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A HIERARCHY OF COMBAT ANALYSIS MODELS

GENERAL RESEARCH CORPORATION

JANUARY 1973

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A HIERARCHY OF COMBAT ANALYSIS MODELS

by

GAMING AND SIMULATIONS DEPARTMENT

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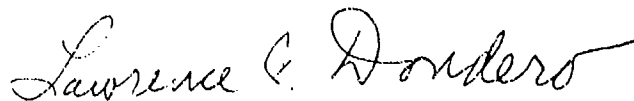
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FOREWORD

This brochure briefly describes the nature, scope, interrelations, and applications of the family of ground combat analysis models under continuous development by the Gaming and Simulations Department of the General Research Corporation Operations Analysis Division. Several of these models were originally developed in support of specific Army analytic tasks and have evolved over the years more-or-less independently of each other. In the past 3 years, however, the major methodological emphasis in this department has been on integrating the separate models into a hierarchy of combat assessments. Thus, the more detailed models of combat at lower echelons—platoon and company e.g.—can "feed" higher echelon games or simulations—brigades or divisions—with close combat assessments inherently more credible than traditional "index of combat effectiveness" inputs.

The respective models are described herein in rough order of ascending model aggregation. Several illustrative hierarchical linkages are also demonstrated and various applications outlined.

Detailed briefings on the models and their uses are available on request. Documentation for most of the models is available in DDC and is cited in the bibliography.



LAWRENCE J. DONDERO, Director
Gaming and Simulations Department

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TO "DRIVE" THEATER MODELS

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CARMONETTE

CARMONETTE is a computerized Monte Carlo simulation of battalion sized or lower units in ground combat (Figure 1-1).

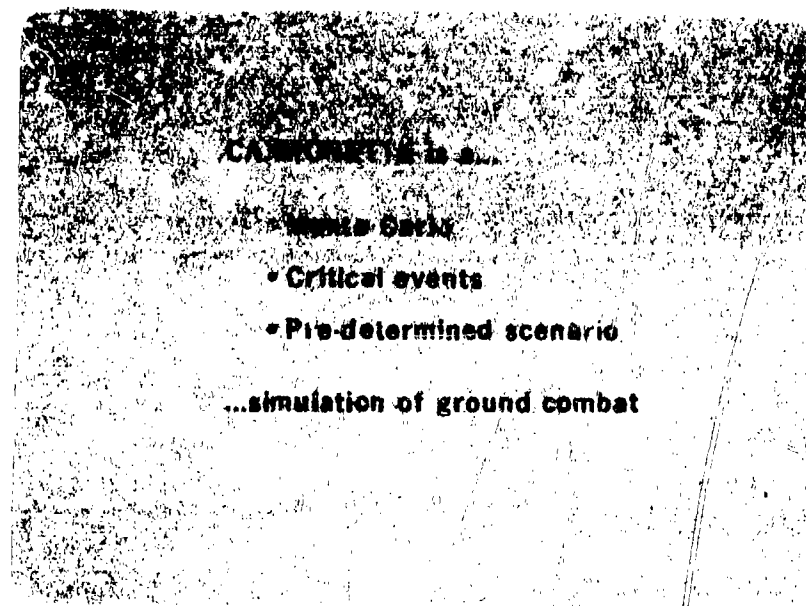


Figure 1-1

Its primary activities are the movement of units, the detection of targets, and the firing of weapons (Figure 1-2).

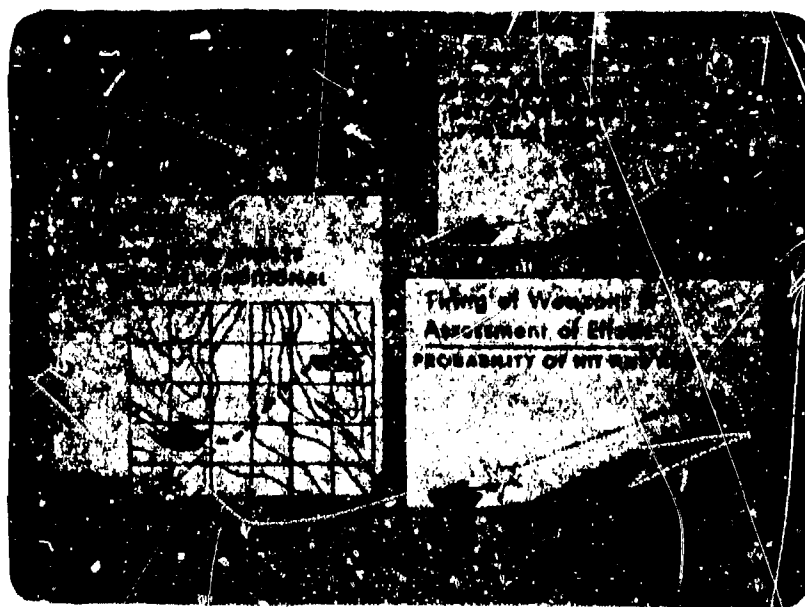


Figure 1-2

Unit resolution can be an individual soldier, a tank, a squad, or a platoon, and each side can have up to 48 units. CARMONETTE is a critical event game with time recorded to 1/10,000th of a minute. The map grid size is selectable but a 100-meter grid on a 6.0 by 6.3 km total map area is normally used (Figure 1-3).

CARMONETTE can play up to 54 weapon types including indirect fire artillery and mortars and direct fire weapons with either fragmenting or solid munitions (Figure 1-4).

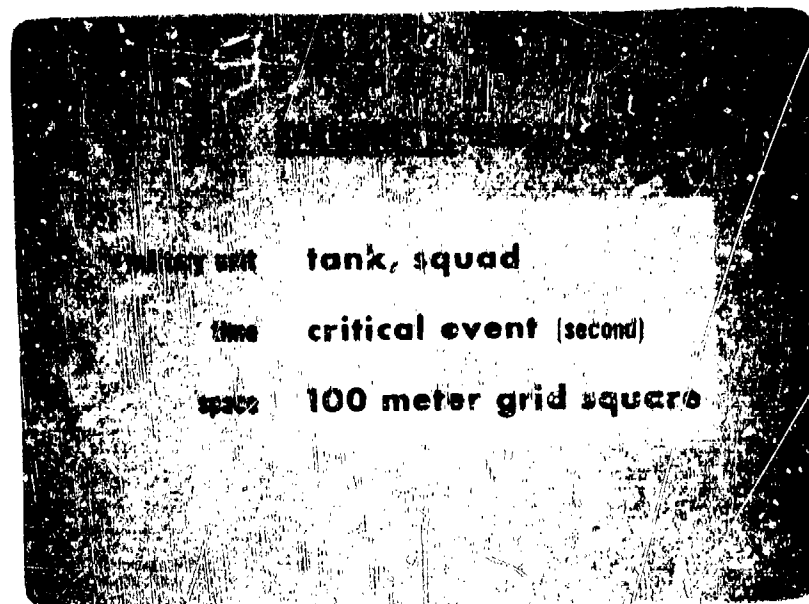


Figure 1-3

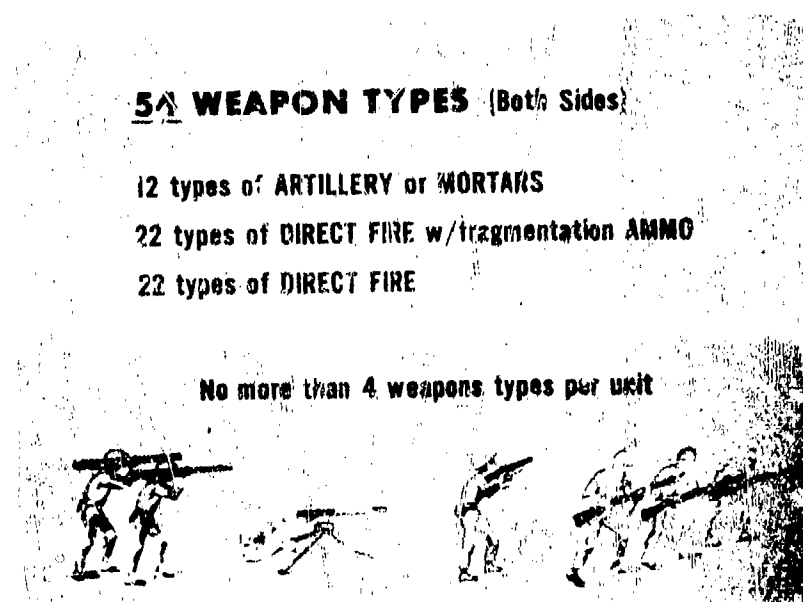


Figure 1-4

Input requirements include detailed descriptions of the units being played, performance characteristics of the various weapon types, a set of orders for each unit based on tactical doctrine in accordance with a predetermined scenario, target detection probabilities, and a detailed description of the terrain (Figure 1-5).

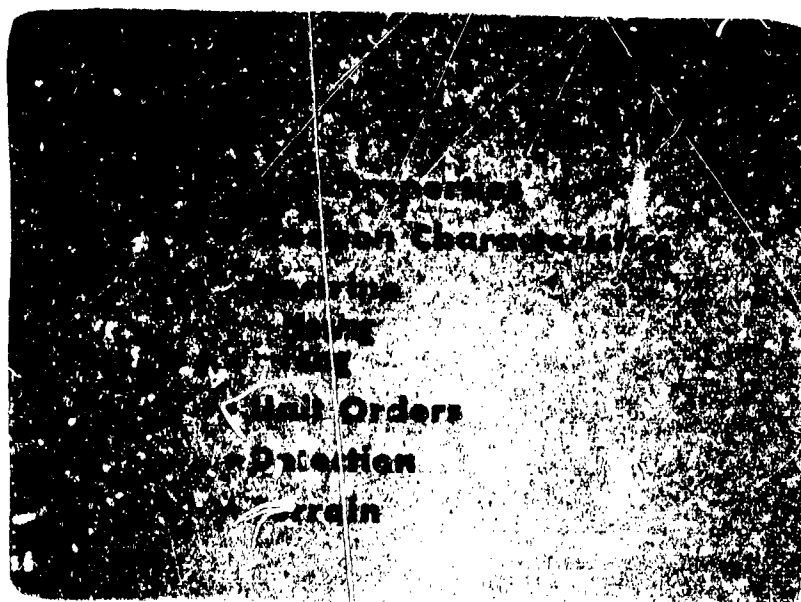


Figure 1-5

The terrain inputs required for each grid square are average elevation, height of vegetation, indexes of cover and concealment, and road and cross-country trafficability (Figure 1-6).

The basic output of a CARMONETTE run is a computer listing of every event assessed during the simulation battle and includes the elements killed, various operational statistics, and data relevant to engagement ranges. Summary routines collect and collate these data on the various actions in the battle for analysis of the results (Figure 1-7).

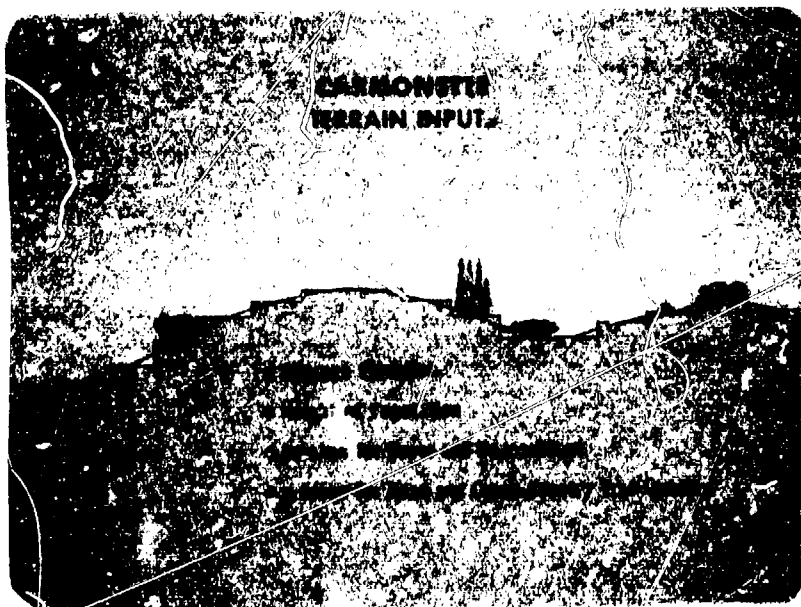


Figure 1-6

EVENT HISTORY	OUTPUT
ELEMENTS KILLED	▶ Target Types Killed by Weapon Type
OPERATIONAL STATISTICS	▶ Beginning and Final Positions ▶ Beginning and Final Strengths ▶ Rounds Fired and Rounds Received ▶ Time of Unit Death ▶ Ammunition Expended
ENGAGEMENT RANGES	▶ No. of Engagements, Rounds Fired and Targets Killed ▶ By Weapon Type and Target Type ▶ By Selectable Range Brackets

Figure 1-7

Figure 1-8 shows examples of the types of history messages concerning a weapon firing event that might appear in a game output. Each line message includes the side, unit number, time of the event, coordinates of unit location, and identification of the message type. In the Position Disclosure (PSN DSCI) message the numbers following I1 to I3 and I3 to I4 identify the opposing units that detected the muzzle flash on firing.

