standpoint of extra input data required by the game to describe processes not of interest to the study, and from the standpoint of additional labor to execute the game. It is thus definitely not desirable to have a single universal war game with an exceptionally detailed resolution. In fact, it is common (and reasonable) practice to develop or modify a war game with a particular study effort in mind.

The GCC Model is characterized by two levels of game resolution. The first of these is the representation of a military force in terms of "game units". The activities associated with ground combat operations, excluding those of the close combat engagement, are treated at this first level of resolution. Included are such administrative functions as command, control and communications, as well as logistics and fire support. Movement of military units which are not engaged in close combat is also treated at this level of resolution. As this level of resolution essentially excludes the close combat engagement, its importance in the sequel arises from its treatment of command and control and of movement to contact.

The second level of game resolution in the GCC Model is the representation of a game unit by a group of "fire units". It is at this level of resolution that the close combat engagement is treated, including the employment of individual and crew-served weapons.

B. GAME UNITS

The GCC Model was designed to support the war gaming activities of the U. S. Marine Corps. Consequently, a typical game to be played using the GCC Model was anticipated to consist of a division size Blue force and a somewhat smaller Red force. These force sizes are planning factors only and do not represent upper limits to the force sizes of a game.

A military force is broken down into a group of game units. A game unit may be taken to be any combination of combat elements which are, throughout the game, under common administration, co-located, and are committed simultaneously to an engagement, an action or a task.

Examples of game units are a mortar, infantry or tank platoon, the headquarters section of an infantry company, or an artillery battery. In the "typical" game involving a division size Blue force, resolution of the game would be expected to have game units of at smallest platoon size. In a larger game, the resolution would be to game units of at smallest company size. On the other hand, the GCC Model could be used to assess the results of individual small unit engagements, each as a single game, in which case the resolution could feasibly be to game units of squad size or smaller.

Among the equipments which are treated at the game unit level are indirect fire weapons. Included in this category of weapons are artillery and mortars of size 81mm and larger. These weapons are treated as being possessed by a game unit, and are fired by the game unit at other game units. Target acquisition and fire control for these weapons is thus treated at the game unit level. The aim point for indirect fire is assumed to be the estimated center of the target game unit, which is dependent upon the quality of available intelligence and the presence or non-presence of an observer for the fire.

Vehicle types which perform the administrative transport of supplies and personnel are also treated at the game unit level. Examples of these vehicles would be a truck, a helicopter, or an LVT (landing vehicle tracked) when employed in an administrative role. Vehicles which would normally be employed in a combat role are excluded. Characteristics of the vehicles treated include the carrying capacity, movement rate, presentation to supporting arms fire, and the vulnerability of personnel in such a vehicle.

Selected communications and electronics devices are treated at the game unit level. Among these are the radio communications equipment associated with command and control functions between game units, such as supporting arms fire direction together with transmission of intelligence and contact reports. The radio nets which provide internal command and control within a game unit, such as within the tank platoon or within the 105mm howitzer battery, are treated insofar as the transfer of (game unit) targeting information occurs among the elements of the game unit.

C. FIRE UNITS

A game unit is represented as a group of fire units during the time the game unit is engaged in close combat. A fire unit may be taken to be any combination of combat elements of a game unit which (1) move, fire, and are suppressed as a single entity; (2) attack or defend only on a single sector; (3) are acquired as a single target in the engagement; (4) communicate instantaneously among themselves any target acquired by one element. Note that all game units have a fire unit representation, not only those units whose mission it is to engage the enemy in close combat, but also those headquarters, artillery and rear echelon units which might conceivably find themselves under attack.

Examples of individual fire units are a USMC fire team, M60 machine gun team, or an individual tank. It is possible, in a game involving sufficiently small forces, to have the individual soldier as a fire unit. A USMC squad (reinforced) could have either of the following two representations as fire units: (1) one squad leader/grenadier team, three fire teams, one M60 machine gun team, one assault team; (2) one squad leader/grenadier team, three individuals with M14E1's, nine individuals with M14's, one M60 machine gun team, one assault team. Note that although the number of fire units is quite different for the two representations (6 and 15 fire units), the number of fire unit types is only modestly changed (four and five fire unit types). It is the description of each fire unit type which is required input to the GCC Model, and so the detailed resolution of the second representation requires only a small amount of additional input. The USMC squad of this example was taken from Table of Organization number M1013 [5].

Among the equipments which are treated at the fire unit level are most weapons which would normally be employed in close combat. Direct fire weapons are included, as well as a few selected indirect fire weapons. Examples are the rifle, machine gun, recoilless rifle, rocket launcher, primary weapon of a tank, and the smaller mortars such as the 60mm. (No consideration is given to the assessment of flame or other incendiary weapons which might be employed in close combat.) These are the only weapons possessed by a fire unit, and are fired at other fire units.

A fire unit can have two types of weapons, a primary and a secondary type, and any reasonable number of each type. The distinction between primary and secondary weapons is best described by an example. If a fire unit sustains casualties, it is assumed that the primary weapon or weapons will always be manned providing that sufficient personnel remain in the fire unit. Although the Table of Equipment corresponding to a fire unit specifies a certain number of close combat weapons, the number actually given the fire unit is the average number of weapons which would be active at any instant during a typical engagement.

It was mentioned that artillery, headquarters, and other rear echelon units must be given a fire unit representation. Note that these fire units will have only those weapons from the Table of Equipment which would normally be employed in a self-defense role. For example, the six 105mm howitzers would be excluded from the fire unit representation of a 105mm howitzer battery, unless these weapons were incorporated into the scheme of defense.

Vehicles which would normally find employment in a close combat role are treated at the fire unit level. For example, a fire unit may consist of a tank, APC (armored personnel carrier), or LVTH (landing vehicle tracked howitzer). In the course of the fire-fight engagement, such vehicle characteristics as carrying capacity, presentations, vulnerability, and movement are treated.

D. APPLICATIONS OF THE FIRE-FIGHT ASSESSMENT

The selection of a level of resolution for a war game determines the range of possible applications or uses which the game can have. This was discussed in paragraph A. Having described the two levels of resolution obtainable in the GCC Model and the degree of detail associated with each, it is now possible to discuss the implications of this resolution as to potential applications of the GCC Model's fire-fight assessment.

The resolution of military forces into fire units makes possible a detailed view of the fire-fight. The treatment of the fire-fight given in the GCC Model permits a quantitative investigation of the manner in which individual rounds are expended, individual casualties occur, and the manner in which time delays occur during close combat. With this level of resolution, four possible applications for the fire-fight assessment are the following:

(i) Applications within the context of the GCC Model as a whole;

(ii) Research applications in the variation of Table of Organization and Equipment (T/O and E) structure;

(iii) Application as fire-fight assessment tool;

(iv) Application as an aid to junior officer training.

These possible applications are discussed separately.

For any application of the GCC Model as a whole, the fire-fight assessment naturally finds an application as a component of the model. A discussion of such applications of the GCC Model is beyond the scope of this report. However, there are aspects of the fire-fight assessment which could seriously affect the range of applications for the GCC Model. Consider the case of an application of the GCC Model to a study which would not focus on the results of the fire-fight assessment, but on other aspects of ground combat. In such a situation, the GCC Model would possess resolution in excess of that required by the study. The detailed inputs required by the fire-fight assessment would not repay the human effort required by an improvement in the study's quality. A more aggregated fire-fight assessment could be substituted in place of the existing assessment without degrading the study. If this substitution cannot be made, the additional cost of providing the detailed inputs to the fire-fight assessment might discourage use of the GCC Model in this proposed application.

A promising area for application of the fire-fight assessment is in the determination of optimal T/O and E structure. The resolution to fire units makes feasible an analysis of the impact on the fire-fight of varying the types and numbers of individual and crew-served weapons. Although this is presently a research objective, the levying of procurement requirements could easily make this an application of the fire-fight assessment to an operational requirement.

The third area of application of the fire-fight assessment is as an assessment tool independent of the GCC Model. This is discussed in detail in Appendix IV. This use of the fire-fight assessment would most likely be in support of U. S. Marine Corps war gaming activities.

The fire-fight assessment could be employed, with the aid of a visual computerized display system, as an aid in the training of junior officers. In such small unit engagements as the infantry platoon or squad in the attack, the effects of variation in tactics, deployment and weaponry could be directly observed in terms of casualties sustained, ammunition expended, and duration of the engagement. The fire-fight assessment, augmented by a visual display, could provide a real-time simulation of the following events: Assuming that the student is the platoon commander or squad leader, the orders issued to him by the next higher command would be displayed visually. The student could perform the basic troop leading steps, indicating his plan of action to the computer. The fire-fight assessment would then determine the results of the engagement, and indicate these visually to the student.

A final comment should be made on the feasibility of developing a fire-fight assessment which would have a more detailed resolution than the one within the GCC Model. An important limitation is the availability of operational data with which the fire-fight could be described in more detail. A second limitation arises in the lack of understanding of the processes and mechanisms which determine the outcomes of engagements. Such processes include the nebulous areas of human factors and the importance of terrain characteristics. Without a better understanding of these aspects of combat, modeling of the fire-fight cannot be refined significantly.

CHAPTER II - MOVEMENT TO CONTACT AND DEPLOYMENT

A. INTRODUCTION

The phase of a military operation which preceeds the close combat engagement is characterized by the movement to contact of opposing units. Important aspects of this phase of operations are the command and control, intelligence acquisition, planning and coordination, and movement of units in preparation for combat. The GCC Model treats these activities of units at the game unit level of resolution. Specific features of the movement to contact phase which directly influence the close combat engagement are the representation of terrain and the criteria by which the beginning of an engagement is determined. A discussion is given of the manner in which the GCC Model treats terrain and the command decision to attack at the game unit level of resolution. Other aspects of the movement to contact phase, such as detection, intelligence acquisition, command and control, which are also treated at the game unit level are not discussed as these are beyond the scope of this report.

The occurrence of the command decision to attack marks the transition in the GCC Model from the game unit level of resolution to the fire unit level. At the time of this command decision, the attacking game unit and defending game unit(s) are given representations each as an array of deployed fire units. The command decision to deploy either an attacking or defending game unit may have preceeded in time this command decision to attack, but the conversion to a fire unit representation is postponed until the time of the latter decision. This is a device employed in the GCC Model as a convenience, for it is not until the time of the command decision to attack that the fire unit representation becomes essential.

B. TERRAIN FEATURES AND AVENUES OF APPROACH

Terrain which is distinguished by its military significance, such as an objective or a defensive position, is given a representation in the GCC Model as a <u>critical</u> <u>terrain</u> <u>feature</u> (CTF). The CTF representation can also be used to portray checkpoints and other locations on the battlefield which are related to command and control but which may or may not be associated with a recognizable piece of terrain.

The configuration of a critical terrain feature is determined by the coordinates (x_1,y_1) and (x_2,y_2) assigned to two points, termed the focii of the terrain feature. The focii are distinguished as "right" or "left" so that the numbering of six sectors about the terrain feature can be done unambiguously (Figure 1). This numbering serves to identify the six sectors. The CTF is considered to be a rectangle placed about the focal points as an approximation of the real terrain feature. Line

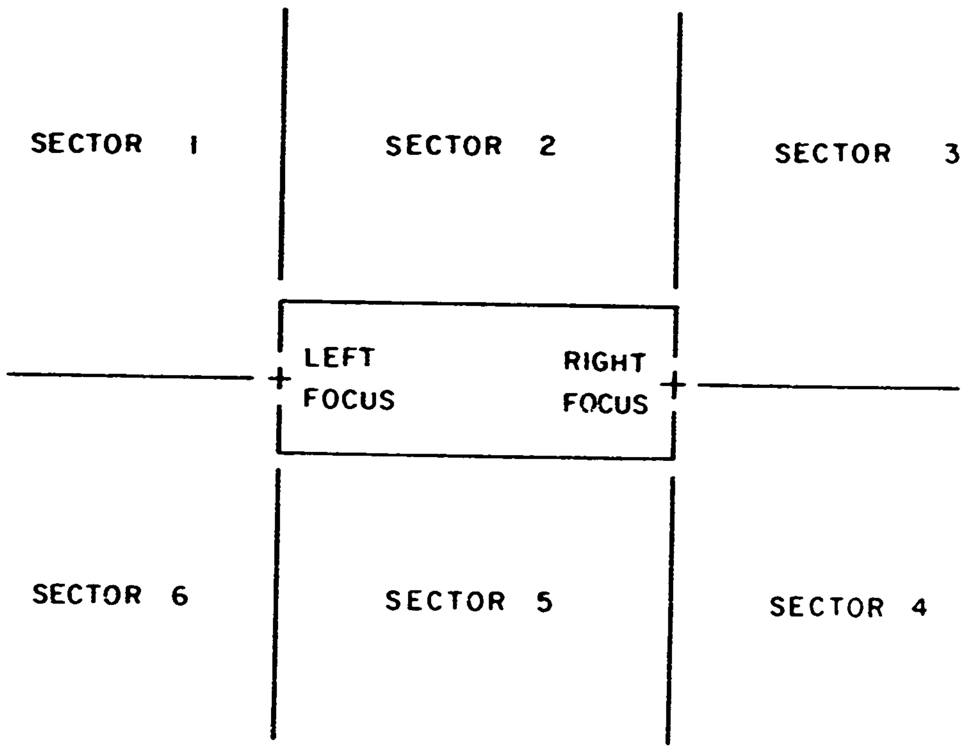

Figure 1

Sectors of a Terrain Feature

of sight and cover characteristics (for indirect and direct fire) are associated with the CTF, and cover characteristics (for direct fire) are associated with each sector. Using these cover characteristics, a distinction can be drawn between the quality of the various directions of approach to the terrain feature.

Avenues of approach, such as a road, trail, axis of advance, direction of attack, or a flight path, are approximated by line segments. The two endpoints of a single line segment, having coordinates (x_1,y_1) and (x_2,y_2), are distinguished as "origin" and "destination." This is the basis of the terminology <u>avenue</u> <u>of</u> <u>approach</u> <u>vector</u> (AAV) which is used to describe one of these line segments.

An avenue of approach vector has associated with it a set of maximum movement rates for game units traversing the avenue. These are given as a function of the game unit's deployment, conditions of light and weather, in addition to the "mode" of the game unit. An avenue can be in one of the three media "land," "water," or "air". Corresponding to each medium, the game unit has three possible modes:

(i) Land - Infantry, wheeled, tracked.

(ii) Water - Swimmer, amphibian, craft.

(iii) Air - Paratrooper, fixed wing, helicopter.

In addition to the movement rates, an AAV has associated line of sight and cover characteristics (for indirect fire).

Terrain may be approximated by AAV's and CTF's in varying levels of detail as required in a particular application of the GCC Model. In Figure 2 the configuration of AAV's and CTF's is shown for two possible treatments of a company attack/platoon defense. A more detailed analysis of the engagement is possible when the breakdown of the attacking company into platoon size game units and the defending platoon into squad size game units is accompanied by a more accurate representation of the terrain in terms of AAV's and CTF's. A limitation upon the degree of detail in which terrain can be represented is that a game unit moving from one CTF to another can use at most ten AAV's. In practice this is not an important limitation.

