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MINE/COUNTERMINE BASIS OF ISSUE
OPTIMIZATION PLAN

by

Thomas D. Pijor

June 1988

Thesis Advisor:

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Mine/Countermine Basis of Issue Optimization Plan

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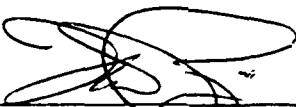
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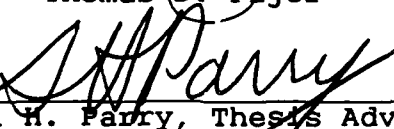
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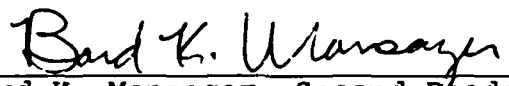
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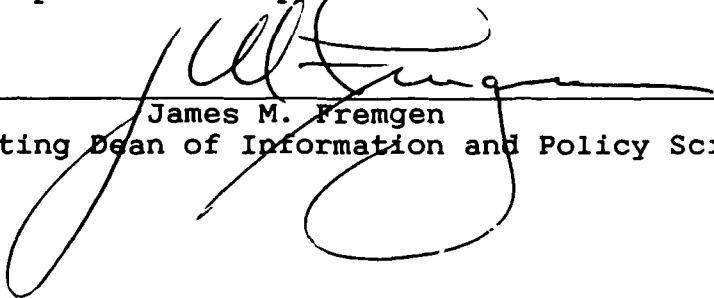

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ABSTRACT

The mobility and effective employment of tanks in a future conflict may be seriously threatened by enemy land mines.

This thesis presents a high resolution stochastically based simulation to be used in the evaluation of measures of effectiveness to determine the optimal basis of issue of mine/countermine equipment. A discussion of the types of breaching equipment and the tactics involved is used to provide background for the simulation.

Several measures of effectiveness are used to determine how the various configurations of breaching equipment affect the battle and battle outcome.



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The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. BACKGROUND

The United States Army currently possesses the most advanced tank in the world, the M1 Main Battle Tank. It is able to move faster, shoot more accurately, and maneuver better than any comparable system. Yet the emphasis on mobility and the high degree of technical sophistication which we have placed on the M1 may be negated by even a World War II vintage anti-tank mine. The use and effectiveness of landmines against tanks have substantially increased since World War I, while our ability to counter the landmine threat has not changed dramatically in the last 40 years. Proponency disagreements appear to have hindered the thorough formulation and development of a comprehensive mine clearing system while the search for and development of one device that would effectively perform all countermine functions has been understandably futile.

While there have been substantial advances in the development of new types of mines and minelaying equipment, the methods of detecting and clearing mines still leave much to be desired [Ref. 1]. There are still very few mine detectors which will detect nonmetallic mines, the most likely type to be found on the battlefield today. Once the mines have been detected they must be cleared or bypassed. The United States has been developing several systems to

enable units to breach complex obstacles. Two of these are the track width mine plow (TWMP) and the track width mine roller (TWMR). Both the plow and the roller have inherent strengths and weaknesses, and neither of them is totally effective.

B. PURPOSE AND GOALS

Although detailed combat models (such as JANUS or CASTFOREM) are heavily used at the tactical level, some analysts and users have doubts about the use of this kind of model when evaluating the impact of a new piece of equipment entering the inventory. Detailed combat models are costly to build, costly to run, are quite demanding in data base requirements, not easily modified, essentially impossible to use for sensitivity analysis and other parametric studies, and not easily communicated to decision makers.

On the other hand, a model can be built rather quickly and inexpensively in order to answer questions of a particular nature. The model is written with specific goals in mind and specific output desired. Development of that type of model is the subject of this thesis. It examines various mixes of the TWMP and the TWMR with the goal of determining the optimal type and number of systems that can effectively be used to breach a series of minefields by an armor battalion. The countermine mix must provide effective mine neutralization in the breached lanes

for the assault with minimum loss of momentum and time, and minimize breaching and assault force losses due to mine detonations.

By constructing the model in this fashion, the number of variables that could impact on the output is kept to a minimum and the output and analysis will provide results with an acceptable degree of accuracy.

C. METHODOLOGY

Through the use of a high resolution combat simulation using clearing and survivability data, output is generated which is analyzed and then evaluated under various measures of effectiveness which have been developed to provide comparisons between different force and equipment configurations. Figure 1 demonstrates the process by which the evaluation will take place. Entering the configuration or inventory, the minefield parameters and enemy actions, and the assault force's actions and decisions into the simulation model results in an exiting vehicle inventory, transit times and unit status codes which are then used to evaluate the desired measures of effectiveness.

In Chapter 2, the Concepts of Mobility and Operations are discussed. Additionally, a discussion of the options available to a unit commander in countering are examined in detail. The characteristics of the breaching equipment,

Functional Simulation and Analysis Model

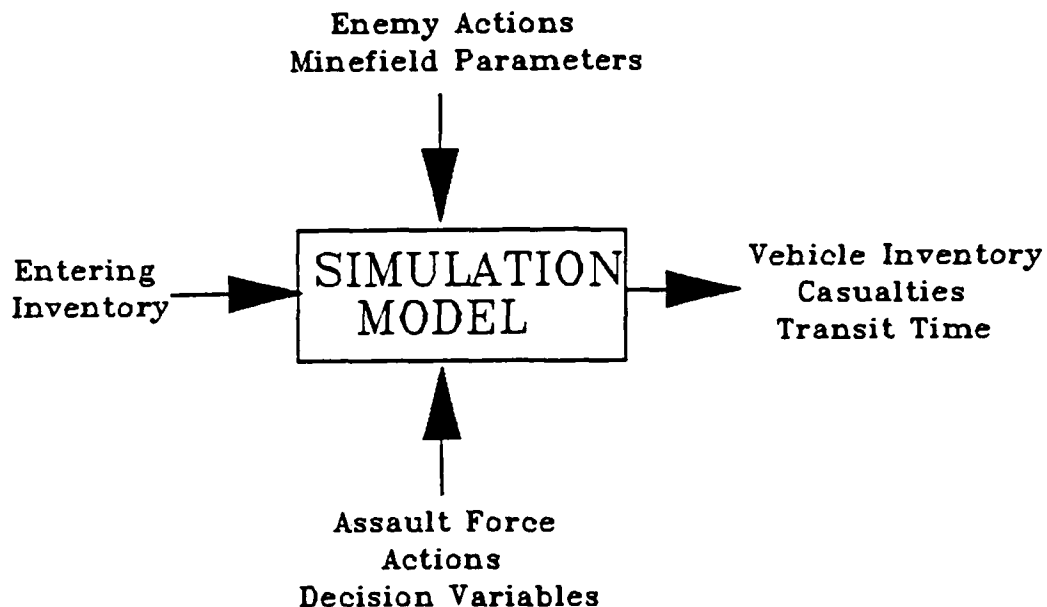


Figure 1. Functional Simulation and Analysis Model

their normal employment and the development of the measures of effectiveness used to analyze the output from the simulation are examined.

In Chapter 3, the layout and flow of the simulation are discussed, along with detailed descriptions of the various modules that compose the model. The tactical scenario which was used in the model development and simulation is included.

Chapter 4 deals with the output analysis and evaluation of the measures of effectiveness used to determine the optimal force structure.

Finally, Chapter 5 provides recommendations for possible future enhancements to the model as well as possible utilizations of this model and other models of this type. In the appendices, variables used in the simulation are defined, the computer code is listed and described in detail, and the data files used in the simulation are presented.

II. NATURE OF THE COUNTERMINE PROBLEM

A. CONCEPT OF OPERATIONS AND MOBILITY

Mobility is oriented toward reducing or negating the effects of existing or reinforcing obstacles to improve movement of maneuver/fire units and movement of critical supplies [Ref. 2].

The concentration of forces and weapons at the critical time and place is a prerequisite for winning both offensive and defensive battles. The firepower and cross-country mobility offered by tanks make them the most important conventional battlefield weapon of today and the future. The overall mobility of the forces may be countered through the use of existing and reinforcing obstacles. Existing obstacles may be considered to be those natural or man made obstacles which currently exist on the battlefield. Reinforcing obstacles are specifically designed to impede the movement of enemy units and are constructed when possible to complement existing obstacles, friendly fires, and scheme of maneuver.

Obstacles are intended to be employed in depth along the expected enemy axis of advance with the intent of stopping, delaying, or redirecting enemy tanks to a location advantageous to the employment of anti-tank weapons. If the obstacles are properly employed they are likely to delay an enemy unit attempting to pass through

them. A delay that occurs within the range of anti-tank weapons covering the obstacles is likely to significantly increase the effectiveness of those antitank weapons. The primary purpose of obstacles is to enhance the effectiveness of friendly fires, to delay or disrupt enemy formations, to allow the tactical commander to use economy of force, and to enable him to protect his flanks.

The Soviet Army places great emphasis on landmine warfare, and they possess rapid and effective means of both laying and breaching minefields. They are likely to use mines extensively in defensive and offensive operations. By doctrine, their minefields are located at the front of defensive positions and are covered by antitank and general supporting fires. Soviet minefields are employed to disrupt the enemy attack by causing vehicle casualties, reducing overall momentum of the attack, and forcing the enemy into confined areas. Minefields located within the main area of defense are employed to provide kill zones for anti-tank weapons and restrict enemy movement to designated areas where the concentrated fires of all weapons are focused on the attacking forces. They are not used with the idea of blocking or destroying the enemy force, but to reinforce natural obstacles, scare the enemy, divert his attention from the defender and influence his maneuver.

[Ref. 3]

Mines are widely recognized as the most effective reinforcing obstacle. While other obstacles can only act passively on tanks, mines have proven themselves to be capable of destroying tanks by themselves. The achievement during the combined employment of anti-tank weapons and anti-tank mines of a greater number of casualties than would be possible by summing the casualty producing capabilities of each acting independently is commonly acknowledged and is referred to as a synergistic effect.

To counter this threat of decreased mobility, tank mounted countermine sets of plows and rollers will give a tank company limited capability to conduct hasty minefield breaches. The countermine mix must provide accurate identification of minefield encounters, provide effective mine neutralization in the breached lanes, provide lanes for the assault force with minimum loss of momentum and time, and minimize breaching and assault forces losses due to mine detonations [Ref. 4].

The roller/plow team has distinct limitations. The roller, by virtue of the fact that it always travels in contact with the ground, is constantly detecting and clearing a path immediately in front of the vehicle on which it is mounted [Ref. 4]. However, due to the weight of the device, the breaching vehicle's mobility is greatly reduced. Additionally, due to the roller's method of neutralizing mines by detonation, it cannot withstand the

rigors of constant breaching operations. The mine plows are not designed to detect mines but to clear a path directly in front of the plow tank once a minefield is encountered/ detected. Since the plow tank travels with the plow in the raised mode, the crew of the plow tank must be able to visually detect the minefield in order to determine when to employ the plow [Ref. 4].

B. TACTICAL RESPONSES TO MINEFIELDS

The offensive force commander must keep one principle in mind when a minefield is encountered: maintain the momentum of the offense. Obstacles must not stop or impede the movement for unusually long periods of time. The tactical commander has three alternatives when faced by an obstacle; he may breach, bypass, or "force through" the obstacle [Ref. 5].

1. The Bypass

To conserve time and manpower, obstacles are bypassed whenever possible. However, if the enemy has employed the obstacles properly, they will be difficult to bypass. [Ref. 6]

2. The Breach

A breach is conducted when the unit possesses the proper equipment to breach. Two methods of breaching may be employed: the assault breach or the deliberate breach. [Ref. 6] We are concerned only with the assault breach. The assault/hasty breach is done quickly during either a

hasty or deliberate attack. The main objective is speed in gaining the breach, since delays may be costly in terms of casualties due to direct fires covering the obstacle. With the mineplow and mineroller, it maybe quicker and easier to attempt a breach than to bypass.

3. The Force Through

The "force through" or "bull" tactic is attempted when no other way to overcome the obstacle exists. The unit does not possess any breaching equipment and will drive through the minefield in hopes of clearing a path. Heavy losses are expected when this tactic is employed. [Ref. 7]

C. TYPES OF BREACHING EQUIPMENT

The track width mine roller (TRMR) is a 10 ton assembly consisting of two banks of rollers. The rollers detect mines by detonating them as it rolls over them. There is a dog bone and chain assembly between the two banks of rollers to activate any tilt rod mines which could cause a belly kill on the breaching vehicle. [Ref. 6] Mine rollers have the potential to provide countermine detection and neutralization only as long as the single impulse pressure fuze mine remains the predominant fuze type. [Ref. 8]

The track width mine plow (TRMP) weighs 3.5 tons and consists of two plow blades. The plow removes surface laid or buried mines from the path of the vehicle's tracks, the tines penetrate the ground to dislodge buried mines and

bring them to the surface where they are cast aside. A dog bone and chain assembly is used to clear tilt rod mines in the same manner as the TWMR. [Ref. 9] It possesses the potential to provide effective mine clearing of surface laid mines and under certain terrain conditions, mines laid below the surface [Ref. 8].

Sweeping operations to clear a path through a minefield is carried out by the roller and plow sections simultaneously or by the roller section alone. When moving through a mined area, travel should be in as straight a line as possible and no sharp turns should be executed, otherwise a mine unearthed by the plow may pass under the tank's tracks. When choosing a movement route, it is desirable that this path lie along the smoothest possible course through the minefield. [Ref. 10] The best overall results are normally achieved when the two systems are used in tandem, with the roller leading until it detects (detonates) a mine. The plow then digs in and leads through the minefield, followed by the roller which proofs the lane. Once the minefield is passed, if further mines are anticipated, the roller resumes the lead. [Ref. 11] The company/team sized element conducting the hasty breach through a threat minefield and continuing on to seize the objective can effectively exert command and control of only one breach. [Ref. 4]

D. MEASURES OF EFFECTIVENESS

The measures of effectiveness concentrate on the principal purposes of countermine equipment which are to decrease the amount of time the unit is exposed in the attack, reduce delay time due to minefields, and to change the force ratio for the attackers. The MOEs are quantitative indicators of the equipment's ability to affect the battle outcome compared to various base case situations, (i.e. when the battlefield is void of obstacles and the battle outcome when the battlefield has minefields and the attacking unit does not possess any breaching/clearing equipment).

An integral factor in the determination of the number of breaching systems is the vulnerability of a specific device to direct or indirect fires, since the loss of a device (due to damage or failure) before or during the breach would require the employment of additional devices. Because of their relatively high degree of accuracy and standard coordinated employment with a minefield, direct fires are generally considered to be the predominant threat.

The final factor that must be considered in the MOE development is the expected reliability and survivability of the clearing or neutralizing device. This reliability denotes the probability of the device actually clearing or neutralizing a mine it encounters and the survivability of

the device is the ability to withstand the rigors of mine detonations which may be encountered when clearing the obstacle.

The primary question of how the number of pieces of breaching equipment affects the battle is best answered by measuring the number of casualties suffered by the attacking force. If the equipment accomplishes its mission, such as allowing a rapid breaching of obstacles, there should be a decrease in the number of casualties due to both mine detonations and direct fire kills, or the minimum range between opposing forces should have decreased.

The MOEs are as follows:

1. percent of blue casualties due to direct fire.
2. percent of blue casualties due to mine detonations
3. percent of blue casualties due to both mine detonations and direct fire.
4. number of blue casualties due to mines/number of pieces of breaching equipment available.
5. number of blue casualties due to direct fire/number of pieces of breaching equipment available.
6. number of total blue casualties/number of pieces of breaching equipment available.
7. Number units going to defensive posture over 50 repetitions of the model.
8. Time of units going to defensive posture (number in the initial, early, middle and late portions of the battle).
9. Average length of battle.
10. Minimum range of blue forces

11. Rate of battle losses = number of casualties/minute
of battle.

III. MODEL DEVELOPMENT

The model developed for this thesis is a time sequenced, stochastic, battalion level, force-on-force simulation. The model conducts the battle in uniform time steps of 30 seconds each. Figure 2 provides the general scheme for the sequence and flow of events in the model. The pertinent elements for the landmine simulation and analysis problem are the mine countermeasures equipment and the maneuver units. Other necessary values are the mine countermeasures equipment at the assault site and the characteristics of the equipment.

The simulation has been written to allow for maximum user flexibility while maintaining a simple and transparent structure. Unit formations can be easily changed, numbers and types of equipment are easily modified, and even the maneuver network can be easily changed. The full flexibility of the model is discussed in detail as each module is explored. Although the program code is listed in its entirety in Appendix B, the critical portions are discussed in the following sections.

The sequence of events for each time interval (30 seconds) contains six main phases: unit status, unit location, movement, Red detect/fire, Blue detect/fire and battle termination/results. The movement phase applies to the blue forces only. Generally, every blue unit is advanced the total distance it is able to travel based on

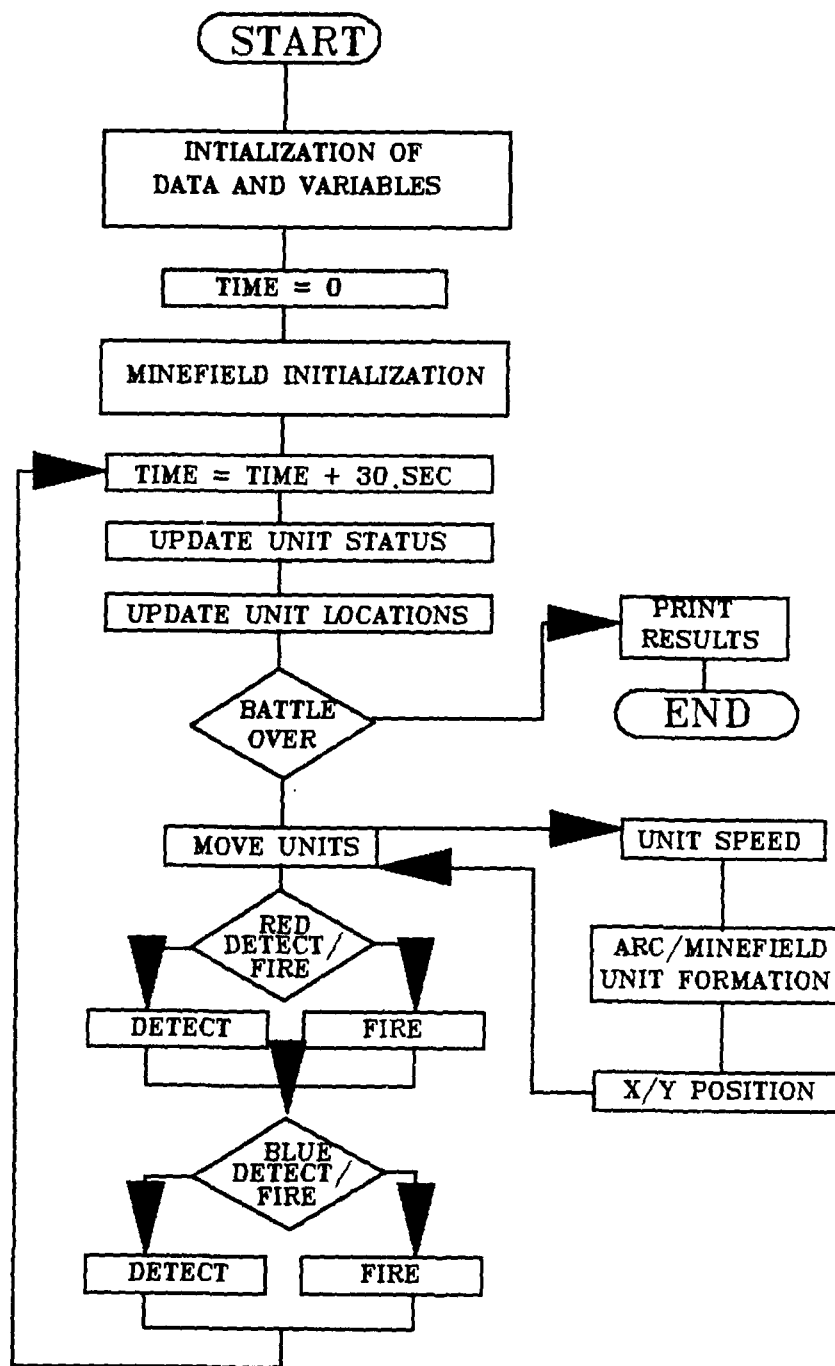


Figure 2. Model Flowchart

unit formation, types of equipment, terrain and location. The detection for both the red and blue forces is similar in that the time to detect is fixed at a given interval of thirty seconds. If it takes longer than 30 seconds to detect an opposing element, then that element is not detected. This concept is explored in more detail later in the chapter. The detection modules also serve to allocate the unit's fire, assigning targets to those elements who have detected them. The fire module is stochastically based, using probabilities of hit and kill given hit in a Monte Carlo model to determine the outcome of an engagement. If a hit on a target does occur, the model determines either a kill or no/unimportant damage to the vehicle. Once a vehicle has been killed it is removed from the simulation, no longer able to either provide additional maneuver or fire, nor can it be detected by the opposing forces.

Within the movement phase is the minefield logic. The module deals with a minefield in two phases, that of actions taken upon entry into a minefield and casualties due to entry, and actions taken during the breaching or bypassing of the minefield. The determination of whether a mine detonation occurs, the exact location of the detonation and the damage incurred is a function of the density of mines in the field, the effective vehicle width and the actual distance traveled in the minefield. Knowledge about the specific location of a minefield is

gained in one of two ways, either by visual detection of the minefield prior to entry or by detonation of a mine after entry. Options based on minefield knowledge are discussed in a subsequent section. The mines are considered to be either surface laid or buried. Two minefields are modelled in the simulation, one emplaced far (approximately 3000 meters) from the objective and one emplaced near (approximately 1500 meters) the objective. The probability of detection for the far minefield is low due to the assumption of no reinforcing obstacles or readily identifiable boundaries. The near minefield's detection probability is set higher due to the likelihood of reinforcing the field with wire obstacles. The detection probabilities are, however, input data and may be changed to conduct additional analysis. Battle termination stops the simulation when either of the following criteria is met:

1. Red force strength falls below 25 percent
2. The minimum range between forces is less than 250 meters.

There are no battle termination criteria used for the blue force other than if a company's strength falls below 50 percent, it assumes a defensive posture.

In addition to the main simulation discussed above, an enhanced simulation was developed based on the concept of limited command, control, and communications (C^3) versus total C^3 . The only control in the initial model is to

insure an alignment of forces with respect to the range to the enemy.

In the enhanced model, in addition to the alignment of forces, the presence of minefields in the area of operations is communicated to the rest of the battalion after initial detonation or detection of the first minefield by the lead unit. This concept is discussed in detail in the minefield logic section of this chapter and is the only modification to the initial model. All other subroutines function the same in both models.

A. TACTICAL SCENARIO

The scenario used in the model is based in West Germany on terrain similar to that found near the Fulda Gap. The NATO forces have assumed an offensive posture and the 3rd Battalion, 35th Armor is to conduct a deliberate attack to secure near side crossing sites on the Ulster River on the East-West German border. Although enemy forces in the area have been weakened by the past days of fighting, front line troops are in prepared defensive positions protecting the crossing sites. The enemy is believed to be in an economy of force posture and has used reinforcing obstacles to strengthen its position. Reconnaissance by the Scout Platoon has been unable to provide enough information about possible minefields or gaps in the defending system, therefore the decision has been made to breach into and through the defending system in all cases except when

breaching assets are not available. The enemy force is believed to consist of a tank company of T-72s reinforced by a platoon of BMPs occupying prepared defensive positions (Figure 3).

OPERATION OVERLAY

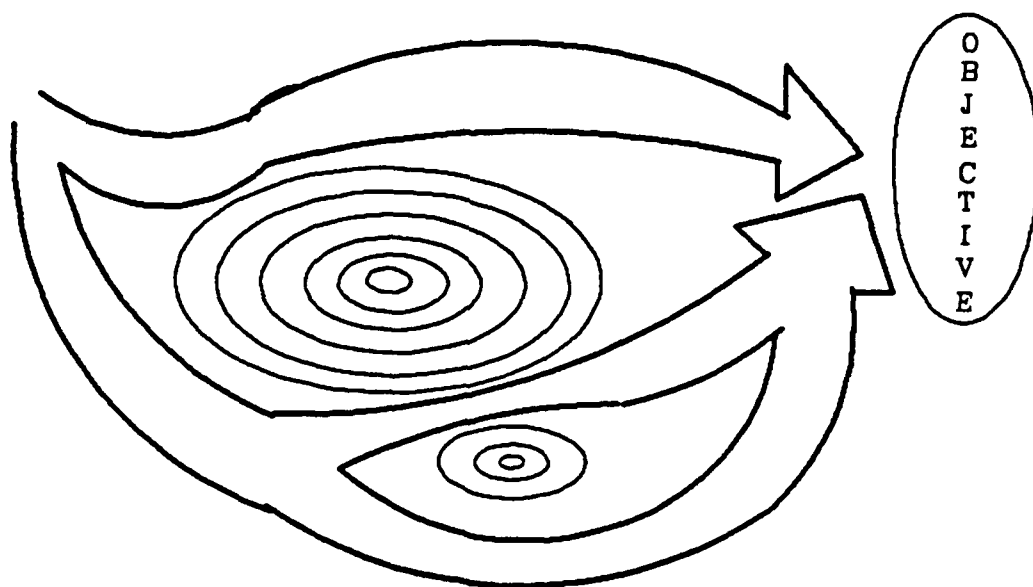


Figure 3. Operation Overlay

A quick attack is to be made by 3-35 Armor along twin axis of advance with selected limited objectives (Figure 3). The battalion will attack with two companies abreast on each of the two axis to secure the high ground on the objective currently held by the red forces.

B. INITIALIZATION AND DATA INPUT

There are fourteen data files which provide support to the simulation. These files support the movement network, the detection/fire modules, and the unit formation and breaching routines and are listed in Appendix C.

Data files 1 through 4 support the movement network by providing arc and node designators, locations of nodes, distances and headings of the arcs, speeds that the unit can maintain based upon terrain, equipment and formation, and the axis of advance for each of the four maneuver units.

Data files 8 through 11 delineate the four possible formations the blue forces are able to use in the conduct of the attack. Figure 4 shows the four formations. Formation configuration and vehicle placement are changed simply by changing the x and y offset positions from the control or ghost vehicle. The purpose of the control vehicle is described in the movement module.

In both versions of the model, formation 0 is used when a unit assumes a defensive posture; formation 2 is the

formation used during the breach or bypass of an obstacle. Formation 1 is the movement/assault formation used by the unit at all other times in model 1. In the enhanced model formation 1 is used by all units until the first minefield is detected/detonated. Formation 3 is then assumed as the standard movement/assault formation at all times except when the use of formation 0 or 2 is invoked.

There are five vehicle type codes used in the simulation. Vehtype1 is the designator for a basic M1. Vehtype2 is for a mineplow tank with the plow in the raised position. Vehtype4 is the designator for the same type of vehicle, with the plow in the lowered or deployed position. Vehtype3 and Vehtype5 are used in the same fashion for the mineroller tank, 3 being used to designate the roller in the raised position and 5 to designate the roller in the deployed position. Both the mineroller tank and the mineplow tank can become a regular M1 tank if the breaching attachment is destroyed during conduct of the battle. Therefore it is possible to begin the battle with 10 tanks, 2 mineplow tanks and 2 mineroller tanks and end the battle with 14 regular tanks, if all the attachments were destroyed during breaching operations.

Data file 14 places the blue elements in specific positions outlined in the various formations (Figure 4). For example, if a unit consisted of 14 vehicles (10 tanks, 1 mineroller tank and 3 mineplow tanks) the entry order of

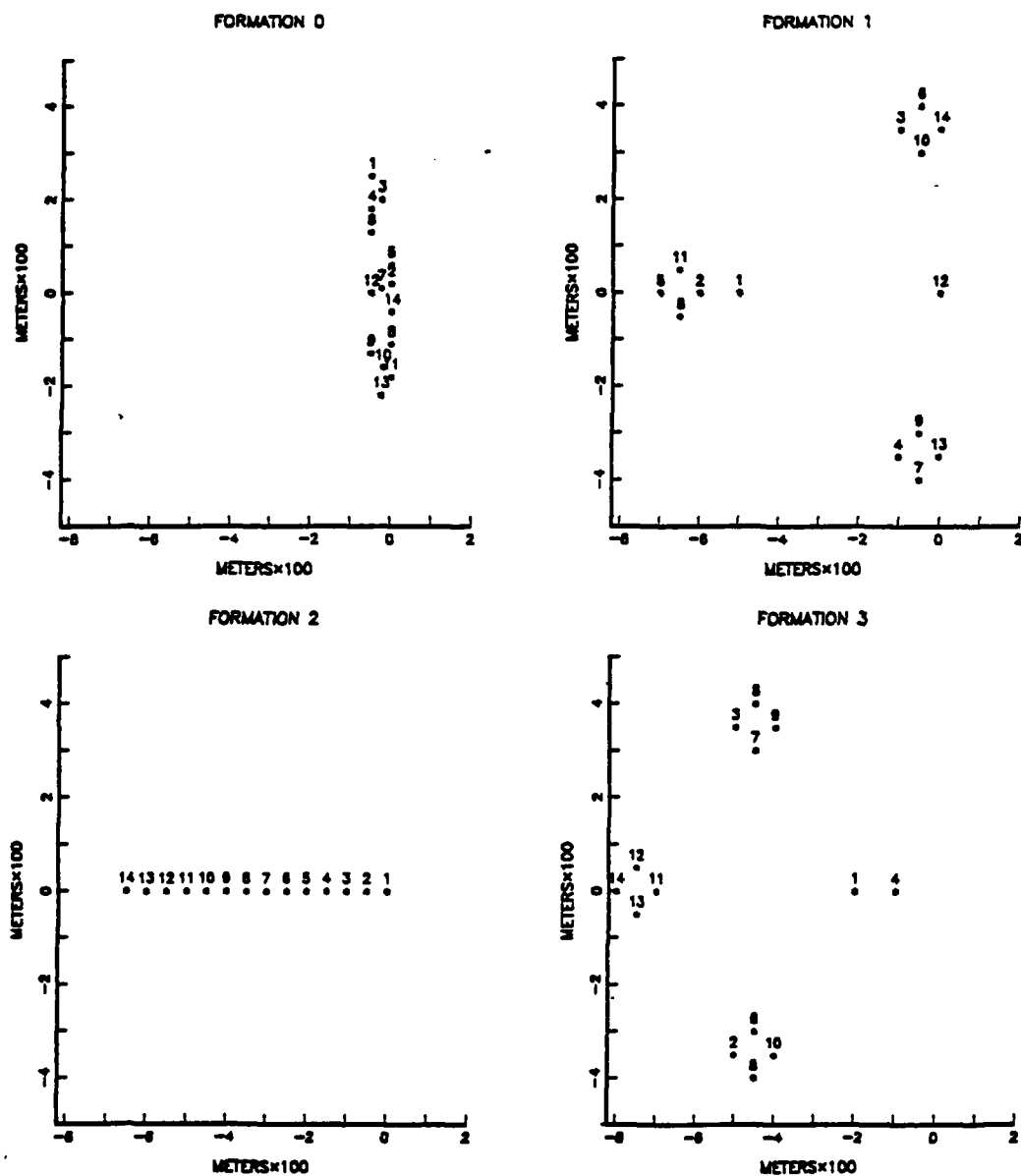


Figure 4. Unit Formations

the vehtype code into data file 14 is the position they would occupy in each of the formations. Therefore if the mineroller tank is entered first as vehicle type 3 in the file, it would occupy the number 1 position in each of the various formations, a mineplow tank entered second as vehicle type 2 in the file would occupy the number 2 position in all formations, etc. This obviously allows the configuration, in terms of numbers and types of equipment, of each unit independently as well as allowing each unit to place that equipment wherever it wishes within each of the formations. The only restriction regarding unit size is that they all must have the same number of total vehicles and that number cannot exceed 20 vehicles without changing the dimensions in the program. For example, one unit could have all tanks while another could have 10 tanks, 3 mineroller tanks and 1 mineplow tank.

The only vehicle type codes that are entered by the user are one, two, or three. The program will automatically change vehicle type 2 and 3 to 4 and 5 appropriately during breaching operations, changing them back to vehicle type 2 and 3 once the breaching operation in that particular unit has been completed.

Data files 12, 13, 15 and 16 support the red forces in such areas as position (file 12), the probability of looking in a particular direction (file 13), the vehicle type, height, and maximum engagement ranges (file 15) and

finally the probabilities of hitting a target and killing the target given a hit, which obviously support the detection and fire modules. Data file 17 provides the probabilities of hit and kill for the blue forces in the same manner as file 16 for the red forces.

In addition to the data files, there are several initial data statements in the program which support the minefield setup module with minefield depths, densities, and probabilities of occurrence, all of which may easily be changed by the user.

C. MINEFIELD SETUP MODULE

The anti-vehicular minefield is represented in the simulation as a uniform distribution of mines which are randomly dispersed within the minefield. The minefields are modeled as continuous with the depths ranging from 150 to 300 meters for the minefields located at approximately 3000 meters from the enemy position and 200 to 300 meters for the minefields located approximately 1500 meters in front of the red force position. The minefield densities are expressed in terms of mines per square meter rather than the standard mines per meter of frontage.

Because the fields in this simulation have only a depth associated with them, this unit of measure for density is preferred. The density of the far field is .003 mines per square meter and the density of the near field is .02 mines per square meter. The densities and depths of the

minefields can be easily changed by changing the data statements at the beginning of the simulation. By setting the maximum and minimum depths of the minefields equal, all fields will be of the same depth. The depth of each minefield is determined by a uniform (0,1) random draw which then determines the field dimension by

Depth of Minefield

$$= \text{mindepth} + ((\text{maxdepth} - \text{mindepth}) * U(0,1)) / 1000$$

(equation 3.1)

The basic concept of the minefield effects calculation is that of the expected distance to a mine encounter. Since the mines are randomly placed, the expected distance to the initial encounter and then each succeeding encounter is exponentially distributed. Therefore the expected distance to a mine encounter given by equation 3.2.

$$E[\text{distance to encounter}] = \ln(1 - U(0,1)) / (-\text{width} * \text{density})$$

(equation 3.2)

where the width is the effective width of the vehicle encountering the mine and the density is the density of the minefield in which the encounter is taking place. Successive distances to each encounter are thus calculated prior to the commencement of the simulation and are stored for future use.

