MANUAL WAR GAMING; HAND PLAYING THE DIVISION BATTLE

An abstract for a thesis presented to the Faculty of the U. S. Army Command and General Staff College in partial fulfillment of the requirements of the degree

MASTER OF MILITARY ART AND SCIENCE

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Fort Leavenworth, Kansas
1966

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	23 May 1966	Master's Thesis August 1965 - May 1966

4. TITLE AND SUBTITLE
MANUAL WAR GAMING: HAND PLAYING THE DIVISION BATTLE

5. FUNDING NUMBERS

6. AUTHOR(S)
Holman, Jonathan L., Jr., Major, US Army

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Command and General Staff
College
1 Reynolds Ave.
Fort Leavenworth, KS 66027

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT ***(Maximum 200 Words)***

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14. SUBJECT TERMS
War gaming; Simulation; Land warfare; Army divisions

15. NUMBER OF PAGES
224

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	UNLIMITED

U. S. ARMY COMMAND AND GENERAL STAFF COLLEGE

(Abstract Approval Page)

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The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

Cursory study of war gaming quickly reveals that one of its central problems is the conflict between the requirement of realism in play and the need for rapid and simple assessment techniques. This thesis investigates war gaming methodologies with the purpose of providing new techniques that will increase realism, speed up and simplify assessment, or do both. Chapter I provides the background necessary to understand the breadth of the problem. Chapter II discusses some modern games and methodologies from which ideas for new techniques may be originated or synthesized. Together these chapters develop the basis for limiting the scope of research to new techniques that will improve the division level manually played training game.

The first proposal, which is intended to increase realism, is discussed in chapter III. This proposal takes the time honored method of force firepower audit, one ingredient of combat power, and describes a method that both tailors firepower to the make up of maneuver battalion task forces and dimensionally allows an incremental build up in firepower as opposing forces close in battle. This is accomplished by using a graphic aid called a "tote board" which contains a "distance between opposing forces scale" and a vertical column of acetate sleeves. The sleeves house

maneuver company "firepower cards". These, when read in column at a specific "distance between opposing forces", yield a firepower "raw" score that a battalion task force, composed of the companies represented by the cards, would have at that specified range from the enemy. In chapter IV, a technique of modifying this firepower "raw" score to account for the effects on firepower of such variables as attrition in unit strength is given. This technique does not vary from present methods of converting unit firepower into combat power. It simply provides a calculator similar to a circular slide rule that multiplies blue and red firepower, percentage strength, and frontage ratios together. This yields a "true" firepower ratio. This ratio, in turn modified by direction of attack and defender posture, yields the blue and red or attacker to defender combat power ratio. Further modification that accounts for attacker mobility and terrain difficulty provides attacker rate of advance. The calculator evolved through three models into the final prototype which is composed of a cardboard base disk and three successively smaller acetate disks. Logarithmic scales on the circumference of each disk provide the means for taking the ratios. A series of tables on the face of the base disk account for the other factors envolved. Indices on the outer acetate disk provide automatic read out of proper combat power and rate of movement

values after the multiplication has been accomplished. This graphic aid should speed up and simplify combat power and rate of movement assessment as it converts three separate steps of division and two of multiplication into a sequentially combined operation. It brings together in one place three separate tables and eliminates two steps of searching for tabular values.

The necessity for assessing rates of movement of deployed forces during a war game is complemented by the need for calculating the semitactical or administrative movement rates of reinforcing units or logistical columns. FM 101-10 (Part 1) provides a list of aids that simplify the required calculations. In chapter V, a technique, alternate to those of the FM, that makes use of a circular calculator similar to that just discussed is proposed. This calculator, called The March Computor, has a base cardboard disk upon the face of which log scales are inscribed that represent distance and time distance, road space and time length of column, and number of vehicles in column. For daylight moves at a standard fifteen miles per hour or night moves at ten miles per hour, indices are provided on an outer acetate disk which when brought opposite the march distance on the cardboard disk provides a time distance readout. The road space occupied by a column and the time length of a column are dependent on

the number and spacing of vehicles in the column. By using the proper formula in the construction of the calculator and providing an index that falls over a log scale representing the number of vehicles, arrow indicators that point out proper values of road space and time length may be inscribed on the outer acetate disk. This is the basis of construction of the March Computor. Its basic advantage over the aids described in FM 101-10 is that by using a circular construction and log scales, problems that cover a greater range of values may be solved.

Chapter VI takes up war game casualty calculation. Lanchester's classic work on battlefield attrition and modern developments based on both his papers and other data are first discussed. It is shown that his equations are not presently useful in providing a method of casualty assessment for the divisional training war game. Rather a method of converting the daily divisional short term casualty statistics contained in FM 101-10 to hourly battalion task force loss rates is described. These hourly rates which vary for the different type actions given in the FM, are each one taken as a mean value on a normal or bell-shaped curve. A spread of possible hourly casualty rate values may be obtained from the curve if a proper standard deviation is first chosen. This is done and the possible range of values is then combined with random number

theory by fitting the hourly casualty rate distribution to random number blocks. This provides the basis for construction of a circular calculator from which both attacker and defender casualties rates caused by the maneuver units themselves may be selected. It is called the Small Arms Casualty Calculator. In usage, a random number is selected from a table and matched to the type action block of random numbers on the calculator. The proper attacker casualty rate is read on the circumference of the calculator directly above the number selected. As in presently used methodologies, this rate is then multiplied by a proportion factor based on the combat power ratio between attacker and defender to give defender casualties. The advantage of this technique is that it introduces "chance" selection of casualties which over a period of many assessments should match the divisional experience data of FM 101-10. This matching of values would probably not occur after recurring small arms casualty assessment by present methods which simply call for arbitrary selection of hourly rates of between one and three percent.

Present methods of artillery and airstrike casualty assessment in the Leavenworth game require volley by volley or pass by pass assessment based on tabular data. This is quite tedious if a number of battalion volleys or aircraft passes into an area must be measured. Cumulative casualties

that would occur in an area bombarded by a successive number of battalion artillery volleys or aircraft passes may be graphed and transformed by a combination linear and polar plot onto a circular calculator. This is done in the development of an Artillery and Airstrike Calculator. In usage, all that is required is that the casualty percentage inscribed above the proper intersection of a circular line representing number of volleys or number of passes and a graphic line representing cumulative casualty percentage be selected. This casualty percentage represents total casualties among troops in the area hit by the bombardment. To find unit casualty percentage, this figure is multiplied [using a log scale on the outer disk of the calculator] by the percentage of the unit's troop strength located in the effected area. This calculator is located on the back of the small arms calculator and together with it provides a new technique for assessing casualties caused by conventional fires. This technique is felt to be, in the case of small arms assessment, more realistic, and in the case of artillery and airstrike assessment, faster.

Chapter VII reviews these developments by discussing their relationship to the various elements of the divisional training war game. It then describes a test that was designed and conducted to ascertain that the graphic aids developed do in fact achieve the objectives of speeding up, simplifying, or

adding realism to the divisional war game. From the test results, conclusions are drawn that the "tote board" and the Small Arms Casualty Calculator do increase realism; that fair assurance exists that the prototype Combat Power and Rate of Movement Calculator and the Artillery and Airstrike Casualty Calculator would simplify and speed up casualty assessment; and that the March Computor does provide an alternate method of computing march rates.

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ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Lt. Col. Thomas R. Dent, Thesis Monitor, without whose guidance and encouragement this thesis would not have been completed, and to his wife, Virginia, and daughters, Laura, Linda, and Lisa for patiently recognizing the long hours necessarily devoted to this work.

The professional interest and able participation of the author's classmates in the conduct of the test presented in Chapter VII cannot go unrecognized. Particular appreciation is expressed to Col. M. Nikic, Yugoslavia; Lt. Col. J. D. Farrar, Arty; Lt. Col. R. A. J. Dyer, Inf; Maj. C. R. Figard, USMC: Maj. J. E. Hazelwood, Inf; Maj. R. G. Hyde, Arm; Maj. E. A. Peloquin, Arty; Maj. H. J. Thayer, Eng; Maj. J. Luger, Arty; Maj. J. T. Polanski, MP; Maj. G. N. Chomko, AIS; Capt. F. F. Jordan, MSC: and Capt. N. Maarbjerg, Denmark. These officers gave willingly and enthusiastically of their time and efforts to assure the highest possible significance in test results.

Deep appreciation is also expressed to Mrs. Melba N. Neill, who typed the final thesis copy. Her highly efficient typing and detailed knowledge of thesis format were invaluable aids in meeting the final thesis deadline.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

The Manual War Game Problem

A problem in manual war gaming is created by the need for realistic simulation of the battlefield situation opposed by the need for rapid assessment of what occurs as the game progresses. Realism is necessary if optimum training value is to be achieved. But realistic simulation of combat action entails a detailed tracking of all the interrelated events that take place as battle progresses. The detailed assessment of the myriad events is time consuming; becomes tedious; and hence player interest is lost.

Thesis Objective

The objective of this research is to provide, by synthesis of techniques found in current games or by innovation, simpler and more realistic procedures. The findings should be applicable to existing manual methodologies used for instructional war gaming of tactical battles at division level.

Necessary Background

In pursuit of this objective, an understanding of the breadth of war gaming today, its evolution from the past, and its training value, provides an understanding of the nature

of the problem. Such review of war gaming provides a feeling for what should or should not be attempted. Consequently, such understanding must first be developed.

