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THE MAGIC (MANUALLY ASSISTED GAMING OF INTEGRATED COMBAT) MODEL--ETC(U)
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Milton G. Weiner

May 1982

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The Rand Corporation
Santa Monica, California 90406

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The MAGIC model isn't. It isn't a "model," in the usual sense of an independent representation or emulation of reality, and it isn't "magic" in the sense of a supernatural activity. Rather, it is one part of a broader method developed for the purpose of evaluating advanced concepts or systems for land warfare. The method was developed at The Rand Corporation for the Tactical Technology Office of the Defense Advanced Research Projects Agency (DARPA) of the United States. It is described in a series of Rand publications[1,2,3] that also present several examples of its use. This paper provides a brief outline of the overall technique and its application to a particular concept for the defense of NATO.

The detailed evaluation of new concepts or systems for ground combat, particularly when they are still in the formulative stage, can assist defense planners and systems designers in understanding the capabilities and limitations of their proposals before major funding and other commitments are made. If the concepts or systems do not differ markedly from current ones, the standard evaluation techniques of gaming or systems analysis are appropriate. Special approaches are likely to be needed, however, for advanced concepts or systems that dictate innovations in how forces are organized, how they will operate, the tactics that they will employ, etc. The evaluation method described here is one such approach. It can be used not only to throw light on the advantages and disadvantages of particular concepts and systems, as can other approaches,[4] but also to illuminate relationships between the concept, the technologies for implementing it, and the tactics for their employment, i.e., on the interactions between tactics and technology.

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*This paper was prepared for presentation at the NATO Symposium on Modeling and Defense Processes, 27-29 July 1982, Brussels, Belgium. All of the descriptions of the technique, the defense concept, and the examples used in this paper were previously published in greater detail in the unclassified series of Rand Reports cited in the references. The reader is referred to these publications for additional details.

The partnership between technologists and tacticians has long been important. It has been especially so in the last half of the twentieth century, a time in which there has been substantial growth in military forces and their technological underpinnings. The two partners often appear to have difficulty in matching their concerns, however. Better than anyone else, military men know that hardware cannot guarantee success in combat. Equally important for them are the organizations and the tactics of the military forces equipped with the hardware. Similarly, the technologist often sees in his efforts the base for a revolution in military capabilities, and he can become impatient with those who see modern warfare as more complex than just a clash of technologies. It has become increasingly apparent that the full dimensions of the partnership are revealed only when tactics and technology are observed in action under conditions where there is a military objective, an intelligent adversary force, and a physical environment. But while this is the ultimate test, the contribution of the analyst in creating a simulated or synthetic environment to explore these issues through gaming and cost-effectiveness analysis has become increasingly recognized in recent years. What is less well recognized is the opportunity, if not the responsibility, of the defense analyst to involve himself in the partnership by broadening his perspective to include the evaluation of new concepts or advanced systems in which the topics of mission, organization, tactics, etc., are open to specification and investigation.

The evaluation method described here is in that arena. It consists of seven steps, as shown in Figure 1, and described in the following paragraphs.

STEP 1: OUTLINE THE CONCEPT

Anyone familiar with military research is aware that defense concepts come in a variety of forms. They may be as specific as a concept associated with a particular piece of equipment or as broad as a concept for defending an entire nation. And anyone familiar with NATO is aware that there have been dozens of different proposals for ways to defend NATO's Central Region. One publication,[5] for example, lists over thirty different concepts for NATO defense and summarizes about twenty of them. In most cases, they incorporate basic tenets about one or more of at least four major considerations:

- the degree of emphasis on conventional or on nuclear weapons
- the extent to which the defense is based on specific geographical battle lines or is extended through a large area

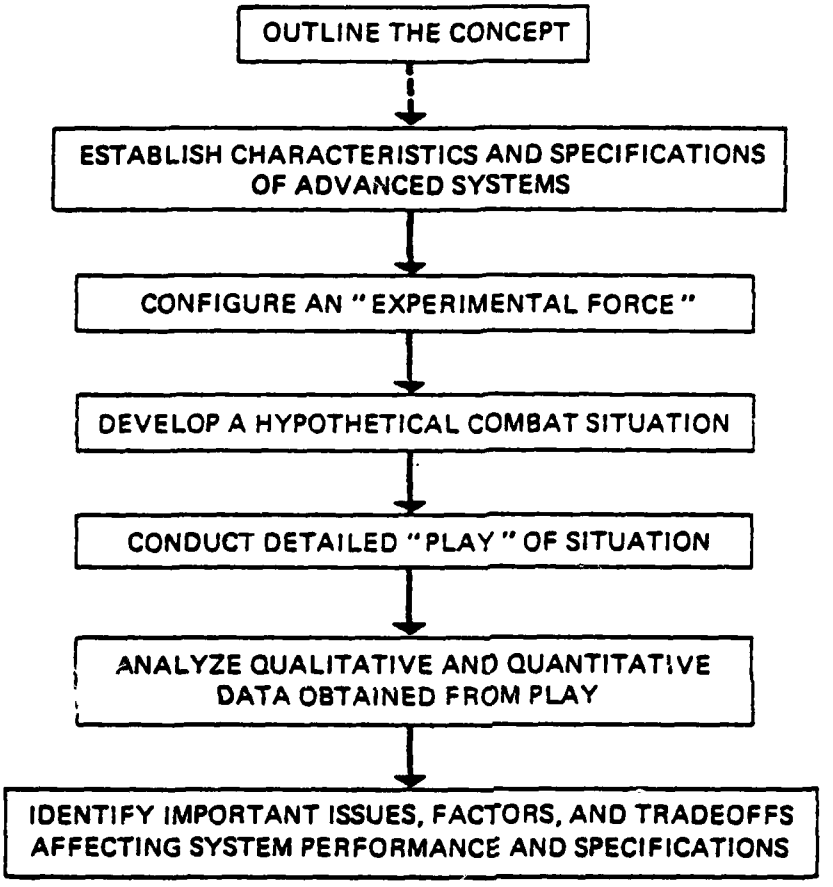

Fig. 1--BASIC STEPS IN EVALUATION METHOD

- the degree of reliance on current weaponry or on advanced technology
- the amount of dependence on regular military forces or on mobilized and reserve forces.