C. <u>THE ROLES OF "DEFENDER" AND "ATTACKER"</u>

A defending game unit is located on a critical terrain feature (CTF). The fire units which comprise the game unit are deployed in an array of 12 defensive lines, three on each side of the terrain feature. For identification, each set of three defensive lines is termed the "front," "rear," "right flank," or "left flank" of the defensive position according to their orientation with respect to the right and left focii of the

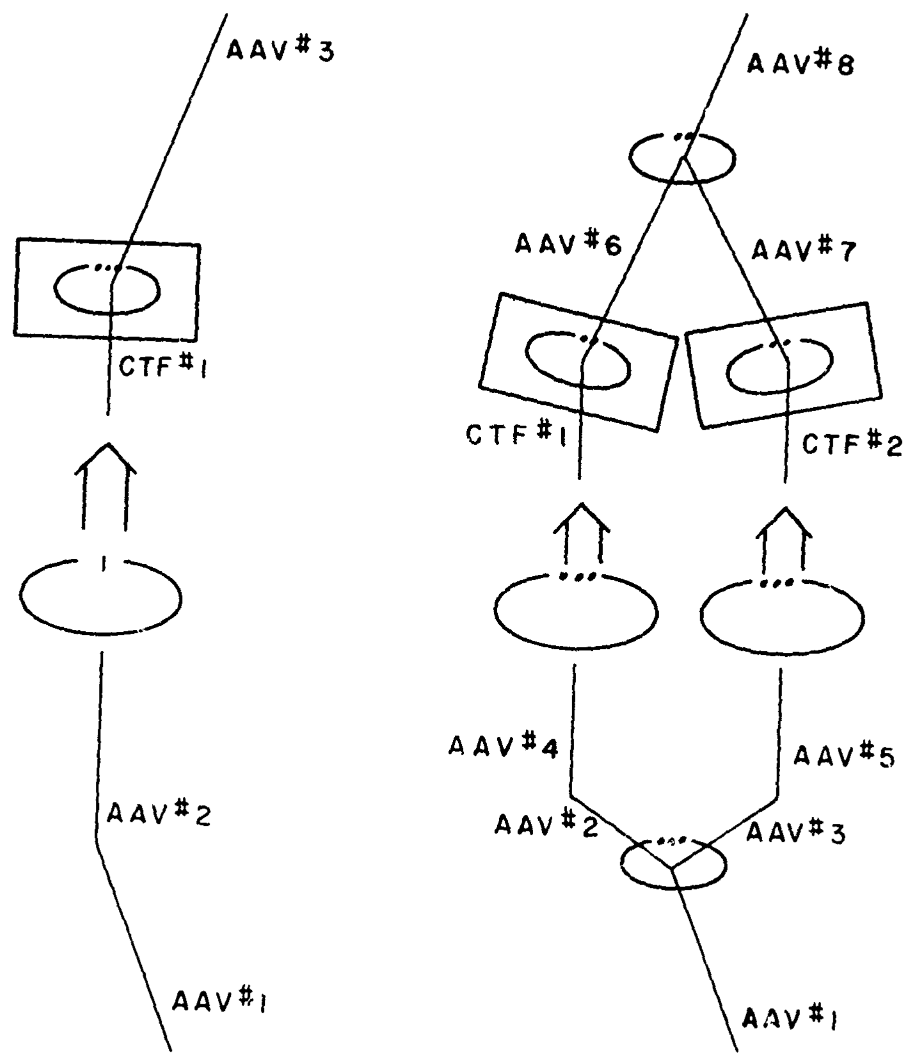

Figure 2

Alternative Representations of a
Company Attack/Platoon Defense

terrain feature (Figure 3). A game unit designated as defender can thus conduct an all-around defense. The spacing or separation of the defense lines is dependent upon the particular terrain feature on which the engagement takes place, but throughout a given engagement the spacing is constant. This is discussed further in paragraph E.

An attacking game unit is located on the approaches to the terrain feature being defended. The fire units of the attacking game unit are deployed on nine (out of 12) attacker waves, three on each of three sides of the terrain feature as determined by the direction of attack (Figure 4). This direction of attack is determined by the circumstances in which the attacker and defender game units move to contact, and is discussed in paragraph D. For identification, each set of three attacker waves is termed the "front," "right flank," or "left flank" of the attacking game unit according to their orientation with respect to the direction of attack.

A single attacking game unit is thus constrained to conduct its attack from three sides of the terrain feature. Such options as the frontal assault, or the frontal assault coupled with a right or left envelopment, are available without further restrictions. An attack from four directions, such as a siege, can only be conducted by two or more game units.

The conduct of the attack is assumed to utilize advance by fire and maneuver together with a base of fire. The fire units deployed in a single sector may all assault the defensive position by fire and maneuver, may all comprise a static base of fire, or the fire units of a single sector may be split between these two roles. In general, fire units assigned to the rearmost wave of each set of three attacker waves are treated as elements of the base of fire, and fire units located on the other two waves are treated as advancing by fire and maneuver. The interval or separation between the attacker waves is treated as a function of the force (i.e., Red or Blue). This implicitly assumes that the separation is of the category of a Standard Operating Procedure (SOP). Spacing of attacker waves is discussed further in paragraph E.

D. TYPES OF ENGAGEMENTS

The assignment of "attacker" and "defender" roles to game units engaged in a fire-fight is determined by the circumstances under which the engagement begins. An important factor is the mission of each game unit, as reflected by the activity of the unit at the time the engagement begins. The single factor which has the most influence upon the assignment of these roles is the particular game unit which actually initiates the engagement.

The engagement commences as a consequence of at least one unit's decision to attack. The criteria used to make this decision are based upon the game unit's status in relation to minimum requirements as to

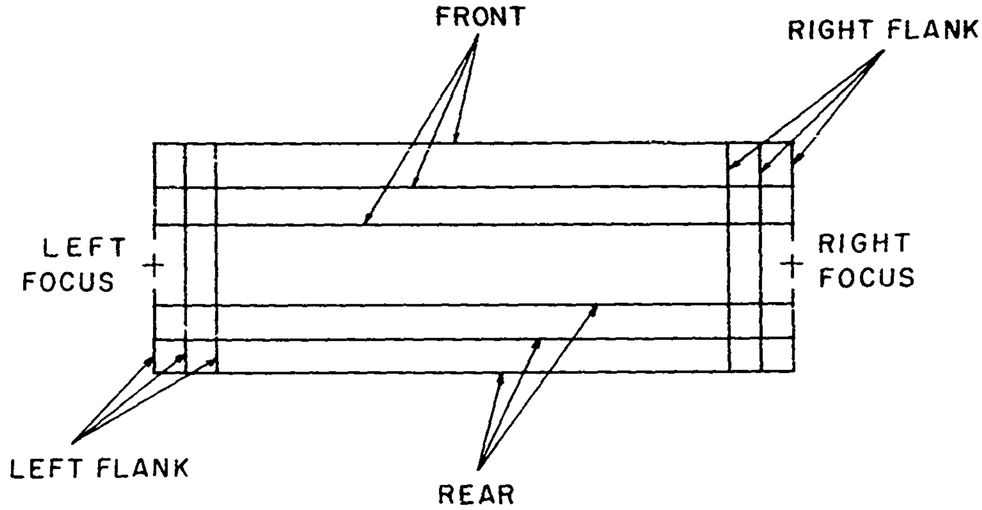

Figure 3

Defensive Lines

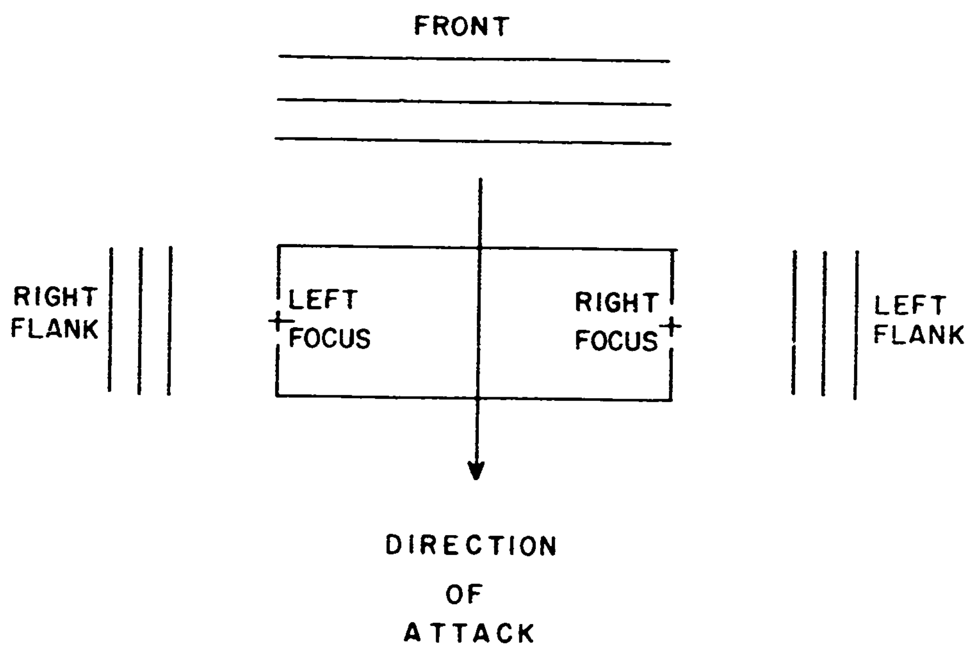

Figure 4

Attacker Waves

the unit's strength, supply levels, coordination with friendly units, penetration, time constraints, and information held as to the location, strength and threat posed by the enemy unit(s) to be engaged. These criteria used to initiate the attack of a game unit are distinct from the criteria used to initiate the fire of close combat weapons possessed by the fire units of a game unit. Hence the opening of the engagement, signaled by the decision to attack, need not coincide with initiation of the exchange of fire.

The Typical Engagement

The standard or typical engagement is characterized by one or more game units occupying a key terrain feature, having a primary mission of defense, and another unit moving along an avenue of approach adjacent to the terrain feature, having a mission of activity seeking the enemy to engage him in close combat.

The unit(s) occupying the terrain feature are cast as "defender(s)," and the moving unit as "attacker". The engagement thus is fought on the terrain feature occupied by the defender. The direction of attack is determined by the location of the attacker relative to the main axis of the terrain feature at the time the engagement commences. The attackers "front" will be either in sector 2 or 5 of the terrain feature depending upon the relation between the attacking game unit's coordinates and the coordinates of the terrain feature's focii.

The Meeting Engagement

This type of engagement is characterized by an encounter between opposing game units, all moving on avenues of approach, with at least one game unit having an assigned mission of seeking the enemy to engage him in combat. This situation may arise when game units collide head-on on the same avenue, or when a game unit overtakes an enemy game unit moving along the same avenue. It is not an absolute requirement that game units meet on the same avenue, but in the case that game units are on different avenues, the avenues must be in sufficiently close proximity to allow the unit, whose mission it is to engage the enemy, to detect units on the other avenue. An example of this would be the meeting of game units at or near a junction of two avenues.

The unit having the mission to engage the enemy is cast as "attacker," the enemy game unit(s) as "defender(s)". Since no unit involved in this type of engagement is initially located on a terrain feature, a "dummy" terrain feature is assigned to the defender unit(s). The size of this terrain feature is a function of the echelon of the defender game unit(s). The attacker is assigned a direction of attack from sector 2 of the terrain feature.

Characteristics associated with the "dummy" terrain features used in this type of engagement, such as the cover available to attacker and defender from direct fire, would differ from those characteristics normally provided for a terrain feature. These should reflect the fact that defender does not have a prepared position. Also, the fact that the attacker has the initiative in this type of engagement may have forced the defender to select an inferior location to establish his hasty defense. It is possible that characteristics of such a terrain feature could actually favor the attacker.

The Ambush Engagement

An ambush is characterized by one or more game units moving along an avenue of approach and another enemy game unit occupying a terrain feature astride or adjacent to the avenue. Further, it is the unit occupying the terrain feature which has the mission of engaging appropriate enemy game units passing him on the avenue.

The ambushing game unit thus initiates the engagement, and is cast as the "attacker," the ambushed unit(s) cast as "defender(s)". Since the defending game unit is not on a terrain feature initially, a "dummy" terrain feature is assigned to the defender as was done in the meeting engagement. The attacking game unit is assigned a direction of attack, his "front" located in sector 2 of the dummy terrain feature.

E. DEPLOYMENT

A game unit is deployed by assigning its fire units to the 12 defensive lines or the nine attacker waves, as appropriate, utilizing one of a set of Deployment Options provided as input to the game. A single Deployment Option specifies how the fire units comprising the game unit should be allocated to the defensive lines or attacker waves, as appropriate. This allocation is given in terms of the percentage of the total number of fire units of a given type which should be assigned to a given line or wave. Two sets of Deployment Options are provided as input to the game, one set for Blue and another for Red. Within each set, the Deployment Options are numbered for purposes of identification.

For a game unit cast as a defender, the particular Deployment Option used is an input item, a function of the unit's mission at the time of the deployment assessment. If no Deployment Option was provided as corresponding to this mission, option number "1" is unconditionally assigned. Such an assignment of a Deployment Option is to be interpreted as an SOP, as might be required for example in the case of an unforseen meeting or ambush type engagement.

For a game unit cast as an attacker, the selection of a Deployment Option is treated in more detail than it is for defender. This selection utilizes a decision table based upon the particular circumstances of the engagement. If the engagement is of the meeting or ambush type, the attacker is assigned option number "1". If the engagement is of the "typical" type and a Deployment Option was specified on input corresponding to the unit's mission, this option is assigned. If no option was specified, option number "1" is assigned if the attacking unit is of platoon size or smaller or if there are several defending game units; otherwise, a selection from among option numbers "2," "4" and "5" (frontal attack, right or left envelopments) is made based upon the cover available to the attacker by sector of the terrain feature and based upon the attacker's knowledge of the defender's deployment. This decision table format again reflects the employment of SOP's for unforseen engagements. In addition, this feature of the game can be used to attain an economy of input.

The spacing of the defensive lines is a function of the dimensions given the terrain feature (CTF). The width W and length L (the distance between the focii of the terrain feature) are used as indicated in Figure 5. This spacing of the defensive lines, computed at the beginning of the engagement, is constant throughout the engagement.

The initial spacing A of the attacker waves is an input item to the game. The distance D of the lead attacker wave from the terrain feature is set at the distance of the attacker game unit from the midpoint of the terrain feature, as computed from the coordinates of the game unit and the focii of the terrain feature. This initial spacing of the attacker waves, shown in Figure 6, is modified as the engagement progresses due to individual movement of the attacker's fire units.

If additional game units enter the engagement at a later time, they are assigned the roles of "attacker" or "defender" and are deployed using the same procedures as outlined above for the game units initially engaged.