The breadth of war gaming today may be sensed from a few of the variety of definitions of the term itself:-

> War gaming (a) -An operations research technique whereby the various courses of action involved in a problem are subjected to analysis under prescribed rules of play representing actual conditions and employing planning factors which are as realistic as possible.[1]
>
> War game (ESN,J,A,) -A simulation, by whatever means, of a military operation involving two or more opposing forces, conducted, using rules, data and procedures designed to depict an actual or assumed real life situation.[2]
>
> War game, Mil. -A training exercise that imitates war, in which commanders, staffs, and assistants perform war duties, but no troops are used.[3]
>
> War game, Kriegspiel.[4]

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[1]U.S. Department of the Army, Dictionary of United States Army Terms, AR 320-5 (Washington: U.S. Government Printing Office, 19 February 1963), p. 420.

[2]U.S. Department of the Army, Dictionary of United States Army Terms, AR 320-5 (Washington: U.S. Government Printing Office, 23 April 1965), p. 438.
U.S. Department of Defense, Dictionary of United States Military Terms for Joint Usage, JCS Pub 1 (Washington: U.S. Government Printing Office, 1 December 1964), pp. 155 and 261.

[3]Clarence L. Barnhart, (ed, in chief), The American College Dictionary (New York: Random House, 1955), p. 1373.

[4]William Allen Neilson (ed. in chief), Webster's New International Dictionary of the English Language, (2d ed., Springfield, Mass: G. C. Merriam Company, n.d.) p. 2875.

> Kriegspiel . . . A game in which blocks, pins, flags, etc., representing contending forces, guns, etc., are moved about according to rules representing conditions of actual warfare.[5]

> Map maneuver (a) -Exercise in which military operations with opposing sides are conducted on a map, the troops and the military establishments being represented by markers, or symbols, which are moved to represent the maneuvering of the troops on the ground.[6]

> Map exercise-An exercise in which a series of military situations are stated and solved on a map.[7]

Each definition, oriented perhaps to its intended audience, describes a method of simulating warfare. The war game, the map maneuver, and the map exercise with their manifold variations have been devised to analyze concepts and doctrine; equipment, both qualitatively and quantitatively; and to train commanders and staffs for future battles. These methods of sham battle have also become most useful in operations research as analytic tools.

> Operations Research, in its continued application, finds itself turning increasingly to a new research tool; that of operational gaming. Because of the considerable amount of research

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[5]Ibid., p. 1376.

[6]U.S. Department of the Army, Dictionary of United States Army Terms, p. 237.

[7]U.S. Department of Defense, Dictionary of United States Military Terms for Joint Usage, p. 86.

> being done in the military field, particular attention has been directed toward War Gaming.[8]

The advent of the electronic computer and its associated technology is the basis of this expanding usefulness.

> The computers that are used for war gaming are general purpose stored program digital computers. They were not developed for gaming but were designed and constructed in response to the computational and data processing needs of the mid-twentieth century. However, it was recognized that many of the capabilities of digital computers were applicable to war gaming, and as a result, these modern electronic devices were soon employed to not only assist in the conduct of war games, but to play entire games without benefit of human participation.[9]

As to the value of the war game for training, a brief review of war game history and a short survey of current publications quickly note its extensive use in US and foreign military schools and colleges. War games or map maneuvers have been used at Fort Leavenworth for training student officers for more than half a century.[10]

The war game has indeed expanded its bounds. At the turn of the century, it was but a sand table or map exercise.

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[8]John P. Young, History and Bibliography of War Gaming (Bethesda, Md: Operations Research Office, The John Hopkins University, April 1957), p. 1.

[9]U.S. Naval War College, Fundamentals of War Gaming (2d ed.; Newport, Rhode Island: U.S. Naval War College, November, 1961), p. 6-1.

[10]Upon the organization of the Army Staff College of Fort Leavenworth in 1904, the war game was made a part of the course of instruction in that college. Farrand Sayre, Map Maneuvers and Tactical Rides (5th ed.; Springfield, Massachusetts: Springfield Printing and Binding Co., 1911), p. 22.

It was used primarily for training purposes in lieu of the field maneuver. It was an inexpensive and efficient way to train commanders and staffs in the performance of combat duties pertaining to plans and decisions, to operations and controls. Its basic advantage over the field maneuver was that troops who would have to be fed and paid and taken away from their own fundamental training for the maneuver were not used.

The Germans are generally credited with the development of modern war gaming.[11] They have used war gaming extensively and have been most enthusiastic over its value. This enthusiasm permeated even the lower ranks of the German Army well before World War I broke over Europe. For instance, R. Eisenschmidt, a German lieutenant in 1903, wrote in his small volume on the subject: "tactical problems, war games and practice rides form, in connection with exercises with troops, the most effective means for the tactical education of officers."[12] He goes on to suggest that study of troop leading, the correct issue of orders, and their tactical

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[11]U.S. Army Command and General Staff College, War Gaming, ST 105-5-1 (Fort Leavenworth, Kansas: The Field Printing Plant, USAC&GSC, November, 1965), pp. 76, 79, 80-81.

[12]R. Eisenschmidt, The War Game: Suggestions, Experiences, Examples, trans. by Harry Bell, Army Service Schools (Berlin: Ministry of National Defense, 1903), p. 1.

application are the valuable objects of the training game.[13]

Opinions that corroborate the positive value of the war game as a training vehicle are readily found today. Francis J. McHugh, operations research analyst of the staff of the war gaming department of the Naval War College cites a general conclusion of the 1955 War Games Conference at the University of Michigan - "War Gaming is an extremely important educational device for training senior officers. . . possibly the best available in time of peace. . . ."[14]

The enthusiasm generated by the advocates of war gaming as a training vehicle is also marked with controversial opinion as to how the game should be conducted and scored. Historical review of the course of evolution of the war game reveals that this enthusiasm has been checked and dampened continuously. Criticism of the methodologies developed, of the rules of play, and of the assumptions adopted, has been constant. Recognizing the finality of war and the far reaching consequences of its outcome, this criticism had been both necessary and valuable in holding the war game within proper bounds. The basic limitation of the war game is the impossibility of perfect simulation

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[13] Ibid., p. 4.

[14] U.S. Naval War College, Fundamentals of War Gaming, pp. 1-21.

of the real battlefield. Models and rules in any degree of complexity have not been found that fully describe all the parameters and variabilities that enter into combat.

Many efforts have been made to codify procedural rules and prescribe mathematical methods of scoring that accurately simulate the battlefield. However, as these rules and procedures more closely approached true battle conditions and accounted for an ever greater number of the influences on the course of battle, their complexity increased. The very volume of rules and procedures generated, in turn frustrated player capabilities to conduct the game.

An American, Colonel Livermore, who was a recognized authority on war game methodology at the turn of the century, produced a very detailed set of rules. His rules enabled players to compute casualties in infantry and cavalry actions. They enabled players to measure firepower, the effects of terrain, fortifications, troop training, morale and a number of other factors. In describing his own rigid set of rules he recognized the tediousness of play. He indicated that minute records had to be kept to account for company, platoon, and squad losses. He required evaluation of march fatigue and disorganization resulting from close combat. Such detailed records required computation and evaluation each two minute period of action, and in

important cases, resolution of game progress occurred each quarter minute. He claimed perfect representation of a small unit action by this methodology. In turn, he admitted a number of assistants were necessary to perform the required computations, and that the game became very tedious when more than a few companies were involved.[15]

Farrand Sayre, another early writer, commented on Livermore's system.

> It may be confidently stated that Colonel Livermore's system is the best of its class; but it cannot be readily and intelligently used by anyone who is not a mathematician, and it requires, in order to be able to use it readily, an amount of special instruction, study and practice about equivalent to that necessary to acquire a speaking knowledge of a foreign language.[16]

Criticism such as Sayre published and the very nature of the rigid formal play devised by such war gamers as Livermore caused a schism in war gaming ranks. Philosophy of play was resolved into "rigid" and "free" forms. The "rigid" form prescribed sets of rules which were rigidly adhered to throughout the course of play. The detail and complexity of these rules varied with the different games depending on the purpose of the game being played. The

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[15]W. R. Livermore, The American Kriegspiel; A Game for Practicing the Art of War Upon a Topographical Map. (Boston: Houghton Mifflin Co., n.d.), p. 4.

[16]Farrand Sayre, p. 22.

"free" form relied on fewer or no rules and was almost wholly dependent upon an umpire team to make judgments based upon the battle experience of the umpire staff.

Proponents of both the "free" and "rigid" forms clearly express their positions. Eisenschmidt, quoted earlier, advocated the "free" form in saying:-

> Heretofore the director of a war game worked with a complicated apparatus of dice tables of losses and compasses. We would recommend to do away totally with the table of losses and with the dice as much as possible. When a decision cannot be justified by the situation and by the acknowledged tactical knowledge of the director, then the use of tables of losses and dice will be of little benefit and will only increase the tediousness of the game.[17]

Livermore countered that it would be fine to eliminate rigid rules and rely on the judgment of an experienced chief umpire. He cited that the necessary qualifications of such a man would not only include long familiarity with war gaming, but would also require extended experience in leading troops in action. These qualifications were necessary to judge correctly the possible result of an action without making calculations or referring to a set of rules. And he stated that: ". . . such men are not always available for umpires. . . ."[18]

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[17]R. Eisenschmidt, p. 16.

[18]Livermore, p. 4.

Even the name "war game" has been controversial. It is generally deemed appropriate for rigid analytical play, but it is not desired for use with the free form, wherein the term "map maneuver" is preferred.

Gradually, criticism of the various forms of war gaming ebbed. Active espousal of either free or rigid play diminished. The various advocates came to realize that there was merit in each of the forms. Likewise there were limitations.

The great value of the free form is focused in the speed and economy of the game.

The great value of the rigid form is the close approximation of real battle conditions.

The limitations of the free form are:

(1) The limited availability of umpire teams that are both battle-wise in the many areas of modern combat and at the same time well versed in the conduct of war games.

(2) The possibility or probability of a conscious or unconscious weighted scoring in favor of one combat element by umpires of branch, service, or personal prejudice.