The positions taken on these and related considerations serve to outline the different concepts. In the evaluation method described here, it is this outlining of the basic tenets of the concept that is the initial step.

To illustrate the method this paper uses a concept developed during the DARPA study. The concept envisions a defense of the Federal Republic of Germany (FRG) by a very large number of small, anti-tank units distributed throughout the forward area of the country. In our study, the concept is called "Distributed Area Defense," although there are many antecedents as well as contemporary versions of the concept with different names.

Distributed Area Defense is essentially an attrition strategy and is based on at least two major factors. The first is the manner in which the "terrain" of the FRG has been changing over the years. The "urban sprawl," government afforestation programs, increased road construction etc., have led to "a shrinking of the main east-west channels through which massed armoured forces can be sent," and made "the control of comparatively large military formation difficult."[6,7,8] The second factor is the development of precision guided, anti-tank weapons which give small units enhanced lethality against armored vehicles. These factors provide both environment and military capability in which it is possible to conceive of the teams as "technological guerrillas" using the terrain of towns, cities, and forests to efficiently hide, move, and ambush enemy forces that are increasingly bound to movement along fixed roads and highways. To take advantage of these factors, Distributed Area Defense creates an anti-tank "sponge" out of a large portion of the eastern half of the FRG by the operation of these thousands of small teams equipped with either direct fire or indirect fire anti-vehicle weapons. The operational mode involves the use of direct fire teams on the outskirts of towns, cities, or forests to force enemy units into the open along or on main roads where the indirect fire teams attrite exposed forces from concealed locations. Supporting the Distributed Area Defense teams in the western portion of the FRG are other forces including a mobile reserve of ground and air forces prepared to respond to breakthroughs or to the massing of enemy forces in concentrated avenues of attack.

STEP 2: ESTABLISH SYSTEM CHARACTERISTICS AND SPECIFICATIONS

Advanced combat systems originate in many ways. Sometimes a new principle or effect, such as nuclear fission, offers the promise of military applications. In other cases, known technical capabilities can be combined into a new system. And in still other cases, a military requirement is the driving force behind a technology advance. In many cases, however, the implications of introducing the advanced system on the mission, organization, tactics, etc., of military forces are not extensively explored early in the formulation stages of the system. On the other hand, if a new defense concept has been outlined, it can take advantage of types of advanced systems that, if developed, would have particularly appropriate characteristics. This is illustrated for the Distributed Area Defense.

The two primary weapon systems are a direct fire and an indirect fire anti-vehicle system. The direct-fire system was conceived as a man-portable weapon with an anti-tank/anti-aircraft capability. Various systems of this type have been proposed by the technical community. A possible set of characteristics, based on one such proposal,[9] would be:

- weight	20-40 pounds
- size	4-5 feet
- range	4-5 kilometers
- time of flight	about 1 km per second
- sight	stabilized, night
- guidance	possible laser beamrider
- warhead	shaped charge

The indirect fire system was conceived as a self-contained system capable of performing target search, acquisition, designation, weapon carriage, launch, and guidance to target all within a single, lightly armored vehicle. An important characteristic of the system was a sensor-designator package that could be elevated or raised so that the vehicle could remain concealed in wooded or moderately built up areas and still conduct target search, designation, and weapon guidance from a protected position. One version of such a system, a precision guided mortar that was coupled to a sensor that was elevated on a powered tether, was used in the initial Distributed Area Defense evaluation. Based on the findings of this evaluation, another version of the indirect fire system was described.[10] One possible set of technical characteristics, based on this second version, would be:

- vehicle	Armored Reconnaissance Scout Vehicle (ARSV)
- elevatable pole	telescoping aluminum pole extendable to about 30 meters in 15 seconds
- sensor head	Forward Looking InfraRed (FLIR)
- laser designator	Nd/YAG; 1.06 micron
- missiles	2-stage, soft launched 10 missiles in external rack 20-50 missiles in internal storage
- external rack	fixed elevation 60-70° azimuth slaved to designator
- missile range	5 kilometers
- guidance	semi-active laser
- warhead	shaped charge

The illustrative indirect fire system which was nicknamed "TALLBOY" in our study had a three-man crew. Each TALLBOY was to operate semi-autonomously during combat, although inter-vehicle communications were available.

In addition to the technical characteristics of the systems, a number of operational specifications are required for the evaluation. Often these are a derivative of technical characteristics but frequently initial values can only be developed or estimated by a combination of technical and tactical expertise. Examples of these specifications for the TALLBOY system included:

- Time to determine that observed target is an appropriate target
- Rate of fire of missiles
- Hit and kill probabilities against various targets
- Time to displace to new location
- Effect of damage on crew performance

These and other planning factors are likely to be influenced by the engagement situation so that the initial values are subject to modification during the evaluation, as well as to sensitivity testing as described later. In general, the greater the difference between the characteristics and specifications of advanced systems and those of currently operational systems, the stronger is the requirement for developing new models for assessing performance effectiveness.

STEP 3: CONFIGURING AN "EXPERIMENTAL FORCE"

Configuring an experimental force is the term used to describe the conceptual activity of defining the combat force that will implement the defense concept using the postulated weapon systems. It is, in effect, a combination of such activities as constructing unit Tables of Organization and Equipment (T.O.E.s); developing a communication structure and plan; specifying a set of operational procedures; etc. (Because the tactics, organization, equipment, and procedures of such a force are considered experimental in the sense that they were hypothetical and have to be tested, the term "experimental force" is used.)