One other feature which is included in the Minefield Setup module is the probability that a particular minefield

is actually emplaced. In the simulation, runs were evaluated under a worse case scenario and a most likely or average case scenario. The most likely or average case scenario used a 70 percent chance of each of the far minefields being in place and a 90 percent chance of each of the near minefields being in place. Therefore the possibly exists on any single run for anywhere from zero to eight minefields to be in place facing the blue force, and on any single avenue from zero to two minefields to be in place, based on the random number draws. By emplacing the minefields in this fashion and then running multiple repetitions of the simulation, a long run average minefield emplacement will be achieved providing a greater degree of variability in the evaluation of the likelihood of success of a particular unit configuration.

D. UNIT STATUS MODULE

The unit status module serves to keep a running total on the losses of equipment by unit and type. It is in this routine that the determination of whether a unit goes to a defensive posture is made. If the unit is less than 50 percent effective (i.e., it has lost over half of its equipment), then it assumes a defensive posture, thereby decreasing the likelihood of acquisition by moving to a hull down position. This aspect will be discussed in more detail in the Red Detect module. When a unit goes to a

stationary defensive posture, there is no impact on the speeds of the remaining units.

E. UNIT LOCATION MODULE

The unit location module exerts command and control over the battalion by delaying units which are moving too fast. The ranges to the enemy force of all four blue units will be in the interval [rngmin, rngmax] where the two limits are determined by the unit closest to the enemy force (rngmin) and the unit farthest from the enemy force (rngmax).

The module computes the range to the objective of each unit. If the range difference between all the units is less than 500 meters, then all units proceed at the maximum speed possible as determined by terrain and equipment in each unit. However, if the range difference between the closest and farthest units is greater than 500 meters, then the speed of the closest unit is adjusted downward by a lag factor, AAA. The factor AAA is computed by equation 3.3:

$$AAA = (rngmax - rngmin) / lag$$

(equation 3.3)

where lag is the maximum distance allowed between the closest and farthest units: in this case, 500 meters. This value is then passed to the movement module where it is used to decrease the speed of the leading unit. As an example, if the range of the closest unit is 2.4 kilometers

and that of the farthest unit is 3.2 kilometers, then the value of AAA would be:

$$AAA = (3.2 - 2.4) / .5 = 1.6$$

This value is then used to decrease the speed of the leading unit by a factor of 1.6. Thus for a speed of 25 kilometers per hour decreased by an AAA of 1.6, the new speed of the unit would be 15.625 kilometers per hour.

F. MOVEMENT MODULE

The movement logic is first discussed in detail without the minefield modules included. Minefield tactics and how they impact on the movement routine are discussed in the following section. The Movement module is made up of three distinct routines; a determination of unit speed, location and distance traveled along an arc, and the location of each of the elements in the unit in x and y coordinates (Figure 5).

Unit movement consists of moving each unit along a network of arcs, each of which has a distance, heading and speed associated with it. The network used to support this simulation is shown in Figure 6. A unit starts at the tail node of the arc, moving as far as possible in the 30 second time interval, based on the allowable speed associated with that particular arc and the type of equipment in the unit. For each 30 second time step the following process is followed for each unit in the Movement module. On entry into the subroutine the first decision is whether or not

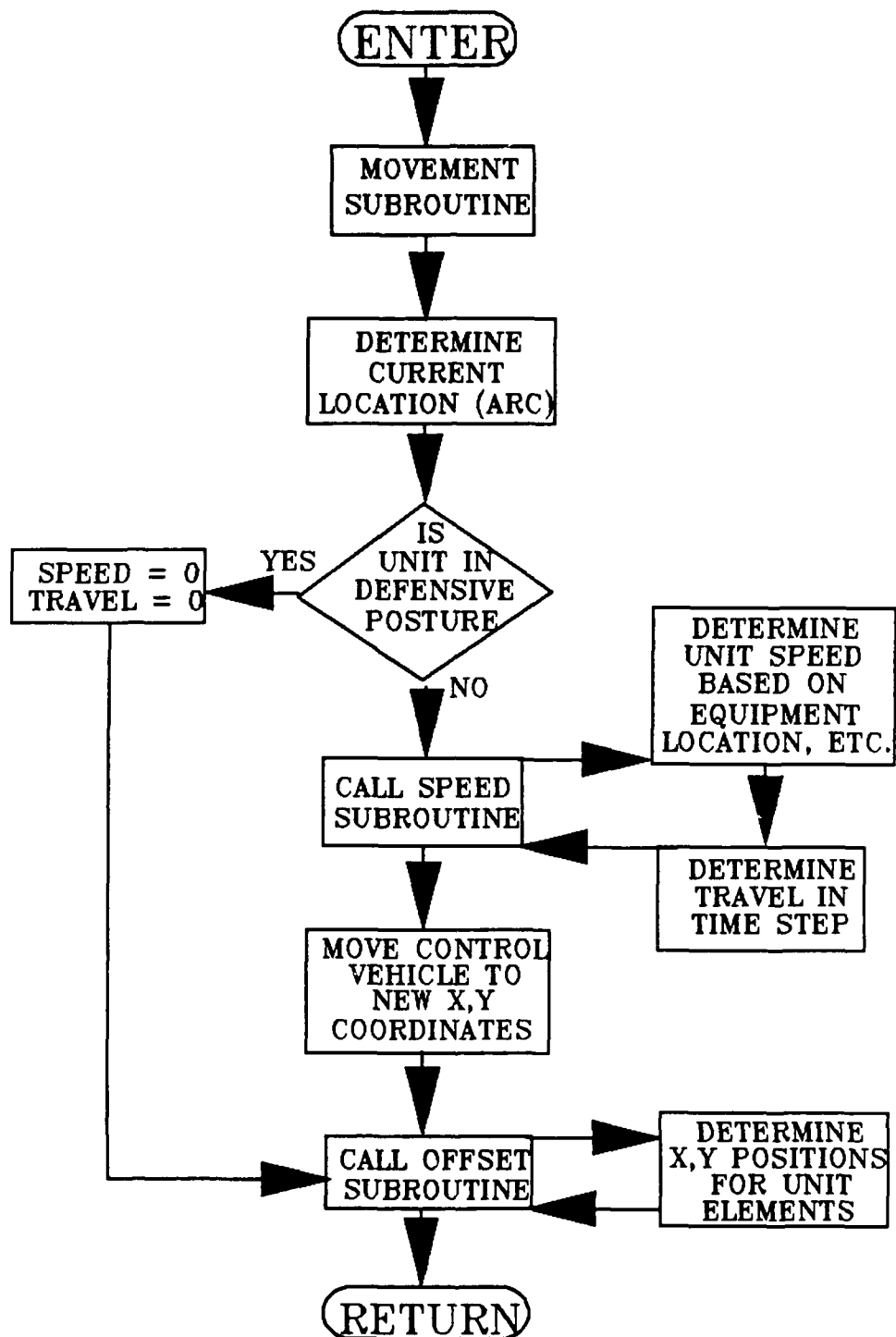


Figure 5. Movement Flowchart

the unit is in a defensive posture. If it is, then the unit speed is set to zero and the logic loops to the offset routine where the x,y position of each element is determined.

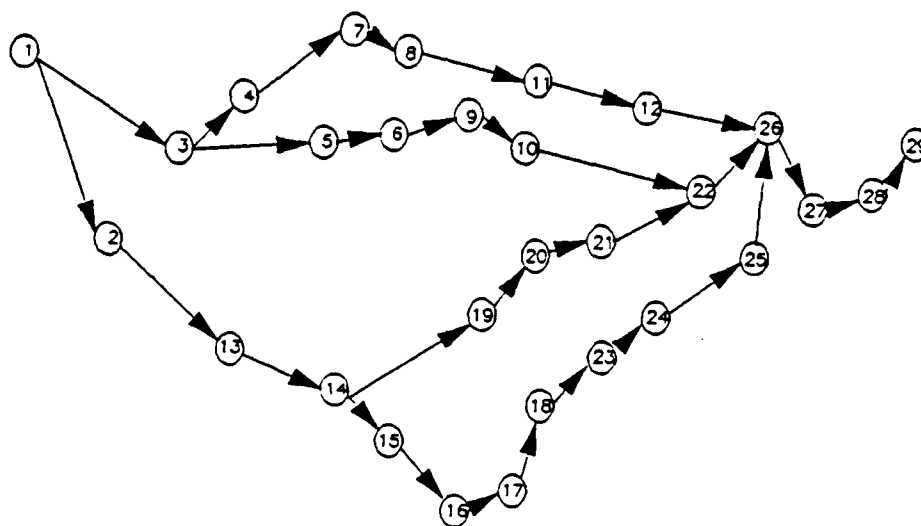


Figure 6. Network Supporting Movement Routine

If the unit is still combat effective the Speed subroutine is entered to determine the unit's speed and travel. The first step is to determine the maximum speed a unit can maintain on a given arc based on equipment in the unit and terrain characteristics for that arc. The trafficability and slope of the terrain are taken into account by degradation of the unit speed as shown in the Speed file (Appendix C).

If the unit has a mineroller tank, then that vehicle is the limiting speed factor unless the unit also has mineplow

tank which is currently being employed, in which case that vehicle is the limiting speed factor. The speed of a unit may vary on a single arc as the unit's equipment changes configuration or is attritted. Once the speed of the unit is determined, if it is the unit closest to the enemy and the lag factor, AAA, is greater than 1, then the speed is decreased accordingly. Once the final speed for the time step is determined, the travel for the thirty second interval is determined and control returns to the Movement module.

The ghost vehicle is the only vehicle that is actually moved and controlled by the model. Once the speed and travel of the unit is determined, the ghost vehicle is moved to a new set of x,y coordinates along the arc. Then, depending on the current formation of the unit, the elements are positioned by the Offset subroutine. The new positions are determined by the x and y offset distances obtained from the appropriate formation data file and are adjusted depending on the current heading of the ghost vehicle along the arc (Figure 7).

As an example, an element that is offset (-1.0,1.0) is 100 meters up and 100 meters behind the ghost vehicle. If the current position of the ghost vehicle is (483,621) and it's heading is due east then the element is located at (482,622). If, however, the ghost vehicle was at the same

location but heading northeast (45 degrees from the x axis), then the location of the element is (483.0,619.6).

DETERMINATION OF ELEMENT X,Y COORDINATES

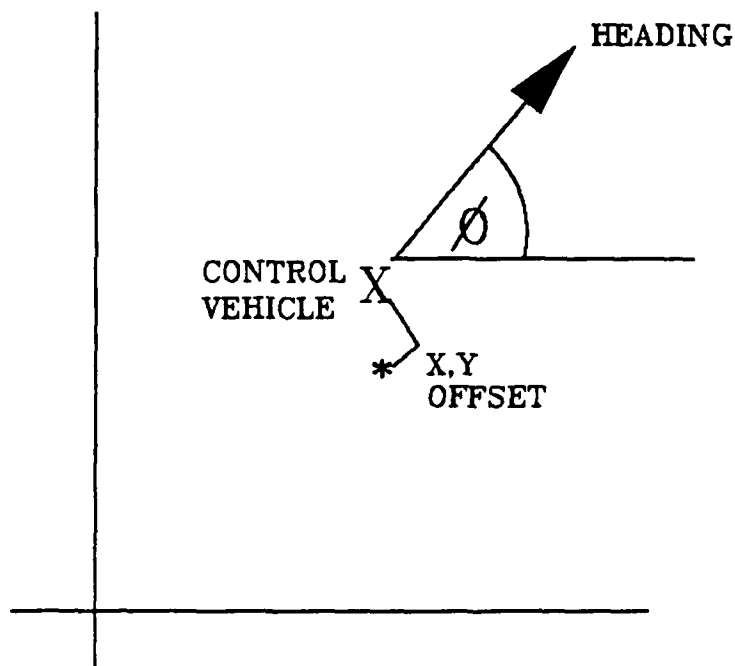


Figure 7. Determination of Element X,Y Coordinates

When the unit reaches the end of an arc, the unit assumes the new heading and speed associated with the next arc in the network. In this fashion, all units are able to move independently over any network which may be developed to support the scheme of maneuver.

G. MINEFIELD LOGIC

Once the Movement routine was developed, it was a simple matter to construct and insert the minefield logic which is the heart of the simulation. The minefield logic, like the rest of the simulation, is flexible in nature, allowing for an unlimited number of configurations. Minefields may be placed on any arc in the network, the only restrictions being that the arc must be longer than the depth of the minefield and only two minefields per avenue of approach may be input. The probability of a minefield being in place, the density of the minefield and the maximum and minimum depths are all input by the user.

The minefield logic is discussed in two phases: first the actions taken on entry into the minefield, and second, the actions occurring during the breach of the minefield.

H. INITIAL ENTRY INTO A MINEFIELD

A decision model has been developed which represents the process by which a unit commander selects one of the three possible options available to him when a vehicle in his unit detonates a mine or the location of the minefield is detected visually. Figure 8 shows the general sequence of events involved in the minefield detection logic. As discussed earlier, he may choose to:

1. conduct a hasty breach if the unit possesses any breaching equipment;

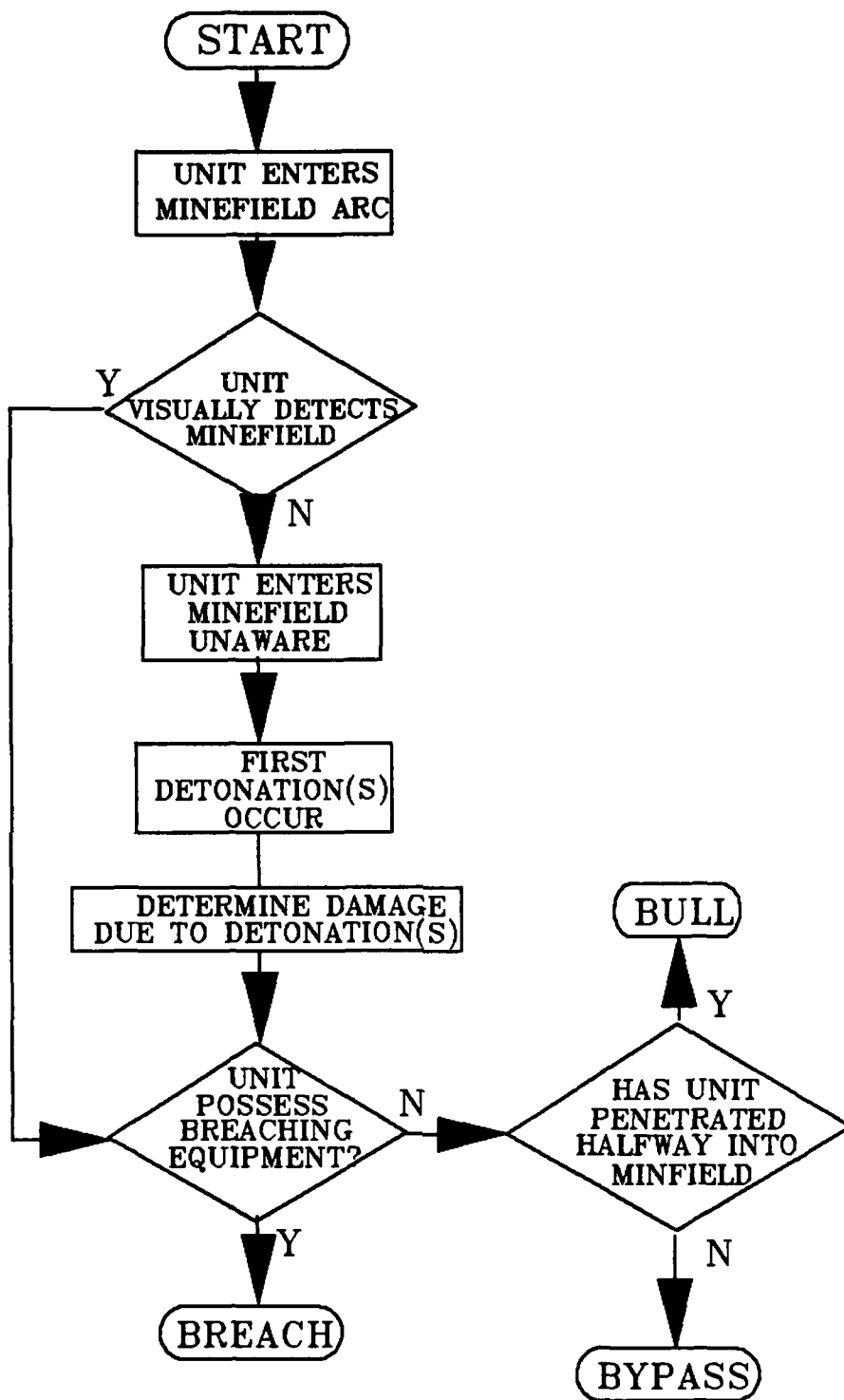


Figure 8. Minefield Logic Flowchart

2. bypass the minefield if the tactical situation permits or he does not possess any breaching equipment; or
3. order a "bull through", hoping to clear a lane without sustaining overwhelming casualties.

The choice the commander makes in the simulation is based on the knowledge he currently possesses about the minefield. Once that knowledge about a particular minefield is gained, it is assumed to be perfect knowledge in regards to the boundaries of the minefield and the unit's location within that minefield. If the knowledge about the minefield is gained prior to entering the minefield, then the model will elect one of two options; either a breaching operation if the unit currently possesses breaching equipment, or a bypass if it does not. The breaching operation begins at the edge of the field and distances to mine encounters are retrieved from the array previously calculated in the minefield setup module.

If the knowledge about a minefield is gained after entry, it is gained the hard way by detonation of a mine. The simulation is able to react in one of three ways. If the unit possesses any breaching equipment, it begins a breaching operation from the point where the mine detonation took place, since it is assumed that up to that point the minefield has been successfully breached. If the unit does not possess any breaching equipment, the decision to "bull through" or bypass is based on the distance into the minefield that the detonation took place, thereby

assuming perfect knowledge for the commander on the specific boundaries of the minefield once it is identified. If the detonation occurred less than half way through the minefield, the unit commander elects to conduct a bypass operation. If the unit has penetrated more than half way through the minefield prior to the first detonation, then the unit will "bull through" the minefield, hoping to minimize losses as compared with attempting to back out and bypass the obstacle.

In all cases, regardless of the option chosen by the unit, the following two actions occur. The unit is assessed a thirty second delay in movement while changing formations and any enemy elements which have been detected by the unit entering the minefield are lost. Therefore, if in the period $(t, t+30)$ the unit had detected an enemy element, during the normal sequence of events that element would have been engaged during the period $(t+30, t+60)$. However, due to the minefield encounter occurring during the period $(t+30, t+60)$, all detections are lost and all elements in the unit entering the minefield must reenter the detection module during the period $(t+30, t+60)$. Additionally, at any time the unit is in a breaching operation all vehicle types 2 and 3, which are now coded as 4 and 5, respectively, cannot conduct direct fire engagements. This restriction occurs because the crew is

occupied with the conduct of the breach as opposed to trying to detect the enemy.

I. BREACHING OPERATIONS

If a minefield has been entered, the breaching operation commences. Although the bypass is not really a breach of the obstacle, it does allow the unit to circumvent the minefield and continue its mission.

In the simulation the bypass option is dealt with rather simply. Rather than building additional arcs and nodes as a bypass route, which would invariably restrict the placement of minefields, the unit's speed is simply degraded and the mine detonation routine is suppressed. In this manner the unit is subjected to enemy fires for a longer period of time and the delay in forward progress accurately simulates the requirement to move parallel to the minefield in hopes of discovering a route around the obstacle.

A similar methodology is used for the "bulling thru" technique. The unit, in it's attempt to "bull thru", maintains a single column formation, thereby reducing the exposure of trailing elements to mine detonations.

The formation the unit uses while breaching the minefield is specified as input to the model. In this simulation, the formation used in all breaching operations is a single column of vehicles with all the breaching assets at the head of the column.

The unit will conduct the breach if it possesses the requisite assets. The simulation places all the breaching equipment at the front of the formation, with all the mineplows leading, followed by the minerollers, then followed by the remaining vehicles in the unit. The order that the vehicles enter and breach the obstacle is user input through the use of formation 2. The simulation does allow for a breaching device to be destroyed without destroying the carrier on which it is mounted. If a breaching device does become inoperable, then that vehicle's type code is changed to a 1 (M1 tank) and it is cycled to the rear of the formation. In this fashion, a vehicle with no breaching device does not lead the breach (unless there are no more breaching assets in the unit).

The simulation will allow any of the following cases to occur depending on the random draw.

1. A clearing device may be destroyed.
2. The carrier of a breaching device may be destroyed.
3. A mine may be left uncleared.

In case 3 a following vehicle may clear the mine if it has a breaching device, or it may detonate the mine and be killed.

In the breaching logic, mine encounters by each type of vehicle are dealt with in the following manner. If a vehicle type 1 encounters a mine, a random draw is conducted to determine a kill or no/unimportant damage.

For the M1, all mines are detonated when encountered and none are left uncleared under the tracks.

If the lead vehicle is a mineroller, there is a two step process in the determination of the probability of clearing and surviving the mine encounter. Figure 9 shows the process for the clearing of mines by the mineroller tank. When a mine is encountered there exists a probability associated with the clearing of the mine and, then given the clearing (by detonation with the rollers), a probability associated with surviving the blast.

Although the operation is similar for the mineplow, a mine encounter involves a three step process to determine the outcome of an encounter. Figure 10 shows the methodology used for an encounter by a mineplow tank. There is

1. a probability associated with clearing the mine,
2. a probability of detonation given the plow cleared the mine and finally
3. a probability of surviving, given the detonation by a cleared mine.

If a unit has breaching assets, then it conducts a breach. However, after losing its last piece of breaching equipment the decision to "bull thru" or bypass is the same as when the field is first encountered. If the unit has not penetrated at least halfway through the minefield, then it conducts a bypass. If it has reached the halfway mark,

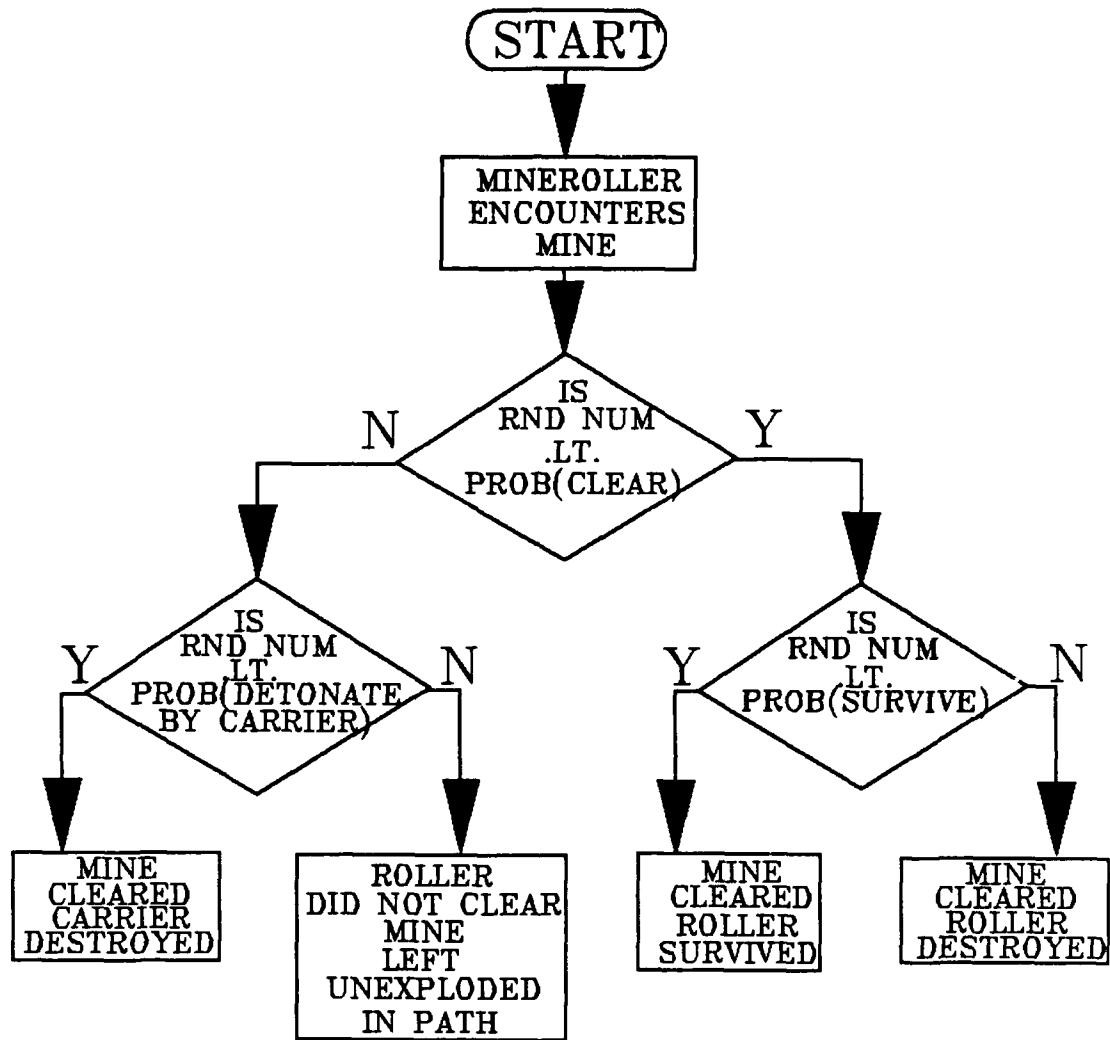


Figure 9. Mineroller Breaching Flowchart

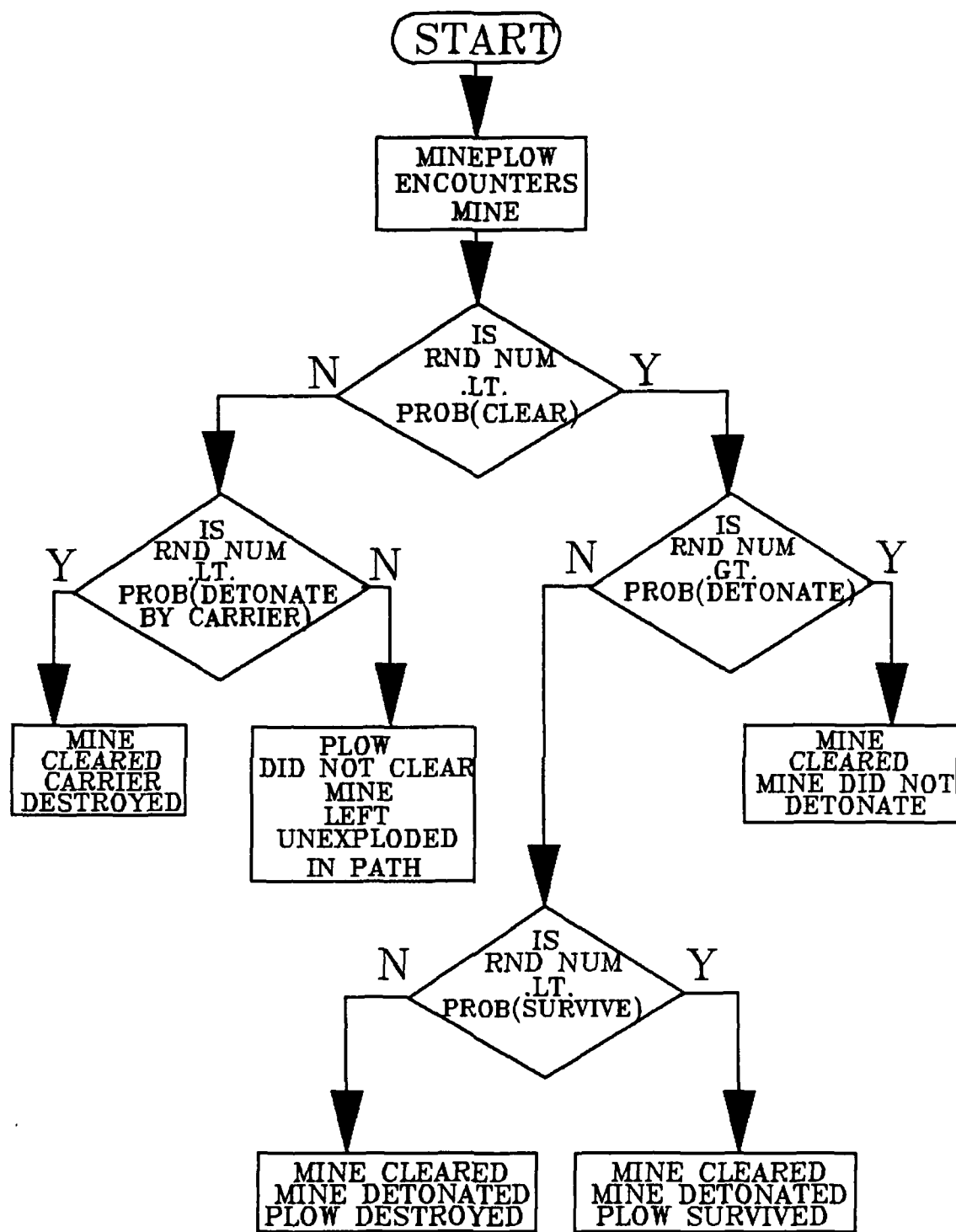


Figure 10. Mineplow Breaching Flowchart

then the unit will "bull" the rest of the way through the minefield.

In Model 1, units encounter and deal with each minefield entirely on their own. There is no communication between units regarding the encounter of a minefield. Each unit stays in formation 1 until they either detect or detonate a minefield, suffering the losses associated with each encounter. Once the field is cleared the unit returns to formation 1, and the process is repeated for the second minefield.

With Model 2, communication regarding minefield locations is simulated. When the lead unit encounters the first minefield, all the other units in the battalion assume a detection formation. Formation 3 in Figure 4 is used for this purpose. The mineroller tank is placed in the lead in hopes of detecting the location of the minefield on the axis of advance by the rollers and avoiding vehicle losses due to detonations. Additionally, when the unit exits the minefield, it resumes formation 3, as opposed to Model 1 where the unit assumes formation 1.

Once a unit has successfully breached a minefield, vehicles in that unit are not subject to mine detonation since the clearing operation is assume to be completely effective. Prior to that point, mines that were not cleared by a breaching vehicle may detonate and cause casualties to following elements.

J. FIRE AND DETECTION MODULES

The Fire and Detection modules operate simultaneously in the model. It is possible for different elements of the same unit to be detecting or firing during the same 30 second time period. The model does not restrict the unit to either the detection or firing phase during each time step. All elements initially start out in the detection mode. When element i detects an opposing element j during the period $(t, t+30)$ then during the following period $(t+30, t+60)$ element i enters the firing module and conducts the engagement. If the detection of element j occurred during the period $(t, t+30)$ then during the following 30 second time period line of sight is assumed to continue to exist for the firing phase. It is also assumed that if element i is busy firing during the period $(t, t+30)$ then no target search is conducted by element i during this time interval.

The red forces may detect or engage , depending on the type of vehicle, up to two enemy elements in the thirty second time period due to their stationary defensive posture. Tanks can detect or engage two elements in the thirty second period while a BMP is able to either detect or engage only one target during the time interval due to the characteristics of the weapon system.

The blue forces, due to their offensive posture, are able to detect or engage only one enemy element in a time

period. As a control for fire distribution only 2 red elements may detect or engage any single blue element at a time while 4 blue elements may detect/engage any single red element at a time.

Once a firer has completed his direct fire engagement(s), he returns to the Detect module during the next time period regardless of the outcome of the direct fire engagement. Even if during the period $(t, t+30)$ element j engaged but did not kill element i , he must still go back to the Detection module during the next time step and attempt to redetect element i .

K. DETECTION MODULE

The Detection modules for the red and blue forces are exactly the same except for minor differences which will be pointed out in the discussion as they occur. Figure 11 shows the flow through the red Detection module. The only difference in the flow through the blue Detection module is that the red forces are always in a defensive posture, therefore there is no need for crossing velocity calculations.

The detection computations used in the simulation were adapted from the DYN TACS model with some minor changes. [Ref. 12] For each element i the computations look at every enemy entity in the thirty second period to determine if they can be detected. A detection rate, DETRATE, for

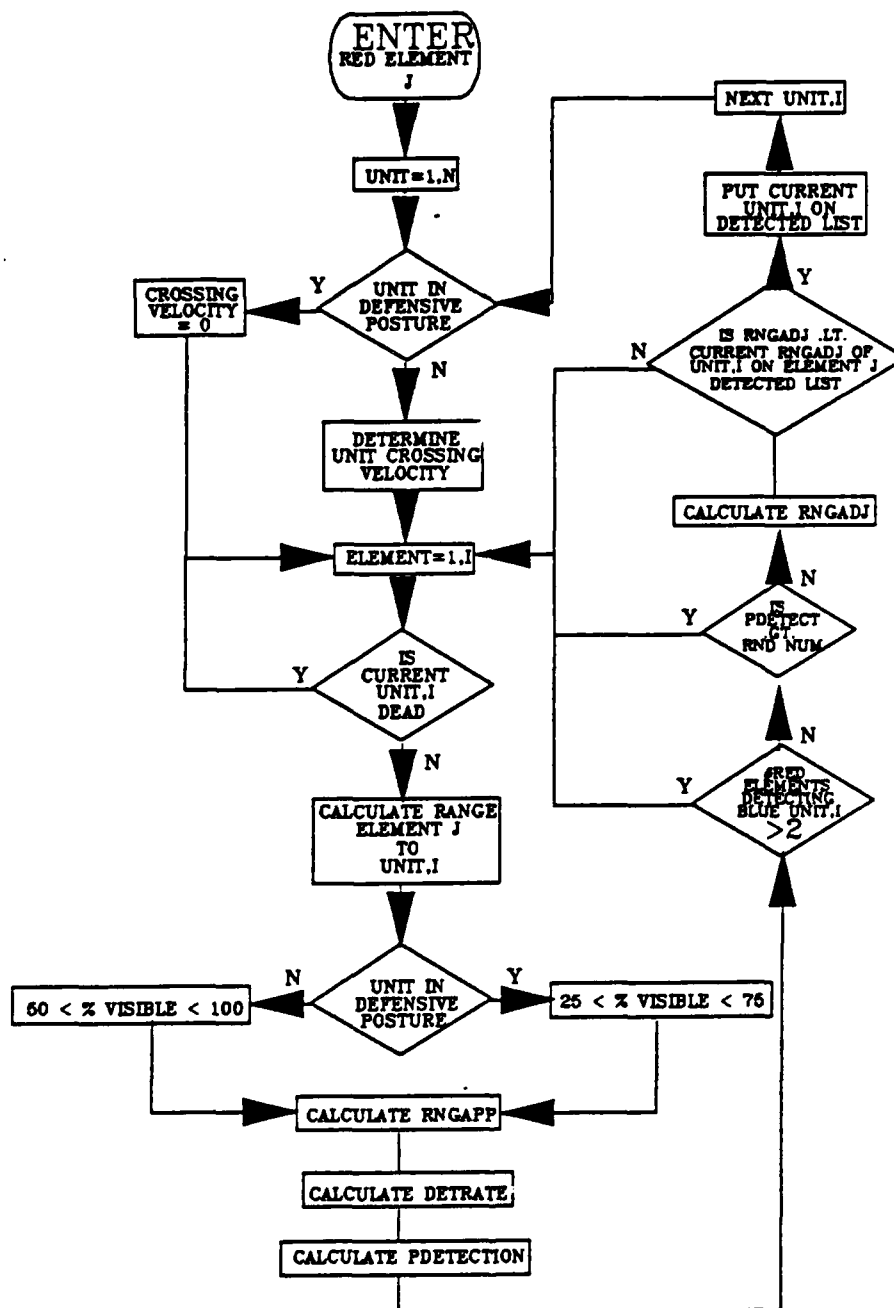


Figure 11. Red Detection Flowchart

every enemy element is computed is assumed to be constant for at least 30 seconds. Then the continuous looking model is used to compute the probability of detection in equation 3.4.

$$\text{REDPDET} = 1 - \exp(-\text{DETRATE} * T)$$

(equation 3.4)

where T equals 30 seconds. Finally a Bernoulli trial is performed to determine whether or not the target is detected.