(3) The general inability of insuring uniform conditions of play.

The basic limitation of the rigid form, speed of play, is still a formidable disadvantage. This disadvantage

is expressed by Colonel E. S. Maloney. He wrote, while associated with the Marine Corps War Game Group at Quantico, that upwards to several days might be required to analyze the results of a single half hour or hour of battle. This depended on game detail in the rigid, manually played analytical game.[19]

To this disadvantage must be added that of increased cost for larger umpire staffs if hand played. The staffs must include personnel to assess casualties, equipment damage, movement rates, and the other variables included in the set of rules.

Although the merit and demerit of each form is now recognized, resolution of the manual war game problem cited is only apparent, in that no one game provides both optimum realism and speedy play. It is doubtful that a perfect methodology will be found in the foreseeable future.

Limitations

By confining the scope of interest to the bounds of the manual division level training game and making a detailed examination of current war game procedures, improved methodology may accrue. Attention will focus on methods of play used at the United States Army Command and General

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[19]E. S. Maloney, "Modern War Gaming, State of the Art," Marine Corps Gazette, (November, 1960), p. 12.

Staff College. A synthesis or origination of new techniques that simplify, speed up, increase training benefits, or reduce requirements for players and umpire personnel may evolve from a comparison of methodologies used at USAC&GSC with those employed elsewhere. War gaming can be strengthened if techniques can be found that lead to a confluence of the realistic rigid game and the fast free game.

On the other hand, as a tremendous library of paper about war gaming already exists, there would be no profit in rehashing past debate on the merits of one existant form or methodology over those of another. Nor will change be proposed for the sake of change. For instance, in the past twenty years, extensive evolution in nuclear weapons techniques has taken place. Today, official Army doctrine is well established in the 101-31 series of field manuals. Any changes proposed for computing nuclear casualties or assessing damage in war gaming that differ from established procedures would but counter the objective of increasing training benefits. Therefore this will be avoided.

Now with the scope of the war game to be investigated generally defined, the first step is to examine current games and methodologies. Useful rules and methods of play may be gleaned from them to synthesize into the hand played divisional game.

CHAPTER II

EVOLUTION OF THE GAME STRUCTURE

Existant Games

A number of divisional, higher and lower unit games exist. A synopsis of the experience gained in formulating and playing a few of these can yield valuable insight into the complexity of the problem at hand. They typically describe the broad range of today's gaming and are pertinent to the solution of the present problem. They provide both a basic understanding of some of the dynamics envolved in game play and a springboard to launch the search for improvement.

The methodologies contained in various manuals provide a selection of rules. They show the variety of factors that must be considered. While the methodology prescribed in the Command and General Staff College manual is used in the game being modified, examination of other methodologies aid in selecting factors appropriate for modification. The games will be considered first, and the methodologies second.

The games selected for synopsis are FAME, TACSPIEL, FOE and INDIGO. FAME is selected because it is a current hand-played divisional game. Although its objective is

analytical analysis of current and future divisional concepts,[1] many of its problems are common to the training game. TACSPIEL is another manual game.[2] It points up the loss in speed of play under conditions of high resolution, and provides a useful check on the completeness of this research because of its great detail. It also describes a method for scoring firepower. FOE complements TACSPIEL and in fact was developed for use with TACSPIEL.[3] The introduction of a "velocity factor" that represents increasing intensity of battle as opposing units close is an innovation that adds considerably to realism. The final game, INDIGO, is a combat intelligence war game.[4] Realistic simulation of battle intelligence is very difficult to depict in war gaming. INDIGO explores this problem in detail.

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[1]Richard E. Zimmerman et al., FAME a War Game for Testing Division Organizations (Bethesda, Maryland: The Operations Research Office, The John Hopkins University, December, 1960).

[2]Edward W. Girard et al., TACSPIEL: War Game Procedures and Rules of Play (Bethesda, Maryland: Research Analysis Corporation, November, 1963), p. 1.

[3]Dorothy Kneeland Clark, Lewis E. Keeger, and William W. Walton, Jr., FOE: A Model Representing Company Action (Bethesda, Maryland: Operations Research Office, The John Hopkins University, December, 1960).

[4]James G. Christianson et al., War Gaming of Division Combat Surveillance: INDIGO, Technical Memorandum RAC(ORO)-T-405 (Bethesda, Maryland: Research Analysis Corporation, January, 1962), p. 65.

FAME

The Operations Research Office (ORO) of the John Hopkins University developed the FAME War game. ORO states that the game is quite complete in its content, although admittedly not a panacea for realistic simulation problems. FAME development covered the efforts of many persons over a two year period.

The FAME problem was construction of a manual division level game that would test future division concepts with the major threats of limited war. The designer's objective was to properly tailor play into problematical or controversial areas that had been judged critical in respect to these new concepts. The game was devised to provide a scheme for studying the interactions of the combat arms and their battlefield support. It addressed itself to problems that might be encountered all the way down to company level in particular cases.

Bodies of rules were developed that encompassed the mathematics describing a combat model, an atomic model, an air tactical model, an intelligence model, a logistics model, and a maneuver model.

Standard practices currently in vogue were used. That is, there was a red and a blue force and a controller team. Map boards, maps, pins and cardboard unit indicators were used.

The game was dynamic in the sense that the mathematical models underwent revision and evolution after each critique of seven trial runs. Additional revision customarily took place in the intervals between game series.

The ORO people concluded that their models and rules were generally satisfactory, except for the combat model. In this model, time comparison of the rates of ammunition expenditure to when targets became available; the interrelationship of rates of advance and attainment of objectives weighed against firepower, casualties, terrain difficulties, and surprise defied apt description in the attempt at compression (aggregation) into simple mathematical models. The "multiple hat" problem was recognized; that is allowing the division commander to move all companies of the division without restriction. Serious distortions of the command function occurred as a consequence, because the commander then perfectly relayed his intentions down the chain of command and the "people" problem was thereby eliminated.

FAME wrestled with time and space resolution. Intuitively one hour in time and one kilometer in space was used. Similarly, it was recognized that the game could not be structured critical event to critical event. Consequently, the rules had to be formulated so that they would satisfactorily describe events aggregated over the chosen time

intervals. The outcome was agreement that internal consistency of all rules would be based on: (1) smallest unit played, (2) space resolution cited, (3) time resolution cited, and (4) player responsibility.

Considerable thought was devoted to resolving the difficulties inherent to this chosen internal consistency. Primarily, level of play had to address itself to the objectives of each game series. Were new battalion organizations being tested? Were new weapon characteristics envolved? Were different T O & E's being compared? FAME dealt with difficulties at battalion level when the battalions themselves were broken down into task teams such as attaching a company of tanks to an infantry battalion and detaching a company of infantry.

Realistic representation of artillery support was troublesome. Such questions as properly representing direct support artillery as opposed to reinforcing artillery or general support-reinforcing artillery were weighed. The solution in FAME was to represent supporting units at one echelon lower than the supported unit. It seemed a natural choice for artillery because of U. S. artillery doctrine.

Space resolution was resolved by assuming equal equipment and personnel densities within the areas occupied by the smallest units in the organizational aggregations. General activity description within the area during

specified game time intervals was deemed sufficient. That is, were the units attacking or defending; being bombed or strafed; or were they relatively dormant. A general terrain classification was possible. Intelligence consistent with acquisition means was provided.

In turn, time resolution was dependent on the tactical events and space interval aggregate. Time had to be compatible with game objectives. It had to be compatible with the mechanical techniques chosen and with the players available.

Principle player responsibility was, perhaps, easiest to deal with. Obviously, army field service regulations had to be followed to lend credence to results. Procedural rules and assessments could not be so complex as to hide the conduct of the battle from the force commander's view. But in turn, command and staff reaction times had to be realistic.

Albeit the objective of FAME was "analytic" rather than "educational", similar design considerations and problem areas plague training games.

TACSPIEL

TACSPIEL is another divisional war game. Study of TACSPIEL reveals that it is an extremely high resolution war game based on statistical probabilities. High resolution is very detailed examination of the interaction of component

influences. As aggregation increases, resolution decreases. In the words of the TACSPIEL authors, it is:-

> . . . a two-sided, free-play analytic, rigidly-assessed, manually-operated war game at the division level with qualified military commanders on each side. The organizations, equipments, situations, forces and missions assigned are selected to accomplish the research objectives of any given play or series of plays, as are the resolution of details of action.
>
> The approach is to operate a basic tactical structure of movement, contact, and battle between opposing units, into which detailed simulations of real combat events that are to be studied can be introduced . . . . Research questions of interest are used to develop simulation models, rules of play, and assessment procedures that insure that the events pertinent to the problems necessarily do occur in the course of play, and that the desired data for analysis are taken.
>
> The game is conducted under rules that are as detailed as years of experience and present ingenuity can make them . . . .[5]

TACSPIEL is of such high resolution that one-half hour of game time may take hours or even several days to assess. This is quite natural for a research game. Although, it might seem ends opposed to our purpose here, the game is useful for several reasons. First, the very fact of its high resolution means that if an influence to the outcome of a tactical battle exists; it most probably will be dealt with in TACSPIEL. Therefore, the game provides a useful check on the completeness and depth of this research.

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[5]Edward W. Girard et al., p. 1.

Secondly, TACSPIEL assessment is almost wholly based on statistical probabilities. Consequently, it provides a basis for many aggregations and a sense of their correctness.