For the example of Distributed Area Defense, the major unit established was a "squadron" of about 850 men with responsibility for a combat area of about 450 km^2. The squadron included no tank, aviation, or scout units. Excluding headquarters, an artillery battery, supply, medical, sections, etc., the active combat force consisted of approximately 650 men. These were organized in units of about 3 to 6 troops depending on whether they were direct or indirect fire (TALLBOY) units. There were 72 such units in the area of responsibility, or roughly a density of one unit per six km^2. The model of operations for operating in forest areas, built-up, and open areas was specified and sets of Standard Operating Procedures for coodinating fire, maneuver, damage, and casualty conditions, etc., were developed. To integrate the unique nature of the weapons, organization, and operating procedures, a special command, control, communications structure was also developed.

STEP 4: DEVELOPING A HYPOTHETICAL COMBAT SITUATION

The evaluation of the combat performance of a novel defense concept requires not only the usual preparations typical of war gaming and combat models, but a significant amount of modification in order

to incorporate the non-standard forces, systems characteristics, operating procedures, etc., of the "experimental force." In addition, the changes that an intelligent adversary might make in his forces, systems, and procedures have to be reflected.

For the Distributed Area Defense concept, the evaluation centered on the squadron-sized defense force opposing a division-sized adversary force in NATO's Central Region. Both sides established objectives, drew up plans, and set up pre-attack positions. The defense forces were assumed to have enough warning to deploy their units from local garrisons to one set of their preassigned defense positions. For the enemy force, it was assumed that they were fully aware of the weapon system capabilities and organization of the defense force, but not aware of the positions that would initially be occupied by the direct and indirect fire defense units. It was also assumed that the enemy forces would operate, at least initially, to seize the initiative and maintain as much momentum as possible to their first objective, a line approximately 25 kilometers inside the FRG, even at the cost of heavy casualties. They would initiate operations with a major artillery barrage, would attack with two regiments each on a main and two supporting routes, a total of six routes, and would rely on tank and helicopter forces to sustain their advance. A variety of other considerations regarding use of attack routes, disposition of forces, order of march, etc., were also specified, but are not described in this paper.

STEP 5: CONDUCTING THE COMBAT EXERCISE

The technique used for carrying out the combat analysis is that portion of the overall evaluation method to which the term MAGIC, or Manually Assisted Gaming of Integrated Combat, is applied. The MAGIC technique or model consists of three components--a three dimensional terrain board, a computer program called TIMER for Terrain Intervisibility and Movement Evaluation Routine, and a set of hand-held calculator programs, or analytic modules, for determining engagement outcomes.

The Terrain Board

The terrain board represents an area of approximately 20 by 25 kilometers along the interzonal border. The area is indicated in Figure 2. The particular area was chosen because it included two potential major attack avenues, one that used a highway (Route 19) directly through a largely open region, including the towns of Mellrichstadt and Bad Neustadt, and a second that was less direct and went through more wooded terrain and several towns between Fladungen and Bischofsheim.