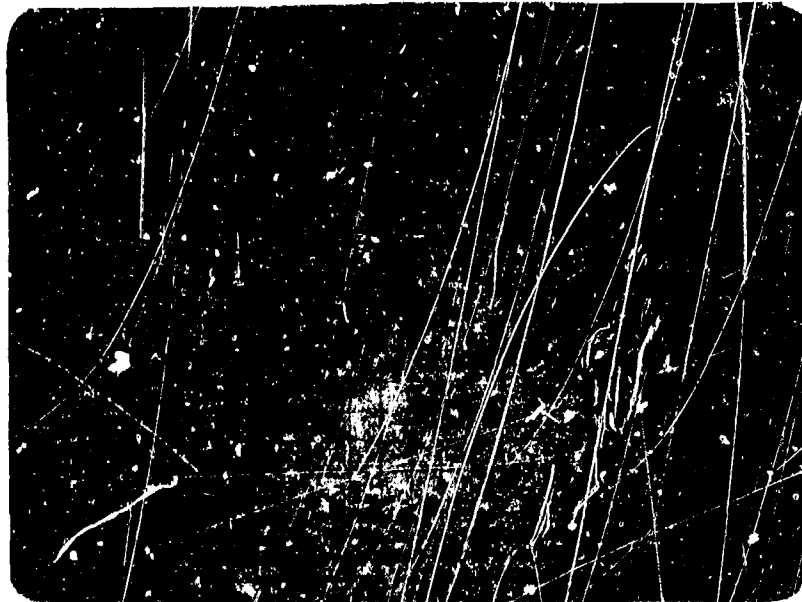


Figure 1-8

CARMONETTE can be used in the solution of various problems. For example, it was used in the Equal Cost Firepower studies (ECF I and II) done for USA ACSFOR to compare the effectiveness of different equal cost mixes of antitank weapons. In a study done for HQ ECOM, it was used to evaluate the effectiveness of low-level units equipped with various night-vision devices (Figure 1-9).

CARMONETTE has also been used to produce casualty assessment data for various mixes of opposing units and the data generated then utilized to assess battle outcomes in a division level war game.

AREAS OF APPLICATION

- Comparison of alternative weapons systems and tactics - real or hypothetical
- Comparison of alternative sensor/target-acquisition systems
- Evaluation of combat potential of low echelon forces
- Generation of data for higher level studies

Figure 1-9

DETERMINISTIC END GAME ASSESSMENT SIMULATION (DEGAS)

DEGAS is a computerized simulation designed to produce estimates of the results of hostile encounters essentially isolated from the general context of battle and involving relatively few participants on each side.

Figure 2-1 shows a typical situation that might be represented in this model. In fact, the model was developed as part of the current SCAT-II study, whose principal concern is the investigation of the combat effectiveness of Army helicopters.

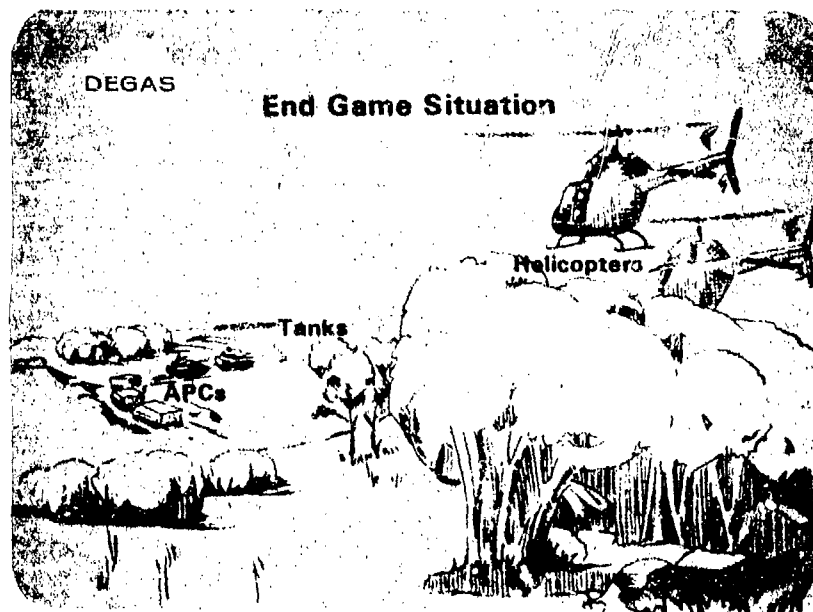


Figure 2-1

In its present usage, the model simulates engagements involving a maximum of six helicopters attacking a ground target complex having a maximum of 16 elements. The time duration of the simulated engagement is limited to about 10 minutes.

Figure 2-2 shows the inputs required by the model. In its present application, the airborne weapons represented in the model include the TOW missile, HELLFIRE, the 30mm, the MINITAP, and 2.75-inch rockets. Ground weapons represented include air defense weapons and missiles, tank main armament, and small arms.

Vulnerable areas for each helicopter and each armored ground element for each opposing weapon are input. In the case of personnel targets, lethal areas of munitions are input.

Movement paths, movement rates, and line-of-sight conditions are input for each participating element for the total duration of the simulated engagement.

Tactics and target priority and selection rules are input by a combination of the model logic and input variables.

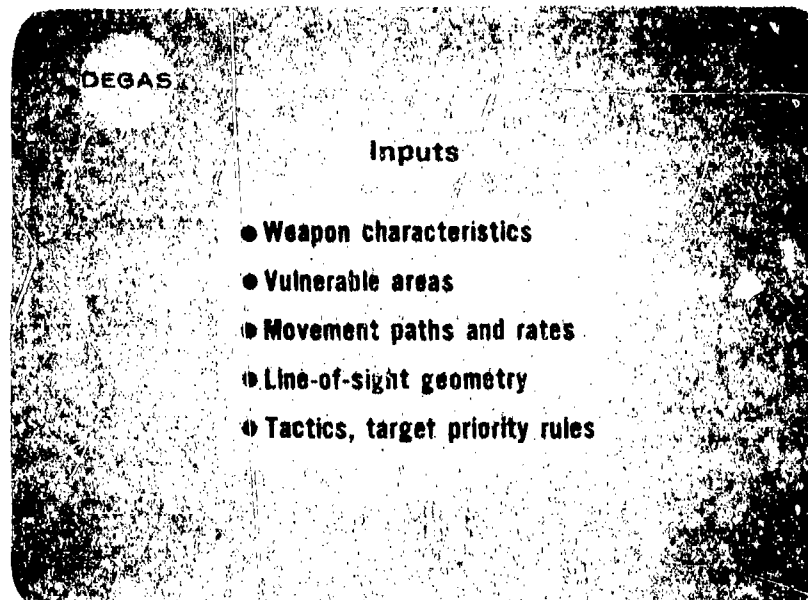


Figure 2-2

The general form of the model logic is shown in Figure 2-3. Target selection is based on input target priorities and is influenced by range and line-of-sight conditions as these conditions vary during the simulated engagement. The time simulated by the basic game loop shown in this figure is a quarter of a second. That is, these activities occur four times during each simulated second of the action:

1. The position (X,Y,Z coordinates) of each attacker and each defender is updated.
2. Line of sight to selected targets is checked.
3. Attackers and defenders fire (as appropriate).
4. Damage to each attacker and each defender is assessed.
5. Target priorities are reassessed (depending on the input engagement rules) and, if appropriate, a new target is selected.

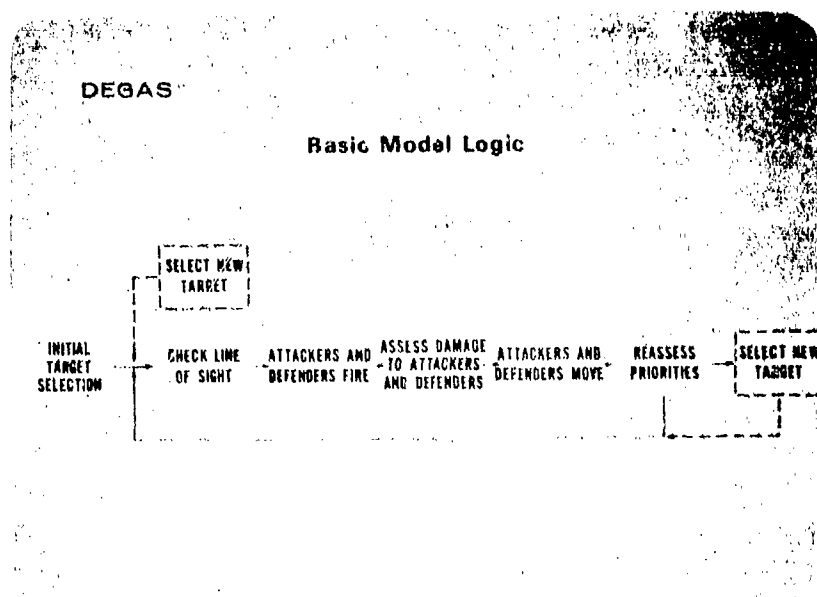


Figure 2-3

This sequence is about what would be expected in a Monte Carlo combat simulation of this scope. The important difference is that Monte Carlo techniques are not used in this model. No random numbers are called. This is a dynamic deterministic model and the engagement results it produces approximate the average results that would be produced by many replications of a comparable Monte Carlo simulation.

The output estimates produced by DEGAS are shown in Figure 2-4. In our present use of the model three categories of helicopter kill are reported: mission abort ("C" Kill), forced landing ("B" Kill), and catastrophic kill ("A" Kill). A single kill category for ground armored vehicles is reported. Personnel casualties and ammunition expenditures on both sides can also be reported. The elapsed time of the engagement is the final output.

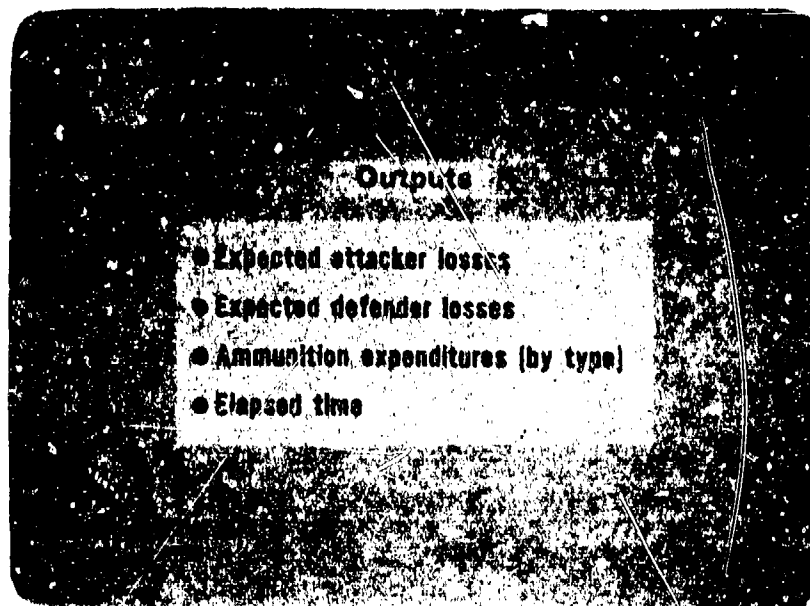


Figure 2-4

The features of the DEGAS model deserving particular emphasis are summarized in Figure 2-5.

First of all, the model is applicable only to the so-called "end game." That is, it is applicable only to actions that occur in relative isolation from the general context of battle and involve relatively few participants on each side. The model is also limited in its ability to represent contingent decisions that might occur within the dynamics of the engagement.

However, this model can produce estimates of the narrow context end game results for a small fraction of what a stable Monte Carlo solution would cost because it produces its estimates of the engagement outcome by a single simulation run. This makes feasible a wider range of

investigations than would be possible if multiple replications of each situation were required.

The DEGAS model is quite sensitive to small variations of input materiel characteristics or tactics. This permits evaluation of the consequences of input variations not practicable with a Monte Carlo simulation.

To illustrate the advantage, in certain situations, of the deterministic model over the stochastic model, consider the tactic of an attack helicopter engaging an armored ground target. What is the optimum range of engagement with respect, say, to the resulting exchange rates. An increase in range tends, of course, to degrade the effectiveness of the ground weapons firing at the helicopter. On the other hand, an increase in range of engagement may increase the time required for the helicopter to detect and acquire a ground target, and thus increase the time of exposure of the helicopter to ground weapons. With a deterministic model such as DEGAS it is practicable to simulate the engagement repeatedly, varying the engagement range with each repetition, and thus determine the range at which the exchange rate is optimum. To accomplish this with a stochastic model would require many replications of the simulation for each variation of engagement range, and the solution produced would still contain the "noise" element that is characteristic of Monte Carlo solutions.

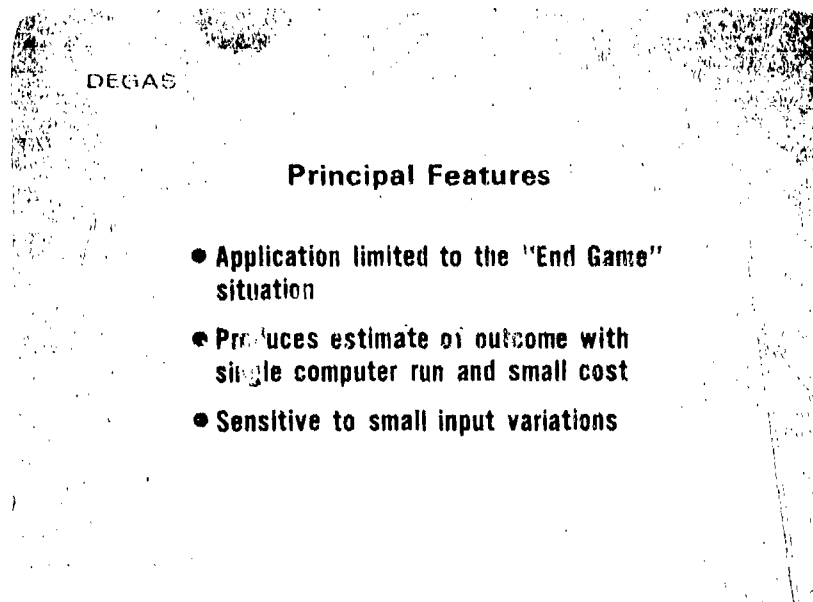


Figure 2-5

X

COMANEX
(COMbat ANalysis EXtended)

During the past several months the Gaming and Simulations Department has been working on the problem of adapting, modifying, and implementing the COMAN model for use in various departmental studies. The COMAN (COMbat ANalysis) model was developed by Dr. Gordon M. Clark at Ohio State University. It was the subject of his doctoral dissertation published in 1970. A modified version of the model has been implemented at GRC on the CDC 6400 computer. The model is operational; it has been assigned the acronym COMANEX (COMAN EXtended). We would like to give you a general idea of what the model is, what it does, and how it does it.