Of particular interest in TACSPIEL was the logic used in developing the number values for individual and crew served weapons which total yielded the firepower score of various maneuver elements.[6]

First, the numbers and types of weapons available to rifle companies and an apportioned share of the firepower from the weapons platoon of the headquarters company was totaled. Next antipersonnel effectiveness of the various weapons available was calculated. To do this, the weapons were grouped into three classes: (1) rifles, (2) automatic rifles and machine-guns, (3) mortars and grenade launchers. Arbitrary assignment of a value of one to each rifle and a value of three to each machine-gun or automatic rifle was made. Mortar evaluation was made by historical research into wound statistics from World War II and the Korean conflict. Analysis of British and American wound statistics showed that mortars caused one and one-half times the casualties caused by rifles and machine-guns. After the number of machine-guns and automatic rifles available to a Germany company of World War II were totaled and compared to the number of mortars

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[6] Ibid., pp. BB-1 to BB-7.

available; it followed that each mortar had the casualty producing value of approximately forty rifles. The value forty was then assigned to the mortar. Similarly, firepower scores for other weapons were deduced.

Such methodology may be criticized. Its weakness is evident. First, values attributed to the machine-gun, rifle, and grenade launcher are arbitrary. Secondly, the correlation of weapons numbers by type to wound statistics is weak. The reason for this is simply that statistics are not available that allow a more credible assessment. On the other hand, more than mere guesswork went into the evaluation and assignment of weapon value. Weaknesses of this type are common to war game methodologies and to war game rules and procedures. The war game players and designers must be aware of these weaknesses so that they might properly judge the credibility of war game results.

FOE

FOE, the third game, models close combat with conventional weapons at company level. Its detailed or very high resolution makes it most suitable for use with a digital computer. If more than a few weapons are envolved, hand-playing the game is very tedious. About twenty minutes of computation are required to judge one time increment of combat when six weapon types per side are included.

Though designed for use with TACSPIEL, the general concept of the model is flexible enough for adaption to higher level play. The introduction of a "velocity factor" in FOE is significant. This innovation permits the build up of small arms and crew served weapons fire as opposing units close in battle. It accounts for the suppressive effects of this fire as the units approach each other. FOE's authors state that this suppressive effect is often disregarded in combat models even though it is acknowledged as a major if not the major effect of fire on the battlefield. Other models, in contrast to reality, have begun with forces fully engaged, and applied attrition as a time function. FOE, on the other hand, starts with zero combatants and builds up intensity of battle proportionately to closing velocities. The fire of each available weapon type is introduced only as it comes into range. FOE makes two assumptions essential to the model: (1) that company size forces are relatively homogeneous and therefore uniform distribution of men and weapons over an area exists and (2) that since historical evidence points to the majority of artillery, mortar, machine gun and rifle fire being directed at suspected target areas rather than specific targets, all such fire is area fire.[7]

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[7]Dorothy Kneeland Clark, Lewis E. Keefer and William W. Walton, Jr., pp. 5-7.

As shall be shown in chapter three, it is possible to introduce FOE's "velocity factor" into game structure with relatively little additional complication. By a method of rapid assessment, the game is not materially slowed down. The assumption of homogeneity of a company size force will also be used, and the area fire assumption too will have its influence.

INDIGO

INDIGO[8] is a hand-played combat-intelligence war game. Most of its contents are classified. Therefore details of play will not be discussed here. It is rigidly structured, and of very high resolution in intelligence play. The methodology of the intelligence play is quite similar to that used in other hand-played divisional games. For instance, it uses zonal concepts to categorize intelligence acquisition probabilities. The major components of the INDIGO information acquisition system are unclassified, and consequently may be used as necessary to formulate G2 activity.

Other Games and Methodologies

Many other war games are being played today. Some of these are referenced in the bibliography. It would be of relatively little additional value to include these as their

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[8]James G. Christianson et al., p. 65.

methodologies are similar to the ones described. Therefore the discussion of current games will be completed with the mention of one other. This is the division-level game played at the Command and General Staff College. The game is played by regular course students in the April-May time frame of the college year. As stated, it is toward this game that efforts of simplification and the provision of additional realism are directed. The USAC&GSC war gaming manual provides the objective and methodology of this game.[9]

From this and other manuals, an overview of the game type with which we are dealing can be developed. This serves to channel the research effort. Additionally, the manuals help place the elements that should be considered in the game into categories.

Other manuals available include those of the Naval War College,[10] the Army War College,[11] the Combat

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[9]U.S. Army Command and General Staff College, War Gaming, ST 105-5-1 (Fort Leavenworth, Kansas: The Field Printing Plant, USAC&GSC, November, 1965).

[10]U.S. Naval War College, Fundamentals of War Gaming (2d ed.; Newport, Rhode Island: U.S. Naval War College, November, 1961).

[11]U.S. Army War College, War Games Control (Carlisle Barracks, Pennsylvania: U.S. Army War College, November 1, 1961).

Operations Research Group,[12] and the USCONARC War Gaming Handbook.[13]

The Naval War College Manual provides an excellent overview of war game classifications, which is shown as Table I.

TABLE I

GENERAL PURPOSE	Educational		Analytical	
SCOPE AND LEVEL	Range of Command Levels	Military Services Involved	Type of Operations	Area of Operations
NUMBER OF SIDES	1	2	N	
AMOUNT OF INTELLIGENCE	Open		Closed	
METHOD OF EVALUATION	Free	Rigid	Free-Rigid	
BASIC SIMULATION TECHNIQUES	Manual	Machine	Computer	

Figure 2[14]

[14]The United States Naval War College, Fundamentals of War Gaming, pp. 1-11.

[12]War Gaming Department, Combat Operations Research Group, Combat Developments Section, Continental Army Command, War Gaming Manual (Fort Monroe, Virginia: Technical Operations, Inc. and Combat Developments Section, Headquarters, Continental Army Command, March 1, 1956).

[13]U.S. Continental Army Command, War Gaming Handbook (Fort Monroe, Virginia: Headquarters, U.S. Continental Army Command, September, 1961).

Table I[15] shows that a number of combinations of methodologies, scopes, and type games may be formed. In formulating a war game, the game objective is the first thing defined. As stated in the Navy Manual:-

> In order to achieve one of the general purposes of any practical extent, it is desirable to narrow the objective area, to conduct a game to provide decision-making experience at one or more specified levels and types of command, or to provide information and data concerning the employment of specific forces or weapons systems, test an organization or distribution system or evaluate a type of operation or a tactical doctrine. These particular reasons, whatever they might be, are the specific purposes for conducting the game. They should be clearly defined.[16]

After the objective of the game has been defined, the appropriate range of command levels, military services played, type of operation conducted and amount of intelligence to be made available may be chosen. As well, the most appropriate method of evaluation; free, rigid, or a free-rigid combination, may be selected. Basic simulation

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[15]Some explanation of the less obvious features of the foregoing table appear appropriate. In referring to amount of intelligence **available** in a war game, "open" means that each side has complete knowledge of the plans and operations of its opponent. "Closed" means information available is less complete, that opponents receive only that intelligence that would probably be available in the real-world situation being simulated. Ibid., pp. 1-14.

A machine played game is similar to the computer game in most respects. Machine, in the table, refers to a special purpose devise specifically designed to simulate military operations. This equipment is something other than a general purpose digital computer. Ibid., pp. 1-18.

[16]Ibid., pp. 1-10.

techniques may be more restrictive. A computerized game is only possible when a computer is available. Finally, as to general purpose:-

> When the primary purpose of a war game is to provide the players with decision-making experience, the game is known as an "educational" type game. When a simulation is conducted in an attempt to obtain information and data that will help the responsible commander to make decisions, the game is referred to as an "analytical" type game . . . educational games have analytic overtones; analytical games, educational connotations.[17]

The statement describing overlap in purpose between the analytical and the educational game should be noted. It provides reason for exploring analytical game methodologies for application to the training game. In fact, there is a double benefit if analytical methodologies can be applied. The training game played with the historical objectives of practice in issuing and executing orders, studying the combined arms, and so forth, has a dimension added in that student officers learn war gaming itself. And with the war gaming technique finding increasing application in combat development, officers assigned staff research positions will be well equipped, having learned analytical techniques common to the training game.

If Table I is followed, the structure of the training game which has interest here may be derived. It is the

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[17] Ibid., pp. 1-12.

division battle in which ground and air elements are envolved. Realistic or "closed" intelligence is appropriate. The method of evaluation is free-rigid since a confluence of techniques is sought, and interest is confined to the manual game.

The specific objective of this divisional training game is that of the Command and General Staff College. Desired is a game that will:-

> Insure consistency of methods, procedural rules, and assessment techniques . . . for instruction in . . . applicatory exercises at the U.S. Army Command and General Staff College.[18]

Game Elements

Now to describe the real world divisional battle in this training game would require consideration of all the parameters that influence that battle. It is obvious immediately that this is quite impossible in a classroom. Consequently, something less must be sought. As a starting point what is sought is a tabulation that categorizes the major parameters that influence division operations. A rationale must evolve then from that tabulation that provides a logic for the aggregations, the methodology, procedural rules, and assessment techniques that are chosen.

Further review of the war gaming manuals cited, aids organization of the many considerations that should be a part

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[18]U.S. Army Command and General Staff College, War Gaming, p. 9.

of the division game. Only those considerations that normally influence the commander and his staff in preparing estimates and plans and reaching decisions should be included. They must also have a definite training value.

The division battle is conducted by troop units in terms of fire and maneuver. These are the elements that concern the commander and his staff. The troop units may be classed as (1) combat, (2) combat support, (3) and combat service support. Maneuver considerations may be organized as (1) combat power, (2) mobility, (3) terrain, (4) and weather. Firepower may be grouped into that integral to the maneuver units and into supporting fire. These are the basic elements of the game structure. However, a number of other things must also be dealt with to make the war game viable as a training vehicle. Most of these are to some degree derivative of fire and maneuver. Of those that are, the basic reason for listing them separately is that they are more easily handled in the game as separate entities.

Table II catagorizes the elements of the game into the general order in which they receive consideration in subsequent chapters.

The participants of the game use the methodology and rules of play developed for dealing with the elements shown in Table II.