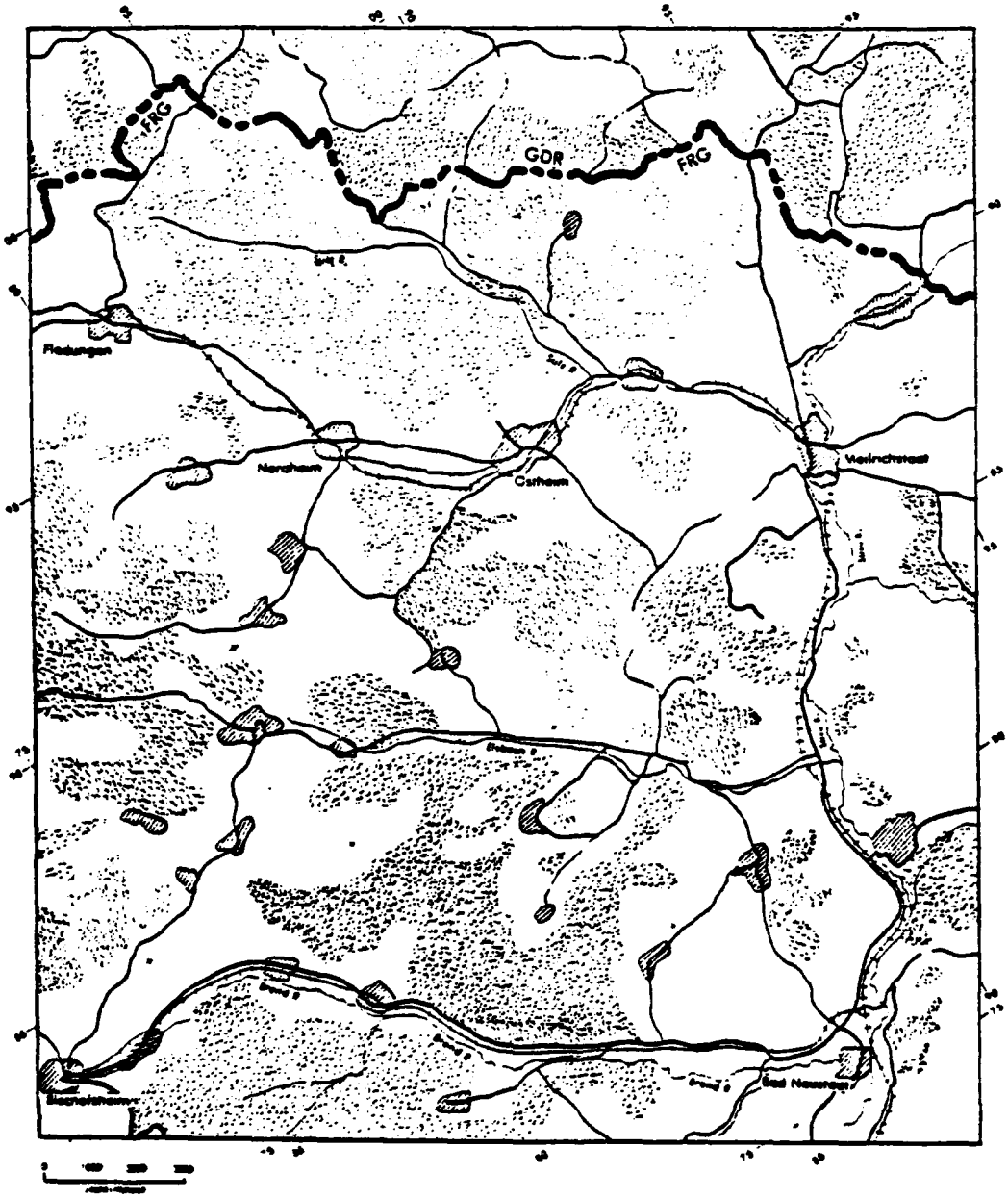

Fig. 2--AREA REPRESENTED BY TERRAIN BOARD

The terrain board was built in a "terrace" style from photographic enlargements of 1:50,000 scale maps of the M-745 series, to produce a scale of 1:10,000. Vertical exaggeration is approximately 2.5:1, with terracing at 20 meter contour intervals. The overall size of the board is approximately 2 by 2.5 meters. The primary purpose of the terrain board is to allow "manual" play of the exercise so that tactical decisions of where, when, and how to deploy and move forces could be directly visualized. The size and scale were chosen largely because effective modern tank/anti-tank combat is increasingly dependent on such factors as intervisibility, "terrain-tuning," "management of seconds," etc., i.e., on the treatment of space-time-mass in considerable detail if interactions between tactics and technology are to be evidenced.

The Computer Program

The TIMER model was developed to determine the effects of terrain on target visibility in terms of such items as the occurrence and duration of visibility (line of sight), the maximum range of contact, the potential rate at which a defense unit could engage attacking units, etc. The program uses the digitized terrain data base of the U.S. Defense Mapping Agency (DMA) for the same area as the terrain board. It was initially written in FORTRAN to operate on an IBM 370/158 with an IBM 2314 disk pack. Using the DMA fine grained data base of one elevation point every 12.5 meters, the TIMER program calculates whether there is a line of sight (LOS) between any two points in the terrain.

With this basic computation capability, it permits the user to:

- input one or more potential avenues or routes of attack and calculate the visibility of targets on the routes from various defense locations.
- specify different target velocities and calculate the length of target exposure on the routes.
- incorporate the reaction times of different defense systems and determine the number of opportunities to engage targets.
- determine, for a given defense force occupying different defense positions, their potential ability to engage attacking forces of different sizes and spacings using one or several avenues of advance.

For an example of the type of basic output available from TIMER, Figure 3 indicates the extent of visibility from 45 TALLBOY positions on each of six enemy attack routes in the area represented on the terrain board.

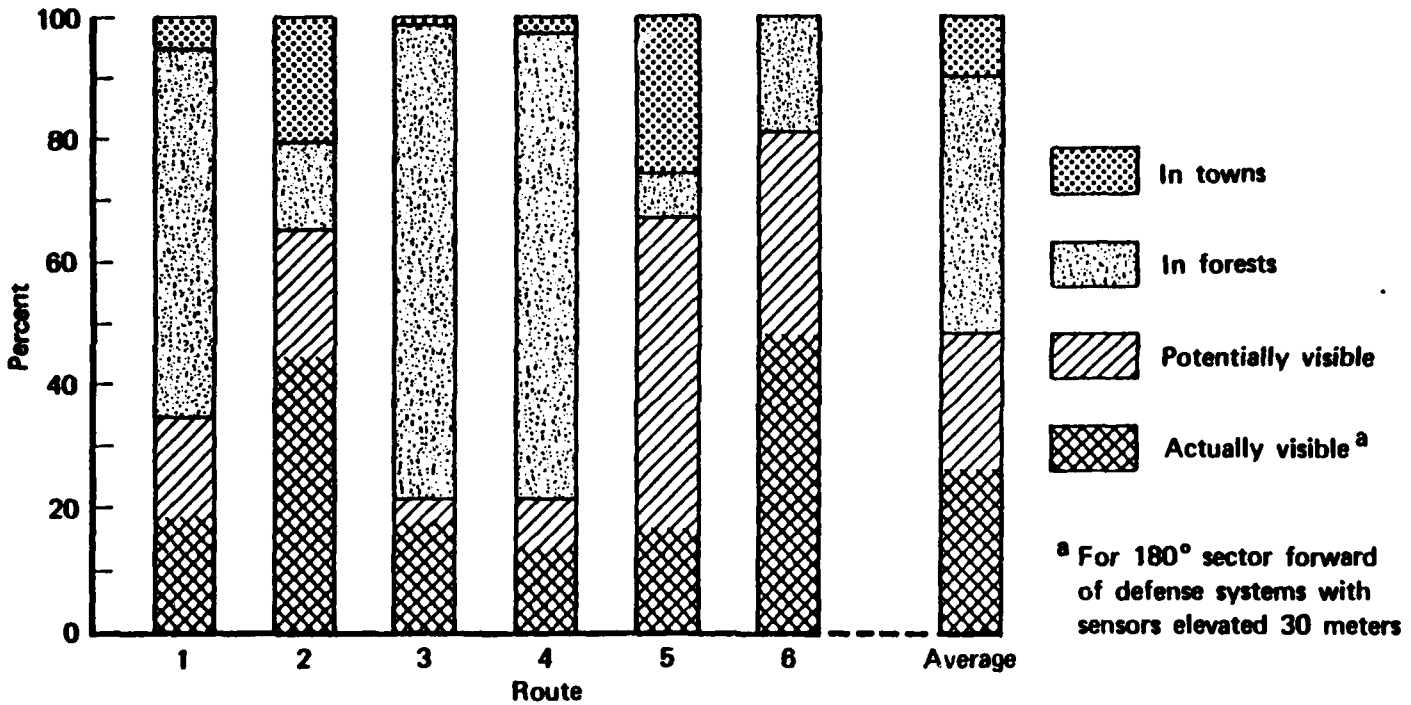

Fig. 3--PERCENT OF TOTAL ROUTE POTENTIALLY AND ACTUALLY VISIBLE

Analytic Modules

To assess a variety of combat situations that occurred during the course of the exercise, a series of modules were programmed for a hand calculator, the HP-67. These analytic modules covered such items as the results of multiple firing on the same target, hit and kill probabilities under different target conditions, etc. As an example, several TALLBOY systems might see and fire on a group of enemy tanks. While assessments of the outcome could be made with an "expected value" approach, this procedure was deemed inappropriate for several reasons. It could result in more "kills" than targets; it did not reflect an allocation of fire process; and it did not allow for the type of statistical variations that permitted a "lucky" enemy to survive several engagements and overrun a key defense position in spite of heavy fire. Most of the analytic modules were thus constructed to deal with combat actions or engagement outcomes where factors of this type were deemed important. Many incorporated a Monte Carlo model from which sampling by random numbers produced the engagement assessment. Some of the programs for analytic modules of MAGIC, as well as for other types of defense problems, have been published separately.[11]