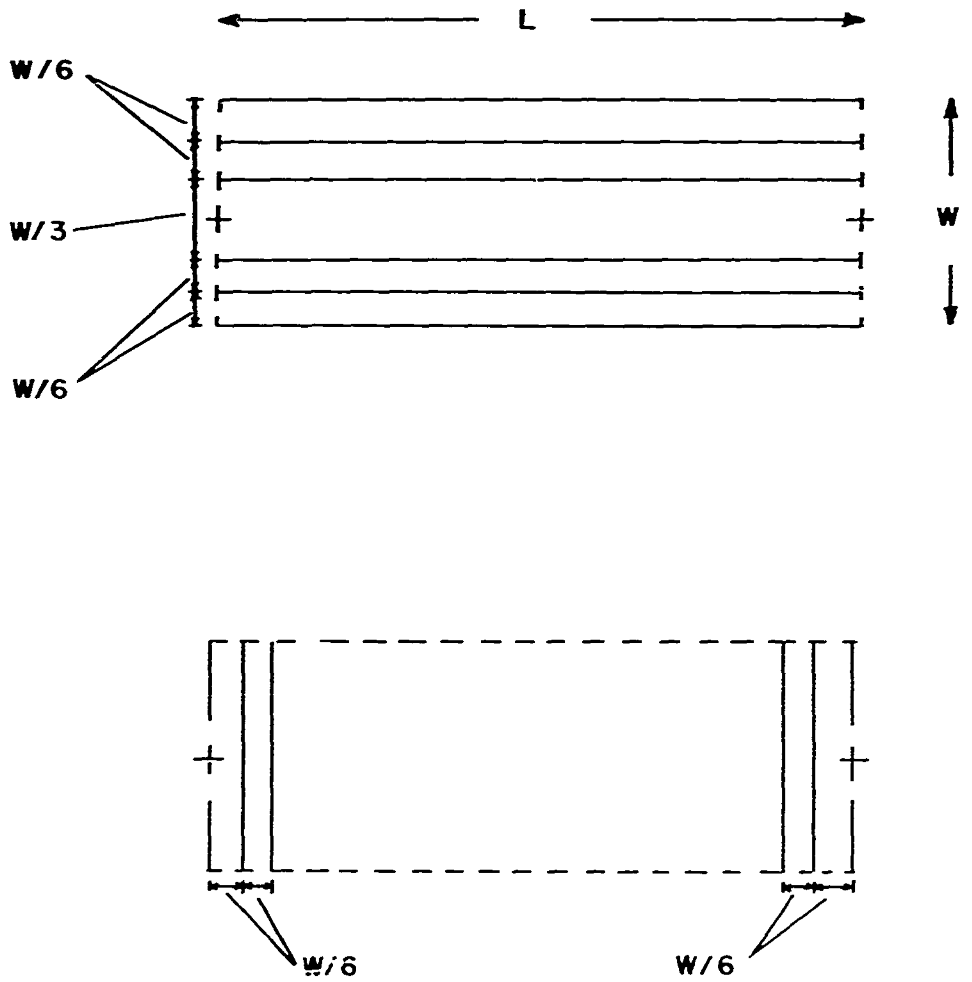

Figure 5

Spacing of Defensive Lines

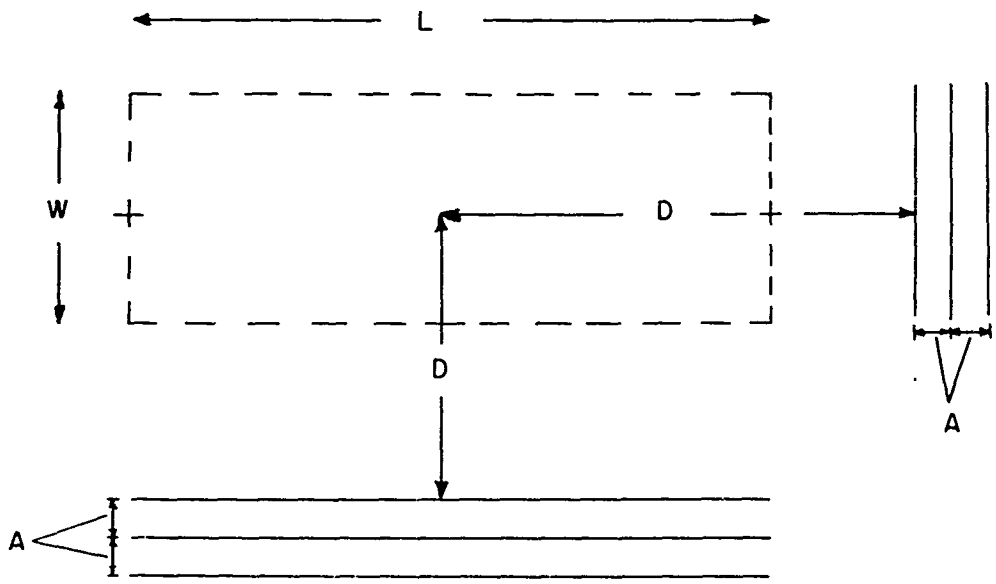

Figure 6

Spacing of Attacker Waves

CHAPTER III - THE FIRE-FIGHT ASSESSMENT

A. INTRODUCTION

The close combat engagement, also called the fire-fight, is treated in the GCC Model at the fire unit level of resolution. The engagement begins with the decision to attack on the part of at least one game unit. From this time until the time the engagement terminates, each game unit is treated as an array of deployed fire units. The activities of movement, detection, target acquisiton, and weapons' fire within the engagement are all treated from the viewpoint of the individual fire unit. As a consequence, the rreatment of weapons' lethality is based on a detailed round-by-round assessment with respect to the presentation of a target fire unit. The termination of the engagement is treated at the game unit level of resolution. A single game unit may disengage itself based upon such criteria as total casualties sustained, elapsed time since the engagement began, and additional intelligence gained through the close contact with engaged enemy units.

These aspects of the fire-fight are described in Chapter III. A more detailed treatment of selected aspects of the fire-fight is given in Appendices I, II, and III.

B. FIRE UNIT SUPPRESSION

It is well known that the effects of fire on the individual soldier go beyond simply the lethal effects of the projectiles. For example, the military doctrine which employs the concept of establishing "fire superiority" over the enemy tacitly assumes that fire has an effect beyond simply producing casualties. To a varying degree which is dependent upon the circumstances of a particular engagement, an individual soldier is reduced in his effectiveness to perform basic combat-related activities when he comes under fire. Among these are his ability to return the fire, which necessitates that he continue to expose himself to incoming fire, and his ability to move. This phenomenon of reduced individual effectiveness in the face of fire is called "suppression".

The effects of suppression are treated in the GCC Model at the fire unit level of resolution. Vehicle fire units are not considered with respect to possible suppression. That is, the only characteristics of incoming fire which are considered for vehicle fire units are the lethal characteristics of the projectiles. In the GCC Model, the term "suppression" is applied exclusively to infantry fire units.

The assessment of the suppressive effects of fire is treated as a function of the type and volume of fire received by a fire unit. For example, a burst of fire from an RPD light machinegun may have a different suppressive effect on a fire team than a burst of fire from an AK rifle. Upon receipt of a burst of fire by a fire unit, a suppressive effects delay time is selected based upon the type of weapon which fired the burst. The fire unit is then said to be suppressed during the interval of time from the receipt of fire until the delay time lapses. Specifically, the suppressed fire unit is (1) not allowed to fire, (2) not allowed to move, and (3) is given a reduced exposure. The treatment of a suppressed fire unit is described further in paragraphs C. and D.

C. FIRE UNIT MOVEMENT

The deployment of the fire units comprising an attacking game unit is modified from the initial deployment as the engagement progresses. This occurs due to the individual movement of these fire units. The rate of movement is a function of the type of fire unit. For example, a fire team may have a different movement rate than an APC (armored personnel carrier) or LVT (landing vehicle tracked).

The fire units of an attacking game unit must move to within an "opening engagement" range, as measured from the terrain feature (CTF), before they may commence fire or be fired upon. This range is a function of the terrain feature sector, and as such reflects line of sight and terrain masking conditions characteristic of each approach to the terrain feature. Once the opening engagement range has been crossed by an attacker fire unit, it may fire at an enemy fire unit or be fired upon by an enemy fire unit if the target-to-firer range is less than a specified maximum weapon range. This range is dependent upon the type of weapon being fired.

At the time a moving attacker infantry fire unit first comes under fire, the character of its movement changes from its previous uniform advance at the movement rate specified for the fire unit's type. With the assessment of a suppression delay for each burst of fire received, the subsequent movement of the fire unit will be characterized by alternating periods during which the fire unit is stationary or during which the fire unit is moving at the specified movement rate.

Fire units which were designated as being employed in a base of fire role continue to move until they reach a "base of fire employment" range, as measured from the terrain feature, and thereafter these fire units are stationary. The base of fire employment range is a function of the fire unit type. An example of an engagement in which this range could actually be different for different fire unit types is a combined infantry-armor attack, say involving an infantry squad in a base of fi. role and a tank section in an overwatching role. Depending upon the terrain, the requirement that the overwatching tanks be in defilade might necessitate their employment at a different range from the terrain feature than the infantry squad.

Fire units which are designated as being employed in a maneuver role continue their movement until they either overrun the defensive position (reach range "0" from the terrain feature) or reach a "minimum separation" range from the terrain feature. This minimum separation range simulates such factors as close-in barriers associated with the defensive position.

Two observations can be made about the manner in which the engagement begins. The first of these is that the opening of the engagement, signaled by the decision to attack on the part of at least one game unit, need not coincide with the initiation of exchange of fire. This is a consequence of the fact that the decision to attack is treated at the game unit level of resolution and the decision to open fire at the fire unit level. Hence the criteria used to determine the beginning of the engagement are distinct from the criteria used to initiate the fire of close combat weapons.

The second observation deals with the impact that the initial deployment has upon the subsequent engagement. The attacker game unit is initially represented by an array of fire units deployed on nine attacker waves, with a uniform interval or separation between waves. This wave separation loses its significance as the engagement progresses because the attacker fire units advance independently of one another towards the terrain feature. This independence of movement is in turn a consequence of differing fire unit movement rates and of differing suppressive delays incurred by the fire units as they individually come under fire. The interval or separation between waves thus varies as the engagement progresses, and also the fire units on a single wave may become staggered. This shows that not only does the wave separation lose its significance as the engagement progresses, but also the "attacker wave" loses its initial character as a group of alligned fire units.

D. FIRE UNIT PRESENTATIONS

The determination of the lethal effects of a projectile fired at a fire unit depends heavily upon the exposure or presentation offered by the target fire unit. In addition, the acquisition of a fire unit as a target depends upon its degree of exposure, which in turn is a function of the fire unit's activity on the battlefield. The presentation of a fire unit at a given instant is a function of whether the fire unit is a vehicle or infantry type, attacker or defender, suppressed or unsuppressed, and also this presentation is a function of the cover available to the fire unit from direct fire.

The presentation given to a target fire unit is also dependent upon the type of projectile fired, either fragmenting or nonfragmenting. In the case of a fragmenting projectile, the target fire unit is given a presentation as a (circular) area of occupation. The size of this area of occupation is a function of the type fire unit. For an infantry fire unit, this represents the area over which the fire unit is typically deployed. For a vehicle fire unit, this represents an approximation to the dimensions of the vehicle. The balance of this section gives a description of the presentations assigned to a target fire unit when the fire consists of nonfragmenting projectiles.

A vehicle fire unit, consisting of a single vehicle, can assume two different presentations during the engagement, each specified by a height and width:

(i) Fully exposed. This exposure is assigned to vehicle fire units in the attacker's maneuver element and to those in the attacker's base of fire element which have not reached their base of fire employment range.

(ii) Reduced defilade. Vehicle fire units in the defensive position and those in the attacker's base of fire element which have reached their base of fire employment range are given this exposure.

An infantry fire unit has an exposure which is a composite of the exposures of its individuals. An individual may have a standing, prone or reduced defilade exposure, each specified by a height and a width, or an individual may have no exposure. The composites of these individual exposures which are possible fire unit presentations are the following:

(i) Moving. This exposure is assigned to moving (hence unsuppressed) infantry fire units of the attacker force. This includes moving fire units in the attacker's maneuver element together with fire units in the attacker's base of fire element which have not reached their base of fire employment range. The moving presentation of a fire unit is an average or typical exposure during an advance by fire and movement. As such, it is a composite of standing and prone individual presentations, where the number of standing individuals is an average number, a function of the type fire unit. If a fire unit has sustained casualties, the number of individuals treated as standing is the minimum of the fire unit's strength and the "average number standing" for an unattrited fire unit of this type. The other individuals of the fire unit are treated as being prone.

(ii) Prone. This exposure is assigned to unsuppressed infantry fire units in the attacker's base of fire element which have reached their base of fire employment range, and to fire units in the attacker's maneuver element which have either overrun the defensive position (reached range "0" from the terrain feature) or reached the minimum separation range from the terrain feature. This exposure is also assigned to unsuppressed infantry fire units in the defensive position. The prone fire unit exposure is a composite of prone individual presentations.

(iii) Reduced defilade. This is one of two exposures assigned to a suppressed attacker or defender fire unit. The reduced defilade fire unit exposure is a composite of reduced defilade individual exposures.

(iv) No exposure. This is a second exposure which may be assigned to a suppressed attacker or defender infantry fire unit. This is a composite of individuals all having no exposure, and hence there is no presented area of exposure associated with this fire unit posture.

Transitions among the various possible exposures of a fire unit occur during the engagement. One cause of chese transitions is the movement of an attacker fire unit, bringing it to within some specified range from the terrain feature, such as a range distinguished either by characteristics of the terrain itself or by its association with aspects of command and control. The transitions in exposure which are of this type are the following:

(i) An attacking vehicle fire unit which is designated for employment in a base of fire role has a transition from the fully exposed to the reduced defilade exposure. This occurs when the vehicle fire unit reaches its base of fire employment range.

(ii) An attacking infantry fire unit which is designated for employment in a base of fire role has a transition from the moving to the prone exposure when the fire unit reaches its base of fire employment range.

(iii) An attacking infantry fire unit which is designated for employment in a maneuver role has a transition from the moving to the prone exposure. This transition occurs when the fire unit closes to range "0" or the minimum separation range from the terrain feature.

A second cause of transitions in fire unit exposure is the occurrence of suppression. As stated in paragraph B, a fire unit is considered to be suppressed from the time fire is received until the expiration of a suppressive effects delay. Since the effects of suppression are treated only in the case of infantry fire units, the transitions in exposure discussed here apply only to infantry fire units of the attacker and defender forces:

(i) If a fire unit is unsuppressed at the time of the receipt of fire (that is, the fire unit's exposure is moving or prone), it is said to be suppressed and its exposure is reassigned as reduced defilade or no exposure during the duration of the suppression. The choice between reduced defilade and no exposure is accomplished by a Monte Carlo assessment utilizing the probability that an infantry fire unit can completely eliminate its exposure in the given area of the terrain feature. The probability is a function of the terrain feature, and for an attacker fire unit it is also a function of the sector of the terrain feature in which the fire unit is deployed.

(ii) If a fire unit is suppressed at the time of receipt of fire (that is, the fire unit's exposure is reduced defilade or no exposure), an additional suppressive delay is assessed but the presentation of the fire unit is left unchanged.

(iii) At the expiration of the suppressive delay, the fire unit resumes the exposure and activity which it had prior to the occurrence of the suppression. In the case of a defender fire unit, this is a transition from reduced defilade or no exposure to a prone posture. In the case of an attacker fire unit, this is a transition from reduced defilade or no exposure to a prone or moving posture.

E. FIRE UNIT TARGET ACQUISITION AND FIRE DOCTRINE

In the GCC Model, the acquisition of a target by a fire unit can occur through either of two distinct mechanisms. The first of these is characterized by an active search for targets on the part of the fire unit. The second mechanism is essentially passive, the fire unit detecting an enemy fire unit as a result of receiving fire from that enemy.

"Active" Target Acquisition

Every fire unit is assigned one of three possible fire doctrines (F.D.) describing the target acquisition means which the fire unit will actively employ and also describing the manner in which the fire unit will conduct its fire after acquiring a target. The three fire doctrines reflect an assignment to a fire unit of a point fire mission (F.D. 1 and F.D. 2), firing only at confirmed priority targets, or an area fire mission (F.D. 3), firing at probable target locations. The conduct of subsequent fire corresponding to each fire doctrine is as follows: fire a total of "N" bursts from the fire unit's primary weapon(s) and then select a new target fire unit (F.D. 1), fire at the target fire unit until a verified kill occurs (F.D. 2), or fire a total of "M" bursts from the fire unit's primary weapon(s) and then select another probable target location to which the fire will be shifted (F.D. 3). Throughout the engagement, a fire unit employs the same fire doctrine (that is, the smae target acquisition and conduct of fire doctrines) that was assigned to it at the beginning of the engagement.