COMANEX is a stochastic model based on Dr. Clark's extensions of the classical Lanchester theory of combat. It is a satellite model; it must be used in conjunction with a high resolution combat simulation model. Its primary function is to take the results of the high resolution model, in terms of numbers and types of casualties for a given force mix, and extrapolate these results to other force mixes not evaluated explicitly by the high resolution model. The extrapolation process can be performed at a tiny fraction of the cost that would otherwise be incurred if the high resolution model itself were used for the evaluation. The short running time of COMANEX also makes it feasible to use the model for directly assessing close combat engagements in division level games as part of the overall assessment routine. Indeed, we are currently using the model for that purpose in DBM applications in SCAT II and COMCAP II.

COMANEX comprises two basic sub-programs—the pre-processor and the simulator. Figure 3-1 illustrates how these programs are used with CARMONETTE serving as the high resolution model.

Data relating to weapons characteristics, combat environment, mission, etc., for a particular mix of opposing forces are input to CARMONETTE. CARMONETTE performs a pre-specified number of replications of the battle. It then outputs, for each replication, a time-sequenced casualty history identifying the time at which a casualty occurred, the casualty type and the killer type. This output is, in turn, input to the COMANEX pre-processor. The pre-processor massages the data and outputs a set of Lanchester-type parameters which represent, essentially, the kill rates for each firer/target combination in the battle. The parameters are then

stored in the COMANEX simulator to be subsequently used in predicting the outcomes of battles involving mixes "close" to the original mix (mixes involving the same types but different numbers of weapons).

The mixes to be analyzed are specified and input to the simulator. In practice, for test purposes, the first such mix is the original one from which the Lanchester-type parameters were calculated. The simulator is exercised for up to 100 replications of the battle. It outputs the expected results of the battle in the form of killer/casualty matrices which list the number of casualties, averaged over all replications, by time period, for each of the target types, for each of the killer types. After verifying that the simulator reproduces the results of the original CARMONETTE run, the remaining mixes are processed and their expected outcomes are listed, again in the form of killer/casualty matrices.

It should be noted that in all cases tested thus far the simulator does indeed reproduce, with a high degree of accuracy, the results of the CARMONETTE runs from which the Lanchester-type parameters were extracted. We have had some success in extrapolating to other force mixes. Additional testing is being conducted to determine the maximum extent to which the results may be accurately extrapolated. We do not know, as yet, how far we can "stray" from the original mix and still obtain reasonable results.

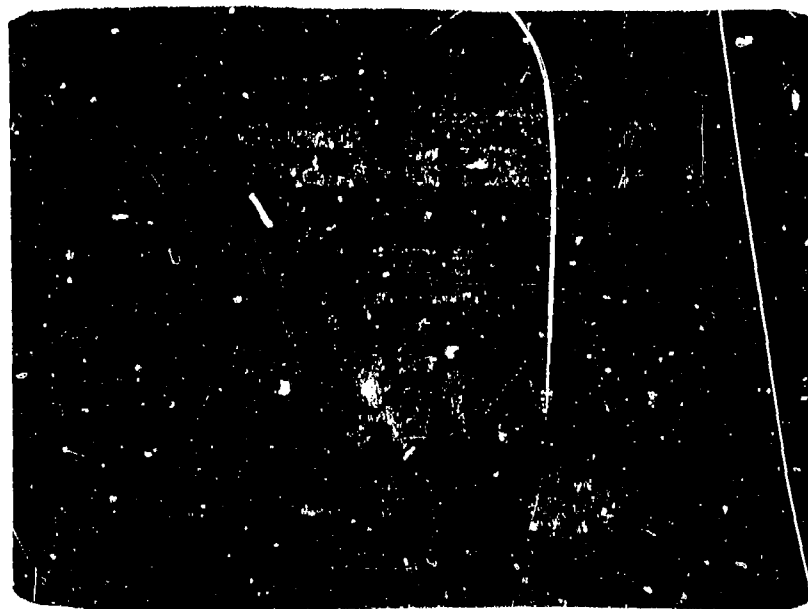


Figure 3-J

We mentioned earlier that COMANEX is based on certain extensions of classical Lanchester theory. To refresh your memories, Lanchester formulated two laws of combat in terms of differential equations—the so-called "Square Law" and the "Linear Law". The square law (direct fire) is applicable to those combat situations wherein the opposing forces are in full view of one another. Each unit is within firing range of every unit in the opposing force. The linear law (indirect fire) is applicable to those situations wherein none of the targets is visible. Fire is concentrated on a certain area known to be held by the enemy.

The first extension of the classical theory (Figure 3-2) is to introduce the concept of target acquisition probabilities. For P_D and P_R equal to zero the mathematical formulation of COMANEX reduces to the square law; as P_D and P_R approach 1 the formulation reduces to the linear law. Thus, the formulation covers combat situations intermediate between the two extremes of total target visibility and total invisibility.

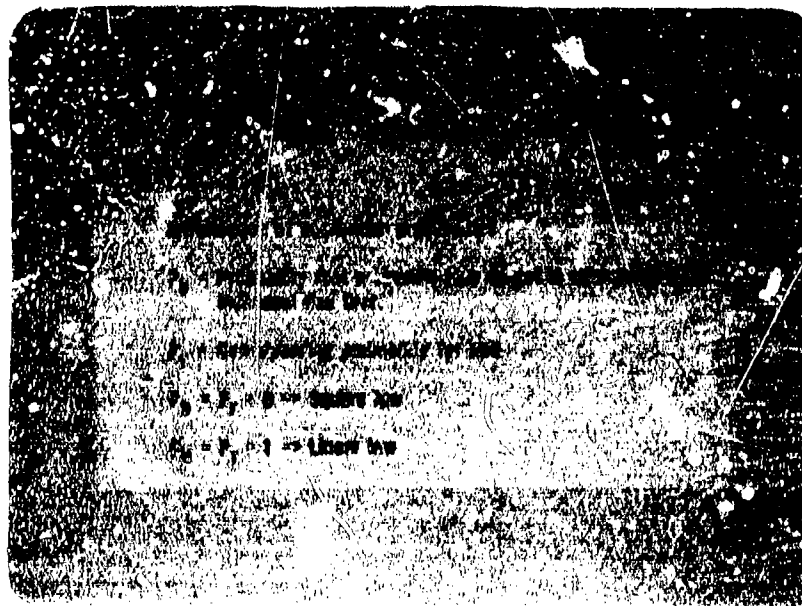


Figure 3-2

The second extension of the theory shown in Figure 3-3 is to introduce the concept of target priorities. Until now we have been talking about "homogeneous" forces—only one type weapon on each side; say tanks against tanks. When two or more types of weapons are involved, a unit is assumed to fire on an acquired target only if it has not acquired any higher priority targets. Target priorities for each weapon type are

input to the model in the form of firer/target preference matrices. We shall return to this point later.

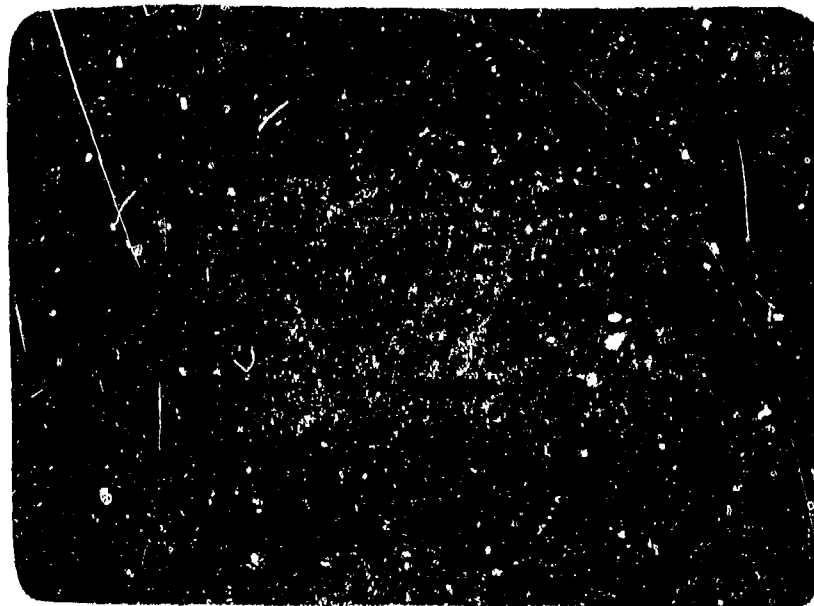


Figure 3-3

Figure 3-4 shows a comparison of the interpretations to be attached to the major parameters involved in each of the formulations. The parameters are usually referred to as attrition coefficients. We have defined them here only for Blue firers; similar expressions apply to Red firers.

The parameters b_{ij} (and r_{ji}) for all firer/target combinations in the battle form the basis upon which COMANEX is constructed. Knowing the values of the parameters, the acquisition probabilities and the numbers of surviving weapons at any given time, the expected casualty rates for each weapon type in the battle can be calculated. The total expected casualty rate, labelled C , is defined as the sum of all the individual rates. Using probabilistic considerations it can be shown that the time between casualties is exponentially distributed with parameter C . ($1/C$ is the mean time between casualties.) Given that a casualty has occurred we can determine the probability that the casualty is of a certain type. Given the casualty type we can determine the probability that the killer is of a certain type.

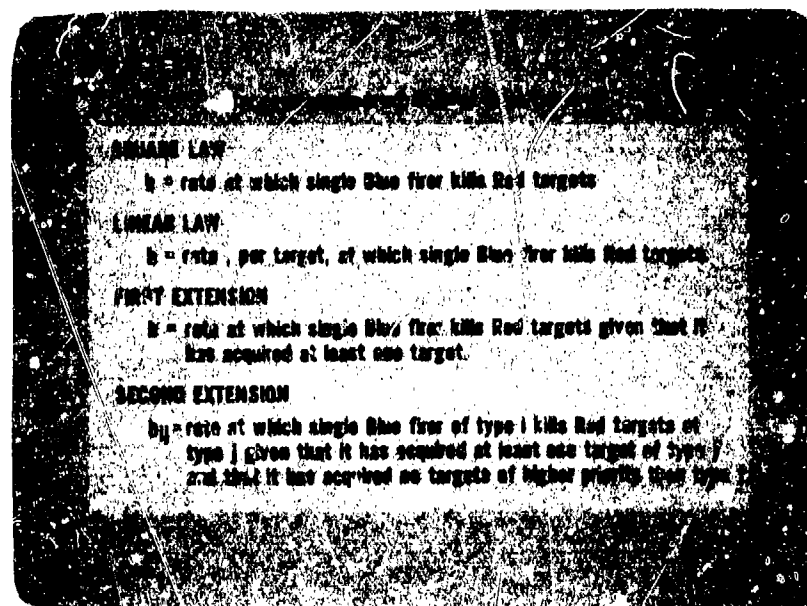


Figure 3-4

We are now in a position to discuss the processing logic employed in the COMANEX simulator (Figure 3-5). The flow diagram shown here is a bit over-simplified in that we have assumed the values of the parameters to remain constant throughout the battle. Actually, in practice, the battle is divided into a series of discrete time intervals each of which may have a different set of parameter values. The principle, however, remains the same.

We start out with the initial numbers of weapons on each side and calculate the expected casualty rate C . We draw an exponentially distributed (with parameter C) random number to determine the time of the first casualty. We then draw a uniformly distributed (0-1) random number to determine the casualty type, another uniformly distributed random number to determine the killer type. After removing the casualty weapon from the battle a new value of C is calculated on the basis of the number of surviving weapons. The process is repeated until the battle is over. The battle may be replicated as many times as desired. Typically, we have been performing 30 replications to determine expected battle results. The battle may be terminated at a pre-specified time or when either side has suffered a pre-specified fraction of casualties--weapons and/or personnel. The output is in the form of the killer/casualty matrices discussed previously.

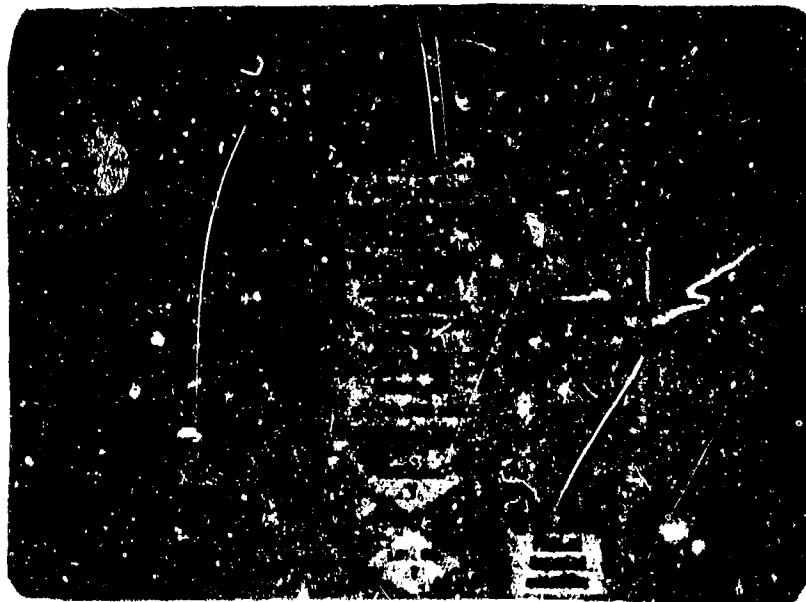


Figure 3-5

As we mentioned at the outset, the values of the model parameters are furnished by the COMANEX pre-processor (Figure 3-6). These values are calculated using the statistical principle of "maximum likelihood." We will not discuss the calculation procedure here as the mathematics is rather involved. Suffice it to say that a unique set of values is obtained that is "most likely" to have produced the results of the CARMONETTE replications of the original force mix. Conceptually, the procedure is analagous to fitting a curve to a set of observed data points by the method of least squares, although the actual mechanics are quite different.