Within the groups shown, and between groups, there are interrelationships between elements. Therefore, it is not usually appropriate during game play to consider them one by one in order shown. However, as shall be shown a logical process can be established to deal with them.

TABLE II

ELEMENTS OF THE DIVISIONAL GAME

<table>
<tr><td colspan="3">UNITS</td></tr>
<tr><td>COMBAT</td><td colspan="2">COMBAT SUPPORT</td><td>COMBAT SERVICE SUPPORT</td></tr>
<tr><td colspan="2">Troop List
Strengths
a) initial
b) casualties
c) replacements
Firepower
Unit effectiveness</td><td colspan="2">Troop List
Strengths
a) initial
b) casualties
c) replacements
Unit effectiveness</td></tr>
<tr><td colspan="4">MANEUVER</td></tr>
<tr><td colspan="4">Combat Power)
mobility)
terrain) Rate of movement
weather)</td></tr>
<tr><td colspan="4">FIRES</td></tr>
<tr><td colspan="2">Integral</td><td colspan="2">Supporting</td></tr>
<tr><td colspan="2">(firepower score)</td><td colspan="2">Direct Support Artillery
other arty) conventional
air support) chemical
missiles) biological
Nuclear</td></tr>
<tr><td colspan="4">Air Defense
Barriers and Obstacles
Communications
Fortifications
Intelligence</td></tr>
</table>

In the first category of Table II are the troop units. Of these, the combat units are the basic elements of the divisional game. Criteria must be established to measure their effective combat power, and from that measurement, determine maneuver rates, which, based on experience are realistic and therefore allowable. This is the order of business for Chapter III and Chapter IV.

CHAPTER III

FIREPOWER AS A MEASURE OF COMBAT POWER

Basic Considerations

The basic wherewithal to fight the division battle is contained in the maneuver battalions, the infantry and the armored forces. Consequently, a war game needs some means to measure the effectiveness of the fire and maneuver of these units. This means should provide a consistent and impartial way to judge success and failure. This means should be appropriately realistic. Maximum realism would obtain, in the training game, if the probable action of each soldier engaged in the war game battle was simulated and his effectiveness with his rifle, machine gun, mortar, tank or artillery piece measured. As has been pointed out, realism in a game depends, to a great degree, on degree of resolution. But the higher the resolution applied to a game, the more complex it becomes. In turn, complexity slows the game down; so that, as in the high resolution game, TACSPIEL, it might take hours or even days to assess one-half hour of game time.[1] Resolution in the divisional

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[1]Supra, p. 18.

training game to the point of assessing the actions of individual soldiers is then hardly desirable. Assessment time must be kept to a minimum not only to keep the game moving and hold student interest up, but also because instructional time itself is at a premium.

Consequently, two problems can be identified in searching for a means to measure the effectiveness of the maneuver battalions. The best way to measure the combat power of the units is one of the problems. The second is to find an appropriate balance between high resolution which affords realism and simplicity which affords speed. This is the same old problem that plagued the earlier war gamers, Eisenschmidt and Livermore.

These two problems may be considered separately. Consider the measure of combat power first.

A time honored method of judging combat power is based on unit strength and unit firepower. It was used by Colonel Livermore[2] in his game. It is used today in games played at the Command and General Staff College.[3]

W. R. Livermore, The American Kriegspiel: A Game for Practicing the Art of War (Boston: W. B. Clarke Co., 1898).

U.S. Army Command and General Staff College, War Gaming, pp. 19, 44.

Firepower

One way to measure unit firepower is to total the TO&E weapons of a unit. Each weapon is valued at one or more points based on its type. The number of weapons organic to a unit by type times point score produces unit firepower. Since soldiers man these weapons, this firepower score is modified both initially and at predetermined intervals as the battle progresses to account for the degradation in capability within units at less than full complement.

The method normally used is to reduce the firepower score by the ratio of assigned strength to authorized strength. This is nothing more than multiplying unit firepower score by the per cent of authorized strength that the unit at the moment enjoys. At the beginning of an engagement the actual strength of a unit may be ninety per cent authorized strength. Subsequently, as casualties occur, actual strength may be reduced to eighty per cent, then to seventy per cent and so forth. This attrition causes a degradation in firepower which must be accounted for in the war game.

This method of judging unit effectiveness is straight forward and easy to deal with, but criticism is warranted since such intrinsic qualities of unit effectiveness (and

hence combat power) as state of training, esprit, morale, and leadership are not included in the measurement.

Again, today's modernized infantry and armored units contain a wealth of infrared devices and radars of various type not available a few years ago. These devices have certainly increased the fighting ability of these units by increasing their ability to find and pinpoint targets at greater ranges, at night, and during periods of reduced visibility. However, their effect is not accountable in the aforementioned firepower tabulation.

These weaknesses must be pointed out; because if unit effectiveness is based solely on unit strength and unit firepower in the free-rigid methodology of this game, the responsible umpire must judge the influence of these factors and degrade or upgrade the firepower scores accordingly. If opposing red and blue units are judged equal in morale, state of training, and esprit; if they are rated as equal in leadership; and if they are of equivalent electronic sophistication, these additional effectiveness factors tend to cancel out. The method of basing effectiveness solely on firepower and strength is then quite credible.

Suffice to say that the lack of a rigorous mathematical formula to measure the intrinsic qualities cited and the burden of additional numerical complexity that would be

introduced by scoring electronic devices and other new equipment leads to basing effectiveness on firepower and strength alone.

Selecting these criteria then, attention may be turned to the second problem. That is, at what level should firepower scores be computed?

Level of Aggregation

For the divisional game, there is a precedence. That is, the division commander and his staff concern themselves with visualizing the activities of the command two levels down. In formulating attack and defense plans, the G-3 normally visualizes attack formations comprised of battalions or battalion task forces. He visualizes battalion implacements in defensive situations. It logically follows then, that aggregation of firepower at battalion level would be appropriate for the division game. The game objective is training for the division commander and his staff. Choice of the battalion as the unit of firepower aggregation is natural. It conforms to training doctrine.

This is corroborated by Col. E. S. Maloney as part of the Marine Corps' experience in their war games. He wrote in the Marine Corps Gazette: -

> The level of detail to be played will, of course, be determined by the size of the forces involved. As more details are included, the play of the game slows down sharply. Experience has shown that an optimum level appears to be the representation of

> the senior command level on each side plus the next two subordinate echelons of command. Thus a division-size force would be physically displayed only down to battalions, with some exceptions in the case of specialized and technical units. Below the command level shown by symbols or markers, the disposition and actions of smaller units are assumed to be in accordance with doctrine and SOP's.[4]

A final advantage of this choice of aggregation is that the umpire/control team need only account for eleven or twelve units in their maneuver computations and judgments.

However, there is a rub. This is the concept of tailored forces. It is standard practice at almost all levels of command in the American army today to tailor forces to best accomplish the mission at hand. Within ROAD brigades, tank, infantry, and mechanized companies are cross-assigned to form battalion task forces. These battalion task forces invariably compose the brigade maneuver units. Consequently, should aggregation of firepower at battalion level be chosen, it would be either awkward or difficult to depict this cross-assignment, and loss of realism would result. Even though the division commander and his staff do not consider battalion task force composition, tailoring normally takes place within the brigades.

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[4]E. S. Maloney, p. 12.

If compositions vary, then can it be realistically assumed, as Colonel Maloney suggests, that the dispositions and actions of smaller units, that is battalions, conform to doctrine and SOP without accounting for variation in composition?

This question may be avoided by aggregating at company level. But should this be done, the accounting problem is increased tremendously. Assuming four companies to each maneuver battalion,[5] and eleven or twelve maneuver battalions within the division, the actions of forty four to forty eight companies would have to be tracked. The resulting loss of speed and the increase in umpire and control personnel necessary to accomplish this accounting task is also contrary to the purpose of simplifying the divisional training game.

Fortunately, a methodology can be introduced that solves the battalion tailoring problem.

It appears that this can be done without appreciably decreasing speed of play or increasing the size of the umpire/control staff. This procedure is simply to compute firepower for company size units and to aggregate this firepower into battalion task forces in accordance with brigade troop lists in a visual display.

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[5]U.S. Army Command and General Staff College, Reference Book: The Division, RB 61-1 (Fort Leavenworth, Kansas: The Field Printing Plant, July 1, 1965), pp. 192, 206, 220.

Firepower Cards and the Brigade Tote Board

Since the Fort Leavenworth divisional war game is of primary concern, the composition of maneuver companies is taken from the Command and General Staff College reference book, "The Division" (RB 61-1).[6] Unit strengths and weaponry are listed in this manual.

Firepower point values could be developed for use with the type weapons in a manner similar to that used in the TACSPIEL game which was discussed in Chapter II. However, this would be a long and tedious task of relatively little profit for the following reasons. First, the TACSPIEL method is open to criticism because of the weak correlations between factors used in its development. Secondly, it has been pointed out that the reason for this weak correlation was that no better data existed. Finally, there is available a complete set of type weapon point scores in FM 105-5, "Maneuver Control", Appendix V, Table IX.[7] Although no rationale for the genesis of these scores is given, this is an official publication. It must be assumed that these scores were generated from experience. On this basis, these point values are chosen for use with the weapons listed in

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[6] Ibid., pp. 104-117, 193-230.

[7] U.S. Department of the Army, Maneuver Control, FM 105-5, (Washington: U.S. Government Printing Office, April, 1964), p. 136.

RB 61-1, Tables VII thru XVI of appendix I show the firepower scores for the maneuver companies. It may be also noted from the field manual and from these tables, that the firepower scores vary at different ranges. This is to be expected since the effective ranges of the different weapons vary. Generally, there is a decrease in unit firepower score as ranges increase.