The assignment of a point fire mission (F.D. 1 or F.D. 2) can be made either to an attacker or a defender fire unit. This mission requires a fire unit to fire only at enemy fire units which have been detected and subsequently identified as being priority target types. In the case of a defender fire unit or the case of an attacker fire unit which has not penetrated within the "free for all" range from the defensive position, the way in which the target fire unit is selected differs as a function of the assigned target selection (T.S.) option. If T.S. option "0" was assigned, the fire unit will first attempt to detect the enemy fire units on the nearest of the three opposite defensive lines/attacker waves (as appropriate) before attempting to detect enemy fire units from the other two. If T.S. option "1" was assigned, no such preference is given to the enemy fire units on one line/wave over those on the other of the three lines/waves. In the case of an attacker fire unit which has penetrated to within the "free for all" range of the defensive position, the fire unit attempts to select a target from any of the 12 defensive lines. The detection and identification of an enemy fire unit on an appropriate line/wave is then determined by a Monte Carlo assessment procedure utilizing probabilities which are a function of the enemy fire unit's type. Target selection from among the detected and identified enemy fire units is then done utilizing a set of priorities ranking enemy fire unit types with respect to their desirability as targets. The fire unit selected as a target is the one having the highest priority.

The assignment of an area fire mission (F.D. 3) is made only to attacker fire units. This mission allows the fire unit to fire into an area which is likely to be occupied by an enemy fire unit. A positive detection and identification of a target fire unit thus need not be made. A randomly selected defender fire unit from within the area is selected to receive the fire. In the case of an attacker fire unit which has not penetrated within the "free for all" range, the selection of the target is done randomly from the defender fire units on the three opposite defensive lines. In the case of a fire unit which has reached this range, selection of a target is done randomly from all 12 defensive lines. Note that the case where a fire unit expends ammunition into an unoccupied area does not occur in the existing assessment procedure. This is recognized as an area for model improvement.

"Passive" Target Acquisition

The second distinct mechanism by which a fire unit may acquire a target comes into play when the fire unit receives fire from an enemy fire unit. If the fire unit has no target at the time it receives this fire, the enemy fire unit is considered as a candidate for a target. If the enemy fire unit is within range of either the primary or secondary weapons of the detecting fire unit, a Monte Carlo assessment determines if the enemy fire unit is located and identified. If the enemy is detected and has nonzero priority, it is selected as a target and will be fired upon after the suppression delay, which resulted from the enemy's fire, expires.

Upon penetration of an attacker fire unit to within the "free for all" range of the terrain feature, the attacker fire unit will acquire targets from among the defender fire units on all 12 defensive lines. Note that defender fire units which are in different sectors of the terrain feature than the penetrating attacker fire unit can only acquire the attacker as a target after first coming under his fire.

F. THE FIRING CYCLE

The conduct of fire for a single fire unit is determined by the target acquisition means, fire doctrine, and weapons' characteristics which are appropriate to the particular fire unit. These factors cause the fires of the fire unit to follow a distinct pattern, called the <u>firing cycle</u> of the fire unit. The firing cycle commences with the acquisition of a target fire unit and terminates when criteria specified in the applicable fire doctrine have been satisfied.

The acquisition of a target is accompanied by a time delay of A seconds, after which the fire unit may commence fire with its P primary and S secondary weapons. Associated with both the primary and secondary weapon types is the number of rounds per burst (R_p and R_s, respectively) and the delay in seconds between consecutive bursts of fire (D_p and D_s). The fire unit continues to fire until it either expends a total of N bursts from its P primary weapons (F.D. 1 or F.D. 3) or attains a verified kill (F.D. 2).

The firing cycle for a fire unit having either F.D. 1 or F.D. 3 will be completed in the time

$$T = A + (N^* - 1)D_p$$

seconds, where N^* is the least integer greater than or equal to N/P. The expression given above for the length of the firing cycle assumes that the firer will not himself be suppressed or sustain attrition. Thus T is actually a lower limit to the length of the firing cycle. During the firing cycle of length T seconds, the P primary weapons of the fire unit will expend N^* bursts each, for a total of N^*P bursts. During the same interval of time, a single secondary weapon will expend M^* bursts of fire, where M^* is the greatest integer which is less than or equal to $(T-A)/D_s + 1$. (A primary or secondary weapon will only fire during the last (T-A) seconds of the firing cycle. In the case of a secondary weapon which has a delay between bursts of D_s seconds, it will fire one more than $(T-A)/D_s$ bursts.) The S secondary weapons of the fire unit will expend a total of M^*S bursts during the firing cycle of length T seconds.

An approximation to the rate of fire of a single primary weapon is

$$\frac{60\ N^* R_p}{T}$$

rounds per minute. Similarly, an approximation to the rate of fire of a single secondary weapon is

$$\frac{60\ M^* R_s}{T}$$

rounds per minute. Again, these two expressions are based on the assumptions that the firer will not himself be suppressed or sustain attrition. Thus $(60\ \hat{N} R_p)/T$ and $(60\ \hat{M} R_s)/T$ represent upper limits to the rates of fire which can be attained by a primary and a secondary weapon, respectively. These numbers can be interpreted to be the analog in the GCC Model of the cyclic rate of fire of a weapon.

G. CLOSE COMBAT WEAPONS ASSESSMENTS

The fire of close combat weapons is treated in units of bursts for the purpose of simulating the internal fire coordination of a fire unit. However, the assessment of the lethal effects of close combat weapons fire is done for each individual round of a burst. The placement of the rounds of a burst on the target fire unit is accomplished by a Monte Carlo procedure utilizing a weapon dispersion which is taken to include both ballistic and aiming error. The impact points of the individual rounds of a burst are thus assumed to be independent of one another in their distribution about the center of the target fire unit. The assessment of close combat weapons fire which follows this placement of the rounds on the target differs as the individual rounds require an area fire (fragmentation) or a point fire (nonfragmentation) assessment. The terminology "area fire" and "point fire" as used here refers to the lethal characteristics of an individual projectile and should not be confused with the similar terminology used in paragraph E. to describe fire doctrine.

Area fire assessment for a fragmenting round uses a lethal area type assessment procedure. A circular lethal area is centered upon the point of impact of the round. The size of this lethal area is a function of both the weapon type and the target fire unit type. The area of overlap of this lethal area and the (circular) fire unit area of occupation is computed, and the ratio of the area of overlap to the area of occupation is used as a probability of hit on the fire unit. If the target fire unit is an infantry target type, each individual of the fire unit is examined to see if he is a casualty. That is, for each individual, a Monte Carlo procedure utilizing the probability of a fire unit hit determines if the individual is hit (becomes a casualty). If the target fire unit is a vehicle target type, a Monte Carlo process using the probability of a fire unit hit determines if the single vehicle of the fire unit is hit (killed). Given a hit, all the personnel of the vehicle fire unit are assumed to become casualties.

Point fire assessment for a nonfragmenting round utilizes a vertical presentation or silhouette for the target fire unit. A round is required to intersect this presentation to result in a hit. If the fire unit is an infantry target type, this presentation is a composite of the presentations of its individuals. A hit on an infantry fire unit results in a single individual becoming a casualty. If the target fire unit is a vehicle type, a hit results in the evaluation of a conditional kill probability by a Monte Carlo technique. This conditional kill probability is a function of the weapon type firing and the vehicle type. Given a vehicle kill, all personnel of the fire unit become casualties.

The casualties resulting from the assessment of a round by either the area fire or point fire assessment methods are treated individually to determine the wound location (head/neck, thorax, abdomen, lower extremity, upper extremity) and to determine if the casualty is a KIA (killed in action), WIA (wounded in action) - litter borne, or WIA-walking. Such a detailed classification of casualties is performed for two purposes. The first of these is to determine the effect the casualty will have on the fire-fight engagement. A casualty could, depending upon the severity of his wound, continue to participate in the engagement with reduced effectiveness or, at the other extreme, other combatants might be required to drop out of the engagement to tend the casualty. Note that these two effects of a casualty are not at present treated in the model. This is recognized as an area for model improvement. The second purpose of such a detailed classification of casualties is to reflect the degree of logistical support required by a combating game unit in the form of casualty evacuation needs.

As examples of the application of the area fire and point fire assessments of individual projectiles fired at target fire units, we have the following: (1) armored vehicles, such as a tank, will in general be coded as "vehicle" fire unit types, and rounds fired at these fire units assessed by the point fire method utilizing a conditional kill probability. (2) Exposed personnel, such as a fire team or M60 machine gun team, are coded as "infantry" fire unit types, and rounds fired at these fire units may be assessed by either the point fire or area fire methods, as appropriate to the ordnance type. (3) The case of open vehicles, such as the half-track, armored personnel carrier (APC), or the "mule," have some of the characteristics of both a vehicle and exposed personnel targets. It is suggested that these fire units should be coded as "infantry," and rounds fired at these be assessed by either the point fire or area fire assessment method, as appropriate. Note that the combination of a "vehicle" fire unit type and the area fire assessment method does not occur.

H. DISENGAGEMENT

The termination of the fire-fight engagement, like the initiation of the engagement, is a result of command and control functions which are treated at the game unit level of resolution. An individual game unit, either an attacker or defender, may withdraw when such criteria as cummulative casualties, degree of coordination with friendly units, time factors, or enemy threat reach preassigned levels. If no game unit withdraws, the termination of the engagement is decided by the total attrition of either the attacking game unit(s) or the defending game unit(s).

The decision to withdraw on the part of a game unit is not evaluated in terms of the ability of the game unit to execute a successful withdrawal. This decision is based only on criteria provided on input to the model (that is, criteria determined prior to the commencement of the engagement). This is another area of the model which is recognized as a possible area for improvement.

APPENDIX I

ASSESSMENT OF NONFRAGMENTING PROJECTILES IN THE FIRE-FIGHT

A. INTRODUCTION

The lethal effects of a projectile are determined by the point fire assessment method if the projectile must strike the presentation offered by a target to produce any casualty. The projectiles which satisfy this definition are nonfragmenting. For example, the point fire assessment method could be used to assess the results of the fire of an M14 rifle against an exposed personnel target, or of a HEAT (high explosive, anti-tank) round fired by an M48 tank against another armored vehicle.

The terminology "point fire" used in this context has no association with the means used to acquire and identify the target. It is intended purely to describe the casualty producing characteristics of one projectile type fired against one particular target type.

The point fire assessment method is a round-by-round assessment. It employs randomization and so is classed as a Monte Carlo technique.

B. INPUT PARAMETERS AND BASIC ASSUMPTIONS

The fundamental parameters which are required model inputs differ as the target fire unit is an infantry or a vehicle fire unit. The case of the infantry target fire unit requires the following parameters:

(1) h_1 and w_1, the height and width of an individual's standing presentation (inches).

(2) h_2 and w_2 the height and width of an individual's prone presentation (inches).

(3) h_3 and w_3, the height and width of an individual's reduced defilade presentation (inches).

(4) σ_x and σ_y, the horizontal and vertical standard deviations of projectile delivery error (mils).

The assessment for the case of a vehicle target fire unit requires the following parameters:

(5) H_1 and W_1, the height and width of a vehicle's exposed presentation (feet).

(6) H_2 and W_2, the height and width of a vehicle's defilade presentation (feet).

(7) σ_x and σ_y, the horizontal and vertical standard deviations of projectile delivery error (mils).

(8) P, the conditional kill probability of the vehicle when hit by a single projectile.

An infantry target fire unit is given a presentation which is a composite of the presentations taken by its N individuals. This presentation is computed as a function of the activity of the target fire unit at the time of the assessment. The resulting fire unit presentation may be "T" shaped (Figure 7 (i), n standing and m prone individuals with n + m = N), it may be rectangular (Figure 7 (ii), all N individuals standing, all prone, or all reduced defilade), or the fire unit may have no exposure (all N individuals have no exposure). Note that, in forming these composite presentations, the lateral spacing between individuals of the target fire unit is assumed to be negligible.

A vehicle target fire unit consists of a single vehicle by definition. It is given a rectangular presentation (Figure 7 (iii)) appropriate to the degree of exposure, either fully exposed or reduced defilade. Note that "no exposure" is not considered as a possible degree of exposure for a vehicle (unless, of course, H_2 and W_2 are artifically provided as input with values of zero).

The exposures given both individuals and vehicles must be viewed as mean exposures, in the sense of a mean over the possible aspects which might be presented to a firer.

The location of the aim point (A.P.) is assumed to be a function of target shape, and specifically the aim point is assumed to be taken as indicated in Figure 7. That is, the aim point is the <u>point in space</u> defined, relative to the target fire unit's location at the time of firing, as indicated in the figure.

The projectile delivery error, also called the projectile dispersion, is assumed to include both weapon aiming error and ballistic error. The projectile delivery error is assumed to have a bivariate normal distribution, with variances σ_x^2 and σ_y^2, taken about the aim point.

The projectile time of flight is assumed to be negligible. This is reasonable for those weapons considered in the point fire assessment, as these have high projectile velocities compared with firer-to-target ranges which occur during the fire-fight. As a consequence, the target fire unit cannot move a significant distance between the time of fire and the time of impact. Hence, the projectile delivery error has a bivariate normal distribution about the point, relative to the target fire unit's location at the <u>time of impact</u>, indicated in Figure 7. The mechanics of the point fire assessment are simplified as a result.

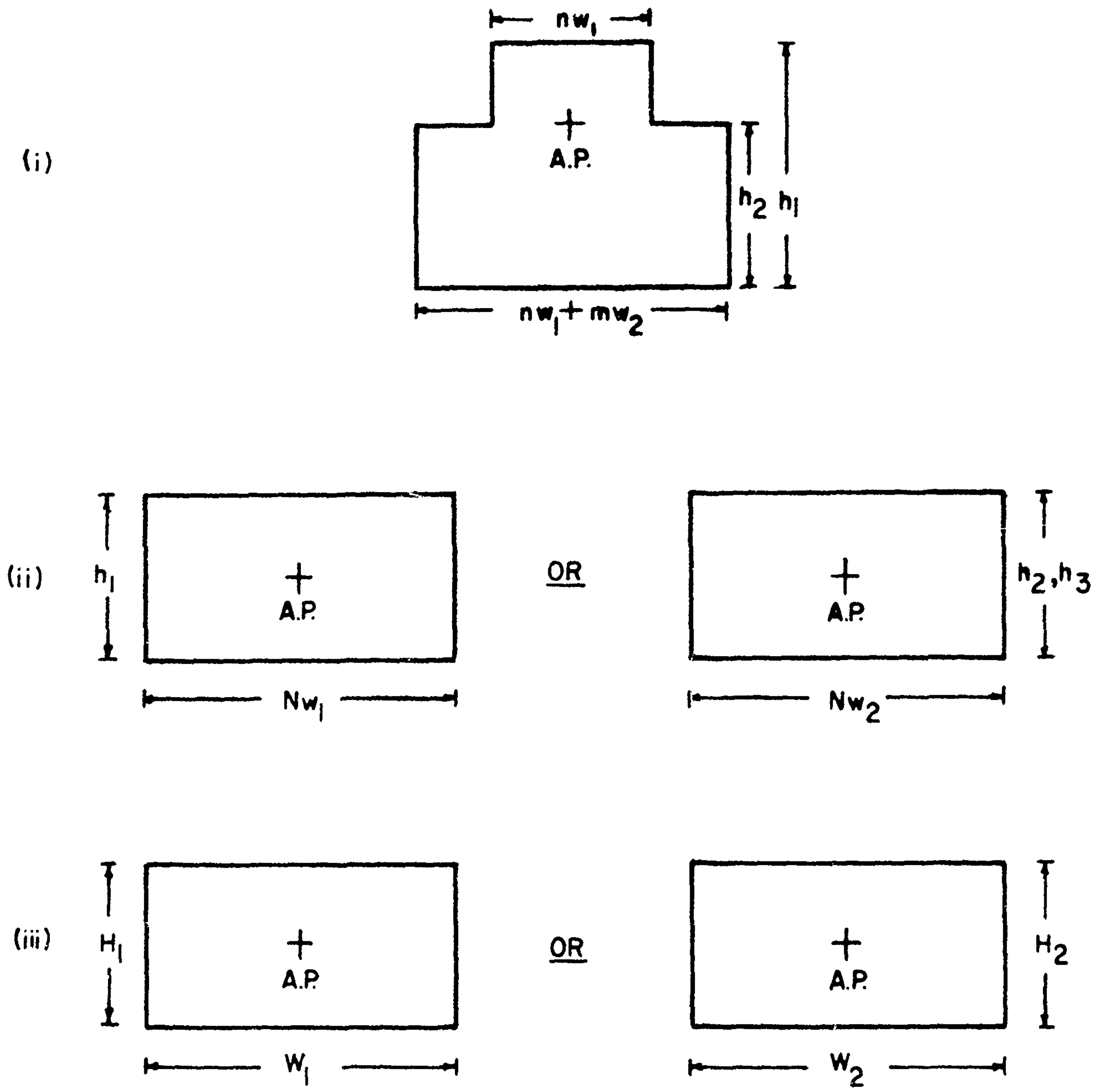

Figure 7

Presentations, aim points considered by the point fire assessment.