The pre-processor inputs are as shown in Figure 3-6. For each CARMONETTE replication of the battle a casualty history table is extracted recording the casualty time, the casualty type, and the killer type. The dashed lines indicate the separation of each battle replication into a set of time intervals for which different sets of parameter values are to be calculated.

COMANEX permits different firer types to have different sets of target priorities. The priorities must be specified and input to the pre-processor for each of the designated time periods. The rows of the matrices, reading from left to right, list, in descending order of priority, the target types for a particular firer type. For example, in this

illustration, Red type 2 units are the highest priority targets for Blue type 2 firers; Red type 1 targets have second priority; Red type 5, third.

	Blue	Casualty Type	Killer Type	Values
Step 1				1 4 3
				2 1 5
Step 2				1 2 4
				2 3 2

Figure 3-6

This completes our general description of COMANEX.

We would now like to show you the results of a typical case comparing CARMONETTE results to those obtained from COMANEX.

The force mix to be analyzed is presented in Figure 3-7. Red is attacking, Blue defending. The numbers on the left serve as identifiers for the particular weapon types. The numbers in parentheses indicate the initial numbers of individual weapons in the battle. Using this force mix, seven replications of the battle were performed by CARMONETTE. The casualty history data were input to the COMANEX pre-processor which output a set of Lanchester-type parameters for each of four consecutive 5-minute time intervals. The parameters were input to the COMANEX simulator which then performed 30 replications of the battle. To give you an idea of the relative computer running times involved: CARMONETTE

required roughly 45 minutes to perform the seven replications; it took approximately 30 seconds to extract the casualty history table, 70 seconds for the pre-processor to calculate the model parameters, and 40 seconds for the simulator to perform the 30 battle replications.



Figure 3-7

Figure 3-8 shows the comparison of results, in terms of expected Blue casualties at the end of 10 minutes of battle. The numbers listed vertically identify the Red firer types; those listed horizontally, the Blue target types. For example, the CARMONETTE matrix indicates that 0.3 TOWs were killed by tanks, 1.2 by APCs, for a total of 1.5. The corresponding numbers determined from COMANEX are, respectively, 0.2, 1.1, and 1.3.

Figure 3-9 shows the comparison of expected Blue casualties at the end of 20 minutes of battle. The last two figures, 3-10 and 3-11, provide a similar comparison for Red casualties.

The comparisons demonstrate rather conclusively that COMANEX can accurately reproduce CARMONETTE battle results. The next step, of course, is to determine how accurately COMANEX can predict CARMONETTE results. That's the problem we are working on at the moment.

Blue-Gray (20 min)								Red (20 min)							
Blue-Gray (20 min)								Red (20 min)							
1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
0.5	0.1	0.3			0.5			1	0.6	0.3	0.2			0.7	
1.0		1.2						2	1.0		1.1				
								3							
								4							
								5							
0.1					6.0			6	0.1					5.8	
0.1								7	0.1						
								8	0.1						
								9							
					0.8			10							
1.7		0.1	1.5		7.3			11						0.9	
Σ	1.7		0.1	1.5		7.3		Σ	1.7		0.3	1.3		7.3	

Figure 3-8

Blue-Gray (20 min)								Red (20 min)							
Blue-Gray (20 min)								Red (20 min)							
1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1.8		0.6	0.4		1.8			1	1.3	0.9	0.4			2.2	
1.5		1.3	1.3					2	1.7		1.1	1.2			
								3							
1.0		0.2	0.0					4	0.9		0.2	0.5			
								5							
0.1					15.2			6	0.1					14.4	
0.1				0.1				7	0.1						
								8	0.1		0.1				
								9							
					1.4			10							
Σ	4.4		2.1	2.4		16.4		Σ	4.1		2.1	2.2		15.5	

Figure 3-9

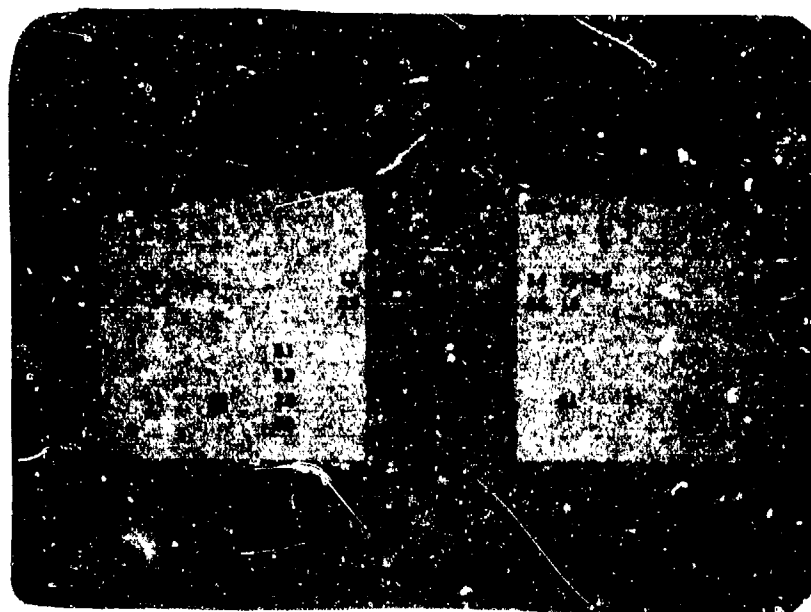


Figure 3-10

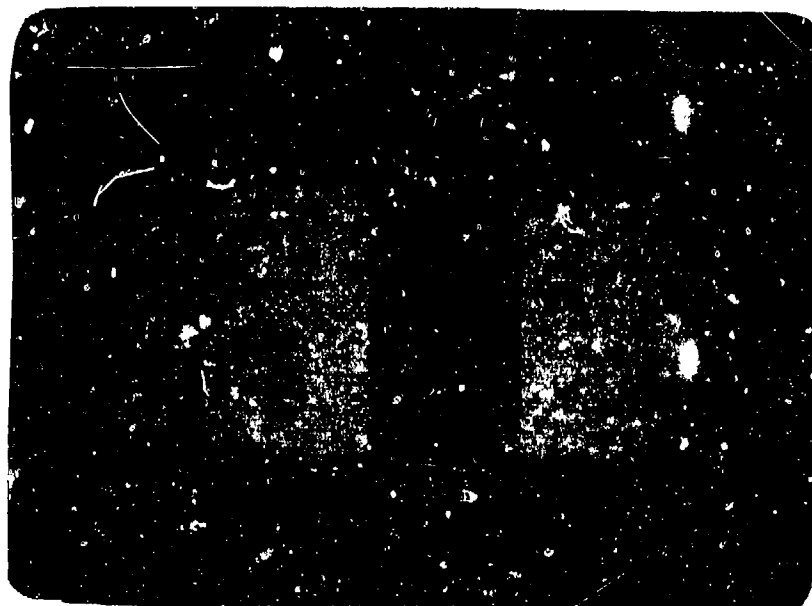
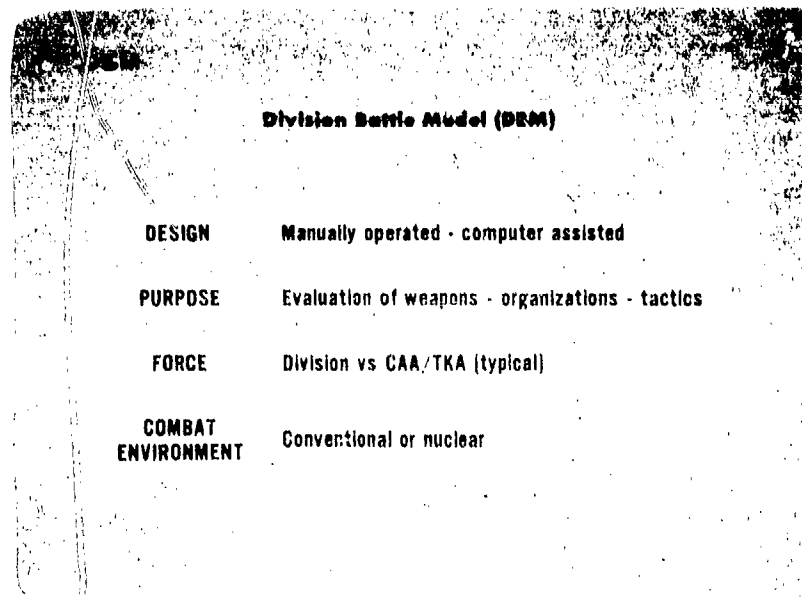


Figure 3-11

DIVISION BATTLE MODEL (DBM)

The DBM is a manually operated, computer assisted war game designed to support studies of the performance of weapons, organization, and tactics employed by a division-size force engaged in combat in a conventional or nuclear environment against an appropriate force (Figure 4-1).



Division Battle Model (DBM)	
DESIGN	Manually operated - computer assisted
PURPOSE	Evaluation of weapons - organizations - tactics
FORCE	Division vs CAA/TKA (typical)
COMBAT ENVIRONMENT	Conventional or nuclear

Figure 4-1

DBM is played on a map with a scale falling within the 1:25,000 to 1:50,000 range. This provides sufficient detail to support the levels of unit, time, and space resolution employed. The normal level of resolution for maneuver units within a division-size force is the company;

however, for opposing CAA or TKA, the battalion may be more satisfactory. In either case detailed records are maintained regarding the inventory of men and weapons assigned to these units and battle assessments are based on current strengths. The battery or battalion is the normal level of resolution for artillery units, and the company or squadron for air units. Assessment procedures are based on salvos fired or sorties flown by these units. Time is measured to the nearest 5 minutes and space to the nearest 100-meter square.

The game may be played in an open, semi-closed, or closed mode, depending on the degree to which information affecting the opposing player decision is considered important to game objectives. The game progresses at an accelerated pace in open play, since a closed or semi-closed mode requires time consuming message center and map-posting activities to keep the restricted player sufficiently advised of the situation to maintain the continuity of the game. In closed play, 2 to 4 hours of combat can be processed per working day with a team consisting of one director, seven gamers, and three support personnel. In open play the rate of play can be accelerated to 4 to 6 hours of combat per working day with a team comprised of one director, three gamers, and two support personnel (Figure 4-2).

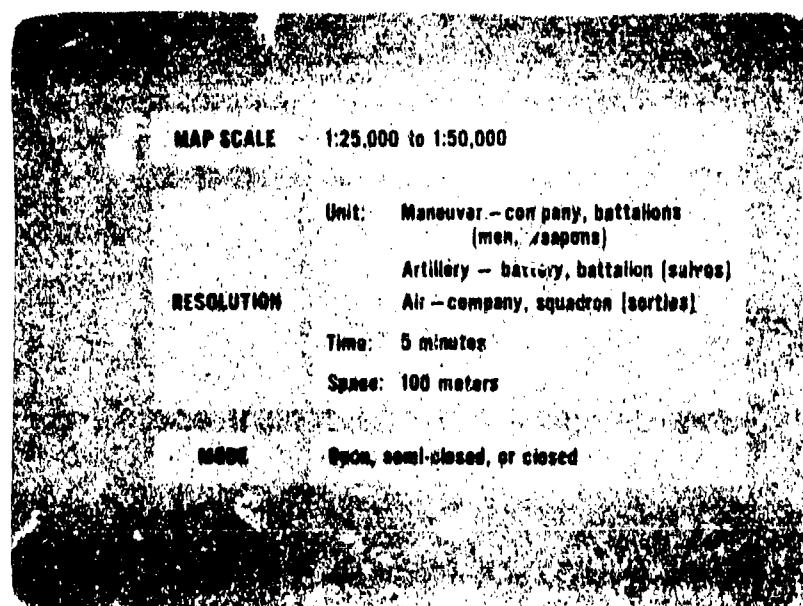


Figure 4-2

The manual operations of DBM are concerned primarily with decision making and the determination and time sequencing of events on the battlefield. The computer programmed portion focuses on the determination of battle losses, tabulation and reporting of battle results, and the updating of stored information (Figure 4-3).



Figure 4-3

Figure 4-4 depicts the activities conducted manually, and by the computer, in the DBM. The game scenario sets the stage for the initial sets of player orders to subordinate units and for requests to higher headquarters for support. These player actions result in unit movements and activities which are recorded on the game map and translated into time-sequenced events by the controller in accordance with applicable game rules. Reports of these events are prepared for delivery to players at the appropriate times. If the event is one which falls within the purview of a computer submodel, for example, an air strike or the joining of close combat between two or more opposed units, the controller also prepares a line entry on the appropriate input sheet for computer assessment following the completion of manual operations. Upon the receipt of unit reports, players may take such action as deemed appropriate, modifying existing orders, issuing additional orders, requesting additional support, etc. These orders and requests are processed by control, as previously described.

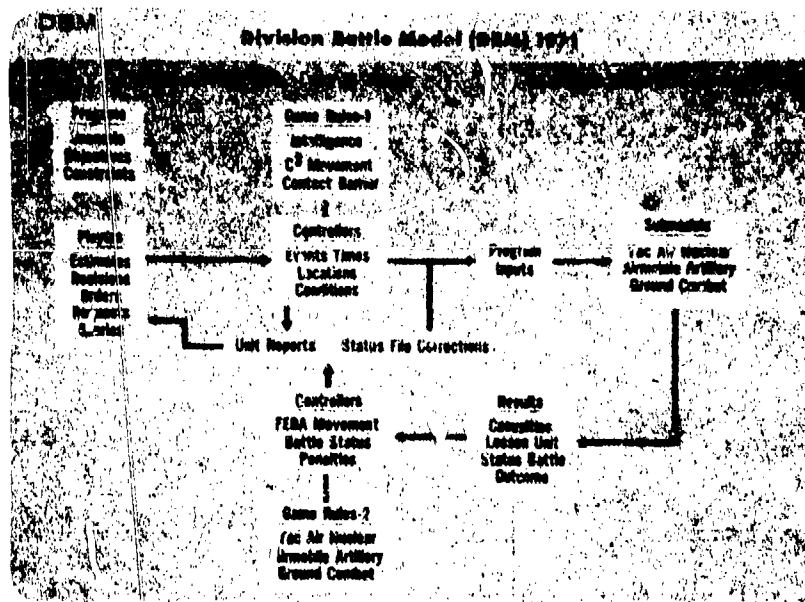


Figure 4-4

Manual operations normally continue in this manner for 4 hours of play (game time), or until, in the opinion of the senior controller, a critical event has occurred. At this point, manual operations are suspended and the computer inputs describing the various combat actions occurring during the manual cycle are processed.