The basic structure of the MAGIC play method is indicated in Figure 4. While the overall objective of MAGIC is to assess the military advantages and disadvantages of new concepts and/or advanced systems, this objective is only partially achieved by determining the outcomes of the combat play. A greater value lies in the fact that during the play literally hundreds of engagement situations develop and can be used as a substantial data base to throw light on questions of the utility of the new concept or system and on the interactions between tactics and technology. The types of questions listed in Table 1 are typical of those that can be answered from the data base of hundreds of fire fights and many-on-many engagement situations that take place during play of the game.

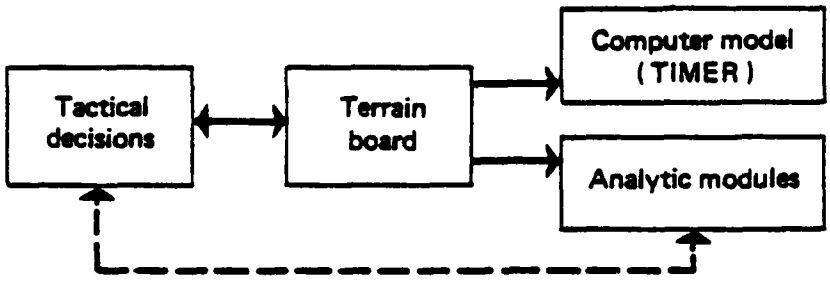

Fig. 4—BASIC STRUCTURE OF PLAY METHOD

Table 1

QUESTIONS ON TACTICS AND TECHNOLOGY

- Who sees whom at what distance for how long?
- How long does it take to bring fire to bear?
- How is fire allocated?
- How frequently are what weapons used against what targets and at what ranges?
- When, where, and why do units move?
- How do units coordinate with each other?
- What communications take place and when?
- How and when are units resupplied?
- How do systems complement each other?
- How vulnerable are these activities to enemy action?

To obtain the detailed data necessary for answering the questions listed, MAGIC often requires a second-by-second play in order to incorporate and obtain data on individual tactical decisions, engagements, movements of forces, etc. The use of event logs, photography, computer listings, etc., contributes to meeting this requirement. While MAGIC uses essentially an "event-sequence" procedure rather than a uniform time line, it can follow the more or less standard steps of manual gaming but it is also flexible enough to include the following conditions:

- Actions in a particular step that do not occur within a single sequence, but in multiple sequences in different places at the same time. Typical of this are fire fights in different parts of the battle area.
- Sequences that may involve different periods of time and have to be coordinated. Typically, some forces are displacing from one position to another while other forces are engaged and the longer movement sequence has to be coordinated in the play with the shorter combat action of the other.
- Special actions that have to be incorporated in the sequence. Typical of these are aperiodic events such as air attacks, the introduction of minefields, smoke, damage repair, etc.

Accounting for these variations is carried out within the usual steps of two-sided terrain board gaming, i.e., the development of tactical plans, movement of forces, establishing whether contact is made, whether engagements occur, assessing the outcome of the engagement, etc.

This general technique of using a terrain board to provide the perspective of a three-dimensional combat environment, of allowing human players (often military officers) to make the tactical decisions,

and of using the computer(s) for most of the calculations regarding system performance and engagement outcomes is not limited to the MAGIC method. Among other very similar techniques is BATTLE.[12] But MAGIC was deliberately developed as a research vehicle within the broad context of a means of evaluating novel concepts or advanced systems. This has required much greater emphasis on concerns with defining objectives for forces, establishing new T.O.E.s, estimating capabilities of systems that have not yet been developed, permitting great flexibility in play, and record keeping not only of events but of the basis for tactical decisions. The consequence of this approach is that it requires at least a small staff (3 to 4 members), several hundred hours of preparation and exercise play, and extensive record keeping. As a result, it is most appropriately used for the evaluation of concepts or systems where detailed examination in a synthetic combat environment will help to understand performance capabilities and the interactions between tactics and technology.

For example, the various evaluations of the Distributed Area Defense concept and its associated systems took several months each, generated several hundred combat incidents for analysis, and contributed to several weapon development programs.

STEP 6: ANALYZING DATA FROM THE COMBAT SITUATION

The data collected during the exercise play include a series of logs. One of these is a time log that gives the events of the play in the format indicated in Table 2, which is annotated to illustrate the entries.

The logs reveal which vehicles or weapons were used in the play, how many times they were engaged, their posture at the time of engagement, the ranges of acquisition and firing, the kills obtained, and other data. Accumulation of the hundreds of events and incidents in this form, while time consuming, provides the basis for a variety of analyses. These analyses cover not only the overall outcome and other data from the entire exercise, but also the basis for specific analyses. As an illustration of the overall results from one of the Distributed Area Defense evaluations, in the guided mortar exercise, Table 3 lists the total enemy losses in two lead regiments during about 2-1/2 hours of combat. Results from the TALLBOY exercise produced even higher loss exchange ratios.

The log data also enabled other results to be extracted. For example, the guided mortar was used in conjunction with the advanced man-portable, direct-fire system. Of the total enemy losses in both the lead and following regiments of the attack, almost 200 were the result of the direct-fire system, whose maximum range was about 5 kilometers. The play produced the kill vs. range data in Figure 5, which indicate the direct-fire system produced over 90 percent of its kills at less than one-half its design range, and about 70 percent of its kills at ranges under 1000 meters.