This leads to a second deference to realism that is well served by electing to compute firepower scores at company level and then aggregating these for battalion task forces. By accepting a general homogeneity of distribution of soldiers and weapons within an area at company level as was done in the FOE War Game, realistic echelonment of companies within the battalion task force is facilitated in regard to firepower assessment.

For instance, the heavy weapons platoon of the infantry battalion's headquarters and headquarters company provides the rifle companies fire support by maneuvering at some distance behind those companies. Similarly, the battalion task force commander's reserve is behind the forward companies. It is more realistic to measure the firepower contribution of these elements from their relative position within the task force, than to measure the aggregated firepower of the battalion at one range which is currently done.

This consideration of location within the battalion task force is facilitated by producing cards of a standard format that reflect company firepower variation with range. A card for each type maneuver unit is found in the jacket of appendix VIII. At the top of the card, the type unit is printed. On the upper left margin for easy reference, the authorized strength is given. Midway down the card is a range scale that is used to position the card in a visual display. The card is positioned an estimated distance in hundreds of meters behind the forward edge of the battle area (FEBA), that best corresponds to the maneuver unit's actual center of mass position within the battalion task force. The firepower computer who will have the task of placing these cards in the visual display must use judgment based on his knowledge of battalion task force tactics to arrange his internal task force organization properly. He must give the internal elements of the task force depth corresponding to standard doctrine. At the bottom of the card, a second scale reflects the variation in firepower with range. Each type card is color coded for easy unit identification. The cards were produced from the firepower data given in tables VII thru XVI of appendix I.

These cards would be produced prior to a divisional war game. They would be distributed to the personnel

responsible for firepower computation in sufficient quantity to allow the formation of battalion task forces responsive to the desires of the commander concerned. These battalion task forces in turn would be grouped into brigade organizations that reflect the division organization for combat. This groupment takes place on a visual display board. This display board could be referred to as a brigade tote board. It is a heavy paper or composition board containing in column sufficient clear acetate sleeves to house all the required maneuver company cards.

At the beginning of the war game, the firepower computer forms battalion task organizations on the tote board using the center index of the cards to line them up in accordance with company position within the battalion. (The center index distances chosen are aligned with the upper left index of the tote board.) Maneuver during the game is followed at battalion task force level. Therefore, initially and at each game interval, the designated firepower computer on the control staff must total battalion firepower scores depending upon engagement range between opposing forces. He does this, after arranging the cards in depth, starting at the range scale at the top of the tote board. Choosing the appropriate range between units, he reads down the column at that range. Normally each battalion will contain

four companies. Therefore this addition can be done manually quite rapidly. Additional speed in computation may be attained if a small adding machine is made available to the firepower computer.

This sum represents the firepower of the task force at the selected engagement range. However, it is the true firepower score of the task force only if the task force is at authorized (full) strength. Therefore, it might be referred to as a firepower "raw score". The fact that this "raw score" is not the true firepower score of a task force at less than full strength need not concern the firepower computer. As will be shown in chapter IV, firepower "raw scores" taken from the tote boards [each side would have one] are properly reduced to account for attrition and for units at less than full strength by using another graphic aid in another set of computations.[8]

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[8]In the course of a division level game, from the onset of play until the critical objective is seized or the enemy repulsed, it is doubtful that battalion task organizations will be changed. Consequently, most of the work faced by the firepower computer is setting up the battalion task organizations called for in the division operations order. As stated, these task organizations will probably not change, but should some special situation arise, whereby he is required to reconstitute a battalion task force from other companies or add additional companies, he must be cautious.

Caution is required so that he, in conjuction with the control or rate of movement computer, may properly account for their unit strength. For instance, should a fresh rifle company at authorized strength be attached to a task force that has been heavily engaged for several hours and

Category I Artillery Aggregation

One other element of battalion task force firepower needs to be considered. This is that additional firepower provided by direct support and reinforcing artillery. Other artillery such as general support is considered separately for reasons which will be developed. Normally division artillery is so alloted that each frontline attacking or defending brigade enjoys the immediate fires of one direct support artillery battalion. In the Leavenworth type ROAD infantry division this amounts to eighteen tubes of 105 howitzer. In the mechanized and armored divisions, there

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which has been reduced to eighty five per cent strength, a new battalion percentage strength must be computed to avoid a disparity. This would be done by computing present company strengths. The authorized company strength is found on the upper left margin of each card. These figures are added for the original battalion task force and multiplied by the present eighty five per cent strength. To this last figure is added the present strength of the new rifle company. This total new strength divided by task force authorized strength is the new task force percentage strength figure that is carried forward. The task force authorized strength is simply the sum of the company authorized strengths.

Should a new task force be formed from elements of other task forces of different aggregated strengths, present company strengths are determined, added, and divided by the total authorized strength to find the total task force percentage strength. These computations illustrate the use of the authorized strength figures on the firepower cards. They are not directly related to the "raw score" firepower computation which are computed for a new or reconstituted task force as previously illustrated. As stated, actual firepower of the task force which accounts for attrition or other variance from authorized strength is computed in another series of computations.

are eighteen tubes of 155 howitzer.[9] These fires are immediately available to the brigade commander because he has at his side a liaison officer from his direct support artillery battalion.[10] In turn, the battalion task force commander has a liaison officer with him as necessary. Each liaison officer provided by the direct support artillery battalion has direct communications with his parent battalion, and consequently can provide artillery fire to the commander of the organization he is supporting in a matter of minutes. Concurrently, artillery forward observers from the batteries of these direct support battalions are provided the line combat companies. Similarly, thru direct communications with their batteries, they can provide all or an apportioned share of the same artillery fire to the supported force. This type of artillery fire is then so closely interwoven into the fire support structure integral to the maneuvering brigade, that the brigade commander can call it his own. Similarly this is true of reinforcing artillery wherein the reinforcing battalion is responsive only to the direct support battalion. It provides additional

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[9]U.S. Army Command and General Staff College, Reference Book: The Division, pp. 162, 163, 168, 169.

[10]U.S. Department of the Army, Field Artillery Techniques, FM 6-20-2 with change, (Washington: U. S. Government Printing Office, January, 1962), p. 18.

liaison officer and forward observers to the maneuver units as directed. These close relationships are recognized by divisional war gamers. Standard practice[11] then is to divide artillery support into two categories. Category one artillery is direct support and reinforcing artillery whose additional combat power is added directly to that other organic to the maneuvering brigade. Category two artillery is general support and general support-reinforcing artillery. This artillery is handled separately in the war game, and it will be discussed with other forms of supporting combat power.

Consequently the additional firepower value of category one artillery must be recognized by the firepower computer and added to brigade and battalion task force firepower scores. Several ways to do this are available. Additional cards could be provided for addition to the brigade tote board. These would be almost identical in format to those of the maneuver units, except that from the nature of howitzer trajectories, a standard firepower value would show on the card throughout the battalion range fan or range fans.[12] The range fan is simply that area within which the battalion

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[11]U.S. Army Command and General Staff College, War Gaming, p. 44.

[12]On a map or a chart, the boundaries within which a battalion or battery may fire takes the appearance of lady's hand fan, hence the name.

or batteries of the battalion may fire without shifting howitzers. This area is limited by the left and right traverse capabilities of the gun tubes on their carriages (left or right azimuths or deflections) and minimum and maximum ranges.

Another method is to provide the firepower computer an acetate cutout in the form of a fan, which would be scaled at the war game battle map scale. It would show maximum and minimum range and deflection limits (left and right howitzer traverse limitations).

A third method is to draft a line representing the maximum range of the direct support artillery on the battle map or acetate covering it; and ignore deflection limits and minimum range.

The first method has the advantage of reminding the firepower computer to add this additional asset to brigade firepower, and thus serves in one way to reduce error. However, it requires additional cards on the tote board, thus adding to complexity. Additionally, the method could confuse the firepower computer, who, if unfamiliar with artillery practice would be undecided as to which battalion task force to credit with the additional artillery firepower point value. The point is, that following the principle of economy of force, direct support artillery firepower through standard artillery fire direction techniques is available where

needed when needed. Consequently, unless maximum rates of fire are exceeded by a player staff, or a staff uses its direct support artillery to fire more support missions simultaneously than it has cannon available; the brigade and the battalions should be credited with the additional firepower. The firepower computer should be alert that possible inconsistancies are not allowed.

The second method, provision of scaled acetate cut-outs representing direct support artillery fans would alleviate these difficulties. The firepower computer, checking the battle map, could determine that the task force would have the additional firepower. He could also determine the time sequence of this availability. But is this necessary?

First, remembering that the divisional game is devised to train divisional level personnel, and accepting that in the game, brigade and lower level personnel will fight the battle as ordered, in accordance with doctrine; it becomes logical to accept certain lower level activity as standard.

This activity or practice is that the brigade, task force, and artillery battalion commanders, following the battle in close communication through the liaison officers are not only able to provide fires within the direct support artillery range fans; but additionally have time to

change direction of fire or change range by leapfrogging batteries forward or backward in consonance with the displacement of the FEBA.

This is the normal way that it is done. Consequently, the firepower computer need only note in reference to direct support and reinforcing artillery: (1) that available firepower is not exceeded, (2) that ammunition resupply is not abnormal, (3) and that artillery movement is not unrealistic. A general indication that one of these factors is out of balance should lead him to confer with other members of the umpire staff and after more detailed consideration of the apparent discrepency, judge accordingly.

This rationale supports elimination of the first two methods of handling category I artillery. For the sake of simplicity, where the player staff indicates that in support of an attack or a defense, this additional firepower has been made avilable, it is credited with impunity.