The detection rate equation 3.5 DETRATE is:

$$\text{DETRATE} = \text{RPLOOK} * (-0.003 + [1.088 / \text{DENOM}])$$

(equation 3.5)

where:

$$\text{DENOM} = 1.453 + (\text{TAU} * (0.05978 + 2.188 * \text{RNGAPP} * \text{RNGAPP}) - 0.0538 * \text{CV})$$

and where the observation conditions are described by:

TAU = terrain complexity code; it can take on values from 1 to 7

RNGAPP = apparent range in kilometers. The apparent range is the range at which a fully exposed M60 tank would present an image which is the same height as the image that is observed for the current target. RNGAPP is computed as:

$$\text{RNGAPP} = (\text{actual range} * \text{M60 height}) / (\text{target height} * \text{percent visible})$$

where the denominator in the simulation is a random variable. For the attacking blue force, the percent

visible ranges from 50 to 100 percent for an offensive posture and from 50 to 75 percent for those unit which have assumed a defensive posture. For the red force the percent visible ranges from 25 to 50 percent due to the availability of prepared defensive positions.

The crossing velocity (CV) is measured in meters per second and is the target velocity component which is perpendicular to the target-observer line. It is the component of target movement which is most noticeable to an observer. The crossing velocity for the red force is zero, since they are in stationary defensive positions. When a blue force goes to a defensive posture, the model also sets their crossing velocity component to zero.

RLOOK is the probability that the observer is looking in the direction of the target and is a user input in the model. For the blue force it is a constant 75 percent chance of looking in the direction of the target and for the red force it is dependent on the avenue of approach.

L. DIRECT FIRE MODULE

The Direct Fire module is stochastically based using probabilities in a Monte Carlo model to determine the outcome of an engagement. The range from the firer to the target is calculated and then used in a table look-up to determine the probability of a hit and of a kill given a hit. The values are then compared to a random draw to determine the outcome of the engagement. The only outcomes

are either a kill or no/unimportant damage. If a target is killed it is assigned a "dead" code and is removed from the simulation.

This completes all the necessary modules required to conduct the battle simulation to generate the data necessary to analyze the measures of effectiveness developed in Chapter 2. The output is analyzed and the MOEs are evaluated in Chapter 4.

IV. OUTPUT ANALYSIS

A. BASIC RESULTS

The purpose of the simulation is to generate output to be used in the analysis of measures of effectiveness (MOEs). In this section numerical results are presented for each configuration and scenario. Fifty repetitions of each configuration were conducted and there were 5 different configurations evaluated against four different scenarios. The output provides a performance evaluation prediction of the mine countermeasures equipment. The four scenarios allow for the MOEs to be evaluated under varying conditions.

Scenario 1 evaluates the unit's performance when facing only direct fire weapons. The purpose of this scenario is to determine the impact of the countermine equipment on the unit's ability to fight when no obstacles are present. Scenarios 2 and 3 evaluate the unit's performance when faced by a combination of direct fire weapons and minefields. Scenario 2 examines the situation where there is a probability that the minefields are emplaced; Scenario 3 looks at the worse case situation: the probability of the minefields being in place is equal to 1. Scenario 4 is used to determine the effectiveness of the countermine equipment when faced only with minefields.

Sample data files used to support the evaluation of the MOEs are shown in Tables 1 and 2 (all tables and figures follow this chapter). In the heading of Table 1, the starting force configuration is shown. Columns 1 through 4 tabulate the direct fire losses by repetition. Column 1 is the total number of losses, column 2 is the direct fire losses of the M1, column 3 is the direct fire losses to the mineplow tanks and column 4 is the direct fire losses to the mineroller tanks.

Columns 5 and 6 of Table 1 give the losses of the breaching device due to mine detonations. Columns 7 through 10 represent the losses to the force due to mine detonations, each column representing the equipment in the same order as for the direct fire losses. Columns 9 and 10 represent the losses of the mineplow and mineroller tanks when they are not in a breach mode, i.e., the breaching device was not employed at the time of detonation.

Columns 11 and 12 represent the losses of the mineplow tank and mineroller tank due to mine detonations while attempting to breach the minefield. Column 13 is the total number of kills due to both direct fire and mine detonations and is the summation of columns 1,7,11 and 12. Column 14 is the length of the battle while column 15 is the minimum range attained by any unit during the battle.

Table 2 gives the status of the minefields on each axis and the time a unit went to a defensive posture. Columns

M1 (far minefield) and M2 (near minefield) give the status of the minefield, a 1 representing an active field while a 0 represents an inactive field. The time to defensive posture is given for each unit, a time of 0.0 meaning the unit did not assume the defense. The last column is the time to battle termination and is the same as column 14 in Table 1.

Tables 3,4,5 and 6 show the results of the evaluation of the output as derived from the MOEs. The sample mean is given, followed by the sample standard deviation in parentheses. Each column is the evaluation of a particular configuration against all applicable MOEs. Obviously in some cases an MOE does not apply due to a quantity required not being available, such as the number of pieces of breaching equipment in the unit configuration 14/0/0.

B. EVALUATION OF MOEs

MOEs 1 (Figure 12), 2 (Figure 13) and 3 (Figure 14) all deal with losses to the blue force versus their starting strength. The value for MOE 1 was found by using column 1, Table 1 divided by 56 to give a percentage of losses due to direct fire. Figure 12 shows the comparison of each configuration under each scenario. Direct fire losses for configuration 14/0/0 are low when no mines are present, but are the highest of any configuration as soon as minefields are introduced into the area of operations. Of interest is the fact that even though the configurations with

breaching equipment have higher direct fire losses than the configuration without breaching equipment, the difference is 3 or 4 percentage points at most.

MOE 2 examines the losses due to mine detonations in Figure 13. Values are found by summing the losses in columns 7, 11 and 12 from Table 1, and dividing by the starting strength of the battalion. Intuition would dictate that the losses to the force with no breaching equipment would be higher than those configurations with breaching equipment. This is not the case. Since each unit acts independently to detect minefields and the formation used does not place the breaching equipment in the lead, losses due to initial entry into a minefield should be the same for all force structures. It is at this point that the casualties due to mines increase for the forces with breaching equipment. The unit with no breaching equipment will usually bypass the minefields and therefore sustain no further mine casualties, while the units with breaching equipment conducts a breach, losing more equipment to mines in the process.

MOE 3 compares the losses to each unit due to both mines and direct fire in Figure 14. The values are found by using column 13 from Table 1 divided by 56. It is interesting to note that in the cases of the probability of minefields with direct fire and 100 percent probability of minefields with direct fire, the 12/1/1 configuration

performed better than the 10/2/2 combination. This is due to the fact that most of the breaching assets in the 12/1/1 configuration are lost during the breach of the far minefield and the unit is able to travel faster in the 2600 to 1500 meter range band, thereby being subjected to the enemy's direct fire weapons for a shorter period. Of the configurations with breaching equipment, the 8/3/3 unit does the best when there is no direct fire.

MOEs 4,5 and 6 compare the losses of equipment versus the number of pieces of breaching equipment available in the unit. Their values are computed in the same manner as MOEs 1,2 and 3 except the denominator is the number of pieces of breaching equipment. Due to a changing denominator, the comparison of the of the various configurations is difficult. However the MOEs show the increasing number of casualties as the probability of the minefields increase (Figure 15). The synergistic effect of the combination of direct fire and minefields is clearly evident (Figure 16). The losses to any of the forces is the lowest when faced by direct fire only, increasing slightly when faced by minefields only, and increasing drastically when the combination of the two systems interact to defeat the enemy (Figure 17).

Since the number of pieces of breaching equipment are the same in the 10/2/2 and the 10/3/1 configurations they may be examined in more detail for these MOEs. The 10/2/2

configuration performed better when the unit was faced by direct fire only or minefields only, however the difference is minimal. When faced with a combination of mines and direct fire, the 10/3/1 configuration fared slightly better in both the number of direct fire casualties per piece of breaching equipment (Figure 16) and the total number of casualties due to mines and direct fire combined (Figure 17).

The number of units going to a defensive posture is shown by MOE 7 (Figure 18). The number is obtained from columns 3,6,9 and 12 from Table 2. In the scenario with direct fire only, the number of units going to defensive posture is relatively the same for all configurations, thereby again substantiating the point that the countermine equipment does not impact a great deal on the unit when it is faced only by direct fire. Even when the units are faced by scenario 2 (probability of minefields and direct fire) the number of units going to defensive posture does not differ a great deal. It is only when there exists a 100 percent chance of minefields that differences becomes large. The best performer for the configurations with breaching equipment when faced only by minefields is the 8/3/3 combination while the 12/1/1 combination was the worst. However when faced by the probability of minefields and direct fire the number of units going to a defensive posture was significantly lower for the 12/1/1 combination

and even the 10/2/2 combination did better. This can be attributed in part to the fact that the breaching equipment is prevented, by the simulation, from engaging while breaching operations are taking place.

MOE 8 examines the period in the battle when the units went to a defensive posture (Figure 19). The battle was divided into four time periods - beginning, early, middle and late - each period representing one fourth of the duration of the battle. The determination of which period a unit went to a defensive posture was calculated by taking the battle time of each repetition and determining in which quarter the defensive times fell.

Once again all configurations performed equally well when there were no minefields and the units were faced only by direct fire. In this MOE all the configurations with breaching equipment performed better than the 14/0/0 configuration. The 14/0/0 configuration tended to go to a defensive posture much earlier in the battle due to the reduced speed imposed by the bypass routine. The 14/0/0 configuration is able to reach the far set of minefields quicker than the other configurations where it is then stopped and is attritted by the enemy. The configurations with breaching equipment were able to keep moving much longer in the battle, with the 10/2/2 combination performing the best.

The length of the battle is described by MOE 9 (Figure 20). Once again the numbers are misleading unless they are examined closely. In scenario 1, the 14/0/0 unit is able to close with the enemy much sooner (due to no speed degradation caused by the breaching equipment) than the units with breaching equipment. The length of the attack is approximately six kilometers and the higher speeds of the M1 unit allows it to travel faster. Similarly, the probability of minefields combined with direct fire still produced quicker battle times for the 14/0/0 combination, since if at least two units did not encounter the far minefield, they could close rapidly with the enemy and defeat him. The time of battle for 100% minefields and direct fire is essentially equal for all configurations, with the 14/0/0 configuration able to move rapidly between minefields and then losing time while bypassing. The average length of battle when there are only minefields present was approximately the same for all configurations with breaching equipment. It was also approximately the same when each configuration is compared between the two scenarios of 100% minefields/direct fire and when there are only minefields present. The big increase in time occurs in the 14/0/0 configuration, starting from a low in the 0%/direct fire scenario to a maximum in the 100%/no direct fire case. It should be noted that the only battle termination criteria that applies in the 100%/no direct

fire is the minimum range requirement of 250 meters and this requirement causes the 14/0/0 configuration to bypass both the far and near minefields.

The average range at battle termination is MOE 10 (Figure 21). All values are approximately the same with one notable exception, that of the 14/0/0 configuration in the scenario of probability of minefields/ direct fire. This dramatic increase, in relation not only with itself but also with the other configurations, is attributed to the fact that the units on the avenues that are not faced by a minefield move rapidly through the area and suddenly find themselves in a direct fire battle with the enemy where they are attritted to a defensive posture early in the battle. This fact is substantiated by consideration of MOE 8, Figure 19, where the number of units going to a defensive posture in the middle of the battle is substantially higher for the 14/0/0 configuration.

The rate of battle losses is the last MOE. Figure 22 shows the rates which were determined by taking the total number of casualties per repetition (column 13, Table 1) and dividing by the length of battle for the repetition (column 14, Table 1). The figures, when comparing the 14/0/0 configuration with the rest of the configurations, are somewhat misleading. The 14/0/0 had the least number of losses in all cases, but since they are able to travel faster, battle time was shorter, causing the rate to appear

artificially high. Among the configurations with breaching equipment, there is no single best performer, although the 12/1/1 and the 8/3/3 configurations were better than the others.

C. SUMMARY OF RESULTS - MODEL ONE

Upon examination of all the configurations with breaching equipment under the four different scenarios, the best performer was the 12/1/1 combination. The reason is that the breaching assets of the 12/1/1 configuration are, in most cases, just enough to allow the unit to breach through the low density far minefield and then continue the attack without being encumbered by the slow moving breaching equipment. The low amount of breaching equipment also means that the majority of the force is able to engage the enemy while breaching operations are taking place.

The only configuration that clearly performs better than the 12/1/1 configuration is the 8/3/3. This configuration is of greater benefit when there is no direct fire and it is in these situations that the 8/3/3 configuration does perform better.

D. SENSITIVITY ANALYSIS USING THE ENHANCED MODEL

Sensitivity analysis was conducted through the use of the second model. As discussed in Chapter 3, the second model was developed using the concept of perfect communications. When one unit encounters a minefield, the

rest of the units redeploy in formation 3, placing the roller assets in the lead to detect the minefields on their avenue. Two configurations, the 12/1/1 and the 10/2/2, were evaluated under two scenarios, the probability of minefields/direct fire and the 100% minefields/no direct fire, and the output was analyzed under the same MOEs and compared to the values found using Model 1. Table 7 shows the mean and standard deviation of the 50 repetitions conducted under each configuration and scenario.

The two configurations are compared against the base case configuration of 14/0/0. Figure 23 shows the comparison using MOE 1. In both configurations the performance using Model 1 was slightly better. However, using MOE 2, the losses due to mines was greatly reduced using Model 2, even to the point that the 12/1/1 configuration performed better than the 14/0/0 configuration (Figure 24). Figure 25 shows the total percent of losses due to both mines and direct fire. The configurations once again performed better under Model 2, even to the point that the 12/1/1 configuration suffered fewer losses than the 14/0/0 configuration in the probability of minefields/ direct fire scenario.

MOEs 4 (Figure 26), 5 (Figure 27), and 6 (Figure 28) compare the configurations when the amount of breaching equipment is constant. In all four cases the losses per piece of breaching equipment dropped under Model 2, however

there was a slight increase in the direct fire losses. This can be attributed to the fact that once the first minefield is detected, the units move only as fast as the mineroller tank. Overall, the two configurations performed better under Model 2.

The percent of units assuming a defensive posture decreased under both scenarios of the 12/1/1 configuration, but the results were mixed for the 10/2/2 configuration (Figure 29). The period in the battle also showed an improvement for the 12/1/1 configuration under Model 2. In the probability of minefields/direct fire scenario, the number going to a defensive posture in the middle phase of the battle dropped dramatically, with a slight decrease occurring in the late battle also.

Once again the average length of battle figures are deceiving unless examined closely. Figure 31 show an increase in all the battle times. This is entirely due to the fact that once the first minefield is detected/detonated, the fastest speed a unit can move is that of the mineroller tank, at least until it is attritted.

Figure 32 shows the average ending range of the battle with the results indicating little or no difference between the two models. Finally, Figure 33 shows the rate of battle losses, again with a dramatic improvement for Model

2. Obviously the contributing factor is the decrease in losses to the force due to mine encounters.

The tactics used by the attacking force, in particular the method of detecting the obstacles, impacts heavily on the performance of the unit. Under Model 2 the 12/1/1 configuration once again performed better than the 10/2/2 configuration when evaluated under the two scenarios, because the majority of the breaching equipment is lost during the conduct of the first breach and the unit is able to travel faster. Also, under the probability of minefields/direct fire scenario, if one unit detects a minefield and is slowed in its progress, it will be able to easily catch up to the unit that did not encounter a minefield, since that unit is moving only as fast as the employed mineroller tank. This allows the units to align themselves to concentrate their fires on the target.

E. FINAL CONCLUSIONS

Based on the evaluation of the MOEs using the output from both Models 1 and 2 the following observations and conclusions can be made. The amount of breaching equipment required to support an armor battalion is situationally dependent.

The various factors weighing heavily on the required number of breaching assets are the enemy, terrain, mission and tactics. If a battalion is assigned a clearing mission in a lightly defended area, a force configured with a

larger number of breaching assets would perform better, although if time was not crucial and the threat involved was low, a smaller number of breaching assets would prove to be just as effective.

If the area of operations is heavily defended, a force configuration that would allow the unit to breach the outer obstacles and then rapidly close with and defeat the enemy force would call for a smaller number of breaching assets. If the terrain restricts maneuver space to such a degree that the bypass option is no longer viable, the number of assets would have to be increased to insure a greater degree of success.

Based on the configurations and scenarios examined in this thesis, a force structure of 12 tanks, 1 mineplow and 1 mineroller tank is recommended, however further analysis in this area should be conducted to confirm the results.

NUMBER OF KILLS BY CATEGORY PER REPETITION											
DIRECT	FIRE	ROLL	PLow	MINEFIELD	PLowCARR	ROLLCARR	TOTKILL	CLOCK	MINRNG		
UNIT 1	UNITCODE 1	EQUIP	TANK 10	MINEPLOW	2	0	MINEROLLER	2	0		
UNIT 2	UNITCODE 1	EQUIP	TANK 10	MINEPLOW	2	0	MINEROLLER	2	0		
UNIT 3	UNITCODE 1	EQUIP	TANK 10	MINEPLOW	2	0	MINEROLLER	2	0		
UNIT 4	UNITCODE 1	EQUIP	TANK 10	MINEPLOW	2	0	MINEROLLER	2	0		
40/30/	3/ 7	1	0	5/ 5/ 0/ 0	4	0	49	54.5	1.278		
25/20/	2/ 3	1	0	5/ 5/ 0/ 0	5	2	37	47.5	1.014		
15/11/	1/ 3	2	0	8/ 8/ 0/ 0	2	0	25	41.0	0.803		
19/12/	5/ 2	0	0	0/ 0/ 0/ 0	2	0	21	40.0	1.228		
16/11/	3/ 2	0	0	4/ 4/ 0/ 0	1	0	21	40.5	1.303		
20/16/	2/ 2	3	0	10/10/ 0/ 0	6	0	36	46.5	1.581		
17/10/	1/ 6	1	0	7/ 7/ 0/ 0	2	0	26	42.5	1.588		
23/15/	3/ 5	1	0	2/ 2/ 0/ 0	1	0	26	43.0	0.711		
17/14/	2/ 1	3	0	4/ 4/ 0/ 0	3	0	24	42.0	0.933		
27/17/	4/ 6	2	0	5/ 5/ 0/ 0	4	0	36	49.5	0.877		
20/14/	3/ 3	5	1	16/16/ 0/ 0	4	0	40	46.0	1.414		
23/14/	4/ 5	1	0	3/ 3/ 0/ 0	1	0	27	41.0	2.141		
22/14/	1/ 7	0	0	1/ 1/ 0/ 0	4	1	28	45.5	0.643		
23/16/	3/ 4	1	0	1/ 1/ 0/ 0	1	0	25	44.0	0.651		
13/12/	0/ 1	3	0	1/ 1/ 0/ 0	4	0	18	43.0	1.113		
20/17/	2/ 1	1	0	4/ 4/ 0/ 0	3	2	29	45.0	0.936		
9/ 5/	2/ 2	0	0	1/ 1/ 0/ 0	0	0	10	35.5	1.525		
16/12/	1/ 3	1	0	1/ 1/ 0/ 0	4	1	22	43.0	0.799		
15/ 9/	3/ 3	1	0	5/ 5/ 0/ 0	2	1	23	41.5	1.105		
30/24/	2/ 4	4	1	10/10/ 0/ 0	5	0	45	50.5	0.910		
29/19/	3/ 7	0	0	6/ 6/ 0/ 0	1	0	36	44.0	0.794		
20/13/	3/ 4	1	0	7/ 7/ 0/ 0	2	3	32	48.0	0.937		
8/ 6/	2/ 0	0	0	1/ 1/ 0/ 0	0	0	9	37.5	1.236		
28/21/	3/ 4	2	0	6/ 6/ 0/ 0	3	1	38	47.5	1.005		
8/ 7/	0/ 1	2	2	2/ 2/ 0/ 0	3	0	13	40.5	1.374		
31/23/	3/ 5	1	0	3/ 3/ 0/ 0	3	1	38	49.0	0.889		
17/12/	1/ 4	0	0	3/ 3/ 0/ 0	4	0	24	42.0	1.110		
20/17/	2/ 1	7	1	13/13/ 0/ 0	5	0	38	50.0	0.356		
19/13/	3/ 3	2	0	1/ 1/ 0/ 0	3	1	24	42.0	0.944		
14/ 9/	2/ 3	1	0	4/ 4/ 0/ 0	3	0	21	40.5	1.152		
22/15/	2/ 5	1	0	2/ 2/ 0/ 0	1	0	25	43.0	0.866		
20/16/	1/ 3	3	0	6/ 6/ 0/ 0	7	2	35	49.0	1.101		
23/16/	3/ 4	0	0	3/ 3/ 0/ 0	3	0	29	42.5	1.119		
22/14/	3/ 5	1	0	2/ 2/ 0/ 0	3	1	28	41.5	1.479		
9/ 5/	1/ 3	1	0	1/ 1/ 0/ 0	0	0	10	38.0	1.349		
11/ 8/	2/ 1	0	0	4/ 4/ 0/ 0	0	0	15	42.0	1.009		
16/ 9/	2/ 5	0	0	2/ 2/ 0/ 0	1	0	19	42.0	1.087		
20/16/	1/ 3	3	0	13/13/ 0/ 0	7	2	42	53.5	1.265		
20/16/	0/ 4	1	0	1/ 1/ 0/ 0	4	0	25	43.5	0.966		
26/19/	2/ 5	0	0	1/ 1/ 0/ 0	1	0	28	44.0	1.104		
16/11/	1/ 4	1	0	1/ 1/ 0/ 0	2	0	19	41.5	1.178		
15/11/	0/ 4	1	1	4/ 4/ 0/ 0	1	1	21	42.0	0.914		
15/10/	2/ 3	0	0	1/ 1/ 0/ 0	2	1	19	42.0	0.963		
20/13/	3/ 4	0	0	4/ 4/ 0/ 0	1	0	25	43.0	1.108		
18/12/	2/ 4	0	0	2/ 2/ 0/ 0	3	0	23	42.5	1.197		
12/ 7/	1/ 4	0	0	3/ 3/ 0/ 0	2	0	17	40.5	1.337		
10/ 8/	0/ 2	0	0	2/ 2/ 0/ 0	3	0	15	42.0	1.131		
24/19/	2/ 3	2	0	2/ 2/ 0/ 0	2	0	28	43.5	1.502		
24/13/	4/ 7	0	0	4/ 4/ 0/ 0	0	0	28	42.0	0.962		
15/11/	1/ 3	1	0	1/ 1/ 0/ 0	4	1	21	44.5	1.040		

TABLE 1. VEHICLE LOSSES, TIME AND RANGE OUTPUT FILE

ACTIVE MINEFIELDS AND TIMES TO DEFENSIVE POSTURE										RUN TIME
AVENUE 1		AVENUE 2		AVENUE 3		AVENUE 4				
M1	M2	M1	M2	M1	M2	M1	M2			
1	1	1	1	1	1	1	1	41.0	60.5	
1	1	1	0	1	1	1	0	0.0	42.5	
1	1	1	1	1	0	0	1	0.0	42.5	
1	1	0	1	0	1	1	1	0.0	43.5	
0	1	1	1	0	1	1	1	0.0	42.5	
1	0	1	1	0	1	0	1	0.0	42.0	
0	1	1	1	1	1	0	1	0.0	40.5	
1	1	1	1	1	1	1	0	0.0	45.5	
1	1	0	0	1	1	1	1	0.0	43.0	
1	1	1	1	0	1	0	1	0.0	42.5	
1	1	1	1	1	1	1	1	42.5	45.0	
0	1	1	1	0	1	0	1	0.0	39.0	
0	0	1	1	1	1	1	1	47.5	49.0	
1	1	0	1	0	1	1	1	0.0	45.5	
1	1	1	0	0	1	1	1	0.0	42.5	
0	1	1	1	1	1	1	1	0.0	44.0	
1	1	0	1	1	1	1	1	0.0	39.5	
0	1	0	1	1	1	0	1	0.0	41.0	
0	1	1	1	0	1	1	1	0.0	43.0	
1	1	1	1	0	0	1	1	0.0	40.5	
1	1	1	1	0	1	1	0	0.0	44.0	
1	1	1	1	1	1	1	0	0.0	41.0	
1	0	1	1	0	0	1	1	0.0	41.0	
1	1	1	1	0	1	1	0	0.0	41.5	
1	1	1	1	0	1	1	0	0.0	43.0	
1	1	0	1	0	1	1	1	0.0	40.5	
1	1	1	0	1	0	1	1	46.0	49.0	
1	1	1	0	0	1	1	1	0.0	46.0	
1	1	1	1	0	1	0	0	0.0	40.5	
1	1	1	1	0	1	0	1	0.0	43.5	
1	1	1	1	0	1	1	1	0.0	35.5	
0	1	1	1	1	1	0	1	0.0	40.5	
1	1	0	1	0	1	1	1	0.0	41.5	
1	1	1	1	1	1	0	1	0.0	46.5	
1	1	1	1	0	0	0	1	0.0	43.5	
1	1	1	1	1	1	0	1	0.0	45.5	
1	1	1	1	0	1	0	1	0.0	42.0	
1	0	1	1	1	0	0	1	0.0	42.5	
1	1	1	0	0	1	1	0	0.0	38.0	
0	1	1	1	0	1	1	1	0.0	46.0	
1	0	1	1	1	1	1	1	0.0	41.5	
1	1	0	1	1	1	0	1	44.5	46.0	
1	1	1	0	0	1	1	1	0.0	42.0	
1	1	1	1	0	1	1	0	0.0	42.0	
1	1	1	1	1	1	1	1	0.0	44.5	
1	1	1	1	0	1	0	1	0.0	42.0	
1	0	1	1	1	1	1	1	0.0	43.5	
1	1	0	1	0	1	1	1	0.0	37.5	
1	0	1	1	1	1	1	1	0.0	43.5	

TABLE 2. MINEFIELD STATUS AND DEFENSIVE POSTURE TIME
OUTPUT FILE

No Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness		14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
	1	0.239 (0.098)	0.251 (0.100)	0.252 (0.099)	0.268 (0.105)	0.235 (0.092)
	2	N/A	N/A	N/A	N/A	N/A
	3	0.239 (0.098)	0.251 (0.098)	0.252 (0.099)	0.268 (0.105)	0.235 (0.092)
	4	N/A	N/A	N/A	N/A	N/A
	5	N/A	7.020 (2.808)	3.525 (1.384)	2.500 (0.983)	3.295 (1.291)
	6	N/A	7.020 (2.808)	3.525 (1.384)	2.500 (0.983)	3.295 (1.291)
	7	16/200	21/200	14/200	20/200	13/200
	8	0 0 0 16	0 0 0 21	0 0 0 14	0 0 0 20	0 0 0 13
	9	24.21 (0.969)	36.80 (1.484)	36.85 (1.543)	36.92 (1.592)	36.28 (1.614)
	10	0.773 (0.227)	1.047 (0.242)	1.045 (0.271)	1.050 (0.267)	1.127 (0.294)
	11	0.548 (0.204)	0.378 (0.139)	0.379 (0.136)	0.402 (0.144)	0.359 (0.128)

TABLE 3. NO MINEFIELDS/DIRECT FIRE STATISTICS

Prob Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness

	14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
1	0.338 (0.127)	0.292 (0.105)	0.328 (0.147)	0.317 (0.133)	0.308 (0.430)
2	0.105 (0.064)	0.153 (0.076)	0.170 (0.087)	0.160 (0.084)	0.174 (0.085)
3	0.444 (0.152)	0.446 (0.144)	0.498 (0.181)	0.477 (0.173)	0.482 (0.184)
4	N/A	4.300 (2.126)	2.380 (1.220)	1.493 (0.782)	2.435 (1.195)
5	N/A	8.190 (2.948)	4.590 (2.056)	2.963 (1.246)	4.320 (1.997)
6	N/A	12.49 (4.039)	6.970 (2.538)	4.457 (1.613)	6.755 (2.570)
7	74/200	71/200	77/200	85/200	81/200
8	1 4 27 42	0 0 10 61	0 4 12 61	0 0 11 84	0 12 4 65
9	33.87 (11.37)	40.02 (5.372)	41.63 (9.287)	40.45 (5.358)	42.70 (13.29)
10	2.096 (3.742)	1.098 (0.300)	1.015 (0.335)	1.026 (0.305)	1.062 (0.292)
11	0.737 (0.160)	0.615 (0.153)	0.660 (0.148)	0.648 (0.184)	0.629 (0.151)

TABLE 4. PROBABILITY OF MINEFIELDS/DIRECT FIRE STATISTICS

100% Minefields/Direct Fire

Unit Configuration

Measure of Effectiveness		14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
	1	0.401 (0.150)	0.357 (0.150)	0.385 (0.124)	0.381 (0.169)	0.361 (0.142)
	2	0.187 (0.070)	0.258 (0.078)	0.253 (0.053)	0.236 (0.056)	0.265 (0.064)
	3	0.589 (0.170)	0.615 (0.172)	0.639 (0.135)	0.616 (0.185)	0.626 (0.157)
	4	N/A	7.230 (2.174)	3.550 (0.739)	2.203 (0.526)	3.705 (0.896)
	5	N/A	9.990 (4.198)	5.395 (1.736)	3.553 (1.579)	5.060 (1.989)
	6	N/A	17.22 (4.319)	8.945 (2.056)	5.757 (1.730)	8.765 (2.193)
	7	124/200	131/200	145/200	142/200	152/200
	8	2 21 50 50	0 11 24 96	0 14 12 119	0 10 24 108	0 8 28 116
	9	46.14 (14.68)	46.90 (12.52)	47.00 (13.34)	46.27 (12.49)	46.18 (11.42)
	10	1.617 (0.445)	1.314 (0.305)	1.045 (0.369)	1.022 (0.373)	1.030 (0.378)
	11	0.729 (0.161)	0.740 (0.114)	0.771 (0.102)	0.744 (0.137)	0.762 (0.113)

TABLE 5. 100% MINEFIELDS/DIRECT FIRE STATISTICS

100% Minefields/No Direct Fire

Unit Configuration

Measure of Effectiveness		14/0/0	12/1/1	10/2/2	8/3/3	10/3/1
	1	N/A	N/A	N/A	N/A	N/A
	2	0.213 (0.052)	0.346 (0.093)	0.356 (0.080)	0.321 (0.062)	0.368 (0.080)
	3	0.213 (0.052)	0.346 (0.093)	0.356 (0.080)	0.321 (0.062)	0.368 (0.080)
	4	N/A	9.700 (2.619)	4.990 (1.116)	2.997 (0.578)	5.155 (1.126)
	5	N/A	N/A	N/A	N/A	N/A
	6	N/A	9.700 (2.619)	4.990 (1.116)	2.997 (0.578)	5.155 (1.126)
	7	2/200	44/200	35/200	14/200	35/200
	8	0 2 0 0	0 0 15 29	0 0 0 35	0 0 0 14	0 0 0 35
	9	62.83 (4.738)	49.91 (7.878)	44.15 (1.408)	44.08 (0.798)	43.92 (1.153)
	10	0.218 (0.022)	0.217 (0.027)	0.215 (0.028)	0.214 (0.024)	0.214 (0.022)
	11	0.192 (0.056)	0.396 (0.119)	0.452 (0.102)	0.409 (0.083)	0.470 (0.105)