It is important to note that projectiles which are fired consecutively from a weapon are treated independently in the assessment of their impact points relative to the target. This assumption of round-by-round independence is admittedly a poor one for weapons which fire bursts of two or more rounds. Experimental evidence indicates a high degree of correlation between the impact points of the rounds of such a burst.

C. THE HORIZONTAL AND VERTICAL MISS DISTANCES

For each nonfragmenting projectile fired during the fire-fight, the horizontal and vertical miss distances D_x and D_y are derived for use in the point fire assessment.

The delivery error is first converted from mils to feet using the range R between firer and target:

$$s_x = R \tan (2\pi\sigma_x/6400)$$

$$s_y = R \tan (2\pi\sigma_y/6400)$$

Note that R is a dynamic parameter within the close combat engagement, and as such, it is generated within the model.

The horizontal and vertical miss distances, relative to the aim point, are then given by

$$D_x = | N_x s_x |,$$

$$D_y = | N_y s_y |,$$

where N_x and N_y are random numbers drawn from the normal distribution N(0,1) having mean 0 and variance 1. The point fire assessment thus uses a Monte Carlo technique to place rounds individually about the target.

D. ASSESSMENT OF A HIT

A nonfragmenting projectile is said to hit the target fire unit when the random placement of the projectile results in its striking the target presentation. There are three cases to be considered, based on the type of target presentation:

(i) No exposure,

(ii) Rectangular presentation,

(iii) T-shaped presentation.

There can be no hit in case (i). For case (ii), a hit will occur if

$$D_x \le \frac{W}{2} \quad \text{and} \quad D_y \le \frac{H}{2}$$

are satisfied (where H is the height and W is the width of the target fire unit). For case (iii), a hit will occur if

$$N_y < 0, \; D_x \le \left(\frac{nw_1 + mw_2}{2} \right), \; D_y \le h_2$$

are satisfied, or if

$$N_y \ge 0, \; D_x \le nw_1, \; D_y \le (h_1 - h_2),$$

are satisfied (where n, m, h_1, w_1, h_2, w_2 are as in paragraph B).

E. ASSESSMENT OF A CASUALTY

If a hit occurs, the determination of the number of casualties resulting from the hit is a function of the type of target fire unit. If it is an infantry fire unit, a single casualty is assessed. If it is a vehicle fire unit, a Monte Carlo assessment is performed using the conditional kill probability P; the occurrence of a kill means that each individual is a casualty, whereas the nonoccurence means that no casualties result from the hit.

To each resulting casualty, another Monte Carlo assessment is performed to classify the casualty as to wound location (head/neck, thorax, abdomen, lower extremity, upper extremity) and as to KIA, WIA-litter borne, or WIA-walking. The classification into one of the last three categories is treated as being conditional upon the wound location.

A vehicle target fire unit is, thus, either unchanged or totally attrited after the assessment of a nonfragmenting projectile. An attrited vehicle has no further influence on the course of the engagement.

The results of the assessment of a nonfragmenting projectile on the subsequent status of an infantry target fire unit are somewhat more varied. In general, the occurence of a casualty results in the strength of the fire unit being reduced by one, and the presentation of the fire unit (a composite of the presentations of its individuals) will be reduced accordingly. A special case occurs for weapons firing bursts of two or more projectiles simultaneously, rather than firing projectiles singly.

As mentioned in paragraph B, the presentation of the target fire unit is initially computed as a function of its current activity. Since the activity of the target cannot change during the assessment of a burst, the presentation is not recomputed for the assessment of projectiles subsequent to the first within a burst. If a casualty occurs due to one projectile of such a burst, the composite presentation is reduced by the amount contributed by the particular individual hit for the assessment of subsequent projectiles of the burst.

F. SUMMARY

The validity of the point fire assessment method naturally hinges upon the degree to which the basic assumptions are justified. Several specific assumptions are common to the point fire and area fire assessment methods. (The latter is described in Appendix II.) One of these is the assumption of negligible projectile time of flight. This is considered to be a sound assumption for the weapons assessed by the point fire method. A second assumption common to the point fire and area fire assessment methods is that of round-by-round independence with respect to impact points about the target. This is seen to be a poor assumption for those weapons assessed by the point fire method which fire bursts of projectiles.

The point fire assessment employs Monte Carlo techniques at three points. The first use of randomization is the placement of individual projectiles about the target, and the second is the evaluation of conditional kill given a hit for vehicle targets. Both of these are viewed as sound probabilistic techniques, largely because of the many projectiles which will be fired during a fire-fight. The third use of Monte Carlo is in the classification of resulting casualties by wound location and KIA/WIA status. This use of randomization presently can have no impact upon the engagement itself since the assessment is performed after the fact of the occurrence of a casualty. (Presently, an individual is removed from the engagement at the time he becomes a casualty.) There are indications of a need to modify the model to allow some WIA's to remain in the engagement, in which case this Monte Carlo casualty classification will have direct impact on the engagement.

APPENDIX II

ASSESSMENT OF FRAGMENTING PROJECTILES IN THE FIRE-FIGHT

A. INTRODUCTION

The lethal effects of fragmenting projectiles fired during the fire-fight are assessed by the area fire assessment method. In this assessment, individual projectiles are characterized by a circle of lethality (also called a mean area of effects), interpreted as a measure of the casualty producing effects of the fragmentation pattern. The area fire assessment method could be used, for example, to assess the results of the fire of an M79 grenade launcher or of a "cannister" round fired by an M48 tank against a personnel target.

As with the point fire assessment method (Appendix I), the area fire assessment method is intended only to assess projectiles fired in a nearly horizontal trajectory. (Indirect fire weapons, such as artillery, are treated in a separate assessment.) However, the definition of the area fire assessment can be broadly interpreted to include indirect fire weapons, such as the 60mm mortar, which would be employed during the fire-fight against specific target fire units. (In contrast, the usual artillery assessment has game units as targets.)

The area fire assessment method is a round-by-round assessment. Randomization is employed, and so this is classified as a Monte Carlo technique.

B. INPUT PARAMETERS AND BASIC ASSUMPTIONS

The fundamental parameters which must be provided as inputs to the model are the following:

(1) r_w, the radius of weapon lethality (feet).

(2) r_t, the radius of occupation of the target fire unit (feet).

(3) σ_x and σ_y, the horizontal and vertical standard deviations of projectile delivery error (mils).

The radius of lethality r_w is defined to be the distance from the point of impact within which individuals will become casualties due to the fragmentation or other effects of the projectile.

The target fire unit may be either infantry or a vehicle. In the case of infantry, the individuals of the fire unit are assumed to be uniformly distributed within the circle of radius r_t. If the target is a vehicle, the circle of radius r_t is intended to approximate the actual dimensions of the vehicle.

The projectile delivery error, also called the projectile dispersion, includes both weapon aiming error and ballistic error. The projectile delivery error is assumed to have a bivariate normal distribution, with variances σ_x^2 and σ_y^2, taken about the aim point. The aim point is the center of the target fire unit at the time of projectile firing. Considering the relationship between projectile velocities and firer-to-target ranges which occur in the fire-fight, the assumption of zero time of flight is reasonable. As a consequence, the location of the target fire unit at time of impact coincides with the aim point. This permits a simplification of the assessment technique, since the projectile delivery error then assumes a bivariate normal distribution about the center of the target fire unit (at the time of projectile impact).

The 60mm mortar is an example of an indirect fire weapon which could be assessed by the area fire method. In this case, the dispersions σ_x and σ_y are interpreted as dispersions in deflection and range, respectively. For indirect fire weapons larger than this, an analysis of the ranges over which they would be typically employed shows that the assumption of zero projectile time of flight will, in general, not hold. This is a prime factor against the assessment of these larger indirect fire weapons by the area fire method.

C. THE RADIAL MISS DISTANCE

For each fragmenting projectile fired during the close combat engagement, the radial miss distance D is derived for use in the area fire assessment.

The delivery error is first converted from mils to feet using the range R between firer and target:

$$s_1 = R \tan (2\pi\sigma_x/6400)$$

$$s_2 = R \tan (2\pi\sigma_y/6400)$$

Note that R is a dynamic parameter within the close combat engagement, and as such, it is generated within the model.

The radial miss distance is then given by

$$D = \sqrt{(N_1 s_1)^2 + (N_2 s_2)^2} ,$$

where N_1 and N_2 are random numbers drawn from the normal distribution N(0,1) having mean 0 and variance 1. Thus the area fire assessment uses a Monte Carlo technique to place rounds individually about the target.

D. ASSESSMENT OF A HIT

A hit on the target fire unit by a fragmenting projectile is taken to be synonymous with the fact that the target fire unit experiences sufficient fragmentation or other effects to cause at least one casualty. A hit then occurs when the point of impact of the projectile and the center of the target fire unit are in near proximity.

The measure of potential casualty producing effects taken here is the area of overlap of the circle representing the area of occupation of the target fire unit and the circle representing the area of lethality. The ratio of this overlap to the area of occupation is taken to be the probability p of a hit on the target fire unit.

Both for infantry and vehicle fire units, the comparison of a random number with probability p decides the occurence of a hit, and so this is a Monte Carlo technique.

The specific form of probability p is derived in paragraph E. The reader may skip this paragraph without loss of continuity.

E. DERIVATION OF THE HIT PROBABILITY

The computation of the ratio of the area of overlap to the area of occupation is considered for three cases, based on the relationship between parameters r_o, r_w, and D. (See Figure 8):

(i) $r_o + r_w \le D$,

(ii) $D \le |r_o - r_w|$,

(iii) $|r_o - r_w| < D < r_o + r_w$.

In case (i), there is no overlap of the area of occupation and the area of lethality, and so no hit can result (i.e., $p = 0$). On the other hand, in case (ii) the ratio of the area of overlap to the area of occupation is $F = (\pi r_w^2)/(\pi r_o^2)$, and so the probability p of a hit is given by $p = \min(1,F)$. It remains to consider case (iii).

Let θ_o and θ_w be the angles indicated in Figure 9. Then the area of overlap for case (iii) becomes

$$A = 2\left[\frac{\theta_o}{2\pi}\pi r_o^2 - \frac{r_o^2}{2}\sin\theta_o\cos\theta_o + \frac{\theta_w}{2\pi}\pi r_w^2 - \frac{r_w^2}{2}\sin\theta_w\cos\theta_w\right]$$

which simplifies to

$$(1)\quad A = r_o^2(\theta_o - \sin\theta_o\cos\theta_o) + r_w^2(\theta_w - \sin\theta_w\cos\theta_w).$$

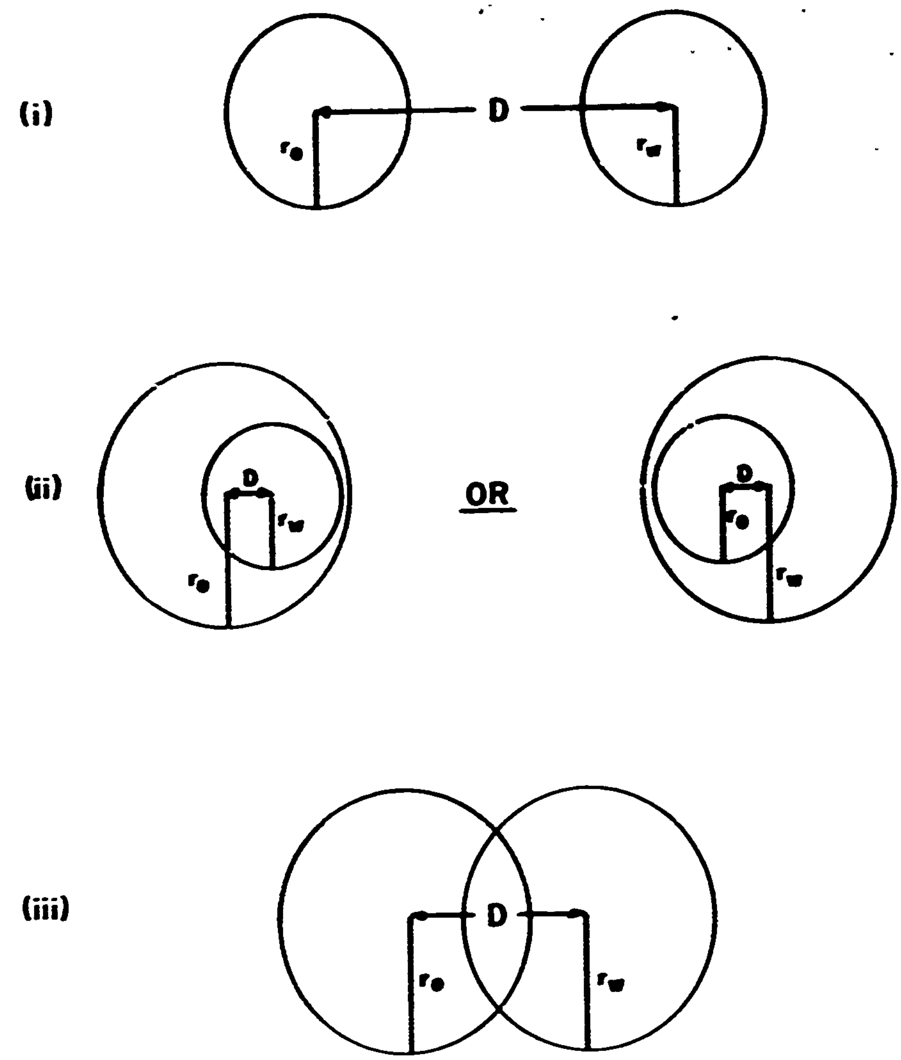

Figure 6

Cases considered by the lethal area assessment.