The point values given artillery are standard values from FM 105-5, "Maneuver Control", used earlier to establish other type weapon point values.[13] They are twenty points for each 105mm howitzer from 0-11,000 meters, and fifty points for each 155mm howitzer from 0-14,600 meters. A 105 battery of six weapons brought to bear on a target would be credited

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[13]U.S. Department of the Army, Maneuver Control, FM 105-5, p. 136.

with 120 points; a battalion, 360 points. For the 155 battery of six tubes, a credit of 300 points would be due, for a battalion 900 points.

Firepower determination integral to the maneuver units is now complete. As previously indicated, all other categories of fire support are handled separately during the division game.

Use of the Tote Board

Now, to assure that the rudiments of this proposed methodology for battalion task force firepower determination are in no way obscure, it is proper to go through an example.

Suppose that the division commander's operation order has given the first brigade commander the task of attacking and seizing a ridgeline to his front. The operation order specifies that to accomplish this mission, the first brigade will be constituted of three infantry battalions and a tank battalion. The first brigade commander decides that he will attack with three battalion task forces and keep one in reserve. One of these task forces will be infantry heavy, composed of an infantry headquarters and headquarters company, two rifle companies, and a tank company. The commander of the infantry battalion from which the headquarters and headquarters company and the two rifle companies were drawn is designated as the task force commander.

He is given the mission of seizing a portion of the brigade objective. He decides that he will attack with a rifle company and the tank company abreast, keep his other rifle company in reserve and support his attack with the heavy weapons available in his headquarters and headquarters company. The companies conducting the attack will be deployed on an eight hundred meter front and extend to a depth of 1200 meters.

The center of mass of the attacking companies depend on internal company platoon arrangement. As previously stated, it shall be left to the judgment of the firepower computer to estimate center of mass distances that should be selected. It is suggested though, that for companies leading an attack the center of mass should be selected at the FEBA. First, it may be surmised that the company commander will so arrange his formation that he will have maximum firepower forward and so disposed to best support his attacking riflemen. Consequently, full firepower allowance may be granted line companies in so far as internal task force organization is concerned. Should this logic be accapted and applied uniformly during the divisional game, it will simplify the tote board arrangement.

The reserve company will follow at 1500 meters extending to a depth of 2000 meters from the lead elements of the attacking companies, and the heavy weapons elements of

the headquarters and headquarters company will support the attack at an initial median range for organic weapons of 1200 meters. The battalion commander knows that the enemy's main battle position is 1000 meters in front of his line of departure.

With this information available, the firepower computer may set up this task force organization on his brigade tote board. (See figure 1 below.) He would first select a Headquarters and Headquarters Company, Infantry Battalion Card. He would slide this card into the topmost acetate sleeve on the tote board so that the "center of mass scale", located halfway down the card, reads 1200 meters, (halfway between 1100 and 1300 meters), directly below the left index of the "distance between opposing forces scale" located at the top of the tote board. He next would select a rifle company card and insert this into the next succeeding sleeve so that its "center of mass scale" would read zero at the left index of the tote board scale. Succeeding this card, he would insert a tank company card with its "center of mass scale" reading the same zero distance at the left index. Finally he would insert the rifle company card denoting the reserve company so that its "center of mass scale" would read 1750 meters down from the left index of the tote board scale. This is the reserve company's center of mass estimated average distance behind the lead elements of the

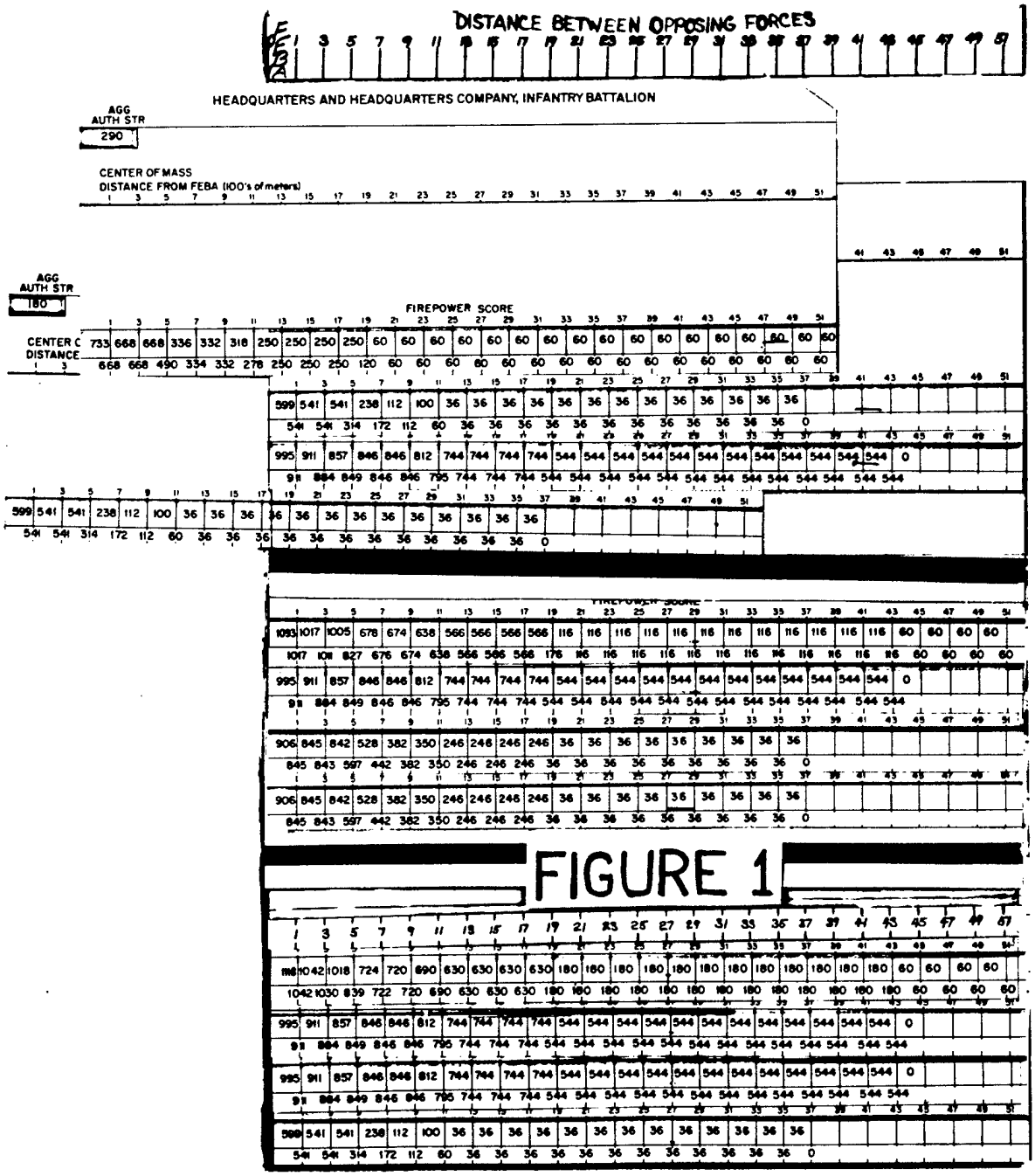
DISTANCE BETWEEN OPPOSING FORCES
HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION
AGG AUTH STR
290
CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)
AGG AUTH STR
180
FIREPOWER SCORE
CENTER C
DISTANCE

FIGURE 1

battalion. This would complete the firepower computer's work for this battalion for the moment. He would next set up the other battalion task forces in the brigade in succeeding sleeves on the tote board.

The war game battle would be initiated. At the first, and at each succeeding game interval, when time is called for the purpose of assessing progress, the firepower computer would have the duty of computing battalion task force firepower scores for his brigade so that rates of movement and casualties could be determined.

Suppose that the battalion just discussed has had phenomenal success, and has been able to advance to an assault line one hundred meters short of the enemy positions along the ridgeline without losing a man or weapon. An assessment time interval is called. The firepower computer must determine this battalion's firepower score. [It is presupposed in this situation that the relative position of internal elements of the task force remain unchanged.] He would go to the tote board, pick off the point on the "distance between opposing forces scale" at the top of the tote board that designates one hundred meters and read directly down the cards. The firepower card for the headquarters and headquarters company would read 250 points. The rifle company card would read 541 points. The tank

company score would be 911 points. The reserve infantry company score would be 36 points. This would produce a total task force firepower score of 1738 points (See figure 2).

It should be noted that the only task facing the firepower computer was that of adding the task force card scores at the lesser range of one hundred meters between opposing forces. Since it was presupposed that the task force internal organization and the relative positioning in depth between companies did not change, no adjustment of cards in relation to each other was necessary.