TABLE 6. 100% MINEFIELDS NO DIRECT FIRE STATISTICS

MEASURE OF EFFECTIVENESS 1

% LOSSES TO DF

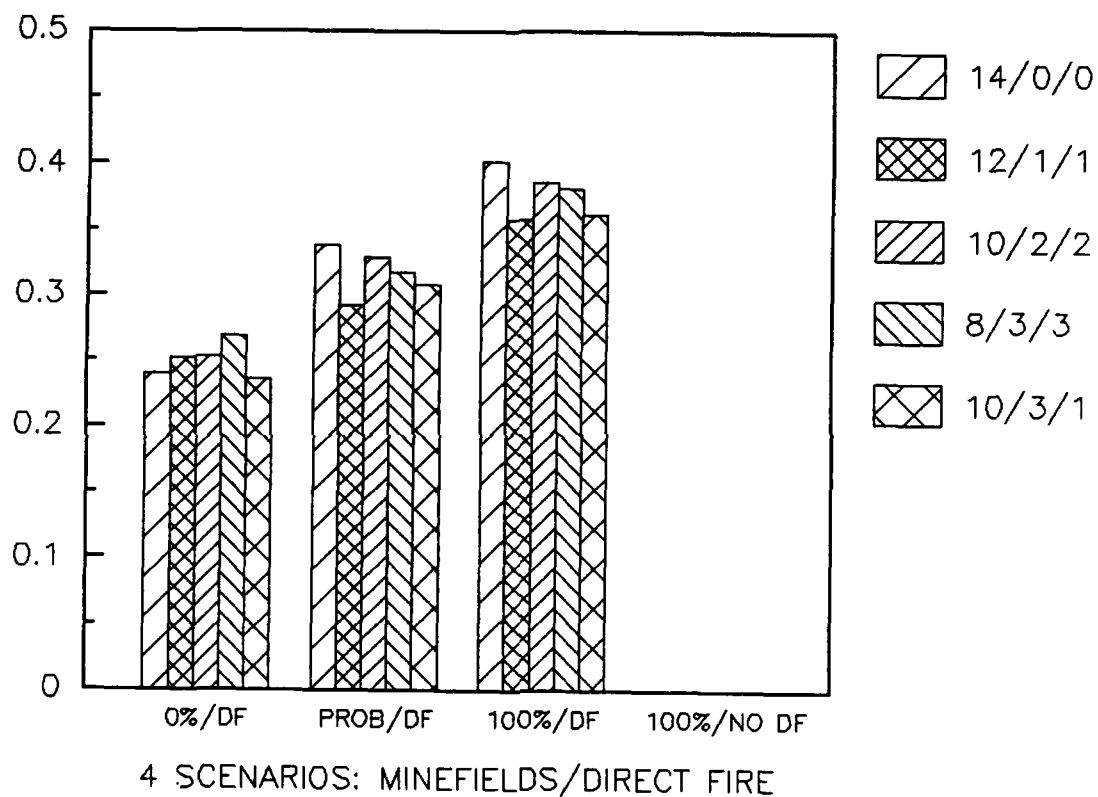


Figure 12. Model 1 Measure of Effectiveness 1

MEASURE OF EFFECTIVENESS 2

% LOSSES TO MINES

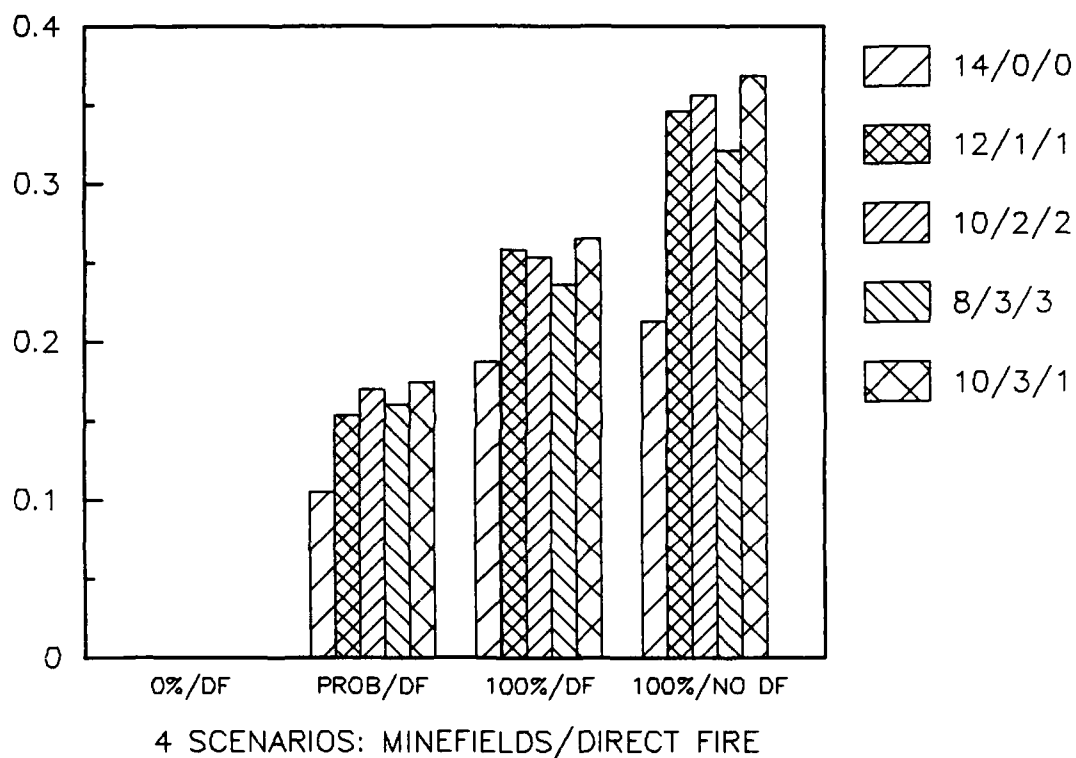


Figure 13. Model 1 Measure of Effectiveness 2

MEASURE OF EFFECTIVENESS 3

% LOSSES TOTAL

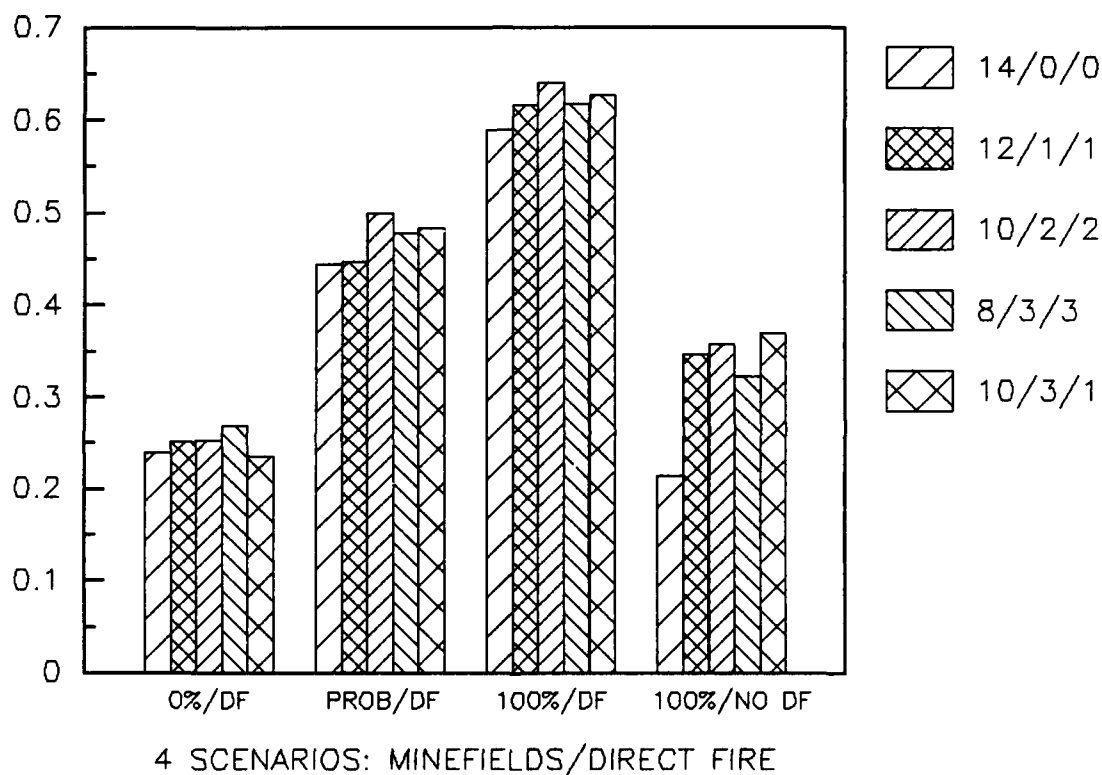


Figure 14. Model 1 Measure of Effectiveness 3

MEASURE OF EFFECTIVENESS 4

MINE CAS PER PIECE

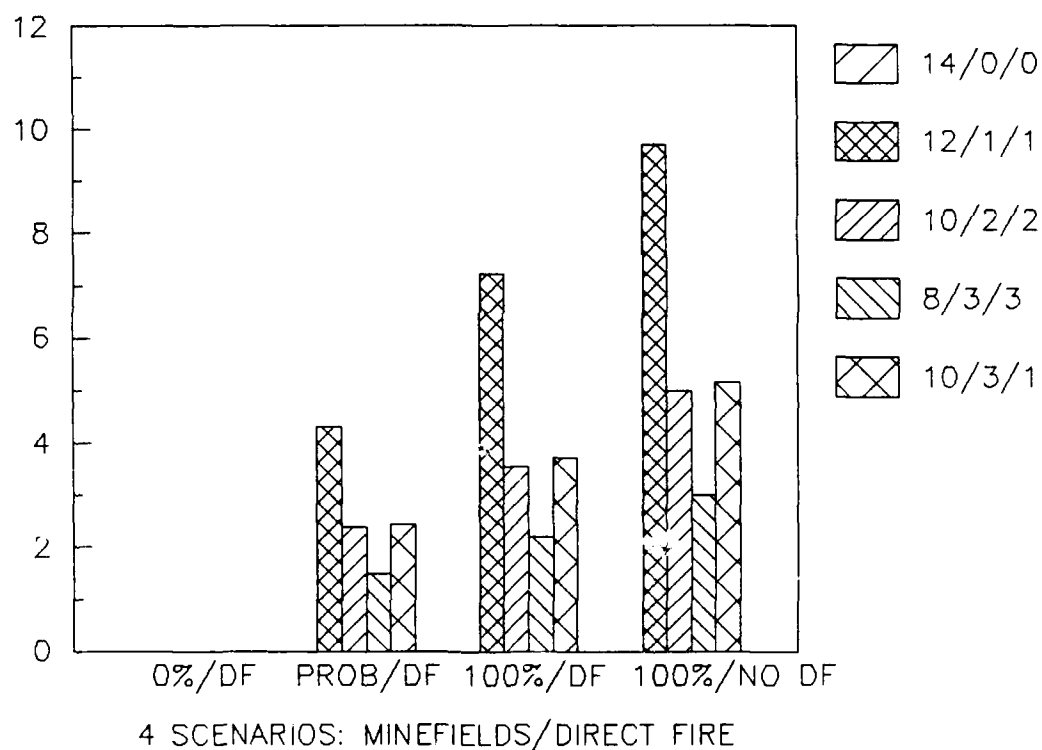


Figure 15. Model 1 Measure of Effectiveness 4

MEASURE OF EFFECTIVENESS 5

DF CAS PER PIECE

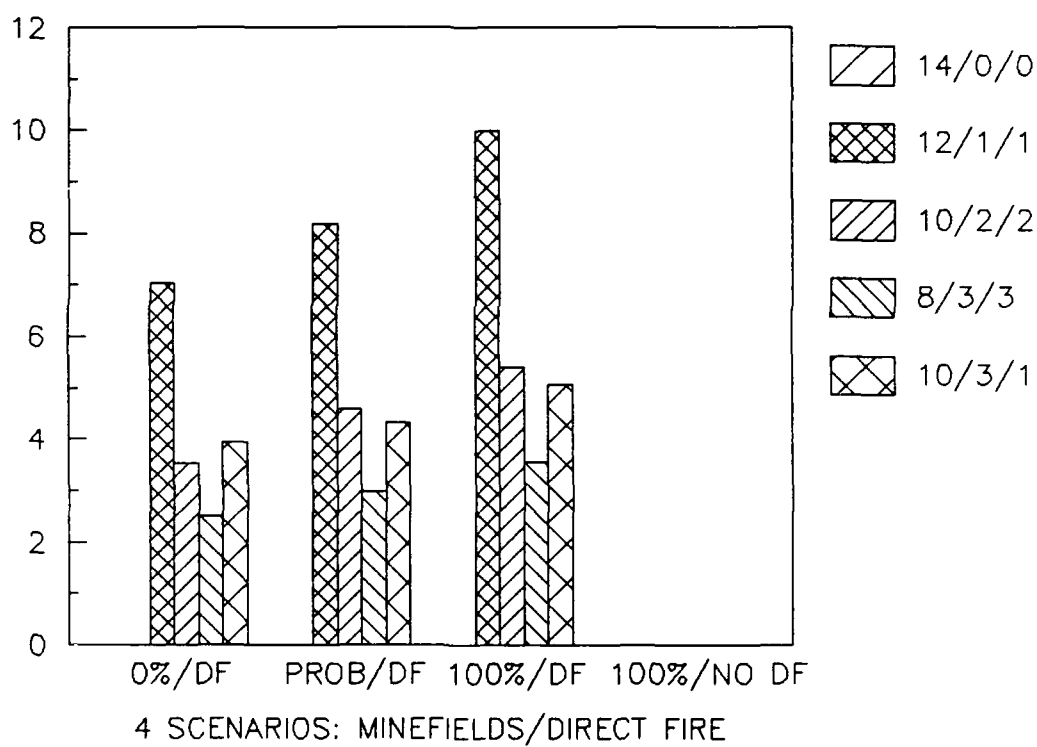


Figure 16. Model 1 Measure of Effectiveness 5

MEASURE OF EFFECTIVENESS 6 TOTAL # CAS PER PIECE

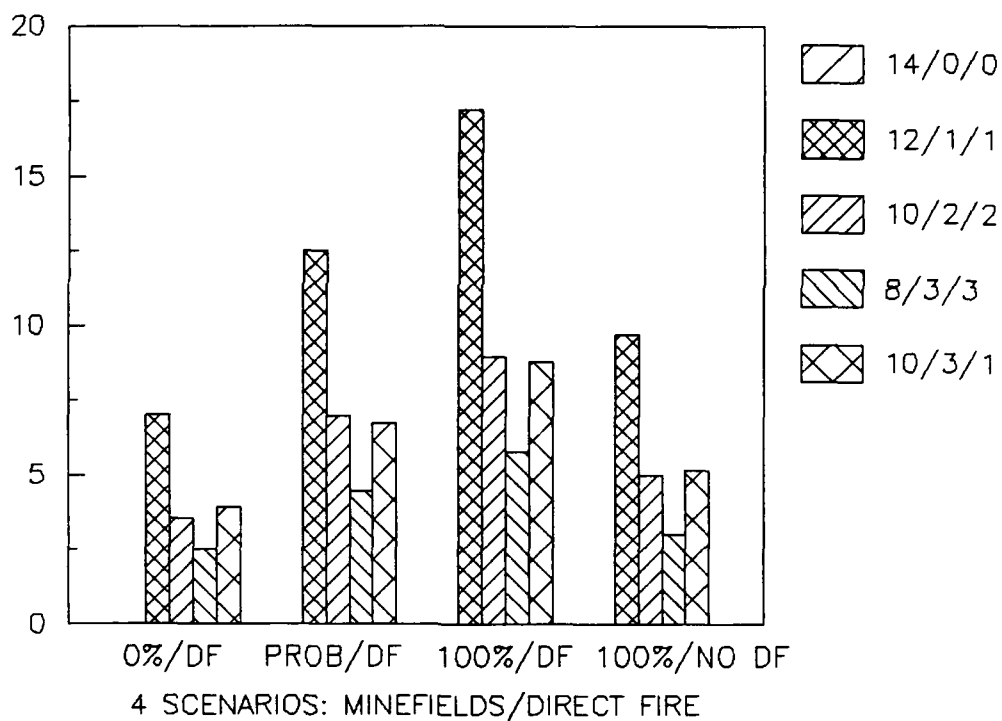


Figure 17. Model 1 Measure of Effectiveness 6

MEASURE OF EFFECTIVENESS 7

% UNITS TO DEFENSE

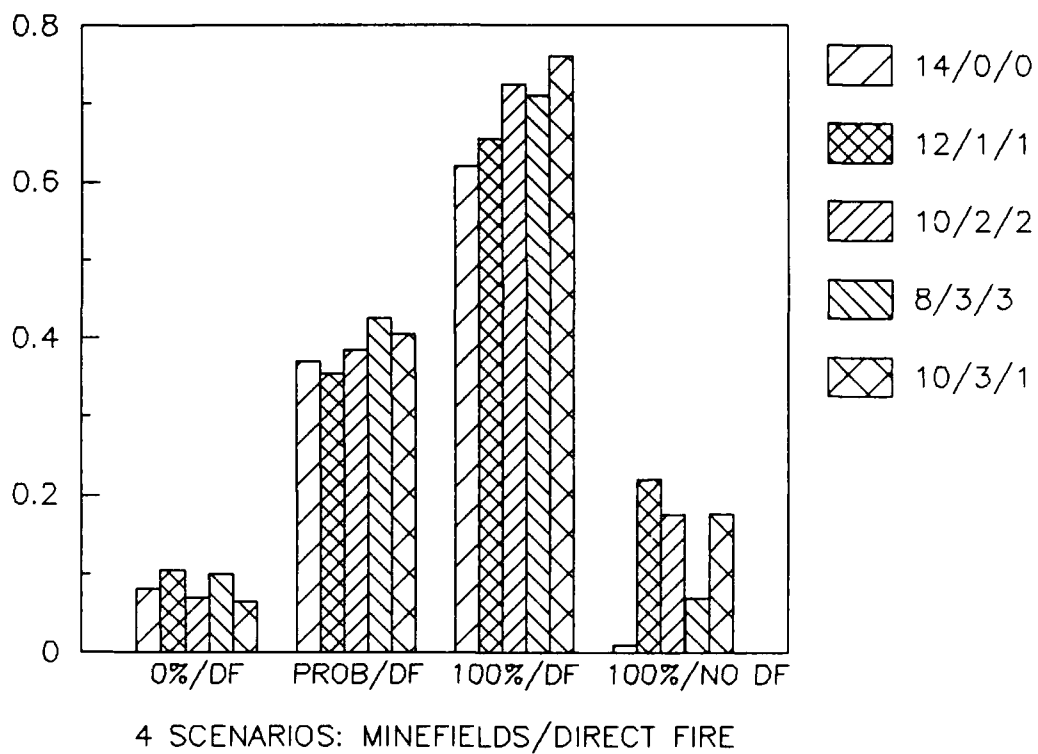


Figure 18. Measure of Effectiveness 7

MEASURE OF EFFECTIVENESS 8

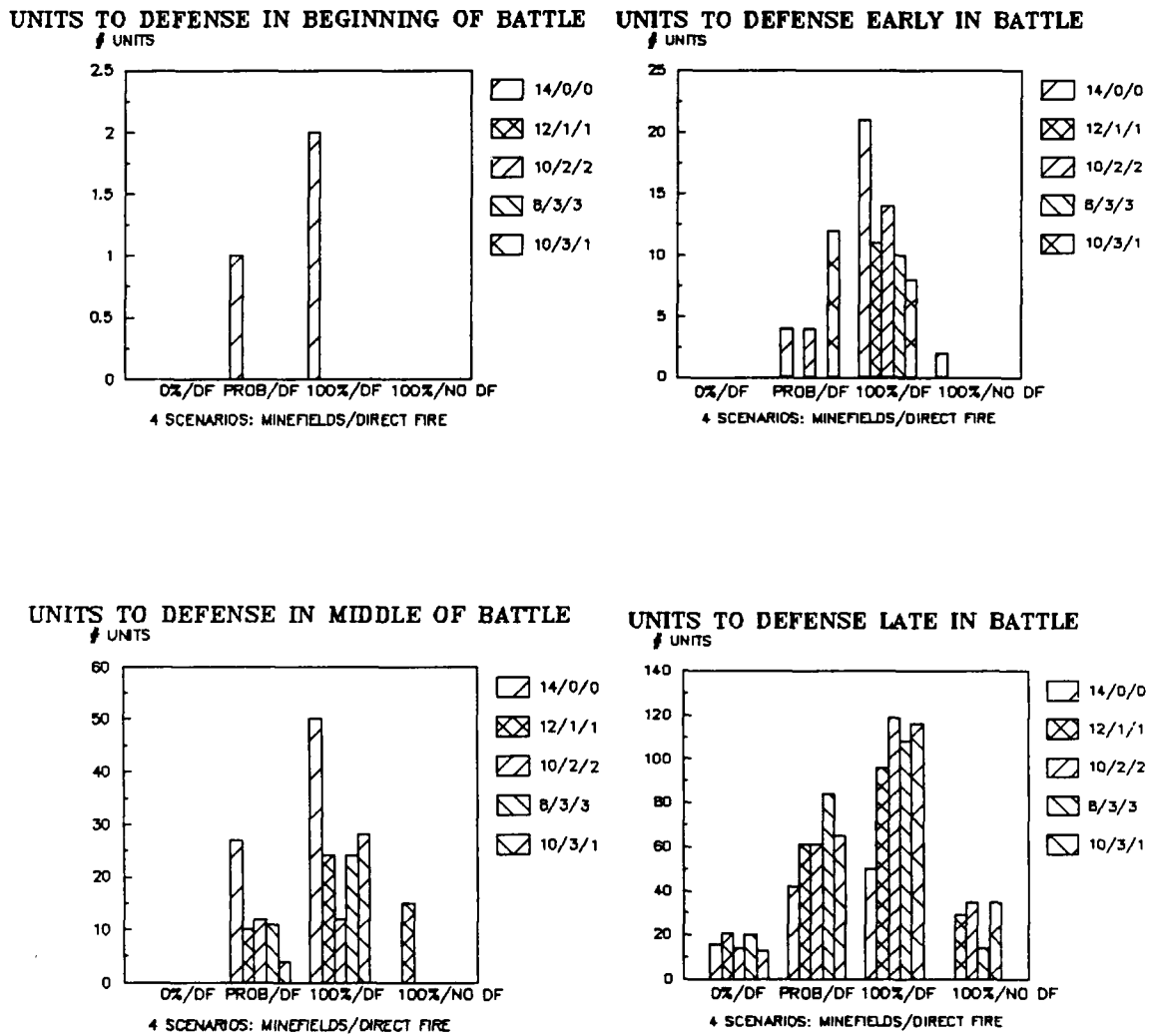


Figure 19. Model 1 Measure of Effectiveness 8

MEASURE OF EFFECTIVENESS 9 AVG LENGTH OF BATTLE

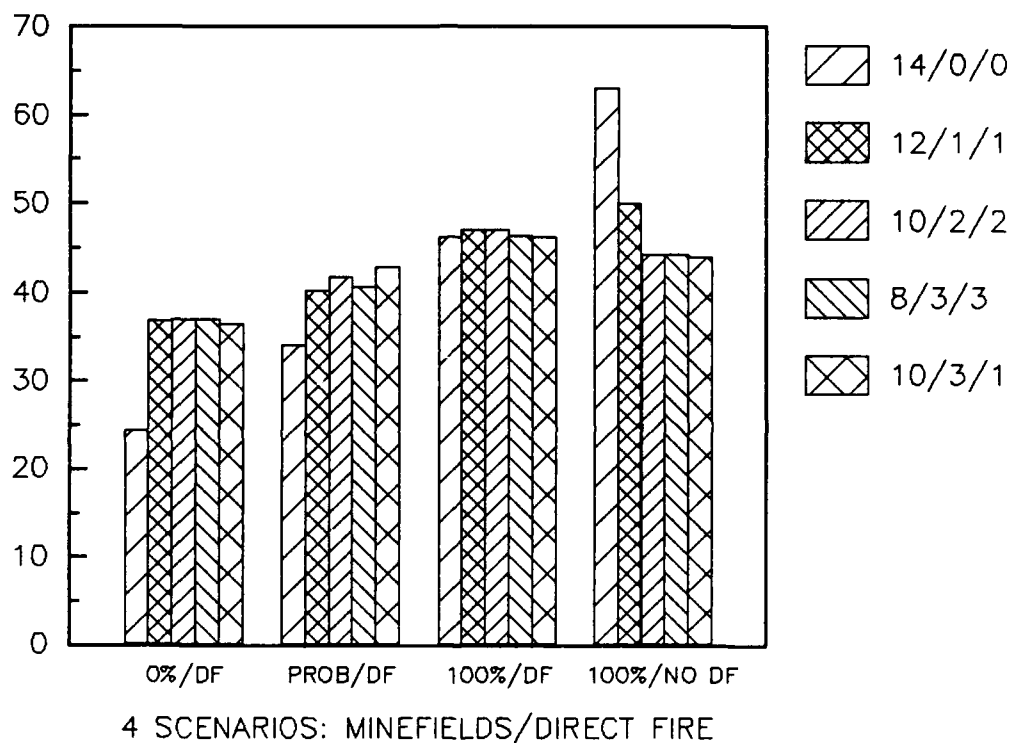


Figure 20. Model 1 Measure of Effectiveness 9

MEASURE OF EFFECTIVENESS 10 AVG END RANGE OF BATTLE

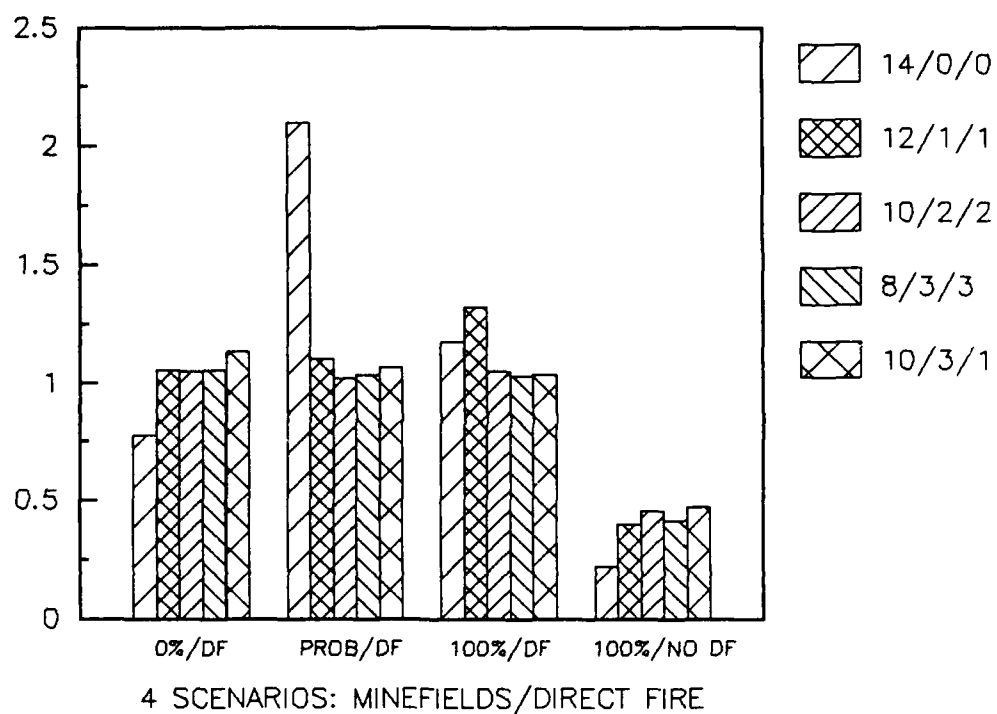


Figure 21. Model 1 Measure of Effectiveness 10

MEASURE OF EFFECTIVENESS 11 **RATE OF BATTLE LOSSES**

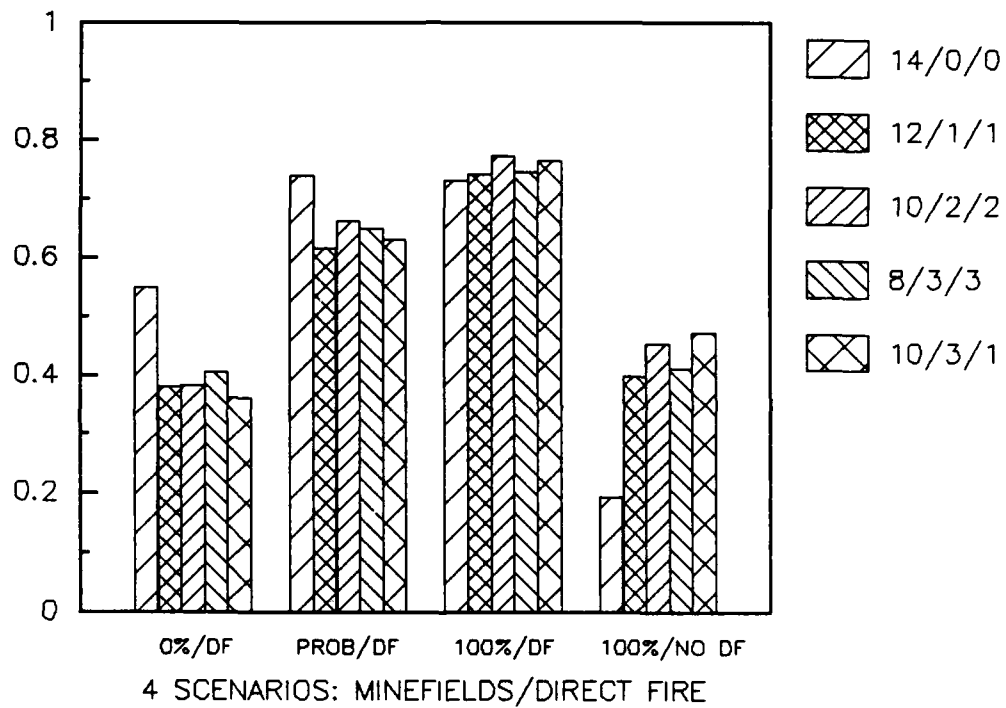


Figure 22. Model 1 Measure of Effectiveness 11

MODEL 2 STATISTICS

Unit Configuration

12/1/1

10/2/2

Measure of Effectiveness

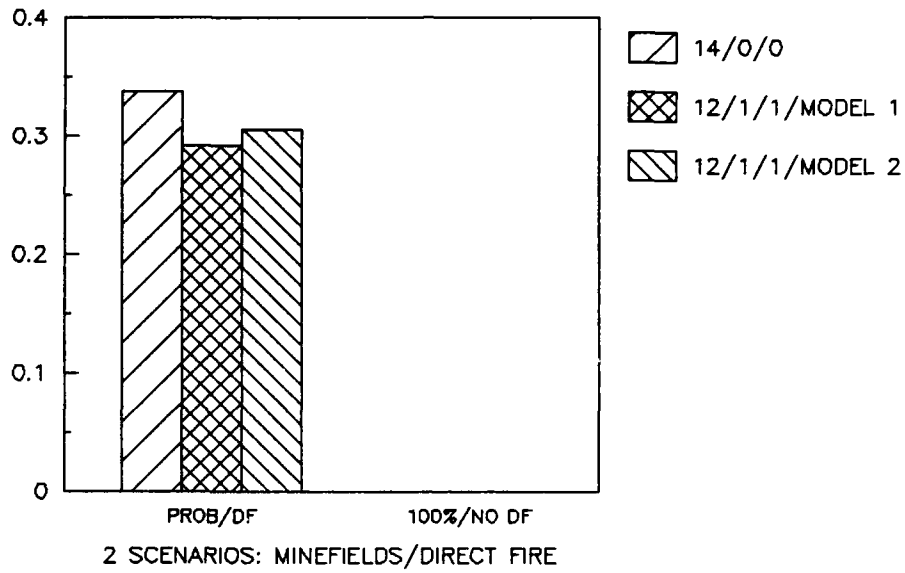
	PROB/DF	100%/NO DF		PROB/DF	100%/NO DF
1	0.305 (0.112)	N/A		0.343 (0.114)	N/A
2	0.098 (0.054)	0.241 (0.102)		0.125 (0.086)	0.257 (0.973)
3	0.403 (0.134)	0.241 (0.102)		0.469 (0.162)	0.257 (0.973)
4	2.760 (1.532)	6.750 (2.856)		1.755 (1.207)	3.600 (1.363)
5	8.540 (3.134)	N/A		4.810 (1.601)	N/A
6	11.30 (3.751)	6.750 (2.856)		6.565 (2.267)	3.600 (1.363)
7	64/200	35/200		91/200	32/200
8	0 0 4 60	0 0 20 15		0 0 6 85	0 0 0 32
9	43.02 (3.620)	55.18 (7.512)		43.71 (3.805)	48.44 (2.251)
10	1.084 (0.438)	0.223 (0.022)		1.122 (0.297)	0.219 (0.027)
11	0.518 (0.144)	0.245 (0.101)		0.590 (0.161)	0.298 (0.112)

TABLE 7 MODEL 2 STATISTICS

MEASURE OF EFFECTIVENESS 1

MODEL 1 VERSUS MODEL 2

% LOSSES TO DF



% LOSSES TO DF

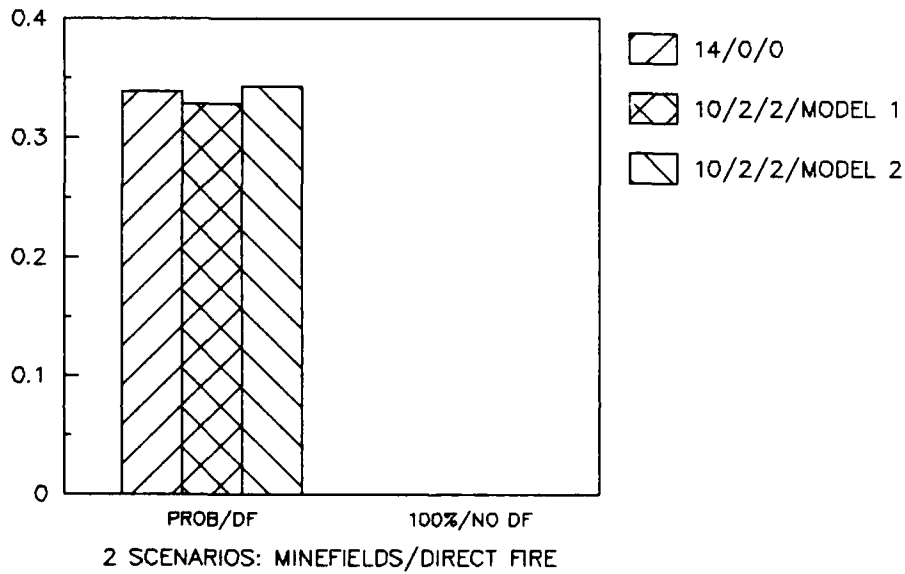
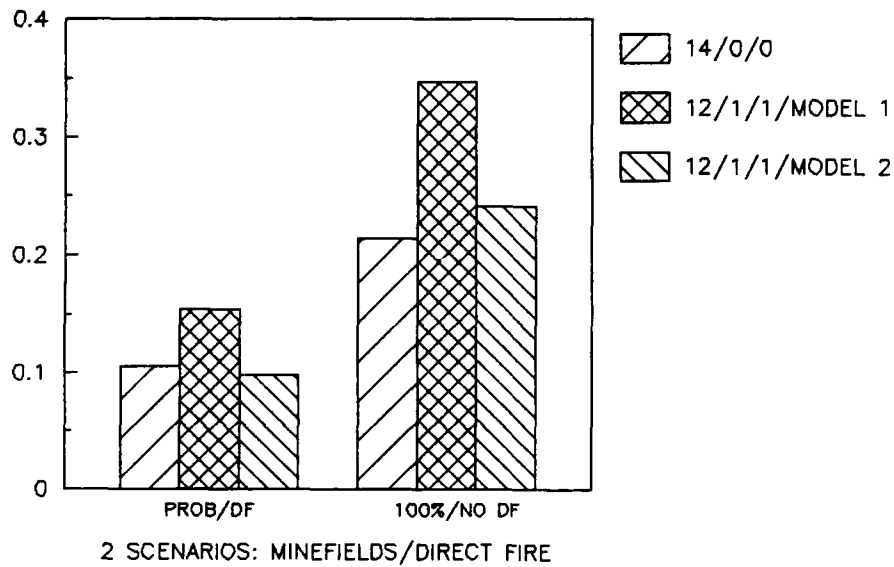