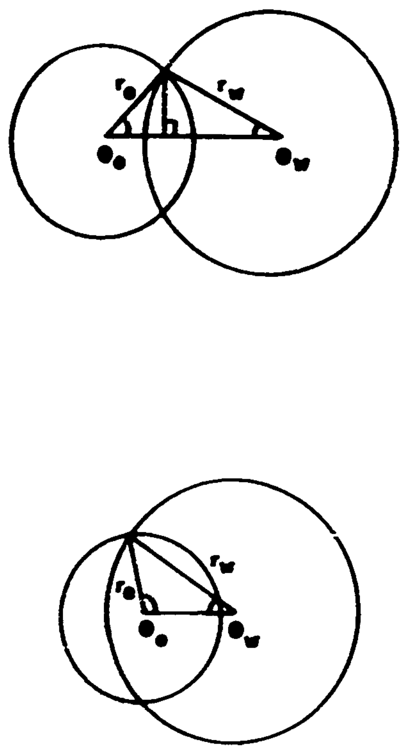

Figure 9

Definitions of θ_e, θ_w in case (iii)

The object is to solve for A in terms of parameters r_o, r_w, and D alone. By the trigonometric identities

$$r_w^2 = r_o^2 + D^2 - 2r_oD \cos \theta_o ,$$

$$r_o^2 = r_w^2 + D^2 - 2r_wD \cos \theta_w ,$$

cos θ_o and cosθ_w are expressed as

$$\cos \theta_o = \frac{D^2 + r_o^2 - r_w^2}{2r_oD}$$

$$\cos \theta_w = \frac{D^2 - r_o^2 + r_w^2}{2r_wD}$$

Observing that $0 \leq \theta_o \leq \pi$ and $0 \leq \theta_w \leq \pi$, since the cosine is a single valued function of these intervals,

(2)

$$\theta_o = \cos^{-1}\left[\frac{D^2 + r_o^2 - r_w^2}{2r_oD}\right]$$

$$\theta_w = \cos^{-1}\left[\frac{D^2 - r_o^2 + r_w^2}{2r_wD}\right]$$

Given θ_o, θ_w computed by (2), sin θ_o and sin θ_w are obtained directly. So equations (1) and (2) together give the desired expression for A in terms of r_o, r_w, and D.

For case (iii), the probability p is thus given by $p = A/(\pi r_o^2)$.

F. ASSESSMENT OF A CASUALTY

For a fire unit consisting of (exposed) personnel, it has been assumed, as already stated, that individuals are uniformly distributed within the area of occupation. Then p is simply the probability of finding a given individual in the area of overlap. The assessment procedure used in this case is to treat each individual separately, interpreting p to be the probability of an individual being hit, and hence, becoming a casualty.

In the case of a vehicle fire unit, the occurrence of a hit is taken to mean that every individual in the fire unit does become a casualty.

To each resulting casualty, a Monte Carlo assessment is performed to obtain the classification of the casualty as to wound location (head/neck, thorax, abdomen, lower extremity, upper extremity) and as to KIA, WIA-litter borne, or WIA-walking. The classification into one of the last three categories is treated as being conditional upon the determination of wound location. The probabilities used in this assessment are a function of weapon type for the case of an infantry target and a function of vehicle type for the case of a vehicle target.

An individual who becomes a casualty as the result of an area fire assessment is removed from the engagement at the time he becomes a casualty. The fire unit which suffers the casualty is treated, in subsequent assessments, as having one fewer individuals but having the same radius of occupation r_o.

G. SUMMARY

The validity of the area fire assessment method naturally hinges upon the degree to which the basic assumptions are justified. Of those assumptions common to the area fire and point fire assessment methods, the assumption of zero projectile time of flight is more critical in the case of the area fire assessment. Consequently, the class of weapons considered can only include selected indirect fire weapons. Another common assumption which takes on more significance in the case of the area fire assessment is the following: projectiles fired at a target are not considered relative to possible casualty producing effects to <u>other</u> targets in the vicinity of the impact point.

It is possible to make several statements about the degree to which the probabilistic methods employed are sound ones. Monte Carlo assessments are employed at three points: individual rounds are randomly placed about the target, the number of casualties is randomly determined using the hit probability p, and the individual casualties are randomly classified as to wound location and KIA-WIA status. In general, there are many rounds fired during an engagement, and so the random placement of rounds is viewed as being a sound technique. The same argument shows that the technique employing hit probability p will yield, in the long run, an acceptable level in the total number of hits to vehicle and personnel targets. Similarly, the method of classifying casualties by wound type and KIA-WIA status will yield in the long run (i.e., if a sufficiently large number of casualties occur) an acceptable distribution among the various categories. However, these last two Monte Carlo techniques, although accurate in the long run, may result in poor individual assessments.

As an example, consider the determination of the number of individuals hit in a personnel target, which employs the hit probability p. This has the disadvantage (common among Monte Carlo techniques sampling from the binomial distribution) of a high variance for an individual assessment. That is, the assessment of some individual projectiles may result in a number of casualties significantly higher (or lower) than the expected number Np of casualties, where N is the strength of the target fire unit. The acceptability of this Monte Carlo technique hinges upon the degree to which we require individual assessments to be accurate.

APPENDIX III

GEOMETRY OF THE FIRE-FIGHT

A. INTRODUCTION

The geometry of the fire-fight consists of those aspects of the simulation which define the spatial relationships between attacker and defender fire units. In short, the geometry consists of the target arrays presented by the attacker and defender units during close combat.

Primarily, the geometry of the fire-fight is used to determine the range between two fire units on the battlefield, which is required in the assessment of target acquisition and weapons' lethality. An important fact is that the fire-fight assessment does not employ a Cartesian or x-y coordinate system. At the time of deployment, the distance or range from the axis of the terrain feature to each fire unit in the deployed game unit is recorded. It is this range to the terrain feature which is updated as attacker fire units move. If the ranges from the terrain feature for two fire units in the same sector are r_i and r_j, the range between these two fire units is taken to be $|r_i - r_j|$. This simplified assessment of the ranges between fire units on the battlefield is certainly an important element in the fire-fight geometry. The validity of this assessment is discussed below (paragraph B.).

Because of attacker fire unit movement, the geometry of the fire-fight is dynamic. A discussion of the assessment of fire unit movement is, as a consequence, an integral part of any discussion of fire-fight geometry. The assessment of fire unit movement has additional importance through its link with aspects of terrain modeling such as the existence of line of sight, cover and concealment. The simulation of these is handled from a geometric viewpoint, where a change in the status of an individual fire unit or a change in the relationship between two fire units can occur as an attacker fire unit closes to within a specified range of the terrain feature. This is discussed below (paragraph C.).

The geometry of the fire-fight is also closely related to certain other assessments made in the GCC Model which are properly considered to be external to the fire-fight itself. Specifically, these external assessments have an interface with the fire-fight assessment, an interface which arises primarily in relation to fire-fight geometry (paragraph D.).

B. EVALUATION OF THE SIMPLIFIED RANGE COMPUTATION

The use of the simplified computation for firer-to-target ranges has a definite impact upon the course of the fire-fight. This is so because the assessment of a weapon's dispersion is treated as a function of range, and thus the weapon's lethality is directly affected. To estimate the degree of impact upon the fire-fight, a comparison must be made with a model in which the firer-to-target ranges are computed accurately using an x-y coordinate system.

For the purpose of this analysis, the situation of an attacker unit advancing against a defensive position was idealized as follows (Figure 10). The attacker and defender units are regarded as having fixed frontages throughout the engagement. These frontages are conceived as parallel straight lines along which elements of the attacker and defender units are uniformly distributed at any given time. An axis of symmetry is assumed to exist perpendicular to the fronts. Finally, the distance or range between the two fronts is allowed to vary during the engagement.

This model of an engagement readily yields an analysis of the error committed in approximating true range T between a firer and his target by range R between the two fronts. A Monte Carlo computation yields the true ranges T_i $(1 \le i \le N)$ between N firer-target combinations whose coordinates are randomly selected along the respective fronts. The expected range error in meters and in per cent are given by

$$E_1 = \frac{1}{N} \sum_{i=1}^{N} (T_i - R)$$

$$E_2 = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{T_i - R}{T_i} \right)$$

From either Appendix I or II, when the firer-to-target range is R, the dispersion in meters given to a weapon is R tan (φ), $\varphi = 2\pi\sigma/6400$. Since

$$\frac{T_i \tan \varphi - R \tan \varphi}{T_i \tan\varphi} = \frac{T_i - R}{T_i},$$

E_2 is also the expected per cent error in dispersion.

Three scenarios were considered: company attack vs. platoon defense, platoon vs. squad, and squad vs. fire team. The units involved in each scenario were assigned the frontages indicated in Table 1, which are regarded as typical for a frontal attack of an isolated defensive position [21]. At each of several typical engagement ranges, N = 100 observations were made to obtain the expected range error in meters (Table 2) and the expected percentage error in range and dispersion (Table 3). The data of Tables 2 and 3 is reported to two significant digits.

The results of this analysis have strong implications as to the game unit resolution which should be used when providing input to the GCC Model. For example, the platoon vs. squad fire-fight will have highly

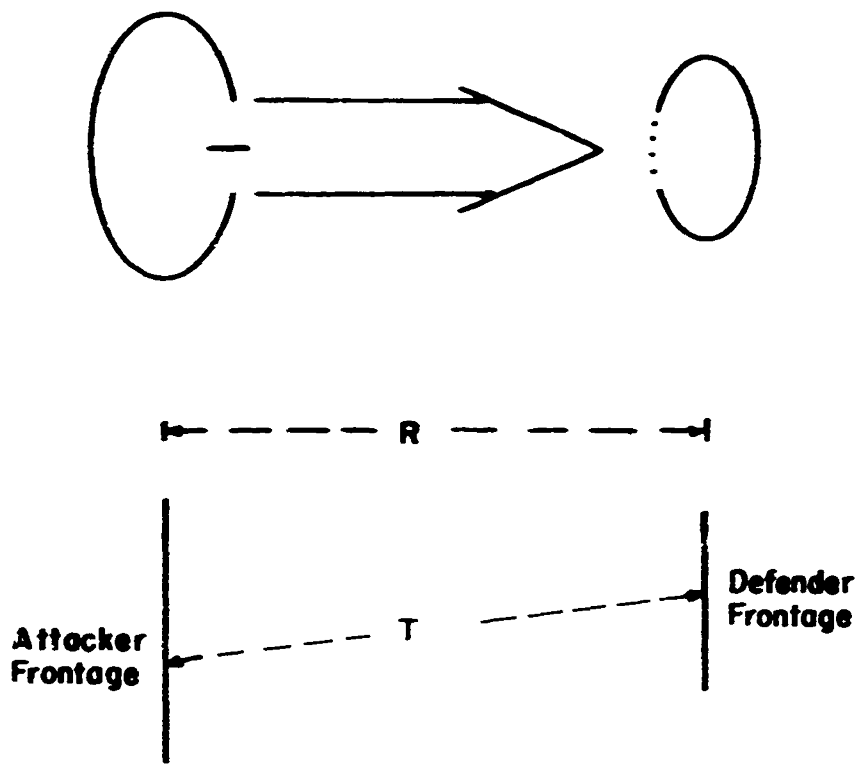

Figure 10

Idealization of the Fire-Fight

	Attacker	Defender
Company vs. Platoon	350	250
Platoon vs. Squad	150	75
Squad vs. Fire Team	35	20

TABLE 1.

Unit Frontage (Meters)

	Range R (Meters)				
	25	50	100	150	200
Company vs. Platoon	83.	77.	55.	41.	29.
Platoon vs. Squad	25.	18.	9.8	7.4	6.1
Squad vs. Fire Team	2.7	1.2	0.64	0.44	0.32

TABLE 2.

Expected Error In Range (Meters)

	Range R (Meters)				
	25	50	100	150	200
Company vs. Platoon	63.	49.	28.	18.	11.
Platoon vs. Squad	40.	23.	8.1	4.5	2.9
Squad vs. Fire Team	8.9	2.2	0.63	0.29	0.16

TABLE 3.

Expected Error in Range and Dispersion (%)

inaccurate individual assessments if the game units are designated as a platoon attacking and squad defending. On the other hand, accurate individual assessments can be obtained if the game units are designated as three squads attacking and a squad defending, provided that separate fire-fights are assessed for each of the zones of action assigned to the squads comprising the attacking platoon.

C. FIRE UNIT MOVEMENT AND FIRE-FIGHT GEOMETRY

The geometry of the fire-fight, the spatial relationships among the fire units engaged, is modified from the initial deployment as the fire-fight progresses due to the individual movement of attacker fire units toward the terrain feature under attack. As an attacker fire unit advances, its status as well as that of other fire units may be modified as a result of closing to within certain specified ranges of the terrain feature. These ranges, and the changes in fire unit status which occur at each range, are associated with specific aspects of terrain modeling and of military doctrine pertaining to the conduct of an attack or defense.

The fire-fight assessment begins at the time the decision to attack is made. At this time the attacking unit and defending unit(s) are assessed as being deployed. However, actual fire may not be exchanged between an attacker fire unit and defender fire unit(s) until the attacker fire unit moves to within the "opening engagement range." The pertinent input parameters here are the following:

(1) m, fire unit movement rate (meters/minute).

(2) R_o, opening engagement range (meters).

The (attacker) fire unit movement rate is a function of fire unit type. The opening engagement range is a function of the sector of the particular terrain feature under attack. As a consequence, fire units in the same or different sectors need not meet this opening engagement range criterion at the same time. On the other hand, the opening engagement ranges may be set artifically high so that at the time of deployment all fire units satisfy the criterion. This opening engagement range is intended to simulate aspects of line of sight, where typically an attacker force deploys at a line of departure which is shielded from observation and direct fire of the enemy.

Once within the opening engagement range, an attacker fire unit can acquire and be acquired by defender fire units according to the applicable target acquisition means and doctrines. However, fire may not commence until the computed range between firer and target fire units is within a "maximum weapon firing range." After an attacker fire unit is within the firing range of the defender, he sustains a delay to his movement for each burst of fire received. The input parameters which apply are:

(3) R_w, maximum weapon firing range (meters).

(4) t_w, suppression delay per burst (seconds).

Both parameters R_w and t_w are a function of the weapon type firing. Hence, attacker fire units will, in general, open fire on or come under fire from the defender fire units at different times, and the movement of attacker fire units may be delayed by suppressions of differing duration. The maximum firing range is intended to simulate aspects of doctrine and is not purely a weapon characteristic. For example, the organization of a defensive position may dictate that fire be withheld until the attacker attains a certain degree of penetration. On the other hand, the maximum firing range could be set artifically high so that fire would commence based only on an attacker fire unit penetrating the opening engagement range.

The employment of a base of fire by the attacking game unit is determined by an allocation, on input, of a certain number and type of fire units to be in this role. Such fire units move only to within a specified employment range from the terrain feature under attack:

(5) R_b, base of fire employment range (meters).

The range R_b is a function of fire unit type only. In this sense, these parameters are independent of the particular terrain feature under attack, and, since they apply to any engagement in which the particular fire unit type might participate, are categorized as Standard Operating Procedures (SOP's). Note that if a particular fire unit has a base of fire range R_b greater than the opening engagement range R_o, it actually moves to range R_o before laying down its base of fire. In this manner the distance separating base of fire and defender can be made to depend entirely upon the particular terrain feature, say by providing ranges R_b on input as having artifically high values.

Three other ranges are considered relative to the movement of an attacker fire unit. These are:

(6) R_i, intelligence update range (meters).

(7) R_f, free-for-all range (meters).

(8) R_m, minimum separation range (meters).

The range R_i is discussed in paragraph D of this Appendix. Penetration of an attacker fire unit to within range R_f of the terrain feature allows him to acquire as a target and be acquired by any defender fire unit, irregardless of the sector in which the defender fire unit is deployed. At the minimum separation range R_m, the attacker fire unit's advance is stopped and he is thereafter treated as having a degree of exposure associated with a defensive posture. Both the free-for-all and minimum separation ranges are intended to simulate aspects of terrain associated with proximity to the defensive position: line of sight over the entire defensive position in the first case, and a close-in barrier or obstacle (as a tank ditch) in the second case. These input parameters are required to satisfy $R_i > R_f \geq R_m$ if all three ranges are to be utilized in the fire-fight assessment.