The computerized portion of DBM employs a unit status file which lists the current inventory of personnel, weapons, and major items of equipment of each unit being gamed, and of a series of combat assessment routines which may be called and recalled in any sequence. Unit status files are adjusted following each assessment to reflect battle losses incurred. Thus, the results of an air strike delivered prior to a ground combat action may be assessed and the strength of the targeted units adjusted to reflect losses occurring before the ground combat action occurs. However, if the air strike occurred following the ground combat action, the calling sequence of the ground combat and air models would be reversed and losses sustained as a result of the strike would not be deducted until after the ground combat assessment was completed.

Following the computer run, a printout of the results is provided to the controllers. Included is a report of personnel casualties and losses of major items of equipment and weapons by cause, ammunition expenditure, and the current state of each unit as reflected in the updated unit status file.

The control team utilizes this information to make adjustments of the FEBA resulting from ground combat and to determine the battle status of engaged units. This information is also passed to the players in the form of unit reports. Adjustments to the unit status file reflecting receipt of supplies and/or replacements may also be made at this time. In this connection the computerized model has an automatic resupply/replacement routine which may be employed if desired.

Manual play is now resumed, following the sequence of operations previously described. This cyclic process is continued until game objectives are attained.

Now, a bit more detail on the DBM computerized-assessment routine. DBM offers an innovative approach to the assessment of ground combat. A small unit combat simulation, CARMONETTE, is employed to develop weapon system performance data which is then used in DBM ground combat assessments. The advantage of this approach over traditional methodology based on weapon firepower scores is that weapon and unit performance measures developed by CARMONETTE reflect variations in the combat environment, including the synergistic effects resulting from the employment of various combinations of weapons. The translation of CARMONETTE outputs into DBM assessments is accomplished by use of the COMANEX model, as earlier described.

Supporting fire delivered by artillery may be assessed either in the ground combat routine or in the separate artillery routine. The first option is normally employed if the targeted unit is engaged in ground combat while the fires are being delivered. The second option is used for fires delivered against targets not directly and immediately engaged in ground combat; e.g., reserve units, headquarters, counter-battery fires, interdiction and harassing fires, preparatory fires, etc. CARMONETTE output data are not required for operation of the DBM artillery routine.

The attack helicopter routine was originally developed to assess missions conducted by attack helicopters, however, these missions are now being processed in the ground combat routine. The attack helicopter routine is now used only in attack missions involving a significant penetration of the enemy force.

At the present time, high performance air (HPA) strikes can be assessed only in the DBM tac air routine, since CARMONETTE does not have an HPA capability and cannot therefore provide the data necessary for the DBM ground combat model. This situation will be corrected with the development of a CARMONETTE HPA routine this year, however, in the interim, HPA strikes against units engaged in ground combat (close air support missions) must be assessed by interrupting the ground combat model at the appropriate time, calling the tac air model to assess the air strike, then recalling the ground combat model to continue the basic assessment.

The DBM tac air routine is also employed to assess the air-to-air, air-to-ground, and ground-to-air actions involved in those air-interdiction, armed reconnaissance, and air defense missions ordered by player teams.

The DBM nuclear routine assesses casualties and materiel losses resulting from the successful delivery of nuclear warheads. The process of delivering the warhead is assessed in either the HPA or artillery routine depending on the delivery means. Residual effects of nuclear contamination are assessed manually.

The airmobile routine is employed to assess losses incurred by units being airlifted by airlift escorts and by defenders.

The man-machine relationship existing in DBM methodology is intended to provide flexible and realistic responses to changing battlefield conditions and an efficient means of assessing battlefield interaction and recording results. Accordingly, estimates and decisions are made by appropriately-experienced men; while calculations, record keeping, and reporting are primarily computer functions. The interfacing of CARMONETTE with DBM avoids the long-standing shortcomings of firepower scores, making it possible to relate weapon and unit characteristics to the combat environment to produce credible weapon and unit effectiveness measures at the division level.

SIMULATION MODEL FOR EVALUATING SYSTEMS IN PROLONGED INTENSIVE COMBAT (EPIC)

The EPIC simulation is a computerized deterministic model designed to evaluate the long-term performance of systems within an operational context. The model was developed as part of the ADAFSS Force Mix study at Research Analysis Corporation. A brief review of the requirements guiding its development should help to convey a general understanding of the design features and potential applications of EPIC.

The model was required to produce the daily and cumulative expected results that might be achieved by different numbers, types, and mixes of attack helicopters over extended periods of combat. Another requirement was to represent the hard facts of operational reality that are generally ignored in high resolution simulations, which focus on a brief fire exchange within a very narrow context. These hard facts include such considerations as limitations on flight hours per day, maintenance time required as a function of flight time, fleet attrition over extended periods, mission availability, aircraft reliability, and repair times for damaged aircraft. Missions had to be distributed throughout successive 24-hour periods to reflect demand as a function of weather and the level of combat activity and aircraft had to be assigned to these missions on the basis of availability and in accordance with the underlying principles that dictate assignment in actual operations.

To accommodate the many operational aspects of interest, EPIC uses a hierarchy of time resolutions as shown in Figure 5-1. The basic time interval is selected to suit the problem at hand. In past applications of the model time steps of 1 minute, 5 minutes and 15 minutes have been used, depending on the maximum resolution required. Use of the hierarchy of time resolutions permits the model to execute very rapidly.

EPIC uses a dynamic mission assignment logic. This logic makes use of feedback loops that control the expenditure of available resources in such a way as to maximize the value of a predefined effectiveness measure. In effect, this logic simulates the mission assignment decision processes of experienced operational personnel.

Figure 5-2 gives a summary of EPIC inputs. The final input items, a table of mission descriptions, is generally produced as the output of high-resolution simulations.

Figure 5-3 shows typical mission results entries input to EPIC for evaluating attack helicopter performance. The mission types here reflect the nature of the target, its posture, visibility and weather. For example, mission type 1 might indicate a reinforced tank company, attacking in the daytime, under good weather conditions. For each mission type the associated times, expected friendly losses, and expected target effects are input to EPIC.

Type Mission Description **TABLE**

AH-64A										AH-1G/TOW									
MISSION TYPE	MISSION DURATION		EXPECTED LOSSES			EXPECTED EFFECTS							EXCHANGE RATIO						
	TOTAL TIME	FLIGHT TIME	"A" HELLS	"B" HELLS	"C" HELLS	TANKS	APCS	PERF CAS	23T	230	57T								
1-1																			
1-2																			
1-3																			
ETC.																			

Figure 5-3

Typical outputs produced by the EPIC model are shown in Figure 5-4. The output processor of the model prepares both periodic and cumulative reports. The time resolution of these reports is a matter of user choice. When longer periods of sustained combat—say, from 30 to 90 days—are simulated on the model, experience has shown that 24-hour periodic and cumulative output summaries are most convenient. When the model was used in support of the Advanced Attack Helicopter Task Force, scenarios of 3 days and 14 days were played. It was found that 2-hour reports provided a suitable level of detail for the 3-day games and that 12-hour reporting was most convenient for the 14-day games.

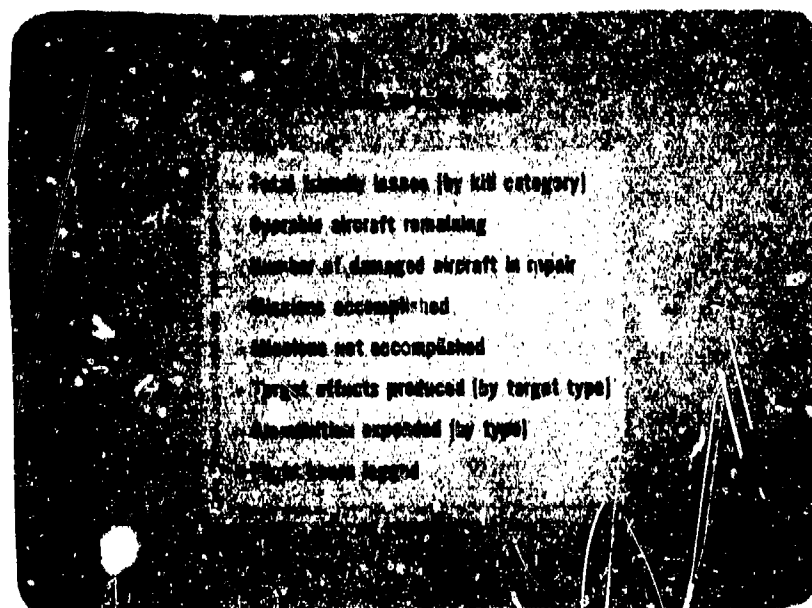


Figure 5-4

The model provides for a total of 36 output items in its periodic and cumulative summaries. When the model is being used for the comparative evaluation of candidate fleets, an output option permits the plotting of any or all of these output items for all candidates on a common scale. The plot in Figure 5-5 was a part of the output produced by one of the runs made in support of the Advanced Attack Helicopter Task Force, and shows missions accomplished vs time for each of four candidate helicopter fleets.

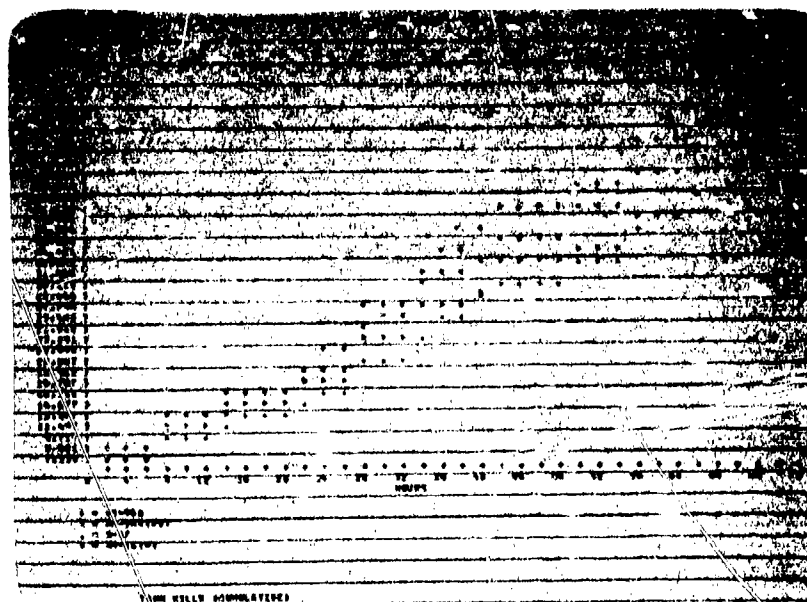


Figure 5-5

Thus far the use of EPIC in helicopter evaluation has been discussed because this has been its sole application since its development; however, the model is by no means limited to this application. Figure 5-6 shows some other applications to which EPIC would readily lend itself. It is interesting to note in this connection that the recent Main Battle Tank Task Force used a slightly modified version of EPIC to evaluate long term tank performance. The model should find application in a wide variety of situations where the requirement is to determine long-term performance as influenced by a large number of operational variables, and where estimates of detailed performance within the narrow contexts are available.

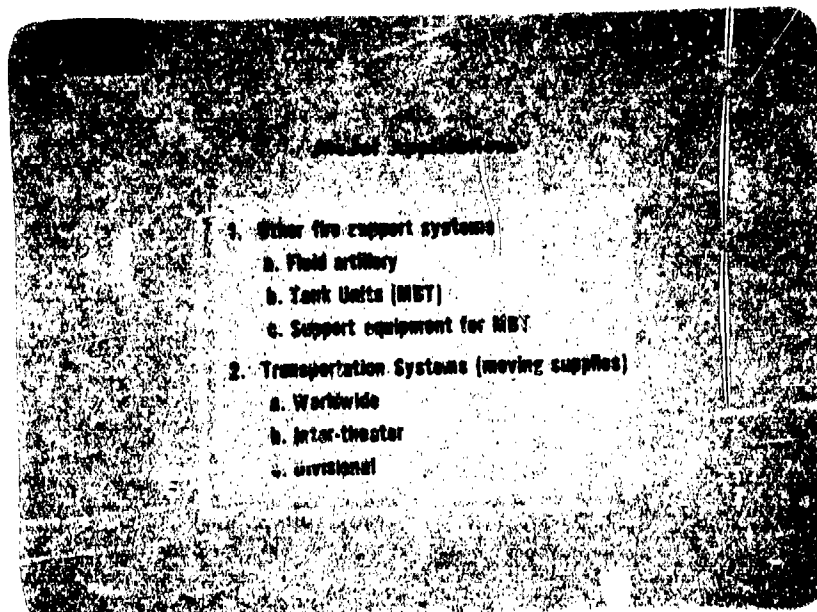


Figure 5-6

EPIC is an expected value model and, as such, produces its solution in a single run. This means it is an economical model to operate. EPIC results have been found to be consistent with the mean results of multiple Monte Carlo replications.

ATLAS - A THEATER LEVEL COMBAT SIMULATION

ATLAS is a computerized theater level combat simulation consisting primarily of four models: the Ground Combat Model, the Tactical Air Model, the Logistics Model, and the Tactical Decision Model.