Figure 23. Model 1 versus Model 2
Measure of Effectiveness 1

MEASURE OF EFFECTIVENESS 2 MODEL 1 VERSUS MODEL 2

% LOSSES TO MINES



% LOSSES TO MINES

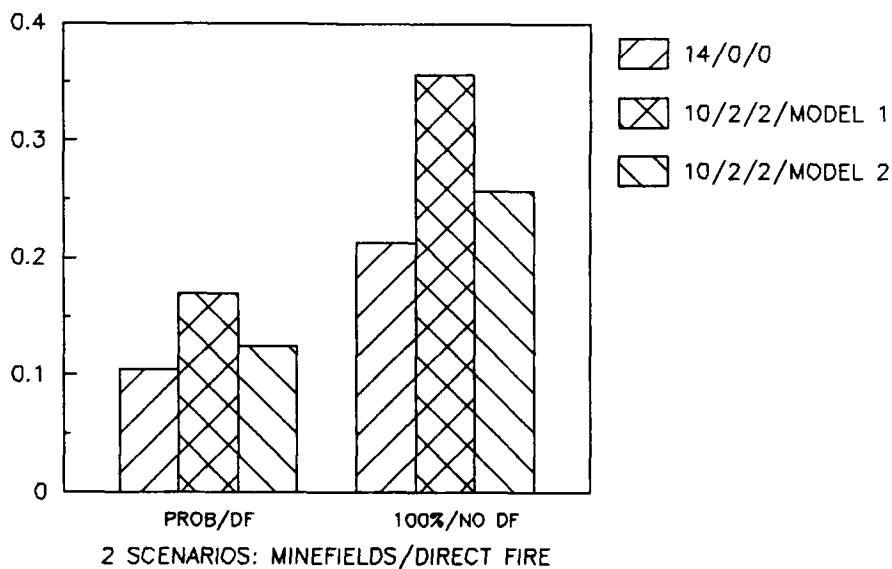
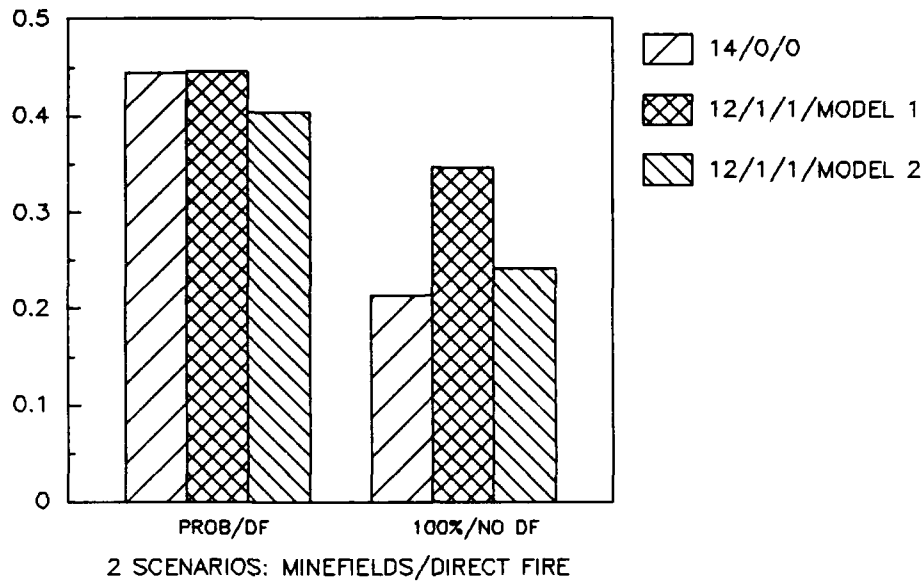


Figure 24. Model 1 versus Model 2
Measure of Effectiveness 2

MEASURE OF EFFECTIVENESS 3 MODEL 1 VERSUS MODEL 2

% LOSSES TOTAL



% LOSSES TOTAL

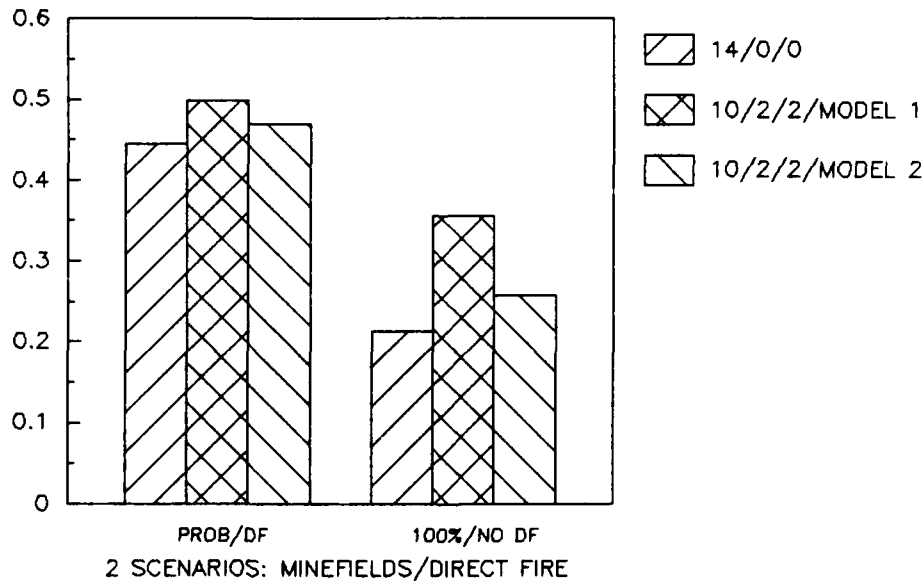
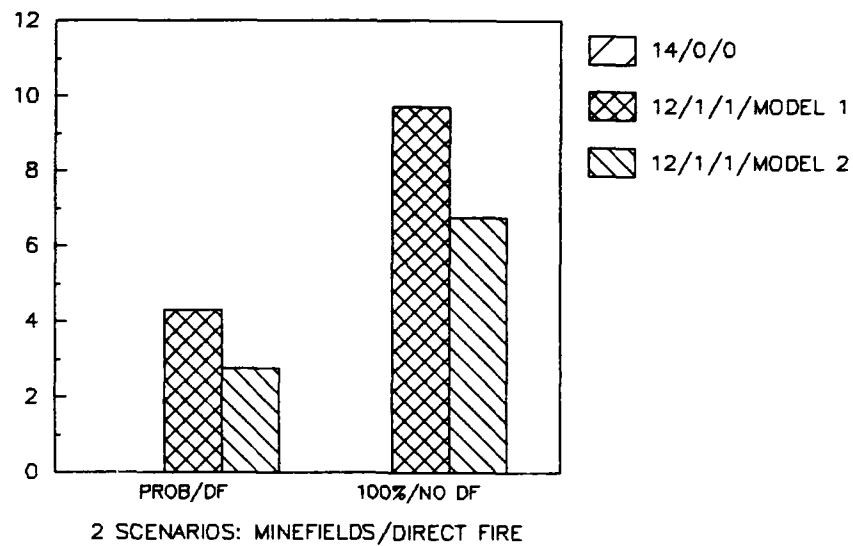


Figure 25. Model 1 versus Model 2
Measure of Effectiveness 3

MEASURE OF EFFECTIVENESS 4 MODEL 1 VERSUS MODEL 2

MINE CAS PER PIECE



MINE CAS PER PIECE

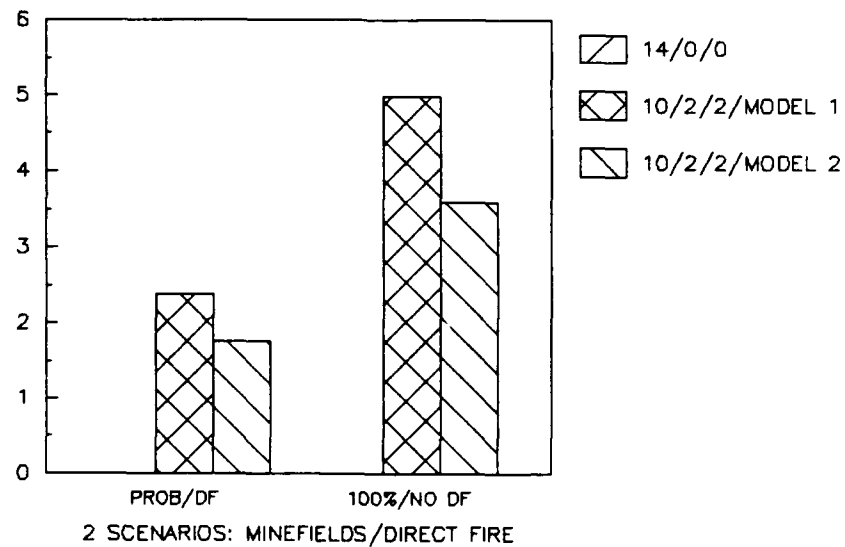
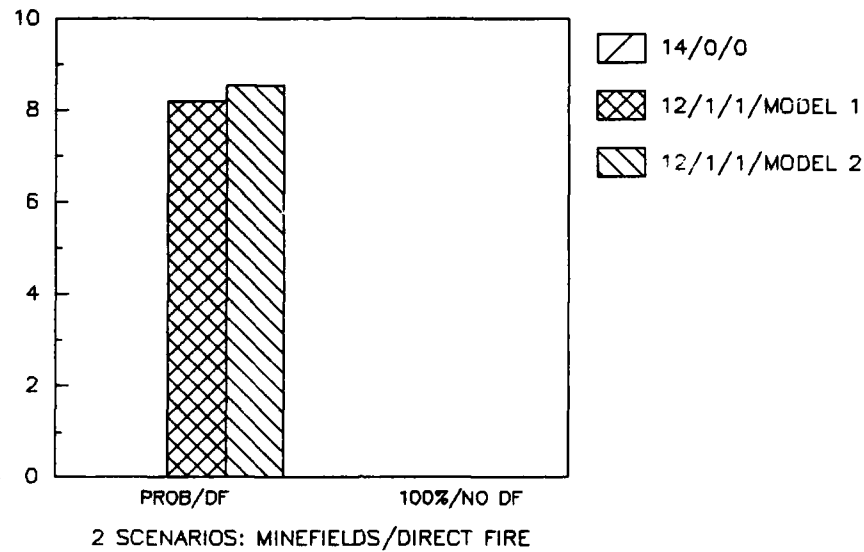


Figure 26. Model 1 versus Model 2
Measure of Effectiveness 4

MEASURE OF EFFECTIVENESS 5 MODEL 1 VERSUS MODEL 2

DF CAS PER PIECE



DF CAS PER PIECE

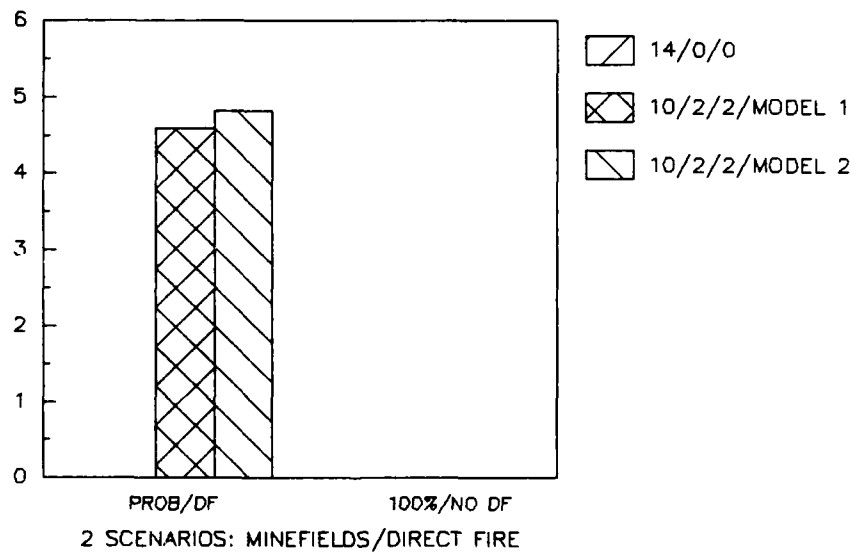
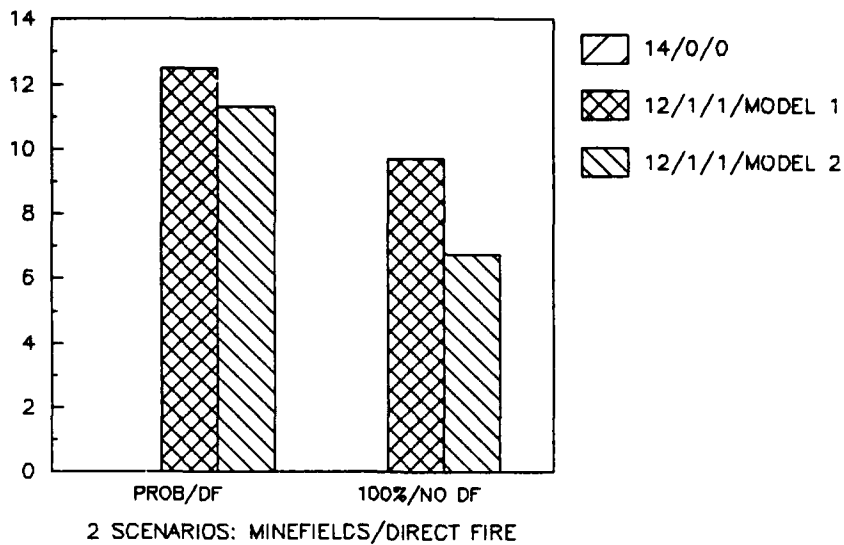


Figure 27. Model 1 versus Model 2
Measure of Effectiveness 5

MEASURE OF EFFECTIVENESS 6 MODEL 1 VERSUS MODEL 2

TOTAL # CAS PER PIECE



TOTAL # CAS PER PIECE

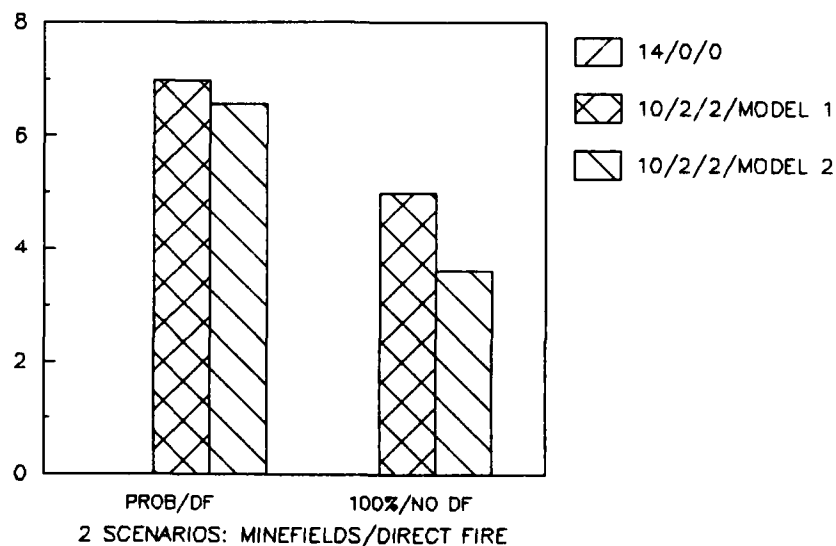
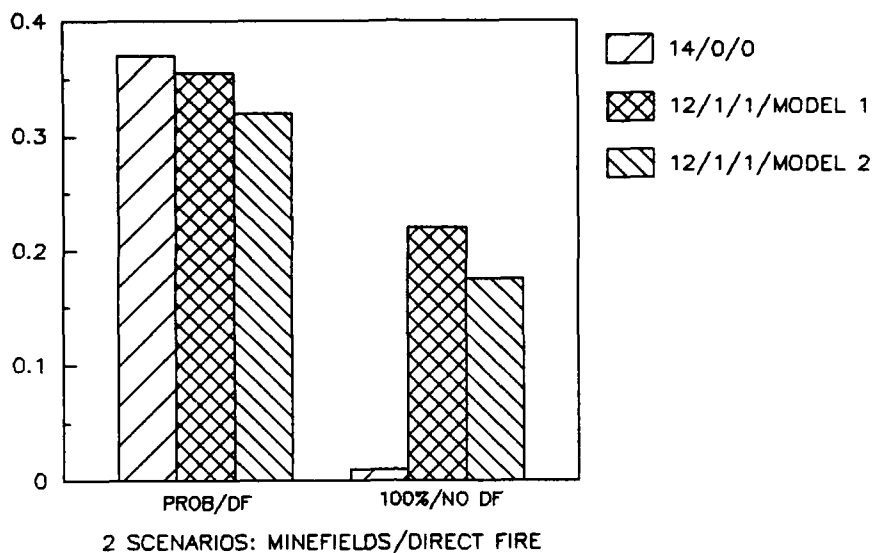


Figure 28. Model 1 versus Model 2
Measure of Effectiveness 6

MEASURE OF EFFECTIVENESS 7 MODEL 1 VERSUS MODEL 2

% UNITS TO DEFENSE



% UNITS TO DEFENSE

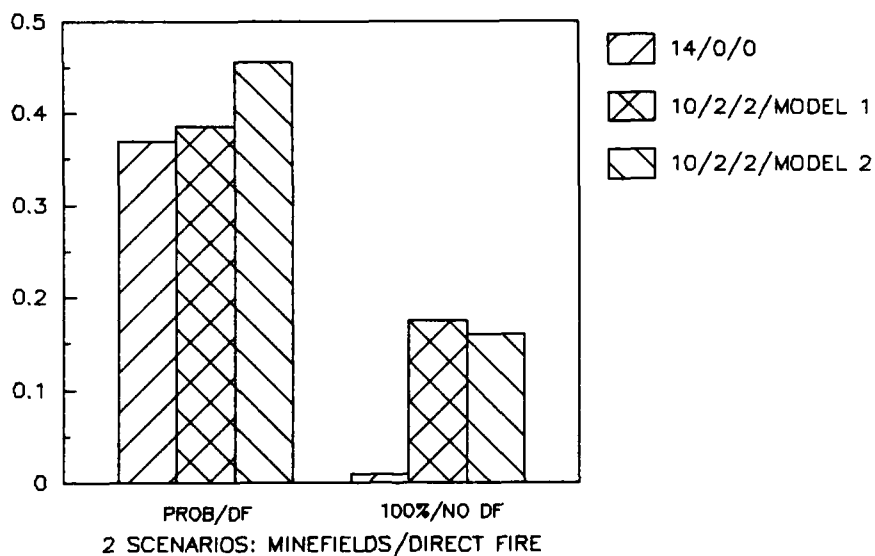
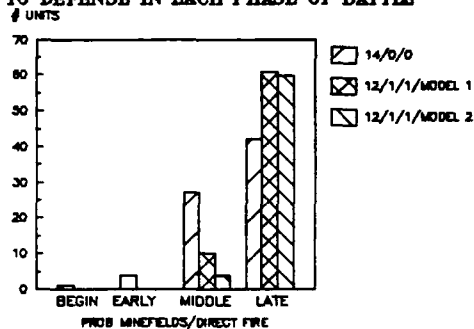


Figure 29. Model 1 versus Model 2
Measure of Effectiveness 7

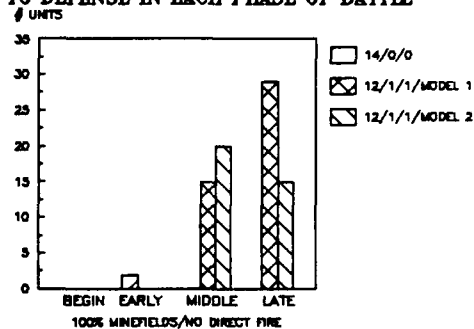
MEASURE OF EFFECTIVENESS 8

MODEL 1 VERSUS MODEL 2

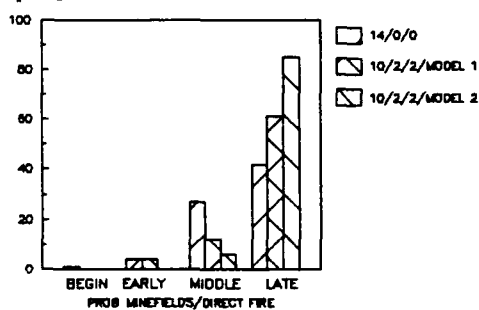
UNITS TO DEFENSE IN EACH PHASE OF BATTLE



UNITS TO DEFENSE IN EACH PHASE OF BATTLE



UNITS TO DEFENSE IN EACH PHASE OF BATTLE



UNITS TO DEFENSE IN EACH PHASE OF BATTLE

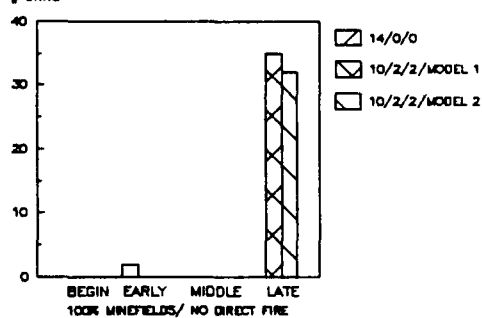
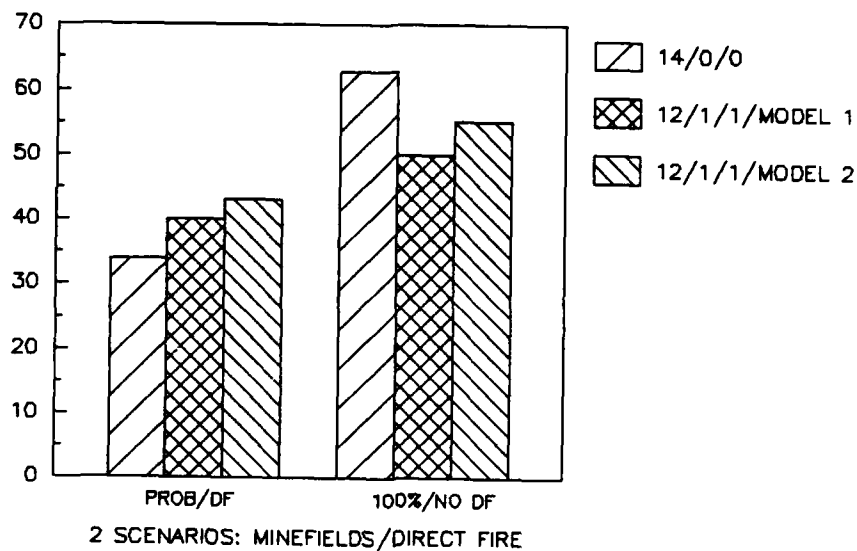


Figure 30. Model 1 versus Model 2
Measure of Effectiveness 8

MEASURE OF EFFECTIVENESS 9 MODEL 1 VERSUS MODEL 2

AVG LENGTH OF BATTLE



AVG LENGTH OF BATTLE

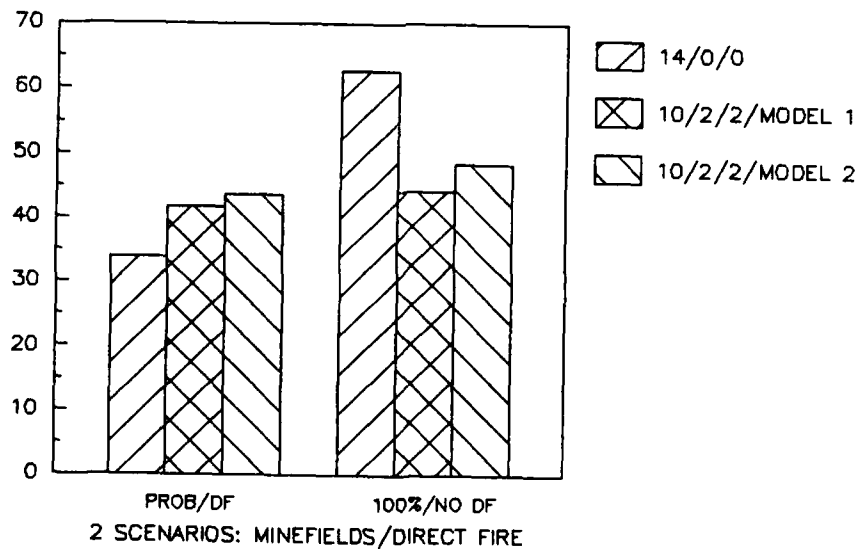
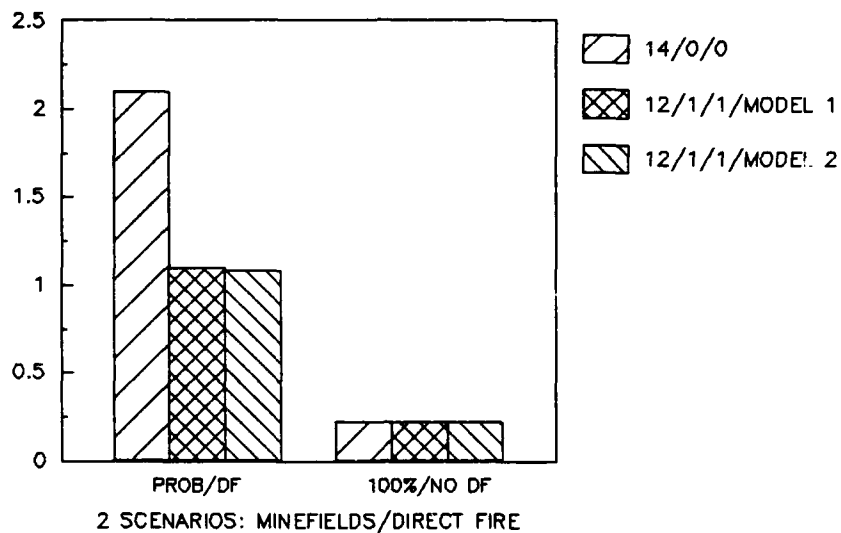


Figure 31. Model 1 versus Model 2
Measure of Effectiveness 9

MEASURE OF EFFECTIVENESS 10

MODEL 1 VERSUS MODEL 2

AVG END RANGE OF BATTLE



AVG END RANGE OF BATTLE

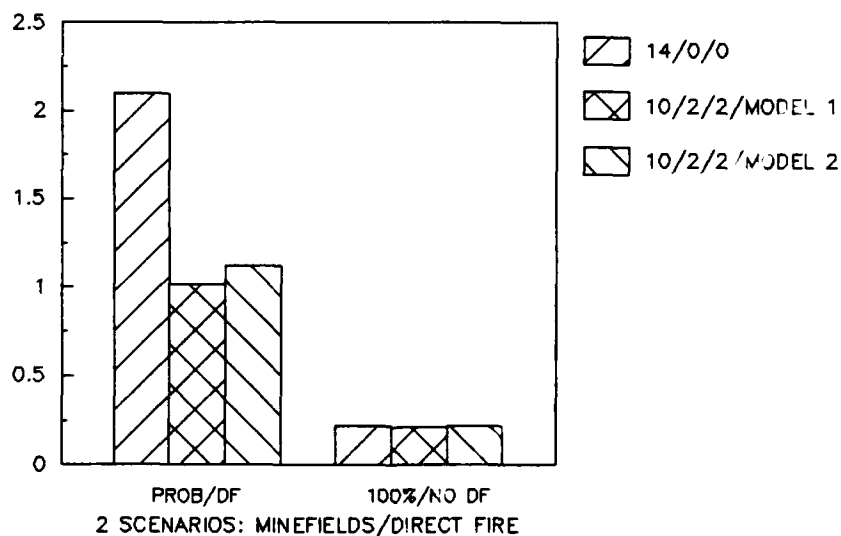
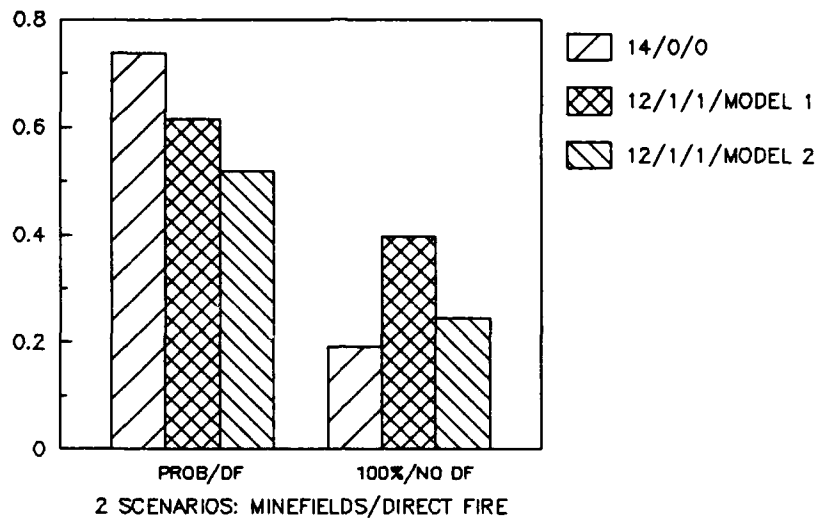


Figure 32. Model 1 versus Model 2
Measure of Effectiveness 10

MEASURE OF EFFECTIVENESS 11

MODEL 1 VERSUS MODEL 2

RATE OF BATTLE LOSSES



RATE OF BATTLE LOSSES

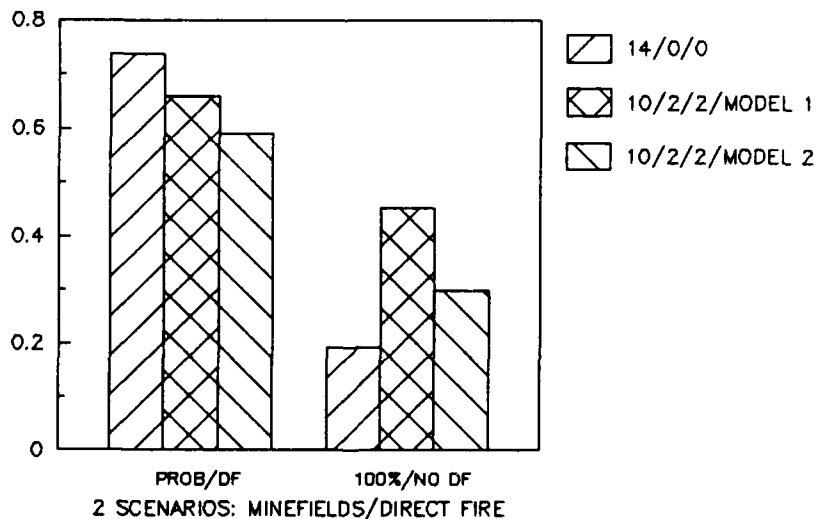


Figure 33. Model 1 versus Model 2
Measure of Effectiveness 11

V. SUMMARY, FUTURE ENHANCEMENTS, AND UTILIZATION

A. SUMMARY

The model, as developed, examines a limited number of different scenarios, tactics and equipment configurations. The combinations examined are by no means all encompassing. Continued analysis using the model as developed will provide answers to many mine/countermine questions concerning equipment and doctrine.

The model is a high resolution stochastically based simulation with a minimal amount of background routines to support the minefield breaching logic. While it will not answer all the questions concerning the basis of issue of countermine equipment, it does improve the analyst's ability to make decisions regarding the effectiveness of the mine/countermine equipment configurations.

B. FUTURE ENHANCEMENTS

The following additions or improvements to the model are recommended:

1. Addition of indirect fire to suppress both forces and allow smoke to be used to obscure the breaching sites through the minefields.
2. Development of a red movement network so a blue counterattack scenario may be examined.
3. A better method of controlling the breaching equipment during the conduct of the breach is required. At present the equipment must stay in the order input in the data file. Therefore if a unit has two mineplow tanks and a mineroller tank, and if the first mineplow clears a lane, the proofing vehicle would be a mineplow tank if it was entered

second in the file, as opposed to the mineroller tank as called for by doctrine.

4. A more accurate method of determining the destruction of a piece of breaching equipment is required. In the simulation, if one side of a mineplow or mineroller is rendered inoperable, then the entire system is considered lost. Additionally, the probability of surviving a mine detonation could be considered cumulative in nature, where the probability of surviving the first mine detonation to a breaching system may be higher than surviving the second etc.
5. The assumption of perfect knowledge concerning the extent of the minefield when it is identified does not accurately model the real world. A method of dealing with unclear or unknown boundaries of an obstacle must be developed to better simulate the actions of a unit encountering the minefield.

C. UTILIZATION

The model as it currently exists may be used to develop, examine and verify tactics. The placement of equipment within a formation, how far in the lead the mineroller should be placed and other tactics may be examined. Formations may dictate the number of breaching assets required. If the breaching equipment is in the forward platoons but not employed, they may encounter a minefield and be rendered inoperative prior to commencement of breaching operations. By changing the depths of the minefield, problems concerning the angle of attack on an obstacle may be examined.

The output generated by this model provides the appropriate information in the proper format required for more analytical models. One such model is a Semi-Markov

Renewal Process which aggregates high resolution data into various transition matrices. [Ref. 13]

Therefore, not only is the model useful as developed to investigate the issuance of countermine equipment, but may also be used in all areas concerning minefields and the tactics used to counter the obstacle.

APPENDIX A DEFINITION OF MODEL ONE VARIABLES

The variables used in Model 1 are defined below. All variables are either integer or single precision. The only double precision variable used in the model was the seed for the random number generator.