Table 2

SAMPLE OF TIME LOG DATA

Item	Entry	Annotation
Time	00200	In seconds from start of combat
Unit	B46	Identification no. of friendly unit
Coord	958 865	Location of unit in UTM coordinates
Vehicles	4	Number of vehicles in unit
Status	PT	Posture: In position in town
Activity	A	Acquires target
Unit	R133	Identification no. of enemy unit acquired
Range	2300	Range to acquired unit
Type	V	Type of acquisition; visual contact
Time C	15	Time in contact, in seconds
Vehicles	3	Number of vehicles contacted
Velocity	15	Speed of vehicles, in kph
Ammo	16	Number of rounds in friendly unit
(A later log entry, at time 00200, would carry additional entries)		
Activity	F	Friendly unit fires
Range	2280	Range at time of firing
Rounds	2	Number of rounds fired
Results	1	One kill on enemy unit

Table 3

RED LOSSES

Initial force ..... 390 vehicles/weapons

Losses:[a]

Number ..... 300 vehicles/weapons

Percent 77%

Location:

Woods ..... 20% of losses

Open ..... 76% of losses

Urban area ..... 4% of losses

Exchange ratio: F/E[b] 8:1

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[a]Cause of loss not presented here.

[b]Ratio between friendly vehicle and weapons losses and those of enemy.

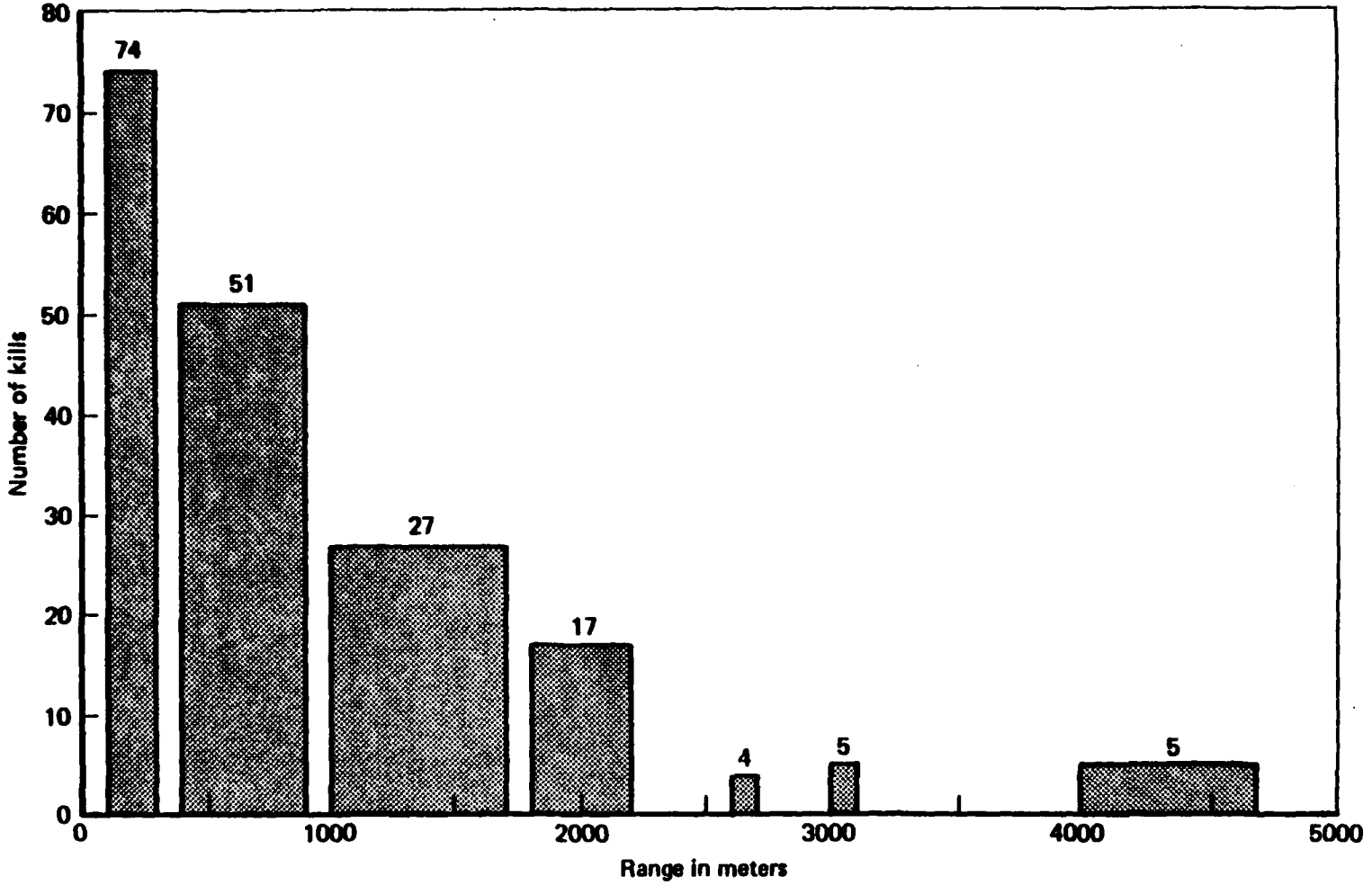

Fig. 5--DIRECT FIRE SYSTEM KILLS VERSUS RANGE (TOTAL KILLS=183)

The heavy weighting of kills toward the shorter ranges is largely due to the tactical concept employed: the direct-fire weapons were positioned to prevent enemy movement through covered areas--forest roads, towns, and the like. Being direct-fire weapons, they were employed from concealed positions whenever possible. The results indicate not only the interaction between the tactics and the technology, but also suggest the type of "sight" mechanism that the weapon should have. For short ranges, a light, bore-sight mechanism would be more appropriate than a heavier, magnification sight that could add additional cost to the weapon. Or, as a design option, the weapon could incorporate interchangeable sights for different tactical situations.