Figure 6-1 shows in a general flow diagram the composition of ATLAS. A game scenario which states the specific objectives, the constraining policies to be followed, and the combat forces available, essentially guides the simulation from the start. From this scenario and the developing tactical situation comes information which triggers the tactical decision model into sending troops, supplies, and equipment to the other models. These models then interact in a tactical sense and thus develop the combat situation.

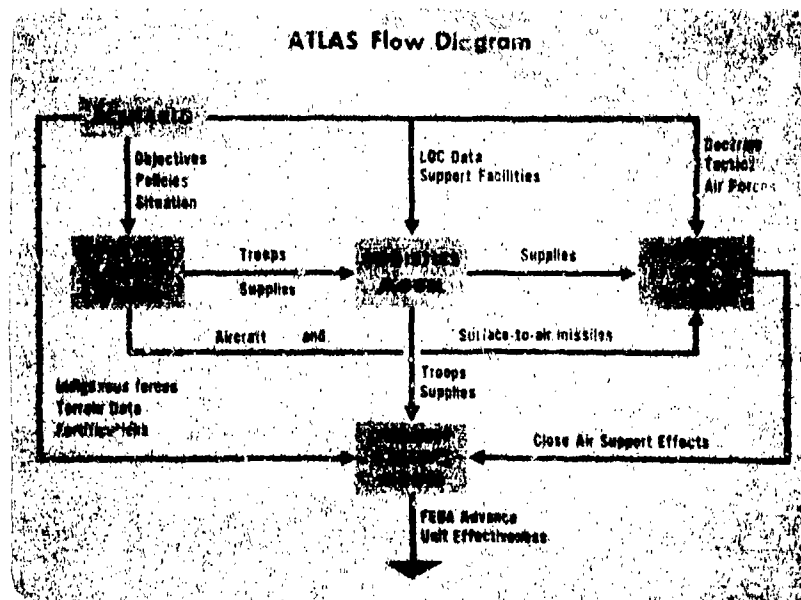


Figure 6-1

The simulation regards the tactical battlefield as being divided into non-interacting battle areas called sectors, shown in Figure 6-2.

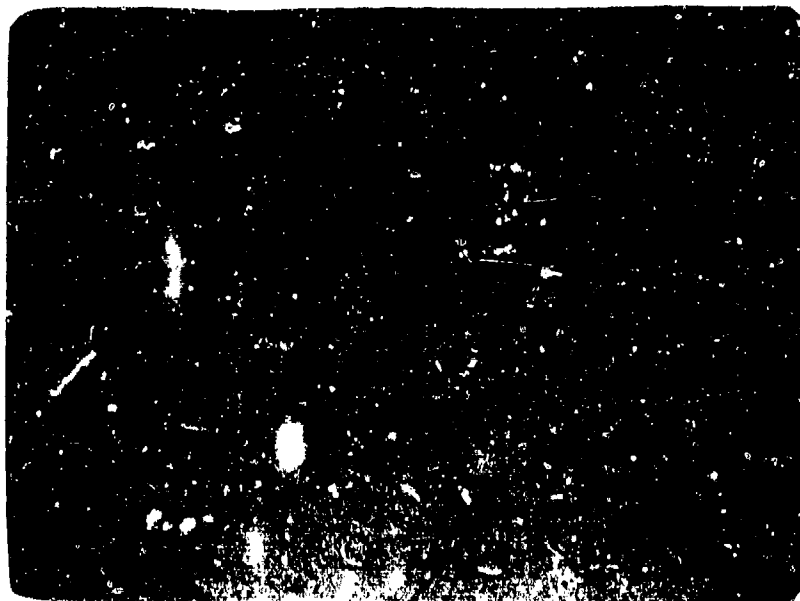


Figure 6-2

In general, the smallest discrete combat unit simulated in any given sector is a combat division. Since the ground combat model is designed to determine unit advance, each sector is further divided into segments so that trafficability within each segment may be considered constant. Terrain and natural or manmade barriers affect military movement, so six types of terrain-barrier combinations are simulated in the model.

Each battle sector also has a logistics system, a one-dimensional supply system extending from theater ports or central staging areas to the most forward supply area near the combat zone. Intermediate supply centers or supply nodes are simulated to service airbases and other rearward elements.

To complete the view of the ATLAS battlefield, we show tactical aircraft activities: interdiction, air-to-air engagements, and close air support.

Tying these three models together so that the simulation may proceed day-by-day with no interruptions is the function of the tactical decision model, which we will describe later.

GROUND COMBAT MODEL

The functions of the ground combat model are shown in Figure 6-3. In attempting to calculate the daily advance of the attacking force, this model examines the forces assigned to combat on each side and determines their present level of combat effectiveness in accordance with a loss of personnel or supplies and equipment.

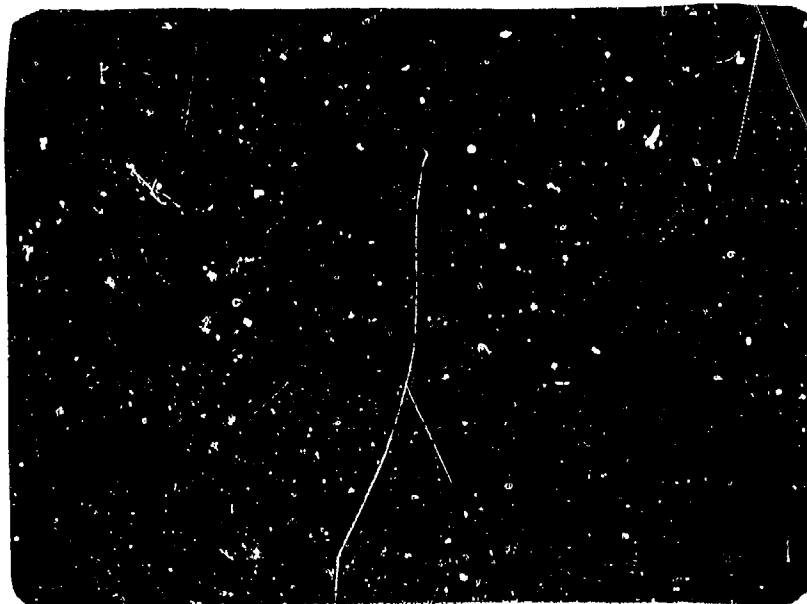


Figure 6-3

The measure of combat effectiveness used in the model is called ICE (Index of Combat Effectiveness), based on the relative firepower of units.

In determining how effective a combat unit is on a given day, we have assumed that its effectiveness can be measured as a function of the percent casualties to the unit, the level of the unit's supplies and equipment, and the particular activity of the unit--attacking or defending. To determine at what point a combat unit becomes ineffective is a difficult procedure. However, the effects of casualties must be taken into account and this is accomplished by the effectiveness curves shown in Figure 6-4. These curves indicate the percent degradation of unit effectiveness as a function of casualties received when attacking or defending. Note that the effect of a given casualty level is greater on an attacking unit than on a defending unit. This is because an attack normally requires rapid movement, good coordination, and higher organizational integrity.

Other curves are available for degrading effectiveness as a function of supply level. The effectiveness value finally used is the minimum of the value due to casualties or the value due to lack of supplies.

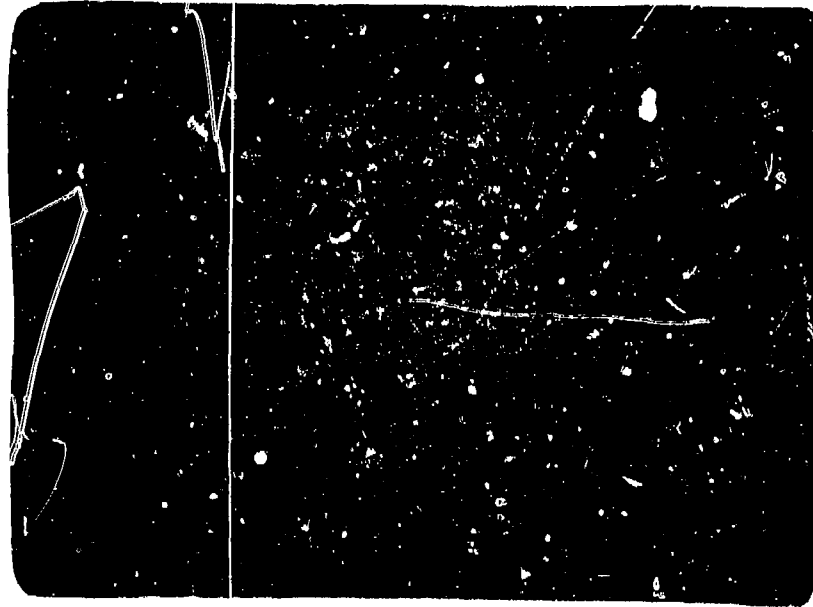


Figure 6-4

The modified combat effectiveness values when viewed as a ratio of values (attacker to defender) are used to determine the daily rate of advance, as shown in Figure 6-5. This force ratio combined with the terrain, the type units in the attacking force, and the type combat engagement determine the distance advanced for that day's action. Shown are the rates of advance for an armor unit attacking in terrain type A, no barrier, against various defense postures.

Also shown are the seven type defense postures simulated in the model—from fortified position thru hasty defense to disorganized retreat.

The casualty rate curves used in the model are shown in Figure 6-6. This set of casualty data is a function of type engagement and force ratio. This completes discussion of the ground combat model.

LOGISTICS MODEL

In order that ATLAS be capable of realistically assessing the outcome of deploying forces rapidly to meet a given threat, a model of the theater logistics capability is required. A model of this nature should simulate such things as the movement of supplies to the deployed combat units, the interdiction of supplies being forwarded, the movement of new units through the theater to the combat zone, and the stockpiling of supplies within the theater, if desired. A basic premise of the model is that the resupply of deployed units takes priority over the deployment of new units, with the building of stockpiles taking third priority.

Within each battle sector, the network of LOCs, both rail and road, are represented by a single series of supply nodes. These supply nodes (see Figure 6-7) are located for each side approximately 1 day's overland journey apart. Each node is described by certain characteristics that indicate the maximum daily output by ground means, lift helicopters, or fixed wing transport aircraft. If a specific node is required to stock a certain level of supplies, this is also indicated. Nodes which simulate ports or large airbases generally are the receiving points for direct delivery of troops, supplies, and equipment into the theater. The operational capabilities of these nodes are scenario dependent and are specified in the input data.



Figure 6-7

For each combat sector the node immediately behind the FEBA is designated the forward supply point, and is responsible for resupplying all the combat troops in that sector. For the first day of combat, the supply node which is to be the forward node is specified in the input data. Thereafter, the movement of the FEBA is examined to discover whether the previous day's forward supply node has been overrun, or if it can now be moved to a more forward node.

The logic that simulates the flow of supplies is the same for each sector and deals first with the forward node. A demand from the ground combat units, which varies with the number and type of demanding unit as well as its combat posture, is created and sent to the forward supply node. If this node cannot meet the demand, the next most rearward node attempts to meet it. If this node also fails, supplies may be forwarded by air from a more rearward node if the capability is available.

When the daily movement of supplies has been completed all remaining ground and airlift capacities are used to move fresh troops and equipment to the combat zone.

The logic of this model was designed so that for stable combat conditions and adequate logistic support, supplies should flow smoothly into the forward supply node and hence to the consuming units. However, if the movement capabilities are low, or the enemy interdiction effort is heavy, the combat effectiveness of active units may be degraded and the total number of combat missions that could be flown from any one airbase may be restricted.

The ground model handles the daily combat actions (and the subsequent FEBA advance) and the logistics model attempts to keep supplies moving forward to insure maximum combat effectiveness.

TACTICAL AIR MODEL

The tactical air model accounts for mission assessments of the type shown in Figure 6-8. Daily operation of the air model depends on a tactical air controller, simulated within the decision model, to assign combat aircraft to each sector. Aircraft are assigned to sectors on the basis of the tactical environment, the airbase capability and the aircraft availability.

Once aircraft are assigned to sectors, the air model makes assignments to specific airbases within the sector for a home base location and logistical support. The home base location is necessary as a basis for evaluating the combat radius of the aircraft. A combat radius determines the maximum depth to which missile sites, airbases, and supply nodes may be interdicted. All distances are calculated from the node that supplies the home base to the nodes associated with the target elements.

Target elements such as missile sites and air bases are specific missions in the general air superiority role. The logic of the air model assumes that all active airbases and missile sites within range of the combat aircraft are vulnerable to attack.

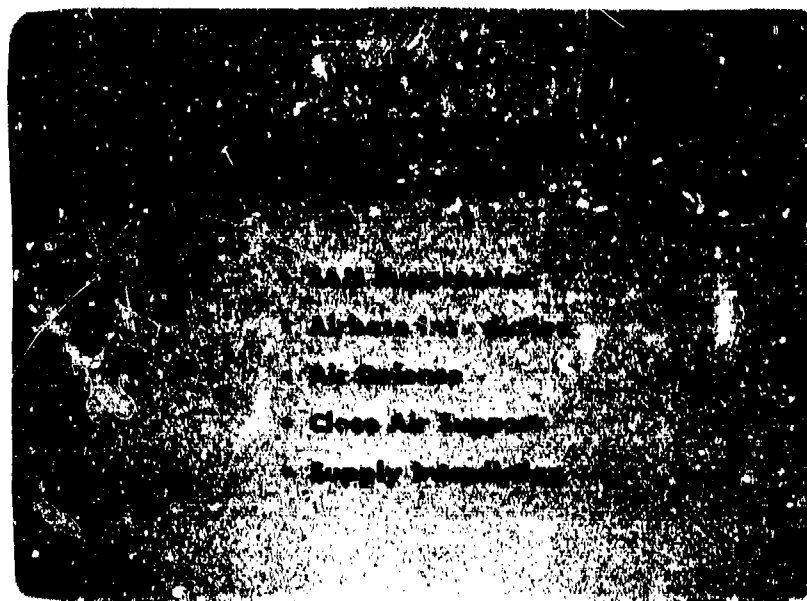


Figure 6-8

Airbase Interdiction

When attacking enemy airbases the number of aircraft assigned to attack each airbase is a function of the nearness of the airbase to the FEBA and the ability of the airbase to handle large numbers of aircraft sorties per day. Assessments are directed to airbase facilities, on-hand supplies, and the parked aircraft. Thus, whenever an airbase is attacked, the capability of that airbase to sustain a given number of sorties per day is a characteristic that is degraded.