AAA	-- Speed adjustment factor to maintain movement control.
ACTIVE1,ACTIVE2	-- The first 2 elements of a unit entering a minefield; they are the candidates for detonating a mine.
ANGLE	-- Heading in radians of the arcs in the network.
ARC	-- Line connecting 2 nodes, supporting the movement of the units.
AVE	-- Avenue of approach, consisting of a series of arcs from the movement network.
BEHIND	-- Binary variable; it is 1 when AAA is greater than 1; 0 otherwise.
BLUECODE,REDCODE	-- Status code of the unit; for the blue force it may be; 0-defensive posture, 1-assault formation, 2-breaching formation. For the red force, if it equals 0 the unit is not combat effective.
BLUEDTECT1, REDDTECT1,2	-- The numerical identifier of the elements on the firer's detection list.
BLUENEGAGE,REDENGAGE	-- Number of elements in one force detecting or engaging an element of the opposing force. Up to four blue elements may detect/engage a single red element while only two red elements may detect a single blue element.

BLUEPDET, REDPDET	-- Probability of detecting an opposing element using the detection rate, DETRATE.
BLUERMAX, RMAX	-- Maximum effective engagement ranges for the weapons systems; user input variables.
BLUESTATUS, REDSTATUS	-- Indicates the current status of an element, the status may be: 0-element is dead, 1-element is in the detecting phase, 2-element is in the firing phase.
BLUEX1POS, BLUEY1POS	-- Actual x,y coordinates of elements in each blue unit.
BLUEXOFF_, BLUEYOFF_	-- These values represent the offset distances in the x direction and y direction from the control vehicle. There is an x distance and a y distance for each of the three formations and are user input.
BLUEXPOS, BLUEYPOS	-- Actual x,y coordinates of the control vehicle in each of the blue units.
BPHITS, BPKILL	-- The probabilities associated with hitting and killing a red target using the range to delineate the probabilities.
BULL1, BULL2	-- Status indicators to determine if a unit is bulling through a minefield.
BVEHORDER	-- An array which stores the order of the units as read from the data file.
BYPASS1, BYPASS2	-- Status indicators to determine if a unit is bypassing a minefield.
CLOCK	-- Keeps track of the time of battle.
CLOSE	-- Binary variable used in conjunction with the AAA variable.

CODEO	-- Records the time a unit goes to a defensive posture.
CV	-- Crossing velocity; used in the detection module and represents the component of movement perpendicular to the target-observer line-of-sight.
DELX, DELY	-- Represents the distance in the x and y directions the control vehicle moves during a single time step.
DENSMINE1, DENSMINE2	-- Represents the densities of the near and far minefields; it is user input.
DEPMINE1, DEPMINE2	-- The depth of a minefield, based on the maximum and minimum depth parameters and a Monte Carlo draw.
DETRATE	-- The rate at which a detection can occur, used in calculation of the probability of detecting a vehicle.
DFKILL	-- Counter to keep track of the number of direct fire kills per repetition.
DFTYPE	-- Counter to keep track of the total number of direct fire kills by type over each repetition.
DIST	-- Actual length of each arc; user input as part of the network.
DISTANCE	-- Cumulative distance traveled along an arc.
DISTDET1, DISTDET2	-- Represents the distance to next detonation of a mine; used in both the initial entry to a minefield routine and during breaching operations.
ENTRY1, ENTRY2	-- Variables used to determine when a minefield has been entered.

EQUIP	-- Used in the Unit Status subroutine to aid in tabulating types of equipment in the unit.
HEAD	-- Head of an arc; a node number.
HEIGHT, RHEIGHT	-- Represents the actual heights of the equipment in the various units; user input.
LAG	-- User input value representing the maximum range deviation in the assaulting units.
LOC	-- Represents the current arc location of the unit.
MAXDEPTH1, MAXDEPTH2	-- User input; the maximum depths of minefields 1 and 2.
MINDEPTH1, MINDEPTH2	-- User input; the minimum depths of minefields 1 and 2.
MINE1, MINE2	-- User input; the arcs on which the minefields located.
MINEDET1, MINEDET2	-- User input; the probabilities associated with detecting the presence of a minefield.
MINEKILL	-- Counter to keep track of the number of kills due to mine detonations per repetition.
MINEPK	-- User input; the probability that a mine kills a tank given detonation.
MOVE	-- Cumulative distance indicator that keeps track of the distance a unit has moved through a minefield.
NARC	-- Number of arcs in the network.
NNODE	-- Number of nodes in the network.
NODE	-- Specific number of a node.
NUMBLUE, NUMRED	-- Number of blue elements per unit and the total number of red elements.

NUNIT	-- Number of blue units in the simulation.
PDETONAT4	-- User input; the probability of a mine detonating when cleared by a breaching device.
PCLEAR4, PCLEAR5	-- Probabilities of a breaching device clearing a mine given an encounter.
PSURVIV4, PSURVIV5	-- Probabilities of surviving an encounter with a mine.
PDETTNK4, PDETTNK5	-- The cumulative probability of clearing a mine, either by the breaching device or detonation by the carrier.
PMINE1, PMINE2	-- User input; the probabilities of a minefield being emplaced, also interpreted the probabilities of encountering a minefield given it is emplaced.
PRCNTEFFB, PRCNTEFFR	-- Used in the Unit Status subroutine, they keep track of the combat effectiveness of the units.
RANGE	-- Range is calculated throughout the simulation and is the distance from blue element to red element.
REDX, REDY	-- Represents the center of mass of the red position in the x,y plane.
REDXPOS, REDYPOS	-- User input; the locations of the red elements in the x,y plane.
RNGADJ	-- The calculated adjusted range to a target based on the range adjustment factors input into the detection model.
RNGAPP	-- The calculated apparent range to a target based on the percent of the target that is visible to the observer.

RNGDET1,RNGDET2	-- Ranges to the detected elements in the blue force; used to determine which vehicles go on the red elements' detected list.
RNGMAX,RNGMIN	-- At any given time step the blue units are in the interval [RNGMIN,RNGMAX] which is the distance from the enemy.
RPLOOK	-- User input; the probability that a red element is looking in the direction of the target.
SPEED	-- User input; the maximum speed each vehicle type is able to maintain on each arc based on terrain characteristics.
STATMIN1,STATMIN2	-- Binary variables; used to indicate the status of minefields.
TAU	-- Terrain complexity code ranging from 1 to 7; used in the probability of detection equation.
RPHITM,RPKILL	-- The probabilities associated with hitting and killing a blue target using range to delineate the probabilities.
PHIT,PKILL	-- The actual values calculated from the table look-up which are then compared to a random number draw.
RRAF,RAF	-- Range adjustment factors for the red and blue forces; used to calculate adjusted ranges for each target.
TDFKILL,TMINEKILL	-- Total number of kills over the 50 repetitions due to direct fire and mines, respectively.

TPLOWKILL, TROLLKILL	-- Total number of mineplows and minerollers killed over the 50 repetitions due to mine detonations. These represent only the breaching device being destroyed, not the carrier.
TPLOWBRCHKILL, TROLLBRCHKILL	-- Total number of mineplow carriers and mineroller carriers killed by mine detonations over the 50 repetitions while conducting breaching operations.
TKILL	-- Total number of kills due to all causes over a single repetition.
TTKILL	-- A tabulating variable used in the output file, representing the total number of kills of all types over fifty repetitions.
UNIT	-- Counter to track which is the current unit; the simulation will allow up to 10 units.
UNITSPD	-- The speed the unit moves based on formation, location and equipment.
VEHTYPE, RVEHTYP	-- These variables are coded for the type of vehicles in the units. The blue force has five types as discussed in Chapter 3 while the red force has two vehicle types; a BMP and a tank.
WIDTH	-- The width is the effective width of the vehicle entering a minefield and is used in the calculation of the distance to a mine encounter.
XNODE, YNODE	-- These values represent the X and Y grid coordinates of the nodes in the network.
XOFFPLT, YOFFPLT	-- The x,y offsets used in the OFFSET subroutine to calculate the actual x,y coordinates.

APPENDIX B

COMPUTER PROGRAM LISTING

```

* SIMULATION MAIN PROGRAM
***** VARIABLE DECLARATION *****
1  INTEGER   TAIL, HEAD, NODE, NNODE, ARC, BLUECODE, REDCODE, DEF
2  INTEGER   AVE, START, NUNIT, LOC, NUMRED, REDENGAGE, STATMIN1, ENTRY1
3  INTEGER   NARC, ISTART, LAST, UNIT, RED, REDSTATUS, VEHTYPE, RVEHTYP
4  INTEGER   BLUESTATUS, ELEMENT, POSITION, NUMBLUE, CLOSE, BEHIND, REP
5  INTEGER   REDDETECT1, REDDETECT2, BLUEENGAGE, BLUEDETECT1, MINE1
6  INTEGER   BVEHORDER, BULL1, BULL2, BYPASS1, MINE2, STATMIN2, ENTRY2
7  INTEGER   BYPASS2, MINEKILL, DFKILL, ROLLKILL, PLOWKILL, ROLLBRCHKILL
8  INTEGER   TMIN EKILL, TDFKILL, TROLLKILL, TPLWKILL, TROLLBRCHKILL
9  INTEGER   PLOWBRCHKILL, TPLWKILL, TKILL, TTKILL, DFTYPE, MTYPE
10 REAL      WIDTH, DIST, ANGLE, XNODE, YNODE, CLOCK, SP, BLUEXOFF1, BLUEYOFF1
11 REAL      BLUEXOFF2, BLUEYOFF2, BLUEX1POS, BLUEY1POS, REDXPOS, REDYPOS
12 REAL      BLUEXOFF0, BLUEYOFF0, MINDEPTH1, MAXDEPTH1, RNG, CODE0
13 REAL      DELX, DELY, TRAVEL, SPEED, DISTANCE, CV, UNITSPD, RHEIGHT, RRAF
14 REAL      RPLOOK, REDX, REDY, BLUEXPOS, BLUEYPOS, LAG, AAA, RMAX
15 REAL      DENSMINE1, PMINE1, DISTDET1, DEPMINE1, MINDEPTH2, MAXDEPTH2
16 REAL      BLUERMAX, DENSMINE2, PMINE2, DISTDET2, DEPMINE2
17 REAL      RPHITS, RPHITM, RPKILL, BPHITS, BPKILL
18 REAL*8     DSEED
19 DIMENSION TAIL(150), HEAD(150), TIME(150), AVE(10, 30), BULL1(10)
20 DIMENSION FLOW(100), DIST(100), WIDTH(100), ISTART(10), BYPASS1(10)
21 DIMENSION ARC(100), SP(100), ANGLE(100), DISTANCE(10), CV(10)
22 DIMENSION NODE(150), XNODE(150), YNODE(150), BLUEDETECT1(10, 20)
23 DIMENSION BLUEXPOS(20), BLUEYPOS(20), RHEIGHT(30), RRAF(30), RMAX(30)
24 DIMENSION SPEED(10, 80), BLUEYOFF1(20), BLUEXOFF1(20), LOC(10)
25 DIMENSION BLUEXOFF2(20), BLUEYOFF2(20), RVEHTYP(30), BLUECODE(10)
26 DIMENSION BLUEXOFF0(20), BLUEYOFF0(20), STATMIN1(10), MINE1(10)
27 DIMENSION BLUEX1POS(10, 20), BLUEY1POS(10, 20), BLUESTATUS(10, 20)
28 DIMENSION REDXPOS(50), REDYPOS(50), RPLOOK(10, 50), UNITSPD(10)
29 DIMENSION RED(50), REDSTATUS(30), VEHTYPE(10, 20), REDENGAGE(100)
30 DIMENSION REDDETECT1(30), REDDETECT2(30), BLUEENGAGE(30), MINE2(10)
31 DIMENSION PMINE2(10), DISTDET2(10, 100), DEPMINE2(10), ENTRY2(10)
32 DIMENSION PMINE1(10), DISTDET1(10, 100), DEPMINE1(10), ENTRY1(10)
33 DIMENSION RPHITS(10), RPHITM(10), RPKILL(10), BPHITS(10), BPKILL(10)
34 DIMENSION BVEHORDER(10, 20), RNG(20), STATMIN2(10), BYPASS2(10)
35 DIMENSION BULL2(10), MINEKILL(100), DFKILL(100), ROLLKILL(100)
36 DIMENSION PLOWKILL(100), ROLLBRCHKILL(100), PLOWBRCHKILL(100)
37 DIMENSION BLUERMAX(10, 20), DFTYPE(20), MTYPE(20), CODE0(10), DEF(10)

*
38 OPEN (UNIT = 54 , FILE = 'SIMUL')
39 OPEN (UNIT = 44 , FILE = 'RESULTS')
40 OPEN (UNIT = 34 , FILE = 'OUTPUT')
41 OPEN (UNIT = 24 , FILE = 'MINETIME')
42 OPEN (UNIT = 23 , FILE = 'TIMEMINE')

***** SET INITIAL OPTIONS *****

*
* SET START NODE
43 START = 1
* SET LAST NODE
44 LAST = 29
* TOTAL NUMBER OF ARCS IN THE SECTOR
45 NARC = 31
* TOTAL NUMBER OF NODES IN THE SECTOR
46 NNODE = 29
* NUMBER OF AVENUES OF APPROACH

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```

47      NUNIT = 4
*      NUMBER OF RED ELEMENTS
48      NUMRED = 13
*      NUMBER OF BLUE ELEMENTS IN EACH UNIT
49      NUMBLUE=14

*      SET INITIAL CONDITIONS
*SET RANDOM NUMBER SEED
50      DSEED=1029395.D0

*SET TERRAIN CODE
51      TAU = 3.5

*
***** READ DATA FROM DATA FILES *****
*
52      READ(1,100) (ARC(I),TAIL(I),HEAD(I),DIST(I),ANGLE(I),I=1,NARC)
53 100    FORMAT(2X,I3,3X,I2,3X,I2,4X,F4.2,3X,F5.3)
54      READ(2,200) (NODE(I),XNODE(I),YNODE(I),I=1,NNODE)
55 200    FORMAT(2X,I3,2X,F5.0,1X,F5.0)

56      READ(3,300)((AVE(K,I),K=1,4),I=1,13)
57 300    FORMAT(2X,I3,2X,I3,2X,I3,2X,I3)

58      READ(4,400)((SPEED(K,I),K=1,5),I=1,NARC)
59 400    FORMAT(2X,5F4.0)

60      READ(9,500) (BLUEXOFF0(I),BLUEYOFF0(I),I=1,NUMBLUE)
61      READ(10,500) (BLUEXOFF1(I),BLUEYOFF1(I),I=1,NUMBLUE)
62      READ(11,500) (BLUEXOFF2(I),BLUEYOFF2(I),I=1,NUMBLUE)
63 500    FORMAT(2X,F5.2,2X,F5.2)

64      READ(17,550) (BPHITS(I),BPKILL(I),I=1,8)
65 550    FORMAT(2X,F4.2,2X,F4.2)

66      READ(12,600) (RED(I),REDXPOS(I),REDYPOS(I),I=1,NUMRED)
67 600    FORMAT (2X,I2,2X,F5.1,2X,F5.1)

68      READ(13,700) ((RPLOOK(K,I),K=1,NUNIT),I=1,NUMRED)
69 700    FORMAT(2X,4F6.2)

70      READ(14,800) ((BVEHORDER(K,I),K=1,NUNIT),I=1,NUMBLUE)
71 800    FORMAT(2X,I1,2X,I1,2X,I1,2X,I1)

72      READ(15,900) (RVEHTYP(I),RHEIGHT(I),RRAF(I),RMAX(I),I=1,NUMRED)
73 900    FORMAT(2X,I1,2X,F3.1,2X,F3.1,2X,F3.1)

74      READ(16,950) (RPHITS(I),RPHITM(I),RPHITL(I),I=1,9)
75 950    FORMAT(2X,F4.2,2X,F4.2,2X,F4.2)

76      TROLLBRCHKILL=0
77      TPLOWBRCHKILL=0
78      TMINEKILL=0
79      TDFKILL=0
80      TROLLKILL=0
81      TPLOWKILL=0

```

```

82          DO 181 REP=1,50

83          WRITE(54,928) REP
84 928      FORMAT('***** REPITITION NUMBER ',I3' *****')

*****
*          START SIMULATION

85          RNGMIN = 20.0

86          MINEKILL(REP)=0
87          DFKILL(REP)=0
88          DFTYPE(1)=0
89          DFTYPE(2)=0
90          DFTYPE(3)=0
91          DFTYPE(4)=0
92          DFTYPE(5)=0
93          MTYPE(1)=0
94          MTYPE(2)=0
95          MTYPE(3)=0
96          PLOWKILL(REP)=0
97          ROLLKILL(REP)=0
98          ROLLBRCHKILL(REP)=0
99          PLOWBRCHKILL(REP)=0

100         CLOCK = 0.0
101         REDX=XNODE(26)
102         REDY=YNODE(26)
103         REDCODE = 1

      *MINEFIELD NUMBER 1 LOCATIONS
104         MINE1(1)=10
105         MINE1(2)=9
106         MINE1(3)=17
107         MINE1(4)=22
108         MINDEPTH1=150
109         MAXDEPTH1=300
110         DENSMINE1=.003
111         PMINE1(1)=0.70
112         PMINE1(2)=0.70
113         PMINE1(3)=0.70
114         PMINE1(4)=0.70

      *MINEFIELD NUMBER 2 LOCATIONS
115         MINE2(1)=13
116         MINE2(2)=12
117         MINE2(3)=26
118         MINE2(4)=24
119         MINDEPTH2=200
120         MAXDEPTH2=300
121         DENSMINE2=.02
122         PMINE2(1)=0.90
123         PMINE2(2)=0.90
124         PMINE2(3)=0.90
125         PMINE2(4)=0.90

126         DO 40 UNIT=1,NUNIT
127         BLUECODE(UNIT) = 1

```

```

128         DEF(UNIT)=0
129         CODE0(UNIT)=0
130         ISTART(UNIT)=1
131         LOC(UNIT)=AVE(UNIT,1)
132         BLUEXPOS(UNIT) = XNODE(TAIL(LOC(UNIT)))
133         BLUEYPOS(UNIT) = YNODE(TAIL(LOC(UNIT)))
134         DISTANCE(UNIT)=0.0
135         UNITSPD(UNIT)=0.0
136         STATMIN1(UNIT)=0
137         STATMIN2(UNIT)=0
138         ENTRY1(UNIT)=0
139         ENTRY2(UNIT)=0
140         BULL1(UNIT)=0
141         BYPASS1(UNIT)=0
142         BULL2(UNIT)=0
143         BYPASS2(UNIT)=0
144         DO 47 POSITION=1,NUMBLUE
145             VEHTYPE(UNIT,POSITION)=BVEHORDER(UNIT,POSITION)
146             BLUESTATUS(UNIT,POSITION)=1
147             REDENGAGE((NUMBLUE*(UNIT-1))+POSITION)=0

*****BLUE MAX ENGAGEMENT RANGE*****
148         BLUERMAX(UNIT,POSITION)= 3.0

149 47      CONTINUE
150 40      CONTINUE

151         DO 13 ELEMENT=1,NUMRED
152             REDSTATUS(ELEMENT)=1
153             BLUEENGAGE(ELEMENT)=0
154 13      CONTINUE

*****      SIMULATION START      *****

155         CALL MINESETUP (UNIT,NUNIT,DSEED,PMINE1,
*             STATMIN1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1,
*             DISTDET1,PMINE2,STATMIN2,MINDEPTH2,MAXDEPTH2,
*             DEPMINE2,DENSMINE2,DISTDET2)

156         DO 20 J=1,200
157             CLOCK=CLOCK+.5

158         CALL UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,
*             BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
*             RNGMIN)

* CHECKS TO DETERMINE IF BATTLE TERMINATION CRITERIA HAS BEEN MET

159         IF (REDCODE .EQ. 0) GO TO 179
160         CALL LOCATION ( LAG,UNIT,NUNIT,BLUEXPOS,BLUEYPOS,RNG,
*             RNGMIN,REDX,REDY,AAA,CLOSE,BEHIND,BLUECODE)

161         IF(RNGMIN .LT. .250) THEN
162             CALL UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,
*             BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
*             RNGMIN)
163         END IF

```

```

164             IF(RNGMIN .LT. .250) GO TO 179

* ENTER MOVEMENT ROUTINE
165             DO 30 UNIT=1,NUNIT

*CHECK TO SEE IF UNIT HAS ENTERED MINEFIELD; 30 SECOND MOVEMENT DELAY
166             IF(ENTRY1(UNIT) .EQ. 1) THEN
167                 ENTRY1(UNIT)=2
168                 GO TO 30
169             END IF
170             IF(ENTRY2(UNIT) .EQ. 1) THEN
171                 ENTRY2(UNIT)=2
172                 GO TO 30
173             END IF

174             CALL MOV1 (LOC,TAIL,XNODE,YNODE,SPEED,TRAVEL,ANGLE,AVE,DIST,
*                 NODE,ISTART,DISTANCE,BLUEXP0S,BLUEYPOS,CLOCK,UNIT,
*                 BLUEXOFF1,BLUEYOFF1,BLUEXOFF2,BLUEYOFF2,ENTRY1,
*                 BLUEX1POS,BLUEY1POS,UNITSPD,NUMBLUE,VEHTYPE,AAA,
*                 CLOSE,BEHIND,BLUECODE,BLUEXOFF0,BLUEYOFF0,DEPMINE1,
*                 MINE1,STATMIN1,DSEED,BLUESTATUS,DISTDET1,REDX,REDY,
*                 BLUEDETECT1,RNG,BULL1,BYPASS1,ENTRY2,DEPMINE2,MINE2,
*                 STATMIN2,DISTDET2,BULL2,BYPASS2,MINEKILL,ROLLKILL,
*                 PLOWKILL,ROLLBRCHKILL,PLOWBRCHKILL,REP,MTYPE)

175 30          CONTINUE

* RED DETECT/FIRE ROUTINE ENTERED
176             DO 43 ELEMENT=1,NUMRED
177                 IF (REDSTATUS(ELEMENT) .EQ. 0) THEN
178                     GO TO 43
179                 ELSE IF (REDSTATUS(ELEMENT) .EQ. 2) THEN

180                     CALL REDFIRE(REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,
*                         POSITION,NUMBLUE,REDXPOS,REDYPOS,NUNIT,VEHTYPE,
*                         REDDETECT1,REDDETECT2,BLUEX1POS,BLUEY1POS,DSEED,CLOCK,
*                         RVEHTYP,RPHITS,RPHITM,RPKILL,DFKILL,REP,DFTYPE)
181                     GO TO 43
182                 END IF

183             CALL REDDETECT (REDXPOS,REDYPOS,BLUEXP0S,BLUEYPOS,
*                 BLUEX1POS,BLUEY1POS,NUNIT,REDENGAGE,BLUESTATUS,
*                 ANGLE,UNIT,UNITSPD,CLOCK,LOC,CV,NUMRED,NUMBLUE,
*                 REDX,REDY,RED,RLOOK,REDSTATUS,DSEED,VEHTYPE,
*                 REDDETECT1,REDDETECT2,ELEMENT,POSITION,TAU,RVEHTYP,
*                 BLUECODE,RMAX)

184 43          CONTINUE

* BLUE DETECT/FIRE ROUTINE ENTERED
185             DO 63 UNIT=1,NUNIT
186                 DO 69 POSITION=1,NUMBLUE
187                     IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) THEN
188                         GO TO 69
189                     ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 4 .OR.
*                         VEHTYPE(UNIT,POSITION) .EQ. 5) THEN
190                         GO TO 69
191                     ELSE IF (BLUESTATUS(UNIT,POSITION) .EQ. 2) THEN

```

```

192      CALL BLUEFIRE(REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,
      *      POSITION,REDXPOS,REDYPOS,RVEHTYP,
      *      BLUEDTECT1,BLUEX1POS,BLUEY1POS,DSEED,
      *      CLOCK,BPHITS,BPKILL)
193      GO TO 69
194      END IF

195      CALL BLUEDTECT (REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS,
      *      BLUEENGAGE,BLUESTATUS,REDSTATUS,DSEED,UNIT,CLOCK,NUMRED,
      *      BLUEDTECT1,ELEMENT,POSITION,TAU,RVEHTYP,RHEIGHT,RAAF,
      *      BLUERMAX)

196 69      CONTINUE
197 63      CONTINUE

      *CHECK TO SEE TIME UNIT GOES TO DEFENSIVE POSTURE
198      DO 159 UNIT=1,NUNIT
199          IF (BLUECODE(UNIT) .EQ. 0 .AND. DEF(UNIT) .EQ. 0) THEN
200              CODE0(UNIT) = CLOCK
201              DEF(UNIT) = 1
202          END IF
203 159      CONTINUE
204 20      CONTINUE

      * RUNNING TOTAL OF LOSSES
205 179      TDFKILL=TDFKILL+DFKILL(REP)
206          TMINEKILL=TMINEKILL+MINEKILL(REP)
207          TROLLKILL=TROLLKILL+ROLLKILL(REP)
208          TPLOWKILL=TPLOWKILL+PLOWKILL(REP)
209          TROLLBRCHKILL=TROLLBRCHKILL+ROLLBRCHKILL(REP)
210          TPLOWBRCHKILL=TPLOWBRCHKILL+PLOWBRCHKILL(REP)
211          TKILL=DFKILL(REP)+MINEKILL(REP)+ROLLBRCHKILL(REP)+
      *      PLOWBRCHKILL(REP)

212      WRITE(44,338) DFKILL(REP),DFTYPE(1),(DFTYPE(2)+DFTYPE(4)),
      *      (DFTYPE(3)+DFTYPE(5)),ROLLKILL(REP),PLOWKILL(REP),
      *      MINEKILL(REP),MTYPE(1),MTYPE(2),MTYPE(3),
      *      PLOWBRCHKILL(REP),ROLLBRCHKILL(REP),TKILL,CLOCK,RNGMIN
213 338      FORMAT(I2,'/',I2,'/',I2,'/',I2,1X,I2,4X,I2,3X,I2,'/',
      *      I2,'/',I2,'/',I2,4X,I2,7X,I2,6X,I3,4X,F4.1,2X,F6.3)
214      WRITE(34,377) DFKILL(REP),DFTYPE(1),(DFTYPE(2)+DFTYPE(4)),
      *      (DFTYPE(3)+DFTYPE(5)),ROLLKILL(REP),PLOWKILL(REP),
      *      MINEKILL(REP),MTYPE(1),NTYPE(2),MTYPE(3),
      *      PLOWBRCHKILL(REP),ROLLBRCHKILL(REP),TKILL,CLOCK,RNGMIN
215 377      FORMAT(2X,13I4,2X,F4.1,2X,F5.3)
216      WRITE(24,577) STATMIN1(1),STATMIN2(1),CODE0(1),
      *      STATMIN1(2),STATMIN2(2),CODE0(2),
      *      STATMIN1(3),STATMIN2(3),CODE0(3),
      *      STATMIN1(4),STATMIN2(4),CODE0(4),CLOCK
217      WRITE(23,577) STATMIN1(1),STATMIN2(1),CODE0(1),
      *      STATMIN1(2),STATMIN2(2),CODE0(2),
      *      STATMIN1(3),STATMIN2(3),CODE0(3),
      *      STATMIN1(4),STATMIN2(4),CODE0(4),CLOCK
218 577      FORMAT(2X,2I4,F5.1,2X,2I4,F5.1,2X,2I4,F5.1,2X,2I4,F5.1,2X,F5.1)

219 181      CONTINUE

```

```

220          TTKILL=TDFKILL+TMINEKILL+TROLLBRCHKILL+TPLOWBRCHKILL
221          WRITE(44,333)
222 333      FORMAT('TOTAL NUMBER OF KILLS BY CATEGORY')
223          WRITE(44,334)
224 334      FORMAT('DIRECTFIRE    ROLL    PLOW    MINE    PLOWCARRIER ',
*              '    ROLLCARRIER    TOTALKILLS')
225          WRITE(44,335) TDFKILL,TROLLKILL,TPLOWKILL,TMINEKILL,
*              TPLOWBRCHKILL,TROLLBRCHKILL,TTKILL
226 335      FORMAT(5X,I3,4X,I3,3X,I3,3X,I3,7X,I3,11X,I3,11X,I3)

227          STOP
228          END
*****

```

```

***** MINESETUP *****
229      SUBROUTINE MINESETUP (UNIT,NUNIT,DSEED,PMINE1,
      *      STATMIN1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1,
      *      DISTDET1,PMINE2,STATMIN2,MINDEPTH2,MAXDEPTH2,
      *      DEPMINE2,DENSMINE2,DISTDET2)
230      INTEGER UNIT,NUNIT,STATMIN1,STATMIN2,PACE
231      REAL RNDMINE,PMINE1,MINDEPTH1,MAXDEPTH1,DEPMINE1,DENSMINE1
232      REAL PMINE2,MINDEPTH2,MAXDEPTH2,DEPMINE2,DENSMINE2
233      REAL DISTDET1,DISTDET2,WIDTH
234      REAL*8 DSEED
235      DIMENSION RNDMINE(100),PMINE1(10),STATMIN1(10),DISTDET1(10,100)
236      DIMENSION PMINE2(10),STATMIN2(10),DISTDET2(10,100)
237      DIMENSION DEPMINE1(10),DEPMINE2(10)

      * EFFECTIVE WIDTH OF M1
238      WIDTH=3.5

239      DO 31 UNIT=1,NUNIT
240          CALL GGUBS (DSEED,90,RNDMINE)
      * DETERMINE STATUS OF MINEFIELD1
241          IF(RNDMINE(1) .LT. PMINE1(UNIT)) THEN
242              STATMIN1(UNIT)=1
      *DETERMINE DEPTH OF MINEFIELD1
243          DEPMINE1(UNIT)=(MINDEPTH1+((MAXDEPTH1-MINDEPTH1)
      *      *RNDMINE(2)))/1000
244          *      END IF

      *SET UP ARRAY OF DISTANCES TO MINE ENCOUNTERS
245          IF (STATMIN1(UNIT) .EQ. 1) THEN
246              DO 32 PACE=1,88
247              DISTDET1(UNIT,PACE)=((LOG(1-RNDMINE(PACE+2)))
      *      /(((-WIDTH*DENSMINE1)))/1000
248              IF (DISTDET1(UNIT,PACE) .GT. DEPMINE1(UNIT)) THEN
249                  DISTDET1(UNIT,PACE) = DEPMINE1(UNIT)/2
250              END IF
251          32      CONTINUE
252          END IF

253          WRITE(54,967) UNIT,STATMIN1(UNIT),DEPMINE1(UNIT),RNDMINE(2)
254          967      FORMAT('UNIT',I2,' STATUSMINE1 ',I3,' DEPTH OF FIELD ',F5.3,
      *      ' RNDNUM ',F5.3)

      * REPEAT ABOVE PROCEDURES FOR MINEFIELD2
255          CALL GGUBS (DSEED,90,RNDMINE)
256          IF(RNDMINE(1) .LT. PMINE2(UNIT)) THEN
257              STATMIN2(UNIT)=1
258          DEPMINE2(UNIT)=(MINDEPTH2+((MAXDEPTH2-MINDEPTH2)
      *      *RNDMINE(2)))/1000
259          *      END IF
260          IF (STATMIN2(UNIT) .EQ. 1) THEN
261              DO 21 PACE=1,88
262              DISTDET2(UNIT,PACE)=((LOG(1-RNDMINE(PACE+2)))
      *      /(((-WIDTH*DENSMINE2)))/1000
263              IF (DISTDET2(UNIT,PACE) .GT. DEPMINE2(UNIT)) THEN
264                  DISTDET2(UNIT,PACE) = DEPMINE2(UNIT)/2
265              END IF
266          21      CONTINUE
267          END IF

268          WRITE(54,977) UNIT,STATMIN2(UNIT),DEPMINE2(UNIT),RNDMINE(2)
269          977      FORMAT('UNIT',I2,' STATUSMINE2 ',I3,' DEPTH OF FIELD ',F5.3,
      *      ' RNDNUM ',F5.3)
270          31      CONTINUE

271      RETURN
272      END
*****

```

***** UNITSTATUS *****

```

273      SUBROUTINE UNITSTATUS(BLUECODE,REDCODE,UNIT,NUNIT,POSITION,
      *      NUMBLUE,BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,CLOCK,REP,
      *      RNGMIN)
274      INTEGER BLUECODE,REDCODE,UNIT,NUNIT,POSITION,NUMBLUE,EQUIP
275      INTEGER BLUESTATUS,REDSTATUS,NUMRED,ELEMENT,VEHTYPE,REP
276      REAL   PRCNTEFFB,PRCNTEFFR,SURVIV,RSURVIV,CLOCK,RNGMIN
277      DIMENSION SURVIV(10),BLUESTATUS(10,20),REDSTATUS(30)
278      DIMENSION BLUECODE(10),VEHTYPE(10,20),EQUIP(10,10),PRCNTEFFB(10)

```

```

      *D DETERMINE CURRENT STATUS OF RED AND BLUE FORCES
279      RSURVIV = 0
280      DO 42 UNIT=1,NUNIT
281      SURVIV(UNIT) = 0
282      DO 36 J=1,10
283      EQUIP(UNIT,J) = 0
284 36      CONTINUE
285      DO 44 POSITION = 1,NUMBLUE
286      IF (BLUESTATUS(UNIT,POSITION) .NE. 0) THEN
287      SURVIV(UNIT) = SURVIV(UNIT) + 1
288      IF (VEHTYPE(UNIT,POSITION) .EQ. 1) THEN
289      EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
      *      = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
290      ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 2) THEN
291      EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
      *      = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
292      ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 3) THEN
293      EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
      *      = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
294      ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 4) THEN
295      EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
      *      = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
296      ELSE IF (VEHTYPE(UNIT,POSITION) .EQ. 5) THEN
297      EQUIP(UNIT,VEHTYPE(UNIT,POSITION))
      *      = EQUIP(UNIT,VEHTYPE(UNIT,POSITION))+1
298      END IF
299      END IF
300 44      CONTINUE

      * CHECK TO SET IF BLUE UNIT HAS REACHED DEFENSIVE POSTURE CRITERIA
301      PRCNTEFFB(UNIT) = SURVIV(UNIT)/NUMBLUE
302      IF (PRCNTEFFB(UNIT) .LT. .5) THEN
303      BLUECODE(UNIT) = 0
304      END IF

305 42      CONTINUE