Log data can be supplemented with data derived from the TIMER computer program. In the Distributed Area Defense evaluation involving the guided mortar, the enemy attack came on six different avenues represented on the terrain board. The location, number, and length of all stretches of these six attack routes that were visible--that is, in which a line of sight (LOS) existed between the elevated sensor and the routes--were calculated. As expected, the higher the sensor the greater the number and length of the visible stretches, and the more opportunities to use the guided mortar. To quantify this relationship, the metric called a "firing opportunity" was developed. It takes two factors into account:

1. The length of time an enemy vehicle is exposed on a visible stretch, which depends on its speed, and
2. The ability to deliver ordnance (the guided mortar round in this case), which depends on the length of time it takes for the system to respond once a target is in view. The system's ability to respond is called its "reaction time," which is defined to encompass LOS contact, orienting, launching, and time of flight (TOF) of the round.

The number of firing opportunities can be determined from the intervisibility data on the number of visible stretches and their lengths. For example, if a target is moving at 30 kilometers per hour (500 meters per minute), and the system reaction time is two minutes, the system requires a stretch of 1000 meters between LOS contact and impact of round. Each 1000 meters of visible stretch thus provides, theoretically, one firing opportunity against targets moving at this speed. By processing the data on visible stretches, the computer calculates the number of firing opportunities for other conditions. For example, it can calculate the effect of increasing the height of the sensor platform on the number of firing opportunities. Figure 6 depicts the relationship between platform height and firing opportunities in the terrain board situation for the following conditions:

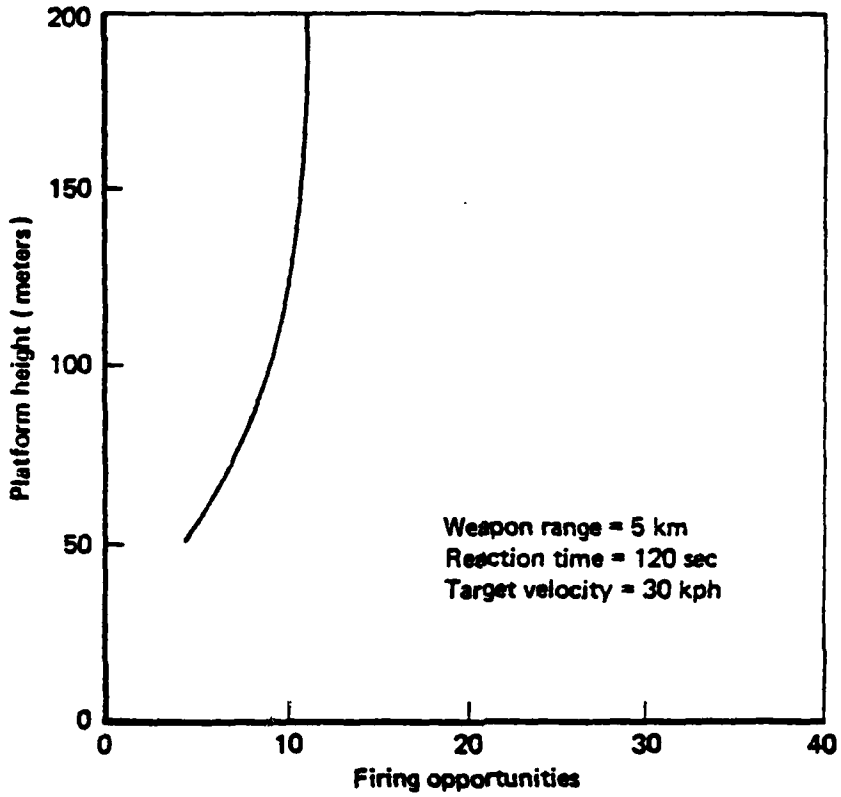

Fig. 6--GUIDED MORTAR FIRING OPPORTUNITIES VERSUS PLATFORM HEIGHT

- The visible stretches forward (180°) of the initial positions of the entire force of the guided mortar sensors;
- A weapon range of 5000 meters;
- Enemy vehicle velocity of 30 kph; and
- A reaction time of 120 seconds for the guided mortars.

Figure 6 provides another illustration of the usefulness of the method: it indicates that the gain in firing opportunities as the height of the sensor platform is increased increases little above 100 meters. Such data are useful for determining the tradeoffs between the technological (with associated cost) implications of sensor platform height and its tactical value. This example also illustrates a qualitative aspect of the evaluation. In the guided mortar system, the sensor platform was elevated by a tethered rotor that took some time to deploy from the vehicle. The higher the platform was raised, the longer it took to retract. On several occasions during game play, a sensor vehicle was almost lost because it

came within range of an enemy tank while still retracting its platform before moving to a new position, i.e., the tactical consequences of a particular technical characteristic was highlighted.

The method also permitted assessment of the effect of changing the reaction time of the guided mortar system. Figure 7 graphs this relationship and illustrates the value of shortening reaction time, which perhaps could be done by designing automated decisionmaking aids for the crew. This would be much more effective than increasing platform height.

The Distributed Area Defense evaluation utilizing the TALLBOY system illustrates another aspect of the method. In the TALLBOY system, the sensor is mounted on an extendable pole, with a maxiumum height of about 30 meters. For that height, Figure 8 shows the relationship among reaction times, firing opportunities, and range of the TALLBOY missiles. This figure permits a comparison of the consequences of shortening reaction times or increasing the range of the missile, or both.