The ranges R_o, R_w, R_b, R_f, and R_m, through their interaction with fire unit movement, are important factors in determining the spatial relationships among the engaged fire units. The aspects of terrain modeling and of military doctrine which these ranges reflect are certainly as important to an accurate simulation of a fire-fight as are the aspects of weapon lethality discussed in Appendices I and II.

D. EXTERNAL ASSESSMENTS AND FIRE-FIGHT GEOMETRY

As has already been noted, the fire-fight assessment has an interface with the portion of the model which assesses the command and control function. Specifically, the fire-fight assessment is performed only from the time at which the command decision is made to engage an enemy unit in close combat to the time at which the command decision to disengage is made by one of the engaged units. This delineates the time frame over which the fire-fight assessment is performed for a given combination of attacking and defending game units. Further, this interface is closely involved with fire-fight geometry because it is the command decision to engage an enemy unit which results in the assessment of a deployment to the attacking unit and the defending unit(s). This deployment assessment determines the initial geometry of the fire-fight.

The fire-fight assessment has an interface with the assessment of intelligence or information acquisition, an interface which is a consequence of the fire unit movement of the attacking unit(s). A specified distance, the intelligence update range R_i, is employed as follows: at the first time a fire unit from an attacker game unit crosses this range, as measured from the terrain feature under attack, an assessment is performed to improve the information held by the attacker unit on the defending unit(s) and to improve the information held by defending unit(s) on this particular attacking unit.

A third interface, that of the fire-fight assessment with the assessment of supporting arms fires, can be considered in terms of fire-fight geometry. A brief description of the assessment of supporting arms fires is given first.

Target acquisition and fire control for supporting arms are simulated only at the game unit level. The aim point for supporting arms fire is the estimated center of the target game unit. Placement of individual ordnances on the target is accomplished by a Monte Carlo procedure utilizing weapon dispersion (in range and deflection) about the aim point. For each ordnance delivered, a rectangular MAE is centered at the hit point. The cumulative coverage (neglecting overlap) of the game unit's rectangular area of occupation by these MAE's then determines the percentage of the game unit's personnel which are attrited by the fire. As a game unit sustains casualties from supporting arms fire, the casualties are subtracted from the strength of the fire units comprising the game unit. This is accomplished by selecting randomly the fire units to be attrited, a single casualty being assessed to each fire unit thus selected until the total number of casualties received by the game unit have been assigned.

For units engaged in a fire-fight, this assessment of supporting arms fire is notable for the fact that fire-fight geometry, the spatial relations between the fire units comprising the game unit, is ignored. The assumption is implicitly made that a detailed assessment, reflecting accurately the location of fire units relative to the ordnance impact points, is not necessary. It is also assumed that the existing assessment method which ignores fire-fight geometry is a reasonable aggregation. These assumptions require verification, however.

The supporting arms assessment has a direct impact on the fire-fight beyond these casualty producing effects. A suppressive delay is assessed to those fire units receiving a casualty, and the fire-fight geometry is affected through the impact of this suppression on fire unit movement.

APPENDIX IV

THE FIRE-FIGHT SUBMODEL

A. INTRODUCTION

The Fire-Fight Submodel is that portion of the Ground Combat Confrontation (GCC) Model which actually performs the assessment of the fire-fight or close combat engagement. Broadly, this consists of the following logical components of the GCC Model: Event 7 (Engagement Fire Direction), Event 13 (Engagement Assessment), Assessment Posting Subroutine, Current Position Subroutine, and the Suppressive Effects Subroutine. The terms "engagement" and "engagement assessment" appearing in this context refer to the close combat engagement and the assessment of the fires from individual, crew-served, tank and antitank weapons as normally employed in close combat. Deliberately excluded are artillery and other supporting arms.

The GCC Model logic which is complementary to the Fire-Fight Submodel will be referred to as the External Game. Interactions between the Submodel and the External Game do exist. These interactions are causal in nature since the external assessments provide inputs to the fire-fight assessment, and conversely. In fact, the External Game provides the command decisions which determine the time and circumstances under which the fire-fight will commence and terminate.

The Fire-Fight Submodel can be treated as an assessment tool independent of the External Game. This is the fact which motivates the use of the terminology "Fire-Fight Submodel." This treatment of the Fire-Fight Submodel as an independent model is possible since any inputs to the Fire-Fight Submodel which are derived from the External Game can in principle be provided directly as input by the user. That is, the assessments performed by the External Game can be suppressed, and manual assessments substituted in their place. In this way the user can have complete control over the circumstances in which the fire-fight assessment is to be performed.

It is assumed in the sequel that the reader is familiar with the principles of an event-store simulation. The essential logical structure of the components of the Fire-Fight Submodel is briefly outlined (paragraph B.). A complete description of this logic is found in the GCC Model Flow Charts [2]. Specific inputs and outputs transferred between the External Game and the Fire-Fight Submodel and between the components of the Fire-Fight Submodel are listed (paragraph C.).

An "input" to an assessment is defined, for our purposes here, as a parameter which is used within the assessment but which has been initialized or modified by some other previous assessment. An "output" from an assessment is a parameter which is initialized or modified during the course of the assessment but which is used by another assessment performed later. The definitions of an input and an output are not mutually exclusive, and some parameters will fall into both categories. This discussion of inputs and outputs will not refer to the detailed GCC Model Tables [2], but rather will classify these parameters into broad categories.

B. COMPONENTS OF THE FIRE-FIGHT SUBMODEL

The logic of the fire-fight assessment is formally subdivided into three components: Event 7, Event 13, and the Assessment Posting Subroutine. The Current Position Subroutine is incidental to Event 7 logic, and as such is considered here to be a part of Event 7. Similarly, the Suppressive Effects Subroutine is considered to be a part of Event 13 logic. Each of these three logical components of the fire-fight assessment will be discussed separately in terms of the functions performed and their sequencing.

Event 7

The combination Event 7/Current Position Subroutine performs the assessment of the deployment of a single game unit for combat. Also, for a unit already deployed and engaged, the receipt of fire from elements of an enemy unit which has not previously been detected results in the posting of a future event, Event 2 (Intelligence). This forms an interface between the Fire-Fight Submodel and the External Game. (The Event 2 will evaluate the receipt of this fire as being in fact a detection, and the enemy unit will be evaluated in terms of identification, possible threat, and other factors having an impact on game unit command and control.) Thus Event 7 performs the three functions of deploying an attacker game unit, deploying a defender unit, and processing a detection arising from the receipt of fire subsequent to the beginning of the engagement. These three logical functions are outlined separately as follows.

Deployment of an Attacker Game Unit

1. Take under fire all enemy game units which are current contacts. Post an Event 7 for each such unit.

2. Select a deployment option.

3. Deploy the fire units to attacker waves and assign each fire unit a target selection (T.S.) doctrine, fire doctrine (F.D.) as specified by the deployment option.

4. Take the next event.

Deployment of a Defender Game Unit

1. If the attacking game unit is a current contact, go to step 2. Otherwise, post an Event 2 and an Event 7 for the defender game unit, take the next event.

2. Take the attacking game unit under fire.

3. Select a deployment option.

4. Deploy the fire units to defense lines and assign each fire unit a target selection doctrine, fire doctrine as specified by the deployment option.

5. Post an Event 7 for each game unit attached to the defender game unit.

6. Take the next event.

Receipt of Fire from a New Enemy

1. If the enemy game unit is a current contact, go to step 2. Otherwise, post an Event 2 and an Event 7 for the game unit, take the next event.

2. Take the enemy game unit under fire.

3. Take the next event.

Note that the Current Position Subroutine is used by Event 7 to obtain the grid coordinates of the center of the game unit being deployed at the time of its deployment.

Event 13

The combination Event 13/Suppressive Effects Subroutine performs the assessment of one minute of close combat between all game units which are deployed and engaged at the time the event occurs. The essential elements of Event 13 logic are outlined as follows.

1. Distribute any casualties sustained by a game unit from supporting arms to its constituent fire units. Assess appropriate suppressive effects.

2. Consider the fire-fight activities occurring during the minute in order of increasing time, as measured in seconds. Such activities are target acquisition and the effects of close combat weapons fires. Detailed consideration is given to the interaction of movement, suppression, and weapons' lethality.

3. Set an Event 7 for a game unit which is fired upon by elements of a game unit not previously detected.

4. Examine each attacker fire unit to see if its status should be updated as a consequence of its movement (Appendix III, C.). Indicate if an intelligence update will occur due to movement to within the appropriate range from the terrain feature.

5. Post an Event 13 for the next minute.

6. Take the next event.

Item 1. is an interface between the Fire-Fight Submodel and Event 15 (Supporting Arms Assessment) of the External Game. In the first minute of close combat for a game unit, this distribution of supporting arms casualties reflects all casualties sustained since the game unit was last in close combat. In minutes other than the first minute of close combat, these casualties are those resulting from supporting arms fires delivered during the last fire-fight interval.

The Suppressive Effects Subroutine assesses the delays to movement, in the case of an attacker fire unit, and the delays to the next-fire-time, in case of an attacker or defender fire unit, which result when the fire unit comes under fire.

Assessment Posting Subroutine

The Assessment Posting Subroutine, the third primary logical component of the fire-fight assessment, is called directly after each Event 13. This subroutine serves to update game unit related data to reflect the outcome of the last minute of close combat. For each game unit which sustained casualties during the minute, a future event, Event 1 (Action Selection), is posted to evaluate the implications of the casualties in terms of game unit command and control. If a game unit reaches 100% casualties as a result of the minute of close combat, a future event, Event 6 (Movement), is posted to update pertinent data describing this change in game unit status. This subroutine is seen to function primarily as an interface with the External Game. The essential elements of Assessment Posting Subroutine logic are performed in the following order.

1. Transmit the expenditure of critical ammunition and the number of casualties sustained during the minute of close combat to game unit tables.

2. Post an Event 6 for a game unit which has sustained 100% casualties.

3. Post an Event 1 for game units sustaining casualties.

4. If an intelligence update was indicated in Event 13 for a game unit about some enemy game unit, update the estimate of the enemy identity, echelon, and strength.

Future Events

The posting of future events relevant to the fire-fight assessment is summarized schematically in Figure 11. Two aspects of this schematic have not yet been explained. First, the initial Event 13 must be provided as input. Event 13 then posts itself to occur each minute thereafter.

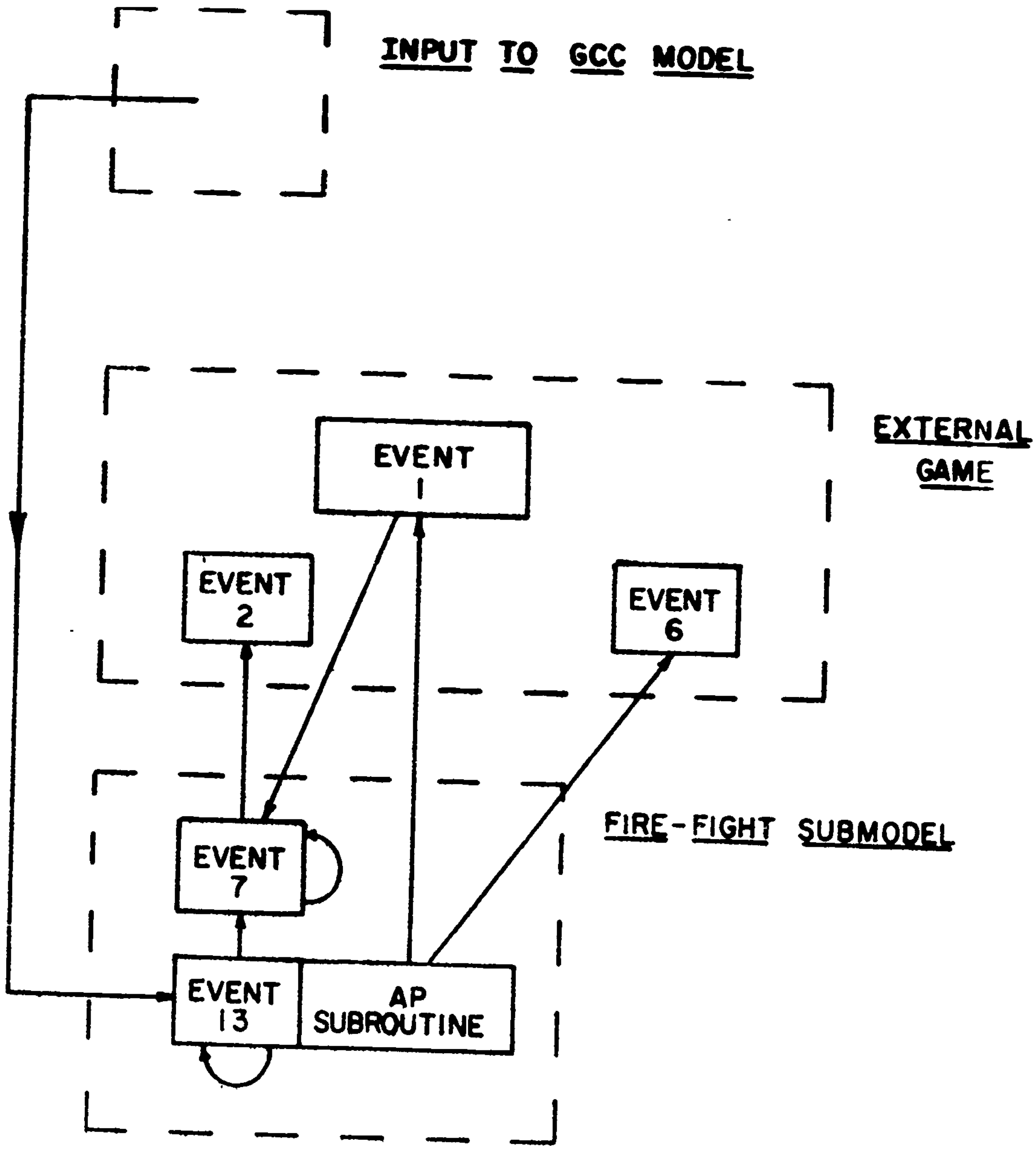

Figure II.

Posting of Future Events

Second, Event 1 (Action Selection) is the agent by which the fire-fight actually commences. At the time the command decision is reached for a game unit to attack, a future event, Event 7, is posted by Event 1 for the attacking game unit. Note that this Event 7 could be provided directly on input, thus dispensing with this use of Event 1.

C. FIRE-FIGHT SUBMODEL INPUTS AND OUTPUTS

The parameters required as input data to the Fire-Fight Submodel are derived from two sources. The first source is the data which must be provided by the user to the GCC Model. The second source is data generated by the External Game. The use of the Fire-Fight Submodel as an independent model requires that the inputs which would otherwise be derived from the External Game must also be provided directly as input by the user.

The inputs to the Fire-Fight Submodel can be classified under the broad categories indicated in Figure 12. A more detailed description of the actual parameters involved is the following:

Table of Organization and Equipment (T/O and E)

1. Fire unit structure of a game unit.
2. Personnel and weapons of a fire unit.

Command and Control

1. On hand personnel, ammunition, casualties.
2. Information on enemy contacts.
3. The command decision to attack or withdraw.
4. Selection of a deployment.
5. Conduct of the attack and defense.