```

```

* TABULATION OF RED STRNGTH
306      DO 89 ELEMENT=1,NUMRED
307          IF (REDSTATUS(ELEMENT) .NE. 0) THEN
308              RSURVIV = RSURVIV + 1
309          END IF
310 89      CONTINUE
311          PRCNTEFFR = RSURVIV/NUMRED
312          IF (PRCNTEFFR .LT. .250) THEN
313              REDCODE = 0
314          END IF

* WRITE OUTPUT TO DATA FILES
315      IF (CLOCK .LT. 1.0 .OR. PRCNTEFFR .LT. .250
          *      .OR. RNGMIN .LT. .250) THEN
316          DO 19 UNIT=1,NUNIT
317              WRITE(54,987) UNIT,BLUECODE(UNIT),EQUIP(UNIT,1),
          *      EQUIP(UNIT,2),EQUIP(UNIT,4),EQUIP(UNIT,3),EQUIP(UNIT,5)
318 987      *      FORMAT('UNIT ',I1,' UNITCODE ',I1,' EQUIP TANK ',
          *      I2,' MINEPLOW ',I2I4,' MINEROLLER',I2I4)
319 19      *      CONTINUE

320      IF (REP .EQ. 1 .AND. CLOCK .LT. 1.0) THEN
321          DO 109 UNIT=1,NUNIT
322              WRITE(44,387) UNIT,BLUECODE(UNIT),EQUIP(UNIT,1),
          *      EQUIP(UNIT,2),EQUIP(UNIT,4),EQUIP(UNIT,3),EQUIP(UNIT,5)
323 387      *      FORMAT('UNIT ',I1,' UNITCODE ',I1,' EQUIP TANK ',
          *      I2,' MINEPLOW ',I2I4,' MINEROLLER',I2I4)
324 109      *      CONTINUE

325      WRITE(44,336)
326 336      FORMAT('NUMBER OF KILLS BY CATEGORY PER REPITITION')
327      WRITE(44,337)
328 337      *      FORMAT(' DIRECTFIRE ROLL PLOW MINEFIELD PLOWCARR',
          *      ' ROLLCARR TOTKILL CLOCK MINRNG')
329      WRITE(24,537)
330 537      FORMAT(10X,'ACTIVE MINEFIELDS AND TIMES TO DEFENSIVE POSTURE')
331      WRITE(24,538)
332 538      *      FORMAT(5X,'AVENUE 1',5X,' AVENUE 2',5X,' AVENUE 3',5X,
          *      ' AVENUE 4',3X,'RUN TIME')
333      WRITE(24,539)
334 539      *      FORMAT('      M1 M2      M1 M2      M1 M2',
          *      M1 M2')

335      END IF

336      WRITE(54,717) RSURVIV,REDCODE,PRCNTEFFR
337 717      FORMAT( 'RED UNIT #SURVIV ',F3.0,' UNITCODE ',I2,' %EFF',F5.3)
338      END IF
339      RETURN
340      END

```

*****LOCATION*****

```

341      SUBROUTINE LOCATION (LAG,UNIT,NUNIT,BLUEXPOS,BLUEYPOS,
      *      RNG,RNGMIN,REDX,REDY,AAA,CLOSE,BEHIND,BLUECODE)
342      INTEGER UNIT,NUNIT,CLOSE,BEHIND,BLUECODE
343      REAL LAG,BLUEXPOS,BLUEYPOS,REDX,REDY,RNG,RNGMIN,RNGMAX,AAA
344      DIMENSION BLUEXPOS(20),BLUEYPOS(20),RNG(20),BLUECODE(10)

345      LAG = 0.5
346      RNGMIN = 20.0
347      RNGMAX = 0.1
348      CLOSE = 0
349      BEHIND = 0

      * CHECK TO DETERMINE IF UNITS ARE ALIGNED
350      DO 57 UNIT=1,NUNIT
351      *      RNG(UNIT)=(SQRT(((REDX-BLUEXPOS(UNIT))*2)+
      *      ((REDY-BLUEYPOS(UNIT))*2)))/10
352      IF (BLUECODE(UNIT) .EQ. 0) THEN
353      GO TO 57
354      END IF
355      IF (RNG(UNIT) .LT. RNGMIN ) THEN
356      RNGMIN = RNG(UNIT)
357      CLOSE=UNIT
358      END IF

359      IF (RNG(UNIT) .GT. RNGMAX ) THEN
360      RNGMAX = RNG(UNIT)
361      END IF
362 57      CONTINUE

      * CALCULATE THE LAG FACTOR AAA
363      IF((RNGMAX - RNGMIN) .GT. LAG) THEN
364      AAA = (RNGMAX-RNGMIN)/LAG
365      BEHIND = 1
366      END IF
367      RETURN
368      END

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MOV1

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369      SUBROUTINE MOV1 (LOC, TAIL, XNODE, YNODE, SPEED, TRAVEL, ANGLE, AVE, DIST,
*        NODE, ISTART, DISTANCE, BLUEXPOS, BLUEYPOS, CLOCK, UNIT,
*        BLUEXOFF1, BLUEYOFF1, BLUEXOFF2, BLUEYOFF2, ENTRY1,
*        BLUEX1POS, BLUEY1POS, UNITSPD, NUMBLUE, VEHTYPE, AAA,
*        CLOSE, BEHIND, BLUECODE, BLUEXOFF0, BLUEYOFF0, DEPMINE1,
*        MINE1, STATMIN1, DSEED, BLUESTATUS, DISTDET1, REDX, REDY,
*        BLUEDETECT1, RNG, BULL1, BYPASS1, ENTRY2, DEPMINE2, MINE2,
*        STATMIN2, DISTDET2, BULL2, BYPASS2, MINEKILL, ROLLKILL,
*        PLOWKILL, ROLLBRCHKILL, PLOWBRCHKILL, REP, MTYPE)
370      INTEGER TAIL, NODE, LOC, ISTART, UNIT, CLOSE, BEHIND, ENTRY1, MINE1
371      INTEGER NNODE, AVE, VEHTYPE, NUMBLUE, BLUECODE, STATMIN1, BLUESTATUS
372      INTEGER ACTIVE1, ACTIVE2, CLEAR, PSN, BLUEDETECT1, BULL1, BYPASS1
373      INTEGER ENTRY2, MINE2, STATMIN2, BULL2, BYPASS2, MINEKILL, ROLLKILL
374      INTEGER TEMPTYPE, TEMPSTATUS, TEMPDETECT, PLOWKILL, PLOWBRCHKILL, REP
375      INTEGER ROLLBRCHKILL, MTYPE
376      REAL DIST, SPEED, DISTANCE, BLUEXPOS, BLUEYPOS, MINEDET, REDX
377      REAL BLUEXOFF1, BLUEYOFF1, BLUEXOFF2, BLUEYOFF2, DISTDET1, REDY
378      REAL BLUEX1POS, BLUEY1POS, BLUEXOFF0, BLUEYOFF0, WIDTH, STEPMINE1
379      REAL XNODE, YNODE, ANGLE, UNITSPD, AAA, DENSITY, MINERND, STEPMINE2
380      REAL MINEPK, MOVE, DEPMINE1, RNG, DEPMINE2, DISTDET2, MINEDET2
381      REAL MINEDET1, PDETONAT4
382      REAL*8 DSEED
383      DIMENSION TAIL(150), NODE(150), LOC(10), BLUEDETECT1(10, 20)
384      DIMENSION DIST(100), AVE(10, 30), SPEED(10, 80), DISTDET1(10, 100)
385      DIMENSION ANGLE(100), DISTANCE(10), ISTART(10), WIDTH(10), RNG(20)
386      DIMENSION XNODE(150), YNODE(150), BLUEXPOS(20), BLUEYPOS(20)
387      DIMENSION BLUEXOFF1(20), BLUEYOFF1(20), BLUEXOFF2(20), ENTRY1(10)
388      DIMENSION BLUEYOFF2(20), BLUEX1POS(10, 20), BLUEY1POS(10, 20)
389      DIMENSION UNITSPD(10), VEHTYPE(10, 20), BLUECODE(10), MINE1(10)
390      DIMENSION BLUEYOFF0(20), BLUEXOFF0(20), MINERND(100), STATMIN1(10)
391      DIMENSION BLUESTATUS(10, 20), CLEAR(20), MOVE(20), DEPMINE1(10)
392      DIMENSION BULL1(10), BYPASS1(10), DISTDET2(10, 100), ENTRY2(10)
393      DIMENSION MINE2(10), STATMIN2(10), DEPMINE2(10), BYPASS2(10)
394      DIMENSION BULL2(10), MINEKILL(100), ROLLKILL(100), PLOWKILL(100)
395      DIMENSION PLOWBRCHKILL(100), ROLLBRCHKILL(100), MTYPE(20)

396      MINEPK=.99
397      STEP=0.1
398      STEPMINE2=9.0
399      STEPMINE1=9.0
400      MINEDET1=0.1
401      MINEDET2=0.5
402      PCLEAR4=.861
403      PCLEAR5=.926
404      PDETONAT4=.10
405      PSURVIV4=.90
406      PSURVIV5=.75
407      PDETTNK4=.999
408      PDETTNK5=.978

*      PRINT*, 'BLUECODE', UNIT, BLUECODE(UNIT), LOC(UNIT)

409      CALL GGUBS(DSEED, 100, MINERND)

410      DO 70 KOUNT=1, 5
411      LOC(UNIT)=AVE(UNIT, ISTART(UNIT))
412      IF (BLUECODE(UNIT) .EQ. 0) THEN
413      TRAVEL = 0
414      UNITSPD(UNIT) = 0
415      GO TO 75
416      END IF

417      CALL SPD( TRAVEL, SPEED, LOC, STEP, UNIT, UNITSPD, VEHTYPE, NUMBLUE,
*        AAA, CLOSE, BEHIND, BLUESTATUS)

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418 IF (ENTRY1(UNIT) .EQ. 0) THEN
419 IF (LOC(UNIT) .EQ. MINE1(UNIT) .AND. STATMIN1(UNIT) .EQ. 1) THEN
420 IF (MINERND(1) .LT. MINEDET1) THEN
421 DO 33 K=1,NUMBLUE
422 IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
423 BLUESTATUS(UNIT,K) = 1
424 END IF
425 IF (VEHTYPE(UNIT,K) .EQ. 2) THEN
426 VEHTYPE(UNIT,K) = 4
427 ELSE IF (VEHTYPE(UNIT,K) .EQ. 3) THEN
428 VEHTYPE(UNIT,K) = 5
429 END IF
430 33 CONTINUE
431 BLUECODE(UNIT)=2
432 CLEAR(UNIT)=3
433 MOVE(UNIT)=0.001
434 ENTRY1(UNIT)=1

435 WRITE(54,767) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
436 767 FORMAT(2X,F4.1,' UNIT ',I1,' DETECTED MINE1 AT ',I3,
* ' BLUECODE IS ',I1)

437 GO TO 98
438 ELSE IF (DISTDET1(UNIT,1) .LT. DISTANCE(UNIT)) THEN
439 DO 52 I=1,NUMBLUE
440 IF (BLUESTATUS(UNIT,I) .NE. 0) THEN
441 RANGE1=(SQRT(((REDX-BLUEX1POS(UNIT,I))*2)+
* ((REDY-BLUEY1POS(UNIT,I))*2)))/10
442 IF (RANGE1 .LT. STEPMINE1) THEN
443 STEPMINE1=RANGE1
444 ACTIVE1=I
445 ELSE IF (RANGE1 .LT. STEPMINE2) THEN
446 STEPMINE2=RANGE1
447 ACTIVE2=I
448 END IF
449 END IF
450 52 CONTINUE
451 BLUECODE(UNIT) = 2

452 WRITE(54,757) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
453 757 FORMAT(2X,F4.1,' UNIT ',I1,' DETONATED MINE1 AT ',I3,
* ' BLUECODE IS ',I1)

454 IF (MINERND(2) .LT. MINEPK) THEN
455 BLUESTATUS(UNIT,ACTIVE1)=0
456 MINEKILL(REP)=MINEKILL(REP)+1
457 MTYPE(VEHTYPE(UNIT,ACTIVE1))=MTYPE(VEHTYPE(UNIT,ACTIVE1))+1
458 WRITE(54,913) UNIT,ACTIVE1,VEHTYPE(UNIT,ACTIVE1)
459 IF (DISTDET1(UNIT,2) .LT. DISTANCE(UNIT) .AND.
* MINERND(3) .LT. MINEPK) THEN
460 BLUESTATUS(UNIT,ACTIVE2) = 0
461 MINEKILL(REP)=MINEKILL(REP)+1
462 MTYPE(VEHTYPE(UNIT,ACTIVE2))=MTYPE(VEHTYPE(UNIT,ACTIVE2))+1
463 WRITE(54,913) UNIT,ACTIVE2,VEHTYPE(UNIT,ACTIVE2)
464 END IF

465 DO 35 K=1,NUMBLUE
466 IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN

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467             BLUESTATUS(UNIT,K) = 1
468         END IF
469         IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
470             VEHTYPE(UNIT,K) = 4
471         ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
472             VEHTYPE(UNIT,K) = 5
473         END IF
474 35         CONTINUE
475             CLEAR(UNIT)=3
476             ENTRY1(UNIT)=1
477         MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+DISTDET1(UNIT,1)

478 913 *      FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED AT MINEFIELD 1',
479                *      ' MMMMMMMMMMMMMMMMMMMMM')
480                GO TO 98
481         END IF
482         DO 59 K=1,NUMBLUE
483             IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
484                 BLUESTATUS(UNIT,K) = 1
485             END IF
486             IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
487                 VEHTYPE(UNIT,K) = 4
488             ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
489                 VEHTYPE(UNIT,K) = 5
490             END IF
491 59         CONTINUE
492             CLEAR(UNIT)=3
493             ENTRY1(UNIT)=1
494             MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+DISTDET1(UNIT,1)
495             GO TO 98
496         END IF
497     ELSE IF (ENTRY2(UNIT) .EQ. 0) THEN
498         IF (LOC(UNIT) .EQ. MINE2(UNIT) .AND. STATMIN2(UNIT) .EQ. 1) THEN
499             IF (MINERND(1) .LT. MINEDET2) THEN
500                 DO 99 K=1,NUMBLUE
501                     IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
502                         BLUESTATUS(UNIT,K) = 1
503                     END IF
504                     IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
505                         VEHTYPE(UNIT,K) = 4
506                     ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
507                         VEHTYPE(UNIT,K) = 5
508                     END IF
509 99                 CONTINUE
510                     BLUECODE(UNIT)=2
511                     CLEAR(UNIT)=3
512                     MOVE(UNIT)=0.001
513                     ENTRY2(UNIT)=1
514
515 766 *      WRITE(54,766) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
516                *      FORMAT(2X,F4.1,' UNIT ',I1,' DETECTED MINE2 AT ',I3,
517                *      ' BLUECODE IS ',I1)
518                GO TO 98
519            ELSE IF (DISTDET2(UNIT,1) .LT. DISTANCE(UNIT)) THEN
520                DO 96 I=1,NUMBLUE

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519         IF (BLUESTATUS(UNIT,I) .NE. 0) THEN
520             RANGE1=(SQRT(((REDX-BLUEX1POS(UNIT,I))*2)+
*              ((REDY-BLUEY1POS(UNIT,I))*2)))/10
521             IF (RANGE1 .LT. STEPMINE1) THEN
522                 STEPMINE1=RANGE1
523                 ACTIVE1=I
524             ELSE IF (RANGE1 .LT. STEPMINE2) THEN
525                 STEPMINE2=RANGE1
526                 ACTIVE2=I
527             END IF
528         END IF
529 96     CONTINUE
530             BLUECODE(UNIT) = 2

531     WRITE(54,756) CLOCK,UNIT,LOC(UNIT),BLUECODE(UNIT)
532 756     FORMAT(2X,F4.1,' UNIT ',I1,' DETONATED MINE2 AT ',I3,
*          ' BLUECODE IS ',I1)

*     PRINT*, 'UNIT ACTIVE1 MINE2',UNIT,ACTIVE1
533         IF (MINERND(2) .LT. MINEPK) THEN
534             BLUESTATUS(UNIT,ACTIVE1)=0
535             MINEKILL(REP)=MINEKILL(REP)+1
536             MTYPE(VEHTYPE(UNIT,ACTIVE1))=MTYPE(VEHTYPE(UNIT,ACTIVE1))+1
537             WRITE(54,943) UNIT,ACTIVE1,VEHTYPE(UNIT,ACTIVE1)
538             IF (DISTDET2(UNIT,2) .LT. DISTANCE(UNIT) .AND.
*              MINERND(3) .LT. MINEPK) THEN
539                 BLUESTATUS(UNIT,ACTIVE2) = 0
540                 MINEKILL(REP)=MINEKILL(REP)+1
541                 MTYPE(VEHTYPE(UNIT,ACTIVE2))=MTYPE(VEHTYPE(UNIT,ACTIVE2))+1
542                 WRITE(54,943) UNIT,ACTIVE2,VEHTYPE(UNIT,ACTIVE2)
543             END IF

544         DO 95 K=1,NUMBLUE
545             IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
546                 BLUESTATUS(UNIT,K) = 1
547             END IF
548             IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
549                 VEHTYPE(UNIT,K) = 4
550             ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
551                 VEHTYPE(UNIT,K) = 5
552             END IF
553 95     CONTINUE
554             CLEAR(UNIT)=3
555             ENTRY2(UNIT)=1
556             MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+DISTDET2(UNIT,1)

557 943     FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED AT MINEFIELD 2',
*          ' MMMMMMMMMMMMMMMMMMMMMMM')
558             GO TO 98
559         END IF
560         DO 94 K=1,NUMBLUE
561             IF (BLUESTATUS(UNIT,K) .EQ. 2) THEN
562                 BLUESTATUS(UNIT,K) = 1
563             END IF
564             IF (VEHTYPE(UNIT,K) .EQ. 2 ) THEN
565                 VEHTYPE(UNIT,K) = 4
566             ELSE IF (VEHTYPE(UNIT,K) .EQ. 3 ) THEN
567                 VEHTYPE(UNIT,K) = 5

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568             END IF
569 94          CONTINUE
570             CLEAR(UNIT)=3
571             ENTRY2(UNIT)=1
572             MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+DISTDET2(UNIT,1)
573             GO TO 98
574          END IF
575        END IF
576      END IF
577      IF (ENTRY1(UNIT) .EQ. 2) THEN
578        IF (LOC(UNIT) .EQ. MINE1(UNIT)) THEN
579          IF (BULL1(UNIT) .EQ. 1) THEN
580            GO TO 41
581          ELSE IF (BYPASS1(UNIT) .EQ. 1) THEN
582            GO TO 46
583          END IF
584        IF (BULL1(UNIT) .EQ. 0 .AND. BYPASS1(UNIT) .EQ. 0) THEN
585          DO 26 IIPSN=1,NUMBLUE
586            IF (BLUESTATUS(UNIT,IIPSN) .EQ. 0) THEN
587              GO TO 26
588            ELSE IF (VEHTYPE(UNIT,IIPSN) .EQ. 1) THEN
589              IF (DISTANCE(UNIT) .GE. DEPMINE1(UNIT)/2) THEN
590                BULL1(UNIT) = 1
591                GO TO 46
592              ELSE IF (DISTANCE(UNIT) .LT. DEPMINE1(UNIT)/2) THEN
593                BYPASS1(UNIT) = 1
594                GO TO 41
595              END IF
596            ELSE IF (VEHTYPE(UNIT,IIPSN) .NE. 1) THEN
597              GO TO 25
598            END IF
599 26          CONTINUE
600        END IF
601 25      IF (MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
602          DO 37 IPSN = 1,NUMBLUE
603            IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
604              GO TO 37
605            END IF
606            IF (VEHTYPE(UNIT,IPSN) .EQ. 1) THEN
607              IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
608                BLUESTATUS(UNIT,IPSN) = 0
609                MINEKILL(REP)=MINEKILL(REP)+1
610                MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
611                WRITE(54,940) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
612 940          *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 1 ',
613                *   ' DUE TO UNCLEARED MINE')
614                GO TO 36
615              ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
616                GO TO 36
617              END IF
618            ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 4) THEN
619              IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR4) THEN
620                CLEAR(UNIT)= CLEAR(UNIT) + 1
621                IF (MINERND(CLEAR(UNIT)) .GE. PDETONAT4) THEN
622 641          *   WRITE(54,641) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
623                *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED A MINE',
624                *   ' IN MINEFIELD 1 SSSS')

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623          CLEAR(UNIT)= CLEAR(UNIT) + 1
624          GO TO 36
625      ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETONAT4) THEN
626          CLEAR(UNIT)= CLEAR(UNIT) + 1
627          IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV4) THEN
628      WRITE(54,941) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
629 941  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED BLAST',
        *   ' IN MINEFIELD 1 SSSS')
        *   GO TO 36
630      ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV4) THEN
631      WRITE(54,942) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
632 942  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/PLOW DID NOT ',
        *   ' SURVIVE IN MINEFIELD 1')
        *   PLOWKILL(REP)=PLOWKILL(REP)+1
633      VEHTYPE(UNIT,IPSN) = 1
634      TEMPTYPE=VEHTYPE(UNIT,IPSN)
635      TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
636      TEMPDTECT=BLUEDETECT1(UNIT,IPSN)
637      DO 61 PSN=IPSN,NUMBLUE-1
638      VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
639      BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
640      BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
641      CONTINUE
642      BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
643 61  *   VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
        *   BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
644      GO TO 36
645      END IF
646      END IF
647      ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK4 .AND.
648      *   MINERND(CLEAR(UNIT)) .GT. PCLEAR4) THEN
649      CLEAR(UNIT)=CLEAR(UNIT)+1
650      IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
651      WRITE(54,945) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
652 945  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
        *   ' MINE/CARRIER WAS KILLED')
        *   BLUESTATUS(UNIT,IPSN) = 0
653      PLOWBRCHKILL(REP)=PLOWBRCHKILL(REP)+1
654      GO TO 36
655      ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
656      GO TO 36
657      END IF
658      ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK4) THEN
659      CLEAR(UNIT)=CLEAR(UNIT)+1
660      WRITE(54,946) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
661 946  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
        *   ' MINE/CARRIER SURVIVED')
662      WRITE(54,947)
663 947  *   FORMAT(' MINE LEFT IN PATH UNEXPLODED')
664      GO TO 37
665      END IF
666      ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 5) THEN
667      IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR5) THEN
668      CLEAR(UNIT)= CLEAR(UNIT) + 1
669      IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV5) THEN
670      WRITE(54,901) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
671 901  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED A MINE',
        *   ' IN MINEFIELD 1 SSSS')
672      GO TO 36
673      ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV5) THEN
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677      WRITE(54,944) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
678 944  *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/ROLLER DIDNOT',
        *   ' SURVIVE IN MINEFIELD 1')
        *   ROLLKILL(REP)=ROLLKILL(REP)+1
679          VEHTYPE(UNIT,IPSN) = 1
680          TEMPTYPE=VEHTYPE(UNIT,IPSN)
681          TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
682          TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
683      DO 65 PSN=IPSN,NUMBLUE-1
684          VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
685          BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
686          BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
687      65  CONTINUE
688          BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
689          VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
690          BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
691          GO TO 36
692      END IF
693      ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK5 .AND.
694  *   MINERND(CLEAR(UNIT)) .GT. PCLEAR5) THEN
        *   CLEAR(UNIT)=CLEAR(UNIT)+1
695          IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
696              BLUESTATUS(UNIT,IPSN) = 0
697      955  WRITE(54,955) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
        *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
        *   'MINE/CARRIER WAS KILLED')
        *   ROLLBRCHKILL(REP)=ROLLBRCHKILL(REP)+1
698          GO TO 36
699          ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
700              GO TO 36
701          END IF
702          ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK5) THEN
703              CLEAR(UNIT)=CLEAR(UNIT)+1
704      948  WRITE(54,948) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
        *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
        *   'MINE/CARRIER SURVIVED')
705      949  WRITE(54,949)
        *   FORMAT('MINE LEFT IN PATH UNEXPLODED')
706          GO TO 37
707      END IF
708      END IF
709      CONTINUE
710      37  CLEAR(UNIT)=CLEAR(UNIT)+1
711      36  MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+MOVE(UNIT)
712      IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
713          ENTRY1(UNIT)=3
714      IF (BLUECODE(UNIT) .NE. 0) THEN
715          BLUECODE(UNIT) = 1
716      DO 38 K=1,NUMBLUE
717          IF (VEHTYPE(UNIT,K) .EQ. 4 ) THEN
718              VEHTYPE(UNIT,K) = 2
719          ELSE IF (VEHTYPE(UNIT,K) .EQ. 5 ) THEN
720              VEHTYPE(UNIT,K) = 3
721          END IF
722      38  CONTINUE
723      END IF
724      END IF
725      END IF
726      END IF
727      END IF
728      END IF
729      END IF
730      END IF
731      END IF
732      END IF

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733 41      IF (BULL1(UNIT).EQ. 1) THEN
734          TRAVEL=TRAVEL/10
735          IF(MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
736              DO 21 IPSN = 1,NUMBLUE
737                  IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
738                      GO TO 21
739                  END IF
740                  IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
741                      BLUESTATUS(UNIT,IPSN) = 0
742                      MINEKILL(REP)=MINEKILL(REP)+1
743                      MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
744                      WRITE(54,967) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
745 967      *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 1 ',
              'DUE TO BULLING THRU ')
746                  GO TO 71
747                  ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
748                      GO TO 71
749                  END IF
750 21      CONTINUE
751 71      CLEAR(UNIT)=CLEAR(UNIT)+1
752          MOVE(UNIT)=DISTDET1(UNIT,CLEAR(UNIT))+MOVE(UNIT)
753          IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
754              ENTRY1(UNIT)=3
755              IF (BLUECODE(UNIT) .NE. 0) THEN
756                  BLUECODE(UNIT) = 1
757                  BULL1(UNIT) = 2
758                  GO TO 75
759              END IF
760          END IF
761      END IF
762      END IF

763 46      IF (BYPASS1(UNIT).EQ. 1) THEN
764          TRAVEL=TRAVEL/40
765          IF (KOUNT .EQ.5) THEN
766              WRITE(54,968) UNIT
767 968      *   FORMAT(' UNIT ',I3,' IS CONDUCTING BYPASS OPERATION AROUND ',
              'MINEFIELD 1 PPPPPP ')
768          END IF
769          IF (DISTANCE(UNIT) .GT. DEPMINE1(UNIT)) THEN
770              ENTRY1(UNIT)=3
771              IF (BLUECODE(UNIT) .NE. 0) THEN
772                  BLUECODE(UNIT) = 1
773                  BYPASS1(UNIT) = 2
774              END IF
775          END IF
776      END IF

777      IF (ENTRY2(UNIT) .EQ. 2) THEN
778          IF (LOC(UNIT) .EQ. MINE2(UNIT)) THEN
779              IF (BULL2(UNIT) .EQ. 1) THEN
780                  GO TO 93
781              ELSE IF (BYPASS2(UNIT) .EQ. 1) THEN
782                  GO TO 92
783              END IF
784              IF (BULL2(UNIT) .EQ. 0 .AND. BYPASS2(UNIT) .EQ. 0) THEN
785                  DO 91 IIPSN=1,NUMBLUE
786                      IF (BLUESTATUS(UNIT,IIPSN) .EQ. 0) THEN
787                          GO TO 91

```

```

788         ELSE IF (VEHTYPE(UNIT,IIPSN) .EQ. 1) THEN
789             IF (DISTANCE(UNIT) .GE. DEPMINE2(UNIT)/2) THEN
790                 BULL2(UNIT) = 1
791                 GO TO 92
792             ELSE IF (DISTANCE(UNIT) .LT. DEPMINE2(UNIT)/2) THEN
793                 BYPASS2(UNIT) = 1
794                 GO TO 93
795             END IF
796         ELSE IF (VEHTYPE(UNIT,IIPSN) .NE. 1) THEN
797             GO TO 72
798         END IF
799 91     CONTINUE
800     END IF

801 72     IF (MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
802         DO 73 IPSN = 1,NUMBLUE
803             IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
804                 GO TO 73
805             END IF
806             IF (VEHTYPE(UNIT,IPSN) .EQ. 1) THEN
807                 IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
808                     BLUESTATUS(UNIT,IPSN) = 0
809                     MINEKILL(REP)=MINEKILL(REP)+1
810                     MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
811                     WRITE(54,741) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
812 741     *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 2 ',
813                 'DUE TO UNCLEARED MINE')
814                     GO TO 78
815                     ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
816                         GO TO 78
817                     END IF
818             ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 4) THEN
819                 IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR4) THEN
820                     CLEAR(UNIT)= CLEAR(UNIT) + 1
821                     IF (MINERND(CLEAR(UNIT)) .GE. PDETONT4) THEN
822 341     *   WRITE(54,341) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
823                 FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED A MINE',
824                 ' IN MINEFIELD 2 SSSS')
825                     CLEAR(UNIT)= CLEAR(UNIT) + 1
826                     GO TO 78
827                     ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETONT4) THEN
828                         CLEAR(UNIT)= CLEAR(UNIT) + 1
829                         IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV4) THEN
830                             WRITE(54,981) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
831                             FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED BLAST',
832                             ' IN MINEFIELD 2 SSSS')
833 981     *   GO TO 78
834                     ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV4) THEN
835                         WRITE(54,982) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
836                         FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/PLOW DID NOT ',
837                         ' SURVIVE IN MINEFIELD 2')
838 982     *   PLOWKILL(REP)=PLOWKILL(REP)+1
839                     VEHTYPE(UNIT,IPSN) = 1
840                     TEMPTYPE=VEHTYPE(UNIT,IPSN)
841                     TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
842                     TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
843                     DO 53 PSN=IPSN,NUMBLUE-1
844                         VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
845                         BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
846                         BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)

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843 53          CONTINUE
844          BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
845          VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
846          BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
847          GO TO 78
848      END IF
849  END IF
850  ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK4 .AND.
      *      MINERND(CLEAR(UNIT)) .GT. PCLEAR4) THEN
851          CLEAR(UNIT)=CLEAR(UNIT)+1
852          IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN
853      WRITE(54,975) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
854 975  FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
      *      'MINE/CARRIER WAS KILLED')
855          BLUESTATUS(UNIT,IPSN) = 0
856          PLOWBRCHKILL(REP)=PLOWBRCHKILL(REP)+1
857          GO TO 78
858          ELSE IF (MINERND(CLEAR(UNIT)) .GE. MINEPK) THEN
859              GO TO 78
860          END IF
861      ELSE IF (MINERND(CLEAR(UNIT)) .GE. PDETTNK4) THEN
862          CLEAR(UNIT)=CLEAR(UNIT)+1
863      WRITE(54,976) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
864 976  FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' PLOW FAILED TO CLEAR ',
      *      'MINE/CARRIER SURVIVED')
865      WRITE(54,937)
866 937  FORMAT('MINE LEFT IN PATH UNEXPLODED')
867          GO TO 73
868      END IF
869      ELSE IF (VEHTYPE(UNIT,IPSN) .EQ. 5) THEN
870          IF (MINERND(CLEAR(UNIT)) .LT. PCLEAR5) THEN
871              CLEAR(UNIT)= CLEAR(UNIT) + 1
872              IF (MINERND(CLEAR(UNIT)) .LT. PSURVIV5) THEN
873      WRITE(54,933) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
874 933  FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/SURVIVED A MINE',
      *      ' IN MINEFIELD 2 SSSS')
875          GO TO 78
876          ELSE IF (MINERND(CLEAR(UNIT)) .GE. PSURVIV5) THEN
877      WRITE(54,934) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
878 934  FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' CLEARED/ROLLER DIDNOT',
      *      ' SURVIVE IN MINEFIELD 2')
879          ROLLKILL(REP)=ROLLKILL(REP)+1
880          VEHTYPE(UNIT,IPSN) = 1
881          TEMPTYPE=VEHTYPE(UNIT,IPSN)
882          TEMPSTATUS=BLUESTATUS(UNIT,IPSN)
883          TEMPDETECT=BLUEDETECT1(UNIT,IPSN)
884      DO 45 PSN=IPSN,NUMBLUE-1
885          VEHTYPE(UNIT,PSN)=VEHTYPE(UNIT,PSN+1)
886          BLUESTATUS(UNIT,PSN)= BLUESTATUS(UNIT,PSN+1)
887          BLUEDETECT1(UNIT,PSN)=BLUEDETECT1(UNIT,PSN+1)
888 45  CONTINUE
889          BLUESTATUS(UNIT,NUMBLUE)=TEMPSTATUS
890          VEHTYPE(UNIT,NUMBLUE)=TEMPTYPE
891          BLUEDETECT1(UNIT,NUMBLUE)=TEMPDETECT
892          GO TO 78
893      END IF
894  ELSE IF (MINERND(CLEAR(UNIT)) .LT. PDETTNK5 .AND.
      *      MINERND(CLEAR(UNIT)) .GT. PCLEAR5) THEN
895          CLEAR(UNIT)=CLEAR(UNIT)+1
896          IF (MINERND(CLEAR(UNIT)) .LT. MINEPK) THEN

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897          BLUESTATUS(UNIT,IPSN) = 0
898      WRITE(54,935) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
899 935      *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
          *       'MINE/CARRIER WAS KILLED')
900          ROLLBRCHKILL(REP)=ROLLBRCHKILL(REP)+1
901          GO TO 78
902          ELSE IF (MINERNND(CLEAR(UNIT)) .GE. MINEPK) THEN
903              GO TO 78
904          END IF
905          ELSE IF (MINERNND(CLEAR(UNIT)) .GE. PDETTNK5) THEN
906              CLEAR(UNIT)=CLEAR(UNIT)+1
907      WRITE(54,938) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
908 938      *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' ROLLER FAILED TO CLEAR ',
          *       'MINE/CARRIER SURVIVED')
909      WRITE(54,939)
910 939      FORMAT('MINE LEFT IN PATH UNEXPLODED')
911          GO TO 73
912      END IF
913      END IF
914 73      CONTINUE
915 78      CLEAR(UNIT)=CLEAR(UNIT)+1
916          MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+MOVE(UNIT)
917      IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN
918          ENTRY2(UNIT)=3
919      IF (BLUECODE(UNIT) .NE. 0) THEN
920          BLUECODE(UNIT) = 1
921          DO 48 K=1,NUMBLUE
922              IF (VEHTYPE(UNIT,K) .EQ. 4) THEN
923                  VEHTYPE(UNIT,K) = 2
924              ELSE IF (VEHTYPE(UNIT,K) .EQ. 5) THEN
925                  VEHTYPE(UNIT,K) = 3
926              END IF
927 48      CONTINUE
928          END IF
929          END IF
930          END IF
931          END IF
932      END IF
933 93      IF (BULL2(UNIT).EQ. 1) THEN
934          TRAVEL=TRAVEL/10
935      IF(MOVE(UNIT) .LT. DISTANCE(UNIT)) THEN
936          DO 82 IPSN = 1,NUMBLUE
937              IF (BLUESTATUS(UNIT,IPSN) .EQ. 0) THEN
938                  GO TO 82
939              END IF
940              IF (MINERNND(CLEAR(UNIT)) .LT. MINEPK) THEN
941                  BLUESTATUS(UNIT,IPSN) = 0
942                  MINEKILL(REP)=MINEKILL(REP)+1
943                  MTYPE(VEHTYPE(UNIT,IPSN))=MTYPE(VEHTYPE(UNIT,IPSN))+1
944      WRITE(54,957) UNIT,IPSN,VEHTYPE(UNIT,IPSN)
945 957      *   FORMAT(' VEHICLE ',2I3,' VEHTYPE ',I3,' KILLED IN MINEFIELD 2 ',
          *       'DUE TO BULLING THRU ')
946          GO TO 84
947          ELSE IF (MINERNND(CLEAR(UNIT)) .GE. MINEPK) THEN
948              GO TO 84
949          END IF
950 82      CONTINUE
951 84      CLEAR(UNIT)=CLEAR(UNIT)+1
952          MOVE(UNIT)=DISTDET2(UNIT,CLEAR(UNIT))+MOVE(UNIT)
953      IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN

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954                                     ENTRY2(UNIT)=3
955     IF (BLUECODE(UNIT) .NE. 0) THEN
956         BLUECODE(UNIT) = 1
957         BULL2(UNIT) = 2
958         GO TO 75
959     END IF
960     END IF
961     END IF
962     END IF

963 92     IF (BYPASS2(UNIT).EQ. 1) THEN
964         TRAVEL=TRAVEL/50
965         IF (KOUNT .EQ.5) THEN
966             WRITE(54,977) UNIT
967 977     *   FORMAT(' UNIT ',I3,' IS CONDUCTING BYPASS OPERATION AROUND ',
968             *   'MINEFIELD 2 PPPPPP ')
969             END IF
970             IF (DISTANCE(UNIT) .GT. DEPMINE2(UNIT)) THEN
971                 ENTRY2(UNIT)=3
972                 IF (BLUECODE(UNIT) .NE. 0) THEN
973                     BLUECODE(UNIT) = 1
974                     BYPASS2(UNIT) = 2
975                 END IF
976             END IF
977             END IF

977 75     DELX=TRAVEL*COS(ANGLE(LOC(UNIT)))*10
978     DELY=TRAVEL*SIN(ANGLE(LOC(UNIT)))*10
979     BLUEXPOS(UNIT)=BLUEXPOS(UNIT)+DELX
980     BLUEYPOS(UNIT)=BLUEYPOS(UNIT)+DELY

981     *   CALL OFFSET (BLUEXPOS,BLUEYPOS,BLUEXOFF1,BLUEYOFF1,LOC,
982     *   *   *   ANGLE,UNIT,NUMBLUE,CLOCK,KOUNT,BLUECODE,
983     *   *   *   BLUEXOFF2,BLUEYOFF2,BLUEX1POS,BLUEY1POS,
984     *   *   *   BLUEXOFF0,BLUEYOFF0)

982     DISTANCE(UNIT)=DISTANCE(UNIT)+TRAVEL

983     IF (DISTANCE(UNIT) .GE. DIST(LOC(UNIT))) THEN
984         ISTART(UNIT)=ISTART(UNIT)+1
985         LOC(UNIT) = AVE(UNIT,ISTART(UNIT))
986         DISTANCE(UNIT)=0.0
987         BLUEXPOS(UNIT) = XNODE(TAIL(LOC(UNIT)))
988         BLUEYPOS(UNIT) = YNODE(TAIL(LOC(UNIT)))
989         GO TO 98
990     END IF
991 70     CONTINUE
992     GO TO 98

993     *   WRITE(54,931) CLOCK,UNIT,LOC(UNIT),BLUEXPOS(UNIT),BLUEYPOS(UNIT),
994     *   *   *   UNITSPD(UNIT),RNG(UNIT)
995     *   *   *   FORMAT(2X,F4.1,' UNIT ',I3,' LOC ',I3,
996     *   *   *   ' POSITION ',2F6.1,' SPEED ',F4.0,' RANGE ',F8.3)

995 98     RETURN
996     END