SAM Suppression

A second major target element is the surface-to-air missile (SAM) unit. The number of aircraft assigned to attack each SAM site is in proportion to the number of fire units at the site. The number of fire units lost to aircraft attack is a function of the number of fire units

available at the site, the effectiveness of the aircraft attacking the missiles, and the total number of aircraft attacking the site.

In computing the aircraft lost to missile fire, two single salvo (or single shot) kill probabilities are used. All kill probabilities are based on the type missile system deployed and its firing doctrine which may be one, two, or more, missiles per salvo. One kill value is applied against aircraft whose mission is to attack the missile site, and another value is applied to all other missions. Since close air support aircraft generally operate at a lower altitude, they receive the lower value missile assessment and thereby become more vulnerable to air defense artillery weapons in the area.

Air Defense Losses

The loss of aircraft to these air defense weapons in the forward combat area is determined by an overall attrition constant per sector. The attrition constant is a weighted average of the effectiveness of air defense weapons organic to combat divisions and supporting elements within each sector. Once the attrition effect is determined for each division, the ratio of air defense effectiveness to division ICE is formed and kept constant. As the division ICE is reduced by close air support or other battle actions, the air defense attrition constant is similarly reduced.

Close Air Support

The close air support effects assessed in the model are determined in a very straightforward manner. Various studies have indicated what a standard or near optimum munition loading would be for aircraft on a close air support mission. Using this standard loading and computing the lethal area of effects for the munitions, an equivalent ICE for a close air support aircraft can be calculated. This value multiplied by the total aircraft assigned to close air support yields the ICE that is to be added to the combat unit's ICE and then assessed in the ground model for that day's action. The ICE for close air support is computed on a daily basis to account for loss of aircraft and/or changes in close air support tactics.

Supply Interdiction

The last mission type to be assessed is the supply point interdiction operation. As before the aircraft will attack supply nodes in depth out to the combat range of the aircraft. The number of aircraft assigned to attack each node is in proportion to the size of the node as determined by its output capacity, its on-hand supplies, and its air resupply capability.

AIR ALLOCATION

To have the air model operate on a 24-hour cycle from day to day without additional mission type orders requires a routine to assign aircraft to tactical missions each day. This is done by a set of mission assignment curves as shown in Figure 6-9. The number of aircraft assigned to each mission is determined by the relative strength of air power per sector. As one side achieves air superiority, more and more aircraft are assigned to close air support and interdiction missions. The curves are entirely arbitrary. Any set of such curves may be used.

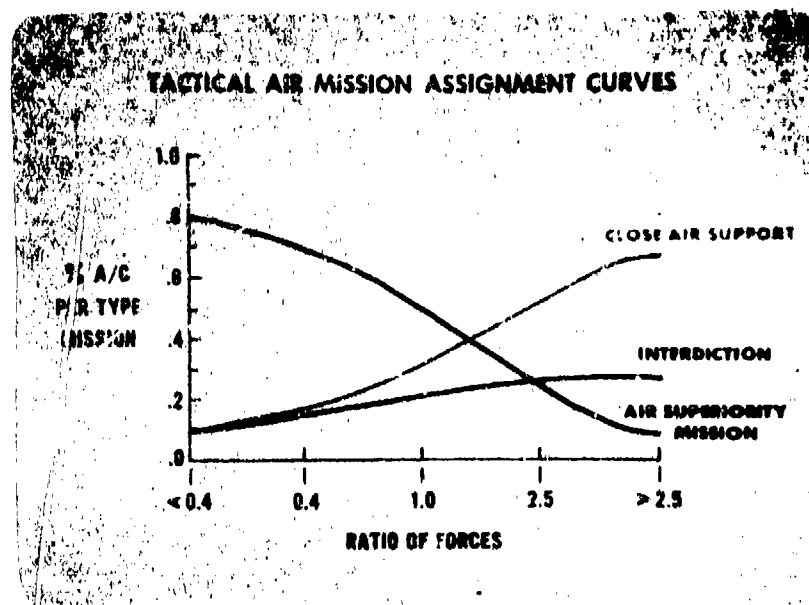


Figure 6-9

TACTICAL DECISION MODEL

The functions of the fourth and last model, the tactical decision model, are shown in Figure 6-10. This model is needed to allow the simulation to proceed through an entire war without interruption. One application of the simulation is to assist in rapid deployment studies, hence in situations where troops, supplies, and equipment will be scheduled to arrive at ports and air bases at various times during a war. This model is specifically designed to determine the sectors to which newly arrived

combat units might best be deployed, to determine the distribution of supplies and missile units as they enter the theater, and to allocate tactical aircraft on a daily basis to each sector for both sides.

The decision model assigns a new unit to a particular sector in the following way: after viewing the type combat actions in all battle sectors, the model determines in which sector the attacking force could reach some predesignated defensive position in minimum time. This position may be a strategic phase line or the enemy's final objective itself. If there is no movement on the front when this assessment is made, minimum distance becomes the criterion instead of minimum time.

Instances may well occur, however, where an additional unit assigned to a sector will overburden the logistics capability of the sector. Therefore, before the new unit is assigned to the sector, the ability of that sector to resupply existing combat units, to transport replacement items and supplies, and to move the new unit through the system is carefully evaluated. If the sector in its present condition is not able to handle the new unit, other sectors are then evaluated as to their capability, always keeping the tactical need foremost in mind.

The allocation of combat aircraft to battle sectors is a function of the tactical situation existing in the sector. Three tactical situations are possible: (1) the aggressor forces advancing, (2) the aggressor forces retreating, and (3) the forces stalemated (i.e., no FFEBA movement).

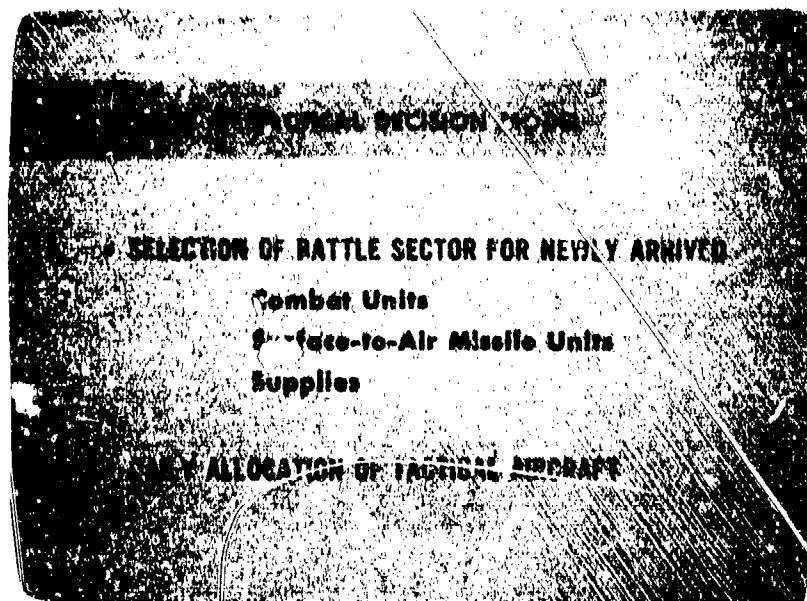


Figure 6-10

These situations are assumed to be assignment priorities in the order 1, 2, 3 for the aggressor force. Thus each day the aircraft are assigned to the highest priority available. If the same situation exists in more than one sector, aircraft are assigned in proportion to the ICE of the opposing force in the sectors involved. Hence any desired change in the logic or priority assignment of aircraft may be made by reordering the above situations.

As supplies enter the theater they may be either earmarked for a specific combat unit or distributed to the various sectors where need is the greatest.

This concludes the description of ATLAS.

ILLUSTRATIVE LINKAGES

The individual models discussed in previous sections may be linked together in many different ways depending on the problem to be solved. Two examples of current applications and a third linkage not currently in use are discussed below.

Figure 7-1 illustrates the linkage currently being used in the NATO Combat Capabilities study (COMCAP II). This study is designed to give comparative measures of the effectiveness of different weapon systems and units. A by-product of the analysis is to be the measure of ammunition expenditures of each type.

Company or battalion organizations, weapons performance data, terrain descriptors, and tactics are input to CARMONETTE. Forces played in CARMONETTE cover a range of forces which are expected to be fought in DBM. Since it is impossible to foresee the exact composition of every company/battalion-sized force which might be engaged in DBM, a method of obtaining results of battles not played explicitly in CARMONETTE is required. In this study, COMANEX is used for this purpose.

Using COMANEX to assess the outcomes of small unit ground engagements, DBM simulates the conduct of division-sized operations over a period of several days. Data generated by DBM (with some feedback from the original CARMONETTE battles) are then analyzed to produce the weapons and unit effectiveness values and munitions expended.

A second example of model linkage is shown in Figure 7-2 and is currently being used in the SCAT II study. This effort is designed to evaluate the effectiveness of alternative mixes of helicopters and alternative employment doctrines.

Again, CARMONETTE and DBM are linked together by the COMANEX model. In this case, however, two additional models, DEGAS and EPIC are used. DEGAS assesses the results of engagements between helicopters and ground forces when the ground forces are not concurrently being engaged by opposing ground weapons. DEGAS battle results are also input to the EPIC model to assure consistency between EPIC and DBM.

The output of DBM in this analysis is the logical progression of a division-level campaign to include a time-sequenced list of requirements



Figure 7-1

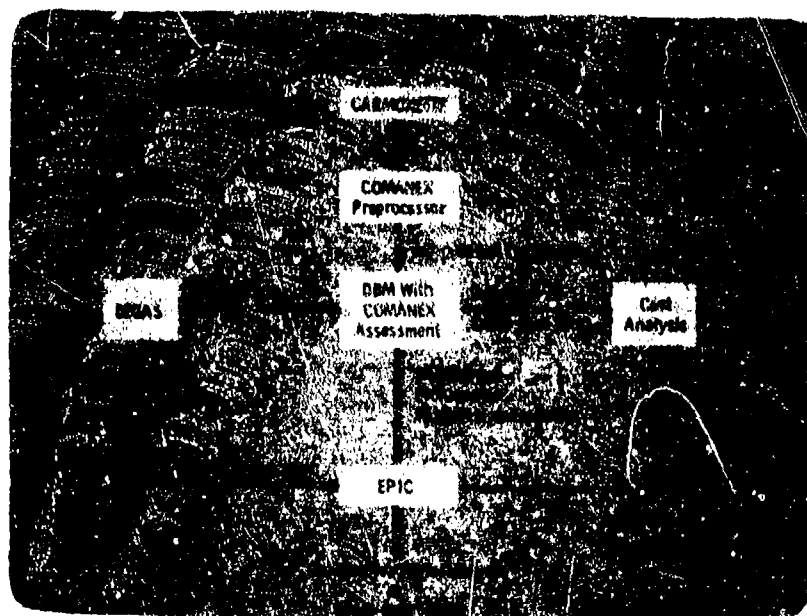


Figure 7-2

for several types of helicopter missions. EPIC projects these division requirements to theater level and, examining local availability, attrition, maintenance cycles, and other factors, determines theater-wide availability and effectiveness of the alternative helicopter mixes.

A third example of a model hierarchy is shown in Figure 7-3. This linkage might be used in a study comparing alternative mixes of divisions in a theater. In this case, the decision involves theater-level effectiveness measurement and a large number of division-level games would be necessary. For this type of analysis, it would be more efficient to use regression equations as the means of loss assessment in DBM since the computer time required is less than with COMANEX. COMANEX could still be used, however, external to DBM, to generate data from which the equations are derived. Independent variables for the regression equations would be numbers of each weapon type involved in the engagement and a separate equation would be derived for assessing each type of loss in which we are interested.

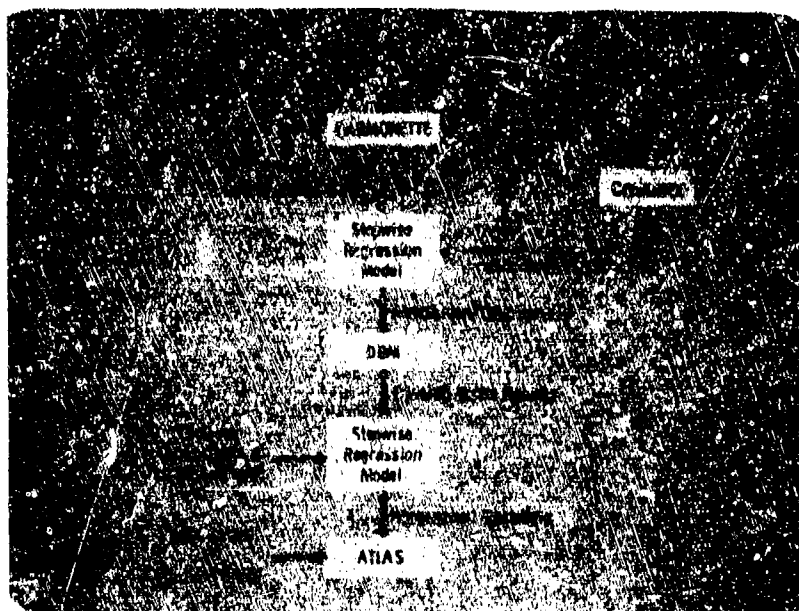


Figure 7-3

Regression might also be used as the interface between DBM and ATLAS. Independent variables in this case might be numbers of each type of battalion involved and the average strength of each (in terms of percent of full strength). Equations could be derived to calculate losses for

each side and, perhaps, movement of the FEBA. Outputs of ATLAS, then, could be used as a basis for evaluating organizational and tactical effectiveness on the theater level.