Target Acquisition and Fire Doctrine

1. Fire unit probability of detection, identification, kill recognition.
2. Target priorities.
3. Fire doctrine.

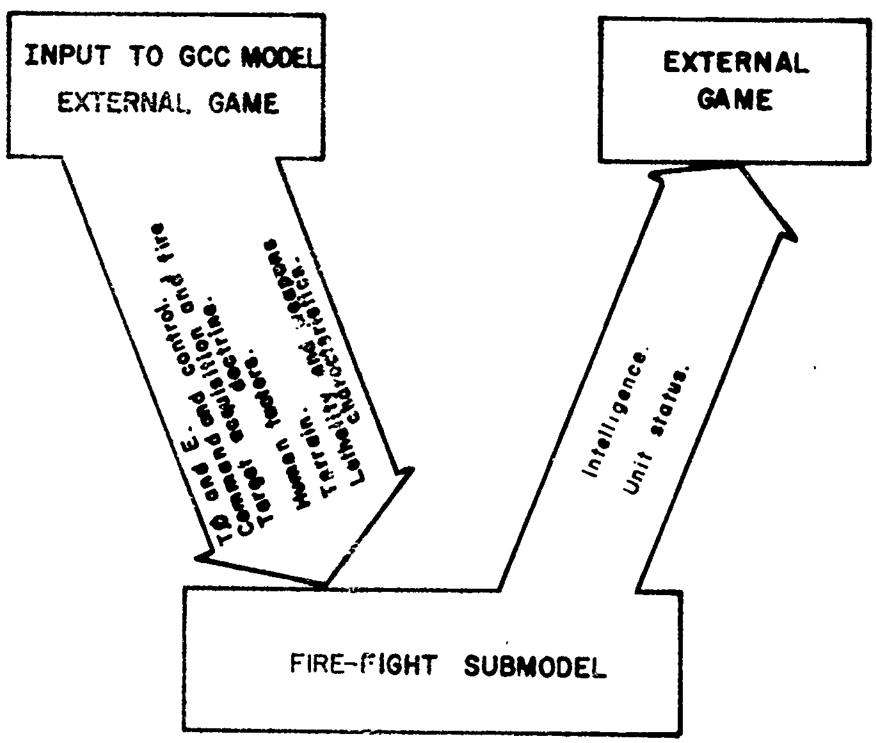

Figure 12

Fire-Fight Submodel Input and Output.

Human Factors

1. Suppression from direct fire and supporting arms.

2. State of training, reflected in rates of fire, accuracy of fire, movement rates.

Terrain

1. Dimensions and grid coordinates of the terrain feature.

2. Line of sight.

3. Close-in barriers.

4. Cover available to an individual.

Lethality and Weapons' Characteristics

1. Average presentations of individuals and vehicles.

2. Probability of wound location and of wound severity for personnel.

3. Conditional kill probability for vehicles.

4. Casualties received from supporting arms.

5. Rates of fire.

6. Weapon dispersion.

7. Weapon range.

The parameters which would be considered to be outputs of the Fire-Fight Submodel are those which are required by the External Game and those which constitute a record or history of the fire-fight. The outputs which are required by the External Game are classified into the categories indicated in Figure 12. These are described in more detail as follows.

Intelligence

1. New (game unit) contacts.

2. Updated intelligence on previously detected units.

Unit Status

1, Cumulative casualties sustained.

2. Cumulative ammunition consumption.

The transfer of information among the three principal logical components of the Fire-Fight Submodel is indicated in Figures 13 through 15. For each of Event 7, Event 13, and the Assessment Posting Subroutine, the source of the required input data is indicated. The outputs derived from any one component are readily determined from Figures 13 through 15 since the outputs of a single component are identical to the inputs derived from the component.

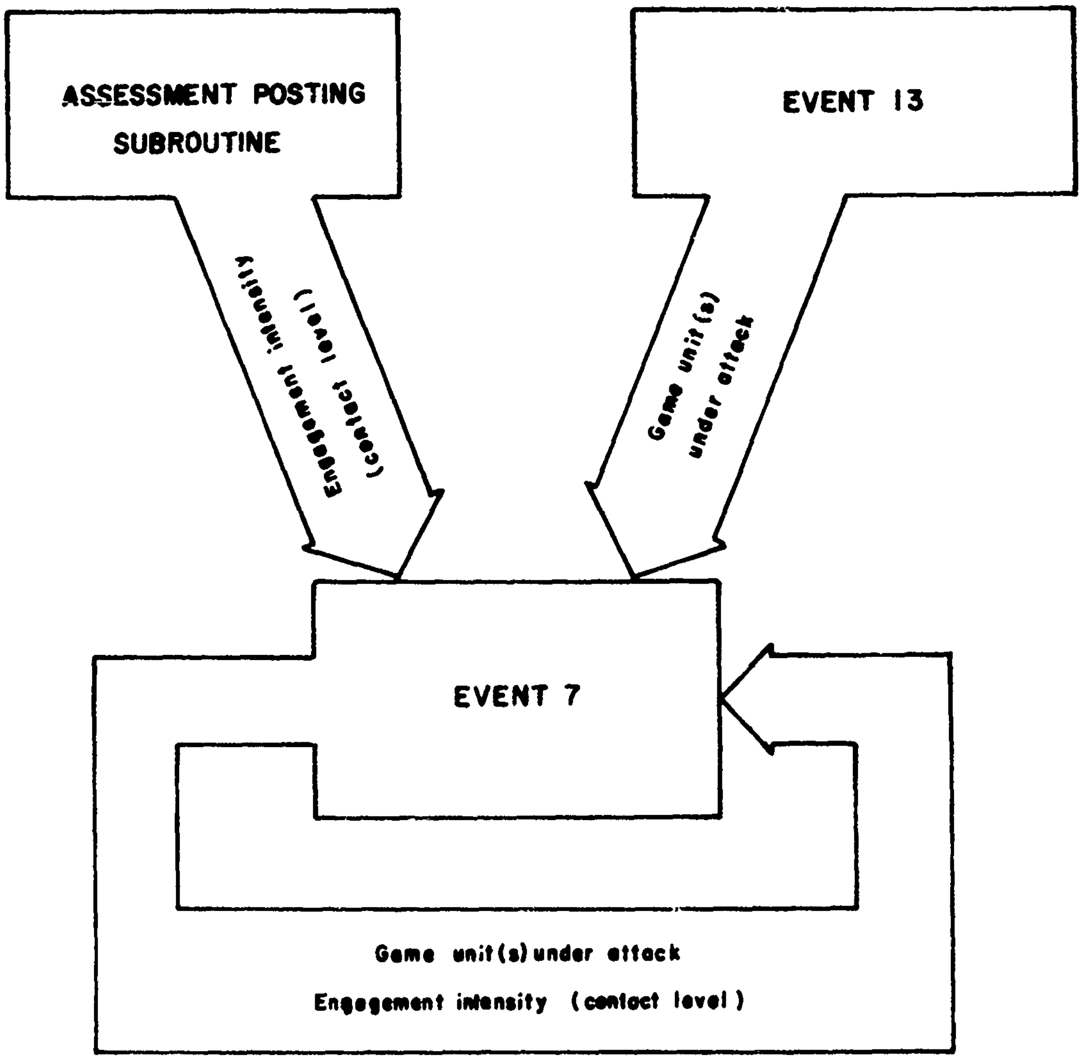

Figure 13

Input to Event 7

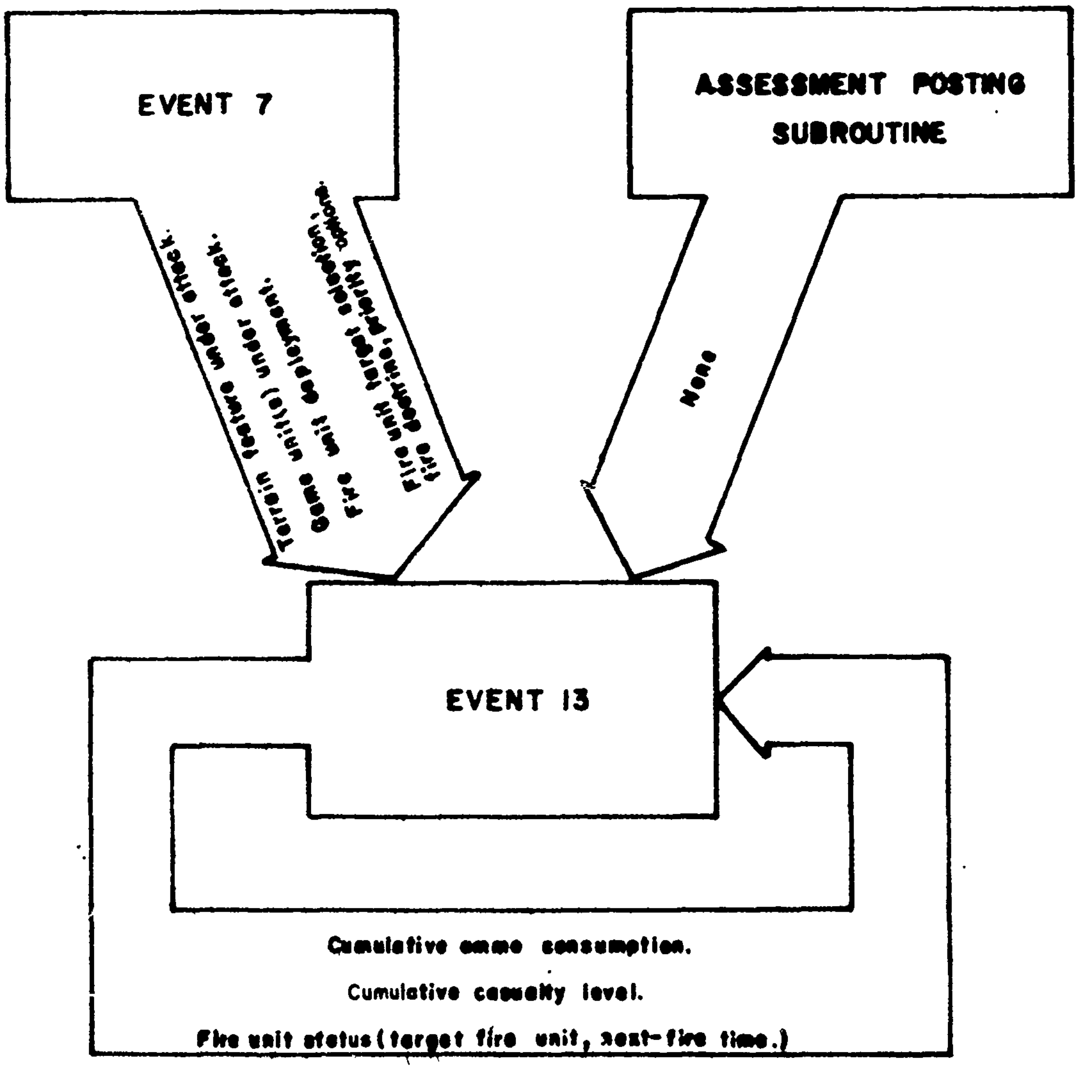

Figure 14

Input to Event 13

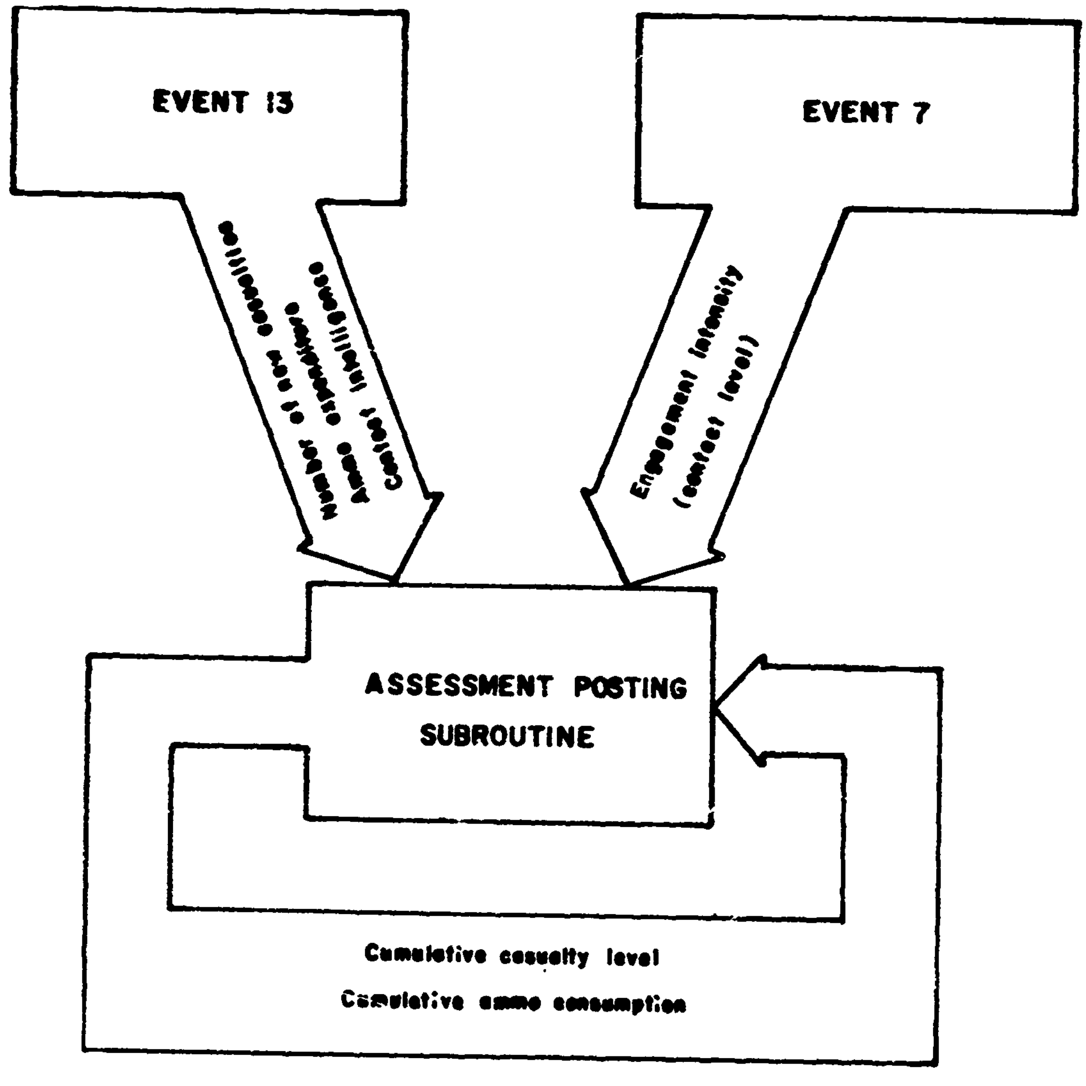

Figure 15

Input to Assessment Posting Subroutine

APPENDIX V

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY

13 ABSTRACT

The Ground Combat Confrontation (GCC) Model is a computerized simulation of selected aspects of ground combat and is coded in STRAP for the IBM 7030 (STRETCH) computer. The purpose of this report is to document the assessment techniques employed in the fire-fight portion of the GCC Model, which is called the Fire-Fight Submodel.

The Fire-Fight Submodel is a tool of military operations analysis designed to assess the results of close combat between opposing forces of mixed infantry and mechanized units. The forces are considered to be composed of "fire units", such as USMC fire team or a single tank, elements of the forces which have their target acquisition, fire and movements internally coordinated. Detailed round-by-round assessments are given to the fires of individual, crew served, tank and antitank weapons possessed by a fire unit. The lethal and suppressive effects of individual projectiles are considered in terms of the activity and presentation of the target fire unit.

Possible applications of the Fire-Fight Submodel to problems of military operations analysis are: (1) applications within the context of the GCC Model as a whole; (2) research in the determination of optimal Table of Organization and Equipment structure and specifically in the selection of mixes of individual and crew-served infantry weapons; (3) application as a fire-fight assessment tool in support of manual war gaming; (4) application as an aid to junior officer training.

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