```

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***** SPEED *****
997 SUBROUTINE SPD(TRAVEL,SPEED,LOC,STEP,UNIT,UNITSPD,VEHTYPE,
    * NUMBLUE,AAA,CLOSE,BEHIND,BLUESTATUS)
998 INTEGER LOC,UNIT,VEHTYPE,NUMBLUE,VEH,CLOSE,BEHIND
999 INTEGER BLUESTATUS
1000 REAL SPEED,TRAVEL,STEP,UNITSPD,AAA
1001 DIMENSION SPEED(10,80),LOC(10),UNITSPD(10),VEHTYPE(10,20)
1002 DIMENSION BLUESTATUS(10,20)

1003 UNITSPD(UNIT)=160

1004 DO 23 VEH=1,NUMBLUE
1005 IF(BLUESTATUS(UNIT,VEH) .NE. 0) THEN
1006 IF(SPEED(VEHTYPE(UNIT,VEH),LOC(UNIT)) .LT. UNITSPD(UNIT)) THEN
1007 UNITSPD(UNIT)=SPEED(VEHTYPE(UNIT,VEH),LOC(UNIT))

1008 END IF
1009 END IF
1010 23 CONTINUE

1011 IF (BEHIND .EQ. 1 .AND. CLOSE .EQ. UNIT) THEN
1012 UNITSPD(UNIT) = UNITSPD(UNIT)/AAA
1013 TRAVEL = (UNITSPD(UNIT)/60)*STEP
1014 GO TO 51
1015 END IF

1016 TRAVEL = (UNITSPD(UNIT)/60)*STEP

1017 51 RETURN
1018 END

```

```

***** OFFSET *****
1019      SUBROUTINE OFFSET (BLUEXPOS,BLUEYPOS,BLUEXOFF1,BLUEYOFF1,
*          LOC,ANGLE,UNIT,NUMBLUE,CLOCK,KOUNT,
*          BLUECODE,BLUEXOFF2,BLUEYOFF2,BLUEX1POS,BLUEY1POS,
*          BLUEXOFF0,BLUEYOFF0)
1020      INTEGER LOC,UNIT,C,KOUNT,NUMBLUE,BLUECODE
1021      REAL BLUEX1PLT,BLUEY1PLT,ANGLE,BLUEXPOS,BLUEYPOS
1022      REAL XOFFPLT,YOFFPLT,CLOCK
1023      REAL BLUEXOFF1,BLUEXOFF2,BLUEYOFF1,BLUEYOFF2,BLUEX1POS,BLUEY1POS
1024      REAL BLUEXOFF0,BLUEYOFF0
1025      DIMENSION BLUEXOFF1(20),BLUEYOFF1(20),ANGLE(100),BLUECODE(10)
1026      DIMENSION BLUEXOFF0(20),BLUEYOFF0(20)
1027      DIMENSION BLUEX1POS(10,20),BLUEY1POS(10,20),LOC(10)
1028      DIMENSION BLUEXPOS(20),BLUEYPOS(20),BLUEXOFF2(20),BLUEYOFF2(20)
1029      DO 60 C=1,NUMBLUE
1030      IF (BLUECODE(UNIT) .EQ. 0) THEN
1031          XOFFPLT=BLUEXOFF0(C)
1032          YOFFPLT=BLUEYOFF0(C)
1033      ELSE IF (BLUECODE(UNIT) .EQ. 1) THEN
1034          XOFFPLT=BLUEXOFF1(C)
1035          YOFFPLT=BLUEYOFF1(C)
1036      ELSE IF (BLUECODE(UNIT) .EQ. 2) THEN
1037          XOFFPLT=BLUEXOFF2(C)
1038          YOFFPLT=BLUEYOFF2(C)
1039      END IF
1040      BLUEX1POS(UNIT,C)=BLUEXPOS(UNIT)+(XOFFPLT*COS(ANGLE(LOC(UNIT))))
*          +YOFFPLT*SIN(ANGLE(LOC(UNIT))))
1041      BLUEY1POS(UNIT,C)=BLUEYPOS(UNIT)+(-XOFFPLT*SIN(ANGLE(LOC(UNIT))))
*          +YOFFPLT*COS(ANGLE(LOC(UNIT))))
1042 60      CONTINUE
1043      RETURN
1044      END

```

***** DETECTION *****

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1045      SUBROUTINE REDDETECT (REDXPOS,REDYPOS,BLUEXPOS,BLUEYPOS,
      *      BLUEX1POS,BLUEY1POS,NUNIT,REDENGAGE,BLUESTATUS,
      *      ANGLE,UNIT,UNITSPD,CLOCK,LOC,CV,NUMRED,NUMBLUE,
      *      REDX,REDY,RED,RPLOOK,REDSTATUS,DSEED,VEHTYPE,
      *      REDDETECT1,REDDETECT2,ELEMENT,POSITION,TAU,
      *      RVEHTYP,BLUECODE,RMAX)

1046      INTEGER UNIT,LOC,NUMRED,RED,REDSTATUS,VEHTYPE,REDENGAGE
1047      INTEGER REDDETECT1,REDDETECT2,ELEMENT,POSITION,NUNIT
1048      INTEGER BLUESTATUS,RVEHTYP,BLUECODE
1049      REAL REDXPOS,REDYPOS,BLUEXPOS,BLUEYPOS
1050      REAL BLUEX1POS,BLUEY1POS,ANGLE,UNITSPD
1051      REAL CLOCK,CV,REDX,REDY,HEIGHT,TAU,DENOM,RPLOOK,REDPDET
1052      REAL RAND,RMAX,RAF,RNGADJ,RNGDET1,RNGDET2,RANGE1,RANGE2
1053      REAL*8 DSEED
1054      DIMENSION BLUEXPOS(20),BLUEYPOS(20),LOC(10),UNITSPD(10),CV(10)
1055      DIMENSION BLUEX1POS(10,20),BLUEY1POS(10,20),ANGLE(100)
1056      DIMENSION RED(30),REDXPOS(30),REDYPOS(30),RPLOOK(10,30)
1057      DIMENSION RAND(10),REDSTATUS(30),RMAX(30),TEMP(30)
1058      DIMENSION VEHTYPE(10,20),HEIGHT(20),RAF(8),REDENGAGE(100)
1059      DIMENSION REDDETECT1(30),REDDETECT2(30),RNGDET1(30),RNGDET2(30)
1060      DIMENSION BLUESTATUS(10,20),RVEHTYP(30),BLUECODE(10)

1061      HEIGHT(1)=2.4
1062      HEIGHT(2)=2.4
1063      HEIGHT(3)=2.4
1064      HEIGHT(4)=2.4
1065      HEIGHT(5)=2.4

1066      RNGDET1(ELEMENT)=300.0
1067      RANGE1=0.0
1068      RNGDET2(ELEMENT)=500.0
1069      RANGE2=0.0
1070      REDDETECT1(ELEMENT)=0
1071      REDDETECT2(ELEMENT)=0

1072      DO 39 I=1,3
1073      RAF(I)=.000
1074 39 CONTINUE
1075      RAF(4)=.10
1076      RAF(5)=.10

```

```

1077 * LOOP 77 NUMBER OF BLUE UNITS
      DO 77 UNIT=1,NUNIT
1078     IF (BLUECODE(UNIT) .EQ. 0 ) THEN
1079         CV(UNIT) = 0
1080         GO TO 66
1081     END IF
1082         OBSVECX=REDX-BLUEXPOS(UNIT)
1083         OBSVECY=REDY-BLUEYPOS(UNIT)
1084         DIRVECX=COS(ANGLE(LOC(UNIT)))
1085         DIRVECY=SIN(ANGLE(LOC(UNIT)))
1086         OBSVECL=SQRT((OBSVECX**2)+(OBSVECY**2))
1087         CVANGLE=ACOS(((OBSVECX*DIRVECX)+(OBSVECY*DIRVECY))/OBSVECL)
1088         CV(UNIT) = (UNITSPD(UNIT)*1000/3600)*SIN(CVANGLE)

1089 * LOOP 79 NUMBER OF BLUE ELEMENTS IN EACH UNIT
      DO 79 POSITION=1,NUMBLUE
1090         IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) THEN
1091             GO TO 79
1092         END IF
1093         CALL GGUBS(DSEED,3,RAND)
1094         RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
      * ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10
1095         IF (BLUECODE(UNIT) .EQ. 0) THEN
1096             RNGAPP=(RANGE*2.8)/(((HEIGHT(VEHTYPE(UNIT,POSITION))/2)*RAND(1))
      * +(HEIGHT(VEHTYPE(UNIT,POSITION))/4))
1097             GO TO 55
1098         END IF
1099         RNGAPP=(RANGE*2.8)/(((HEIGHT(VEHTYPE(UNIT,POSITION))/2)*RAND(1))
      * +(HEIGHT(VEHTYPE(UNIT,POSITION))/2))

1100 55     IF (RANGE .LT. .250) THEN
1101         REDPDET=1.0
1102         GO TO 34
1103     END IF
1104         DENOM=1.453+(TAU*(.05978+(2.188*RNGAPP*RNGAPP)-
      * .5038*CV(UNIT)))
1105         DETRATE=RPLOOK(UNIT,ELEMENT)*(-.003+(1.088/DENOM))
1106         IF (DETRATE .LE. 0.0) THEN
1107             DETRATE = 0.0
1108         ELSE IF (DETRATE .GT. 5.0) THEN
1109             REDPDET=1.0
1110             GO TO 34
1111         END IF
1112         REDPDET=1-EXP(-DETRATE*30)
1113 34     IF (REDENGAGE(((NUMBLUE*(UNIT-1))+POSITION)) .GE. 2) THEN
1114         GO TO 79
1115     END IF
1116         IF (REDPDET .GE. RAND(2)) THEN
1117             IF (RANGE .LE. RMAX(ELEMENT)) THEN

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1118      RNGADJ=(RANGE/(1-(RAND(3)/2))) + RAF(VEHTYPE(UNIT,POSITION))
1119      IF (RNGADJ .LT. RNGDET1(ELEMENT)) THEN
1120          RNGDET1(ELEMENT) = RNGADJ
1121          RANGE1=RANGE
1122          REDSTATUS(ELEMENT) = 2
1123          REDDETECT1(ELEMENT)=(NUMBLUE*(UNIT-1))+POSITION
1124      ELSE IF (RNGADJ .LT. RNGDET2(ELEMENT)) THEN
1125          IF(RVEHTYP(ELEMENT) .EQ. 1) THEN
1126              RNGDET2(ELEMENT) = RNGADJ
1127              RANGE2=RANGE
1128              REDSTATUS(ELEMENT) = 2
1129              REDDETECT2(ELEMENT)= (NUMBLUE*(UNIT-1))+POSITION
1130          END IF
1131      END IF
1132  END IF
1133
1134 79      CONTINUE
1135 77      CONTINUE
1136          IF (RNGDET1(ELEMENT) .LT. 200.0) THEN
1137              REDENGAGE(REDDETECT1(ELEMENT))=REDENGAGE(REDDETECT1(ELEMENT))+1
1138          END IF
1139          IF (RNGDET2(ELEMENT) .LT. 200.0) THEN
1140              REDENGAGE(REDDETECT2(ELEMENT))=REDENGAGE(REDDETECT2(ELEMENT))+1
1141          END IF
1142      RETURN
1143      END

```

```

1144      SUBROUTINE BLUEDETECT (REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS,
*          BLUEENGAGE,BLUESTATUS,REDSTATUS,DSEED,UNIT,CLOCK,NUMRED,
*          BLUEDETECT1,ELEMENT,POSITION,TAU,RVEHTYP,RHEIGHT,RRAF,
*          BLUERMAL)
1145      INTEGER UNIT,NUMRED,REDSTATUS
1146      INTEGER BLUEDETECT1,ELEMENT,POSITION
1147      INTEGER BLUESTATUS,RVEHTYP,BLUEENGAGE
1148      REAL REDXPOS,REDYPOS
1149      REAL BLUEX1POS,BLUEY1POS,DETRATE
1150      REAL CLOCK,RHEIGHT,TAU,DENOM,RNGAPP,RANGE,BLUEPDET
1151      REAL RUHD,BLUERMAL,RRAF,RNGADJ,RNGDET,RANGE1
1152      REAL*8 DSEED
1153      DIMENSION BLUEX1POS(10,20),BLUEY1POS(10,20)
1154      DIMENSION REDXPOS(30),REDYPOS(30)
1155      DIMENSION RUHD(10),REDSTATUS(30),BLUERMAL(10,20)
1156      DIMENSION BLUEDETECT1(10,20),RNGDET(10,20),BLUEENGAGE(30)
1157      DIMENSION BLUESTATUS(10,20),RVEHTYP(30),RRAF(4),RHEIGHT(30)
1158      RNGDET(UNIT,POSITION)=300
1159      RANGE1=0.0
1160      BLUEDETECT1(UNIT,POSITION)=0
1161      DO 29 ELEMENT=1,NUMRED

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1162          IF (REDSTATUS(ELEMENT) .EQ. 0) THEN
1163              GO TO 29
1164          END IF
1165          CALL GGUBS(DSEED,3,RUND)

1166          RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
*              ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10

1167          RNGAPP=(RANGE*2.8)/(((RHEIGHT(ELEMENT)/2)*RUND(1))
*              +(RHEIGHT(ELEMENT)/4))

1168          IF (RANGE .LT. .250) THEN
1169              BLUEPDET=1.0
1170              GO TO 14
1171          END IF

1172          DENOM=1.453+(TAU*(.05978+(2.188*RNGAPP*RNGAPP)))
1173          DETRATE=.75*(-.003+(1.088/DENOM))

1174          IF (DETRATE .LE. 0.0) THEN
1175              DETRATE = 0.0
1176          ELSE IF (DETRATE .GT. 5.0) THEN
1177              BLUEPDET=1.0
1178              GO TO 14
1179          END IF

1180          BLUEPDET=1-EXP(-DETRATE*30)
1181 14      IF (BLUEENGAGE(ELEMENT) .GE. 4) THEN
1182              GO TO 29
1183          END IF

1184          IF (BLUEPDET .GE. RUND(2)) THEN
1185              IF (RANGE .LE. BLUERMAX(UNIT,POSITION)) THEN

1186                  RNGADJ=(RANGE/((.25+(RUND(3)/4)) + RRAF(RVEHTYP(ELEMENT)))

1187                  IF (RNGADJ .LT. RNGDET(UNIT,POSITION)) THEN
1188                      RNGDET(UNIT,POSITION) = RNGADJ
1189                      RANGE1=RANGE
1190                      BLUESTATUS(UNIT,POSITION) = 2
1191                      BLUEDTECT1(UNIT,POSITION)=ELEMENT
1192                  END IF
1193                  END IF
1194              END IF

1195 29      CONTINUE
1196          IF (RNGDET(UNIT,POSITION) .LT. 200.0) THEN
1197              BLUEENGAGE(BLUEDTECT1(UNIT,POSITION))=
*              BLUEENGAGE(BLUEDTECT1(UNIT,POSITION))+1

1198          END IF

1199          RETURN
1200      END
*****

```

***** FIRE *****

```

1201      SUBROUTINE REDFIRE(REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,
*          POSITION,NUMBLUE,REDXPOS,REDYPOS,NUNIT,VEHTYPE,
*          REDDETECT1,REDDETECT2,BLUEX1POS,BLUEY1POS,DSEED,
*          CLOCK,RVEHTYP,RPHITS,RPHITM,RPKILL,DFKILL,REP,DFTYPE)
1202      INTEGER REDSTATUS,ELEMENT,REDENGAGE,BLUESTATUS,UNIT,POSITION
1203      INTEGER NUMBLUE,SHOT,REDDETECT1,REDDETECT2,LOOP,NUNIT,RVEHTYP
1204      INTEGER VEHTYPE,DFKILL,REP,DFTYPE
1205      REAL RANGE,REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS
1206      REAL PHIT,PKILL,RNDNUM,CLOCK,RPHITS,RPHITM,RPKILL
1207      REAL*8 DSEED
1208      DIMENSION REDSTATUS(30),REDENGAGE(100),REDXPOS(30),DFKILL(100)
1209      DIMENSION REDDETECT1(30),REDDETECT2(30),REDYPOS(30),VEHTYPE(10,20)
1210      DIMENSION BLUESTATUS(10,20),BLUEX1POS(10,20),BLUEY1POS(10,20)
1211      DIMENSION RNDNUM(10),RVEHTYP(30),RPHITS(10),RPHITM(10),RPKILL(10)
1212      DIMENSION DFTYPE(10)

1213      REDSTATUS(ELEMENT)=1

1214      SHOT=REDDETECT1(ELEMENT)
1215      LOOP = 1
1216      GO TO 67

1217 97      SHOT = REDDETECT2(ELEMENT)
1218      LOOP = 2

1219 67      IF (SHOT .EQ. 0) THEN
1220          GO TO 87
1221      ELSE IF (SHOT .GT. 0) THEN
1222          DO 27 I=1,NUNIT
1223              IF (SHOT .LE. I*NUMBLUE) THEN
1224                  UNIT = I
1225                  POSITION = SHOT - ((UNIT-1)*NUMBLUE)
1226                  GO TO 88
1227              END IF
1228 27      CONTINUE
1229      END IF
1230 88      * RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
*          ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10

1231      IF (RVEHTYP(ELEMENT) .EQ. 2) THEN
1232          IF(RANGE .LT. .250) THEN
1233              PHIT = RPHITM(5)
1234              PKILL = RPKILL(5)
1235          ELSE IF (RANGE .LT. 1.000) THEN
1236              PHIT = RPHITM(6)
1237              PKILL = RPKILL(6)
1238          ELSE IF (RANGE .LT. 1.500) THEN
1239              PHIT = RPHITM(7)
1240              PKILL = RPKILL(7)
1241          ELSE IF (RANGE .LT. 2.500) THEN
1242              PHIT = RPHITM(8)
1243              PKILL = RPKILL(8)
1244          ELSE IF (RANGE .LT. 4.400) THEN
1245              PHIT = RPHITM(9)
1246              PKILL = RPKILL(9)
1247          END IF
1248          GO TO 76
1249      END IF

1250      IF(RANGE .LT. .500) THEN

```

```

1251          PHIT = RPHITM(1)
1252          PKILL = RPKILL(1)
1253          ELSE IF (RANGE .LT. 1.000) THEN
1254              PHIT = RPHITM(2)
1255              PKILL = RPKILL(2)
1256          ELSE IF (RANGE .LT. 2.000) THEN
1257              PHIT = RPHITM(3)
1258              PKILL = RPKILL(3)
1259          ELSE IF (RANGE .LT. 3.300) THEN
1260              PHIT = RPHITM(4)
1261              PKILL = RPKILL(4)
1262          END IF
1263 76      CALL GGUBS(DSEED,2,RNDNUM)
1264          IF (BLUESTATUS(UNIT,POSITION) .EQ. 0) GO TO 87
1265          IF (RNDNUM(1) .LE. PHIT) THEN
1266              IF (RNDNUM(2) .LE. PKILL) THEN
1267                  BLUESTATUS(UNIT,POSITION) = 0
1268                  DFKILL(REP)=DFKILL(REP)+1
1269                  DFTYPE(VEHTYPE(UNIT,POSITION))=DFTYPE(VEHTYPE(UNIT,POSITION))+1
1270                  REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) = 2
1271          WRITE(54,747) CLOCK,ELEMENT,RANGE,UNIT,POSITION,
1272 747      *   FORMAT(1X,F5.1,' RED ',I2,' RANGE ',F6.3,
1273          *   ' KILLED BLUE',I3,' VEHTYPE ',I2,' BBBBBBBBBBBB')
1274          GO TO 87
1275          END IF
1276          REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) =
1277      *   REDENGAGE((NUMBLUE*(UNIT-1))+POSITION) - 1
1278 87      IF (LOOP .EQ. 1) THEN
1279          GO TO 97
1280      END IF
1281      RETURN
1282      END
*****

1282      SUBROUTINE BLUEFIRE(REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,
1283      *   POSITION,REDXPOS,REDYPOS,RVEHTYP,
1284      *   BLUEDETECT1,BLUEX1POS,BLUEY1POS,DSEED,
1285      *   CLOCK,BPHITS,BPKILL)
1286      INTEGER REDSTATUS,ELEMENT,BLUEENGAGE,BLUESTATUS,UNIT,POSITION
1287      INTEGER BLUEDETECT1,RVEHTYP
1288      REAL RANGE,REDXPOS,REDYPOS,BLUEX1POS,BLUEY1POS
1289      REAL PHIT,PKILL,RNDNUB,CLOCK,BPHITS,BPKILL
1290      REAL*8 DSEED
1291      DIMENSION REDSTATUS(30),BLUEENGAGE(30),REDXPOS(30)
1292      DIMENSION BLUEDETECT1(10,20),REDYPOS(30)
1293      DIMENSION BLUESTATUS(10,20),BLUEX1POS(10,20),BLUEY1POS(10,20)
1294      DIMENSION RNDNUB(10),RVEHTYP(30),BPHITS(10),BPKILL(10)
1295      BLUESTATUS(UNIT,POSITION)=1
1296      ELEMENT=BLUEDETECT1(UNIT,POSITION)
1297      *   RANGE=(SQRT(((REDXPOS(ELEMENT)-BLUEX1POS(UNIT,POSITION))**2)+
1298      *   ((REDYPOS(ELEMENT)-BLUEY1POS(UNIT,POSITION))**2)))/10
1299      IF (RVEHTYP(ELEMENT) .EQ. 2) THEN
1300      IF(RANGE .LT. .500) THEN

```

```

1297          PHIT = BPHITS(5)
1298          PKILL = BPKILL(5)
1299      ELSE IF (RANGE .LT. 1.000) THEN
1300          PHIT = BPHITS(6)
1301          PKILL = BPKILL(6)
1302      ELSE IF (RANGE .LT. 2.000) THEN
1303          PHIT = BPHITS(7)
1304          PKILL = BPKILL(7)
1305      ELSE IF (RANGE .LT. 3.300) THEN
1306          PHIT = BPHITS(8)
1307          PKILL = BPKILL(8)
1308      END IF
1309      GO TO 74
1310      END IF

1311      IF(RANGE .LT. .500) THEN
1312          PHIT = BPHITS(1)
1313          PKILL = BPKILL(1)
1314      ELSE IF (RANGE .LT. 1.000) THEN
1315          PHIT = BPHITS(2)
1316          PKILL = BPKILL(2)
1317      ELSE IF (RANGE .LT. 2.000) THEN
1318          PHIT = BPHITS(3)
1319          PKILL = BPKILL(3)
1320      ELSE IF (RANGE .LT. 3.300) THEN
1321          PHIT = BPHITS(4)
1322          PKILL = BPKILL(4)
1323      END IF

1324 74      CALL GGUBS(DSEED,2,RNDNUB)
1325          IF (REDSTATUS(ELEMENT) .EQ. 0) GO TO 83
1326          IF (RNDNUB(1) .LE. PHIT) THEN
1327              IF (RNDNUB(2) .LE. PKILL) THEN
1328                  REDSTATUS(ELEMENT) = 0
1329                  BLUEENGAGE(ELEMENT) = 4
1330          WRITE(54,777) CLOCK,UNIT,POSITION,RANGE,ELEMENT
1331 777      *  FORMAT(1X,F5.1,' BLUE ',2I4,' AT RANGE ',F6.3,' KILLED RED ',I3,
1332              *  ' RRRRRRRRRRRRRRR')
1333              GO TO 83
1334          END IF
1335      END IF

1336          BLUEENGAGE(ELEMENT) = BLUEENGAGE(ELEMENT)-1

1336 83      RETURN
1337      END
*****

```

APPENDIX C

DATA FILES TO SUPPORT THE PROGRAM

This appendix contains the data files used in the program listed in Appendix B. Most data files can be expanded or reduced as long as the appropriate parameters are changed in the program.

The network is supported by the MINEMET data file shown below. The first column is the arc number, the second column is the node number of the tail of the arc while the third column is the node number of the head of the arc. The fourth column is the distance associated with the arc while the last column is the heading of the arc in radians.

1	1	2	2.92	5.616
2	1	3	3.13	5.989
3	2	13	1.44	5.692
4	3	4	0.67	1.107
5	3	5	1.25	0.499
6	4	7	1.86	0.633
7	5	6	0.54	0.381
8	7	8	0.41	6.141
9	6	9	0.48	0.322
10	8	11	1.26	6.141
11	9	10	0.92	6.056
12	10	22	1.23	6.064
13	11	12	1.00	6.141
14	12	26	0.61	0.000
15	13	14	0.92	6.064
16	14	19	1.84	0.704
17	19	20	0.81	0.704
18	14	15	0.92	5.865
19	15	16	0.70	6.005
20	16	17	0.62	0.464
21	17	18	0.71	1.373
22	18	23	0.76	0.785
23	23	24	0.71	0.785
24	24	25	0.99	0.785
25	20	21	0.64	0.675
26	21	22	0.99	0.644
27	22	26	0.54	0.927
28	25	26	0.82	1.816
29	26	27	0.70	5.819
30	27	28	0.53	0.927
31	28	29	0.00	0.000

The NODLOC file is the physical location of each node in the network. The first column is the node, the second is the x coordinate while the third is the y coordinate. If the x and y coordinate were put together they would represent the standard six digit grid coordinate system.

1	583	229
2	606	211
3	613	220
4	616	226
5	624	226
6	635	230
7	631	237
8	635	236
9	639	231
10	648	229
11	647	232
12	657	232
13	618	203
14	627	201
15	636	197
16	643	195
17	649	198
18	650	205
19	640	214
20	647	218
21	652	222
22	660	228
23	653	212
24	658	217
25	665	224
26	663	232
27	669	229
28	672	233
29	672	233

The Avenue Data is used to support the Movement network. Each value is an arc number, with each avenue represented by a column of arcs. The last arc in the network, arc 31 is an arc with no speed associated with it, so if a unit reaches that arc (which is past the objective) it would essentially remain in position until the arrival of the rest of the units.

2	2	1	1
4	5	3	3
6	7	15	15
8	9	16	18
10	11	17	19
13	12	25	20
14	27	26	21
29	29	27	22
30	30	29	23
31	31	30	24
31	31	31	28
31	31	31	29
31	31	31	30

The SPEED file represents the speeds that the various types of equipment in the unit are able to maintain over the various arcs. The speeds are affected by terrain, roads, cities and other natural objects such as forests. The columns in order represent an M1, a mineplow tank with the plow in the raised position, a mineroller tank with the rollers in the position, a mineplow tank with the plow employed, and finally the mineroller tank in the breaching mode.

raised position, a mineroller tank with the roller	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	20	13	10	9	8
	24	19	13	8	10
	27	21	16	9	12
	24	19	13	8	10
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	20	13	10	9	8
	13	8	7	4	5
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	33	26	19	9	12
	33	26	19	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	27	21	16	9	12
	17	11	8	5	7
	27	21	16	9	12
	27	21	16	9	12
	40	31	24	9	12
	27	21	16	9	12

This file is used to input the type and order of the equipment in each of the units. The only three codes used are: 1 for an M1, 2 for a mineplow tank, and three for a mineroller tank. The vehicles can be placed in any order and the units do not have to be configured the same, either in the type of equipment or the order in which it is entered.

2	2	2	2
2	2	2	2
3	3	3	3
3	3	3	3
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1

The following is an example of the file that support the formations. The offsets in the x and y directions are given in hundreds of meters, therefore the value -2.50 would be two hundred and fifty meters in either the minus x direction if it was in the first column or the minus y direction if it was in the second column.

-5.00	.00
-7.00	.00
-6.50	.50
-6.50	-.50
-6.00	.00
-0.50	4.00
-0.50	-4.00
-1.00	-3.50
-0.50	-3.00
-0.50	3.00
-1.00	3.50
.00	.00
.00	-3.50
.00	3.50

The data used in this file represents the blue probability of hitting a target given a range band and then the probability of killing the target given a hit. The first column is the hit probability while the second is the kill probability.

X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX
X.XX	X.XX

The REDPOSN file represents the physical location of each red element in the unit. The first column is the element number, the second is the x coordinate, and the third is the y coordinate. If the two coordinates were put together they would represent a standard eight digit grid coordinate.

1	666.5	228.0
2	668.0	228.5
3	665.5	230.0
4	663.5	229.5
5	663.5	230.5
6	662.0	231.5
7	662.0	232.5
8	661.0	235.0
9	661.5	235.0
10	663.5	233.0
11	667.0	229.5
12	665.5	231.0
13	663.5	232.0

The RPL00K file is used in the red DETECTION subroutine and represents the probability that the observer is looking in the direction of the target, in this case each of the four avenues of approach used by the blue forces. They are user input and the probability of looking in all directions does not have to add to 1.

0.10	0.10	0.35	0.40
0.10	0.10	0.35	0.40
0.10	0.10	0.35	0.40
0.10	0.25	0.40	0.20
0.10	0.25	0.40	0.20
0.10	0.25	0.40	0.20
0.40	0.40	0.10	0.05
0.40	0.40	0.10	0.05
0.40	0.40	0.10	0.05
0.25	0.25	0.25	0.25
0.05	0.10	0.40	0.40
0.05	0.10	0.40	0.40
0.30	0.40	0.15	0.10

The RVEHTYP file supports the red unit in terms of type of equipment, height, range adjustment factor and maximum effective range. The first column is the vehicle type, with a 1 representing a tank, while a 2 represents a BMP. Column 2 is the height of the vehicle while column 3 is the range adjustment factor (RAF) used in the simulation. The RAF represents the range difference that would be required between a tank and a BMP before the the BMP would be engaged. The last column is the maximum effective range of the weapon system.

1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
1	2.3	0	3.0
2	2.1	0.4	4.0
2	2.1	0.4	4.0
2	2.1	0.4	4.0

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