The flexibility inherent in the ability to structure a hierarchy of models to fit a given problem provides a wide range of possible applications. Some of the more obvious ones are:

1. Mobility - firepower trade-offs.
2. Target acquisition - firepower trade-offs.
3. Evaluation of alternative mixes of tank/antitank systems.
4. Evaluation of alternative tactics for armed helicopters.
5. Evaluation of alternative division organizations.
6. ECM systems for armed helicopter survivability.
7. Evaluation of artillery support families.
8. Armed helicopter vs fixed wing tactical air trade-offs.

Appendix A

CONCEPT FOR USE OF DBM SIMULATION TO "DRIVE" THEATER MODELS

CONCEPT FOR USE OF DBM SIMULATION TO "DRIVE" THEATER MODELS

PROBLEM

The analytical community studying Army problems involving the combined arms—armor, infantry, and artillery—has accepted the necessity of using a war game or simulation. But the input to high-level games (theater level) often involves firepower scores or other equally unconvincing indices. These have by now been thoroughly discredited—see, for example, the discussion in RAC-R-121, MEFORD, and RAC-R-145, ECF-II—and an alternative must be found. Thus the next step in improving the state of the art of theater-level games must be the construction of a division level computer simulation for the purpose of assessing engagements between the units of resolution in a theater-level war game. The division computer simulation should be based on the proven DBM* game.

The remainder of this concept paper discusses the way in which the output from a body of DBM simulations might be used to assess the close combat actions in ATLAS.**

ATLAS AND ITS GROUND COMBAT MODEL

The output of the ATLAS ground combat model, which is also the major output of ATLAS, is net daily advance of the divisions in a sector (usually a US corps) and daily casualties. The first is a function of certain inputs to the model: a force ratio computed from the firepower scores of the divisions and their support; posture; degree of mechanization of the divisions; and terrain. Casualties are computed from the inputs: force ratio as above; and posture. In the past only personnel casualties were computed. In the future we may wish to compute tank and APC attrition.

* RAC-R-145, The Equal Cost Firepower Study, Vol. III, The Division Battle Model (DBM 72).

** RAC-TP-266, The Computerized Quick Game.

ALTERNATIVES

In principle a set of the manually operated, computer assisted DBM games could be run and the output of these games processed for use in substitution for the current ATLAS combat model. As a practical matter, however, this is out of the question since, as we will soon see, several hundred games are the rock-bottom number required of variations on the basic scenario and there is much reason to want several thousand games. At 2 weeks per game this would require many years of running. The only alternative, if we wish to get the ATLAS inputs out of DBM, is to transform the DBM into a rapid playing, pure-computer simulation.

If this alternative should unexpectedly prove infeasible, there is another approach to getting rid of the present way in which the firepower scores in ATLAS are computed. This approach involves running CARMONETTE* some large number of times and then basing the firepower scores for ATLAS on the casualty potential of weapons abstracted from CARMONETTE. This approach is not desirable since it fails to provide for defensible daily casualty and movement rates in ATLAS. As an expedient however it would represent an improvement for ATLAS and could be in hand much sooner, perhaps for use on an interim basis until the DBM results became available. This expedient will not be further considered by this concept paper.

DEFINITION OF DBM SIMULATION

The present manually operated, computer-assisted game** is described by the following flow diagram, Figure A-1.

A computer assessment program already exists for many but not all of the DBM models. (One that is still manual is the intelligence routine.) Thus the job of turning DBM into a pure-computer simulation requires that computer routines be written to take over the duties currently handled on a manual basis by the players and control.

So far as computerizing control is concerned, this has been done many times for other simulations. Additional study is required before good estimates of just how much labor is involved can be made. Moreover, we must produce control routines which run very rapidly and this could prove to be a problem.

* RAC-R-28, CARMONETTE III Documentation, Vols I, II, and III.
RAC-D-12-CR, CARMONETTE IV and V.

**As described in the first footnote, the ground combat assessment uses regression equations based on a series of CARMONETTE runs. A body of such runs will soon exist so that it is unnecessary in this paper to plan for additional runs so long as the scenario involves NATO in the next 5-8 years.

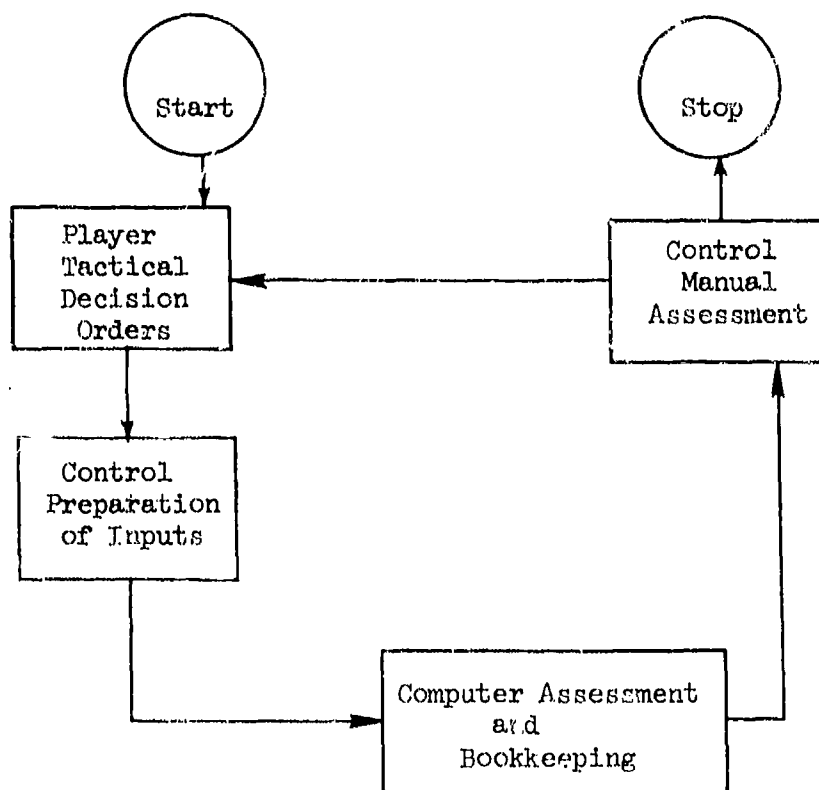


Fig. A-1 Flow Chart of the Present Manually Operated, Computer-Assisted DBM.

Computerizing the player function of making tactical decisions is more difficult. Not that there is any doubt that it can be done in some form. There are two forms a tactical decision model can take. It can be simply an extensive list of all the contingencies which can occur with the specific decision to be applied in each case. Or it can be a routine whose internal logic approximates to some degree the logic of a decision maker. For simple games the first approach can be sufficient and so it might be in the present case. But as the games become more realistic and detailed the list of all possible contingencies becomes impossibly lengthy. We believe we are approaching this situation. It is time to start work on the second approach. Note that success in this venture would be advance in the state of the art of gaming and simulations and would have wide applicability at all echelons.

STEPS IN DBM CLOSE COMBAT MODEL

To make the problem of turning the DBM into a simulation a little more concrete, consider the DBM close combat model.

Step 1. Player writes orders to all his units covering the next 4 hours. These orders specify terrain objectives, timing, and desired posture.

Step 2. Control reviews all the movement orders and determines what collisions between antagonists will occur and when. Taking these "battle groupings" in the order in which they occur, he reports to the players, with appropriate delays, general information about the battles. He might, for example, tell Blue that a particular company has run into heavy resistance halfway to his terrain objective and is unable to continue his advance.

Step 3. Again with appropriate delays, Blue may wish to reinforce with a fresh company or otherwise alter the original orders.

Step 4. This continues for 4 hours at which time control prepares the input cards which specify which units are in battle with each other.

Step 5. The computer program then determines* the outcomes of the battles in terms of casualties and the occurrence of "breaks" and prints out this information for control.

Step 6. Control computes the movement of the unit and reports to the players approximately what happened. Players repeat step 1 and the next cycle is underway.

In order to have an all computer simulation these six steps must be carried out by the computer. Note that in its present form only step

* By appeal to a set of regression equations based on a series of CARMONETTE runs, as mentioned in a previous section.

5 is computerized. Steps 2, 4, and 6 include manual assessment of movement and battles which are logically a part of step 5. Steps 1 and 3 require that there be a tactical decision routine available.

NUMBER OF DBM SIMULATION RUNS REQUIRED

The most straightforward and satisfying method of determining the number of runs required is to take all the combinations of a large number of different levels of the independent variables and then form them into a complete set of regression equations. These equations will give the personnel and materiel attrition and the daily advance in the sector. Our first task is to count up these combinations based on the number of independent variables and the number of levels felt necessary to define each one.

Inspection of the present ATLAS model shows that the advance of the FEBA in one 24-hour period is a function of six postures, the force ratio (essentially continuous but with nine levels explicitly noted in the table in RAC-TP-266), three levels of terrain, and whether the force is mechanized (2 values). The force ratio in turn is a function of the firepower scores of the included weapons, the percentage of the force still surviving, and a recovery model based on the replacement rate and the number of days since the casualties were taken.

In the ATLAS model the firepower score system yields a force ratio which is intended to be a refined measure of the ratio of the combat force of the two sides. It is an absolute measure of combat power based on weapons and independent of the national origin of the combat unit or its organization, doctrine, and strategy. But the whole purpose of the hierarchy is to dispense with such absolute measures of combat force as being unobtainable.

In the original ATLAS work it was assumed that the effects of force ratio—advance of the FEBA and casualties—were symmetrical as regards Red and Blue. That is a given force ratio would have the same consequences for Red as for Blue. In this concept paper we must redefine force ratio and abandon the idea of symmetry in favor of allowing the consequences of what we will call a given "strength ratio" to be different depending on which side enjoys it. (This is a costly position to take since it approximately doubles the number of games which must be played.)

The measurement of the strength ratio in the present concept is straightforward. Here all we mean to imply by the term strength ratio is a gross measure of the relative size, e.g., the number of combat battalions on each side. The implications or consequences of this relative size are to be found in the corresponding DBM simulations, not in the very tenuous historical data used in the development of ATLAS.

Note that the DBM simulation will not impose a reduction in the effectiveness of a unit beyond that implied by the actual strength reduction. The break points applied to the close combat model of the DBM take account of this feature of combat as the day progresses. However, ATLAS has a curve of effectiveness vs strength which must still be applied at the start of each day to yield an effective strength parameter which will be used to modify the strength ratio.

Posture must be recognized as a distinguishing characteristic. We will take these to be six: rout, delay, defense, static, attack, and exploitation. The point is that not all combinations of strength ratio and posture are meaningful. Table A-1, below, shows the combination of posture and strength ratio which make sense and for which it would be desirable to run the DBM simulation. Note that the effects of posture are not considered to be symmetrical. Thus each posture is treated on each side. For example, there is one set of columns for Blue attacking and a second set for Red. It seems at least possible, perhaps likely, that the exploitation vs rout need not be played. This would leave 24 cells to be played.

Providing only 2 levels for mechanization is considered to be inadequate. In NATO all the units are mechanized. That is not the distinguishing characteristic. What makes the difference is how many tanks there are. It is considered that both Blue and Red should have the percentage of tanks in their units explicitly recognized. Specifically, since the effect of the several levels of tanks is probably non linear, there should be 3 levels of each, say 15%, 50%, and 85%, which should be played in the body of DBM simulations. The percentages refer to the number of tank battalions compared to the total number of combat battalions.

Only two levels of Red and Blue artillery need be played since we are not concerned with non-linear effects.

Finally, three levels of terrain should be played; corresponding to the 3 levels in ATLAS.

Combining these levels—24 strength ratio/posture x 3x3 tank levels x 2x2 artillery levels x 3 terrains—yields 2592 as the number of DBM runs required for a complete factorial design. As we shall see in the next section, this results in a sizeable computer budget. A possible way of reducing the computer requirements is to accept an incomplete design, depending on a regression system to fill in the unplayed cells.

An experimental design model that requires the play of only 260 judiciously selected games may be used to construct regression equations for use in ATLAS. Results from these 260 games can be used to derive all main-order, quadratic, and first-order interaction terms.

Table A-1

POSTURE-STRENGTH RATIO COMBINATIONS

Posture Red Strength Ratio Blue/Red	Atk	Atk	Stat	Def	Delay	Delay	Rout	Explt	Explt
	Delay	Def	Stat	Atk	Atk	Explt	Explt	Delay	Rout
0.2	X	X						X	X
0.33	X	X						X	X
0.5	X	X							
0.67	X	X	X						
1.0		X	X	X					
1.5			X	X	X				
2.0				X	X				
3.0				X	X	X	X		
5.0				X	X	X	X		

Note: 28 cells to be filled (24 if rout is not played)

81 cells total

DBM SIMULATION COMPUTING TIME

An estimate of the time it takes to complete one DBM simulation day is as follows. One company battle assessed by using regression equations based on CARMONETTE might take a few seconds, say one. In one division there might be 6 battalions on the FEBA, each with 2 companies up and 1 back. Thus 12 seconds computer time would be required each 4-hour cycle. Doubling this to take account of other subroutines, including the tactical decision routine earlier referred to, yields 24 seconds per 4-hour cycle. For the day (24 hours) this is 6 cycles or 144 seconds (2 minutes, 24 seconds). The full factorial design requires 2592 runs or 111 hours. The cost for such time falls between \$50K and \$200K, depending on how much central processor time there is on the CDC 6400. This is feasible if the project were given a very high priority, but in the normal course of events is high by a factor of 5-10. This makes the incomplete regression analysis approach look necessary. In that case the estimate of the computer budget required falls in the interval of \$10K to \$40K.

Appendix B

SELECTED BIBLIOGRAPHY OF RAC/GRC
GAMING-SIMULATIONS PUBLICATIONS

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