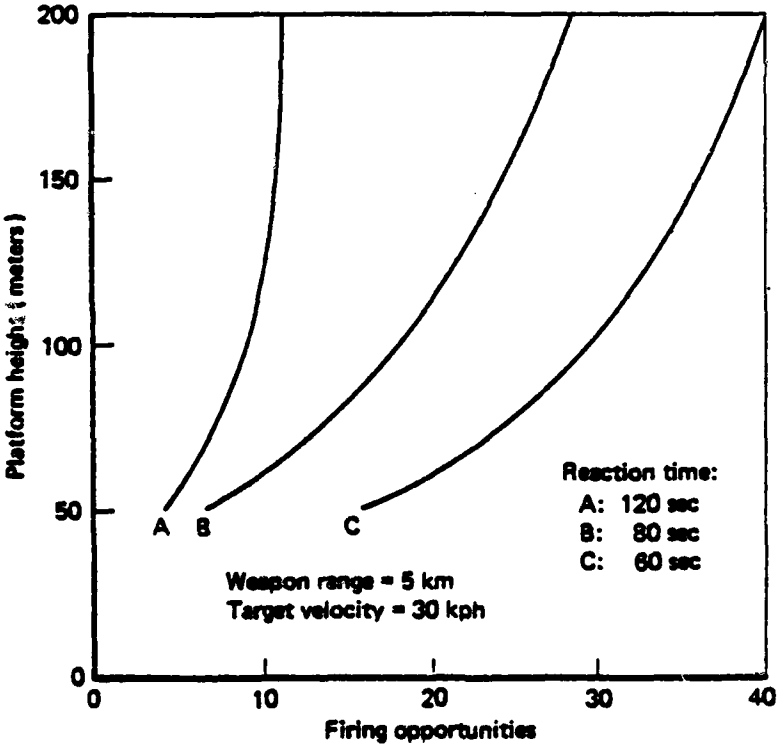

Fig. 7--GUIDED MORTAR FIRING OPPORTUNITIES FOR VARIOUS REACTION TIMES

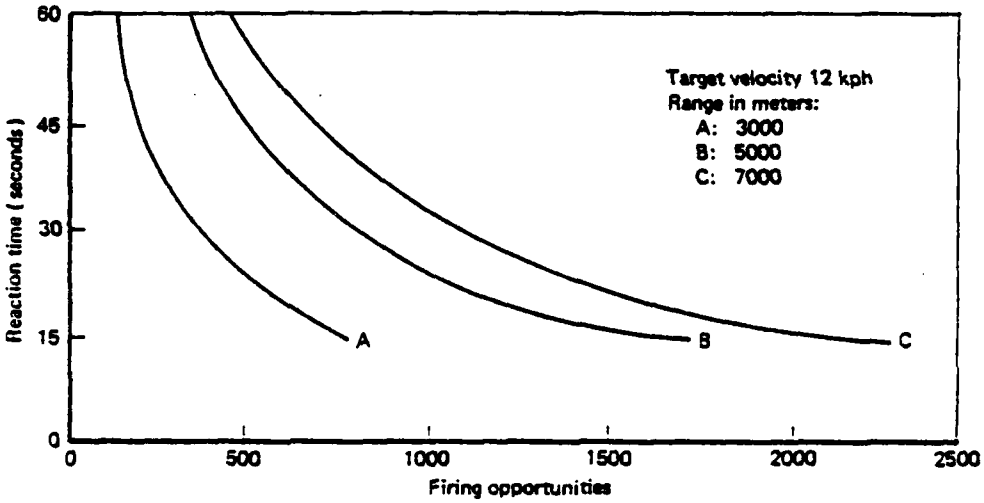

Fig. 8--EFFECT OF TALLBOY REACTION TIME ON FIRING OPPORTUNITIES, FOR A SENSOR HEIGHT OF 30 METERS

This step of the evaluation method is useful in providing data on both overall combat outcome as well as detailed information on specific system performance, as illustrated in the examples. For each of the questions on tactical-technological interactions listed in Table 1, quantitative and qualitative data can be collected and a variety of analysis can be conducted, including analyses that use metrics such as "firing opportunities" and "servicing rates" (rates at which enemy targets are engaged), etc.

In addition, without describing the more detailed results and conclusions of those portions of the evaluations that dealt with specific systems (beyond those illustrated for Step 6), some general observations of the method can be made:

1. Detailed play involving an experimental force, with tactical freedom of action by both sides, can provide a "synthetic history" of combat under controlled conditions. By judicious use of the evaluation procedure, a large amount of data covering many combat conditions can be collected and analyzed, revealing the performance of novel concepts and of advanced systems in a dynamic environment.

2. The method is most useful if it is employed early in the conceptualization phase. This is particularly true the more extensive are the organizational and tactical implications of the innovation.

3. Even for some systems that are in development, the method can be useful in defining the significant aspects, particularly for field tests. To the extent that the method can identify critical performance or design questions, it can direct the focus of the field tests on these issues. In the extreme, major field tests of a system should be preceded by an analytic test to identify the significant issues to be examined. An analytic test costs so much less that it will probably pay for itself in the enhanced value of field test results.

4. Like all evaluative methods, this method includes a large number of subjective components. When used in its fullest form for evaluating new concepts and advanced systems, the subjective aspects of configuring an experimental force are very large. Even in the narrower use of the terrain board with a computer, the results are influenced by the geographic area, the "scenario," and the players' tactical decisions. At best, board play is a battlefield laboratory, not a battlefield, and the results should be judged accordingly.

Conceptual and technological innovation for combat will continue, and is likely to become more expensive. For new concepts and advanced systems, the greater the potential cost, the greater the need to understand its capabilities and limitations before major commitments are made. Evaluation methods of the type described in this paper can be valuable in servicing that need.

STEP 7: RECOMMENDING STUDIES, FIELD TESTS, AND SIMULATION ON IMPORTANT ISSUES

The final step in applying the method is to derive recommendations based on the analyses. Except perhaps in extreme cases, these recommendations are not intended to answer the question of whether the concept shall be implemented or the advanced system should be developed. Rather, they are intended to highlight some of the military issues, design requirements, and technical tradeoffs that should be considered and perhaps to suggest field tests, experiments, and simulations that would help to answer important questions or reduce uncertainties in further developments.

In very broad terms, the most significant result was that the Distributed Area Defense concept, i.e., a concept in which small units are distributed throughout an extended area and equipped with advanced direct and indirect fire weapons, can inflict substantial attrition on an attacking tank force. The results also indicated that the loss exchange ratio of friendly to enemy forces can be quite high. These general findings are consistent with similar studies and this congruence of result suggests that the analytic work should lead to a program of field tests and experiments.

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