Now suppose during the next game period, the enemy reacts violently, and the battalion task force commander is logically assumed to commit his reserve. His battalion closes in the assault. Friendly and enemy forces become intermixed. Heavy weapon firepower elements of the headquarters and headquarters company are disposed to provide maximum support. Direct support artillery fires of the 105mm direct support battalion are pumped in at their maximum available rate. In this case, the umpire staff and the firepower computer could logically assume that the center of masses of the opposing forces had become coincident. At the next assessment time interval, the firepower computer would "close his board" for this battalion (See figure 3). That is, he would shift his headquarters and reserve company cards to the

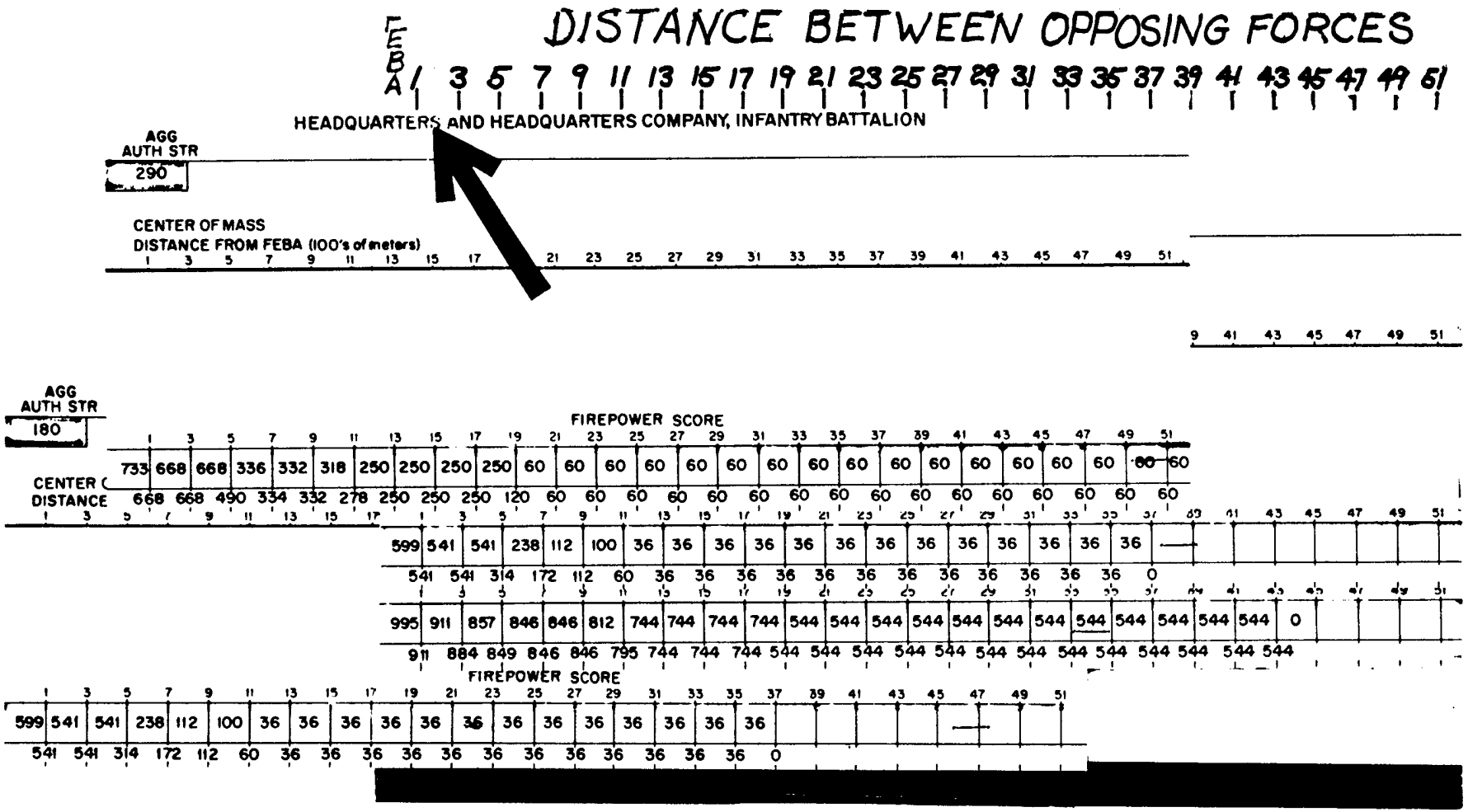
DISTANCE BETWEEN OPPOSING FORCES
FEBA
HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION
AGG AUTH STR
290
CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)
AGG AUTH STR
180
FIREPOWER SCORE
CENTER OF MASS DISTANCE
FIREPOWER SCORE

FIGURE 2

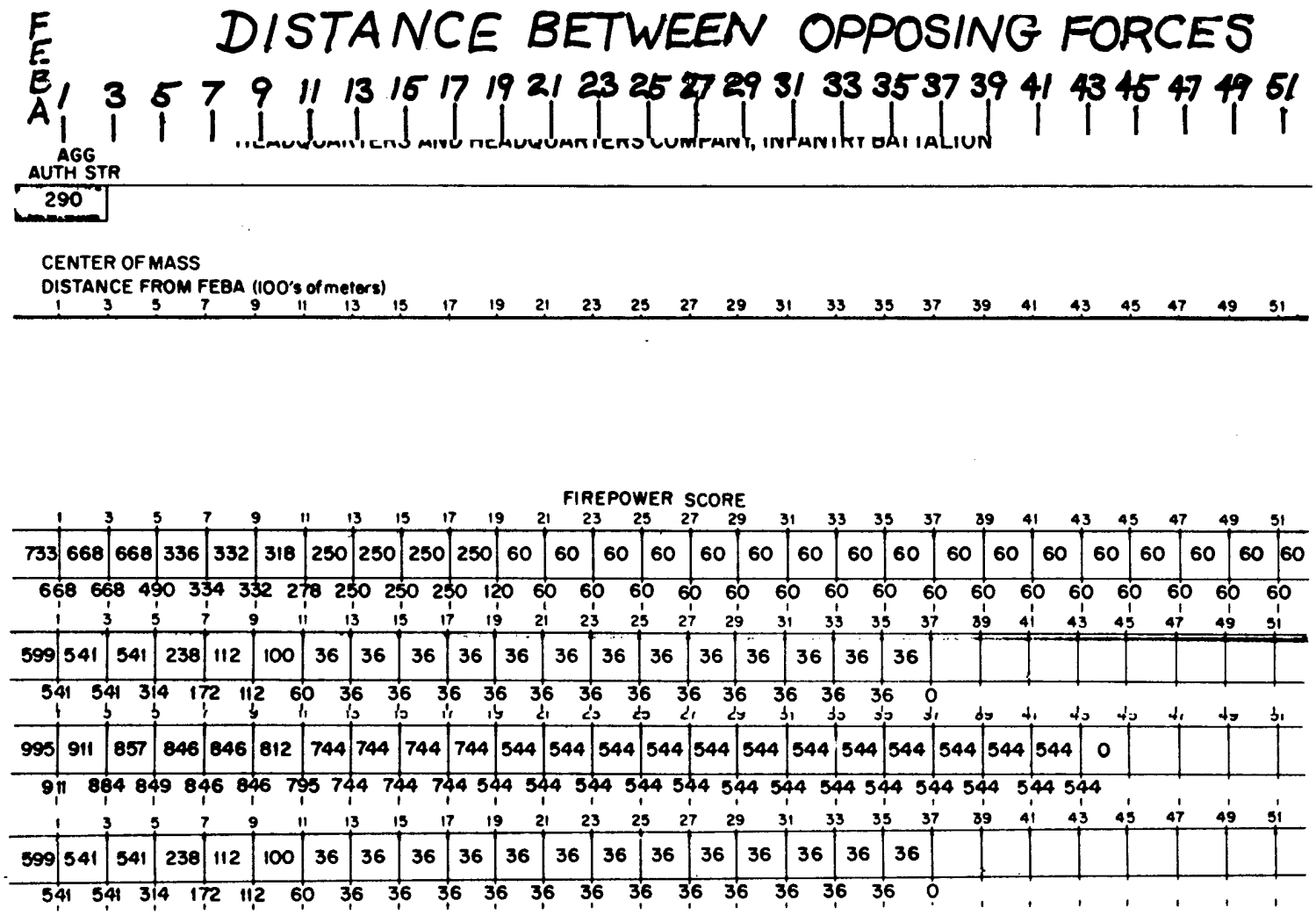
DISTANCE BETWEEN OPPOSING FORCES
FEBA
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
AGG AUTH STR
290
CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
FIREPOWER SCORE
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
733 668 668 336 332 318 250 250 250 250 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60
668 668 490 334 332 278 250 250 250 120 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
599 541 541 238 112 100 36 36 36 36 36 36 36 36 36 36 36 36 36
541 541 314 172 112 60 36 36 36 36 36 36 36 36 36 36 36 36 36 0
995 911 857 846 846 812 744 744 744 744 544 544 544 544 544 544 544 544 544 544 544 544 0
911 884 849 846 846 795 744 744 744 544 544 544 544 544 544 544 544 544 544 544 544 544
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
599 541 541 238 112 100 36 36 36 36 36 36 36 36 36 36 36 36 36
541 541 314 172 112 60 36 36 36 36 36 36 36 36 36 36 36 36 36 0

FIGURE 3

right in the tote board so that they lined up even with the left index. The task force firepower available would read 733 for the headquarters and headquarters company, 599 for each of the rifle companies, and 995 for the tank battalion. To this total of 2926 would be added 360 points for the 105mm direct support artillery battalion whose fires were available at maximum rate. The grand total firepower the battalion task force could bring to bear on the enemy in this assault mêleé would be 3286 points. But remember this is the "raw score" which in later computations would be reduced to account for attrition.

This example illustrates only one of many possible game courses. It should be evident from the example that much depends on the logic followed by the umpire staff and particularly the firepower computer in setting up the tote board, positioning cards and repositioning them as the battle develops. It should also be apparent that the tote board and cards methodology has an inherent flexibility through its card shifting capability to provide a realism difficult to obtain in present methods of firepower determination.

Evaluation of the Proposed Technique

Recapitulating to evaluate the innovations prescribed, the major changes are the introduction of the

brigade tote board and the company maneuver unit cards. To weigh these against present methods of determining firepower refer to the C&GSC manual, "War Gaming", page 44, paragraph 4.7.[14] This paragraph gives aggregated firepower scores for type battalion, company, and in some cases, platoons. It includes direct support artillery scores. It states that accurate records of effective firepower are maintained at all times and that charts are provided for this purpose.

With unit firepower scores determined on a battalion basis from the tables provided, these charts are maintained manually. The difference between the two methods is not great. The major initial work of forming the brigade task organization may be accomplished prior to game time if that time is defined as when the units first move. In the proposed method, the firepower cards comprising battalion task organization are inserted into the tote board in proper spatial relationship. In the current method, firepower is recorded on a chart from the table which provides aggregated battalion, company, and platoon scores which vary between three hundred and one thousand meters in two hundred meter increments. This has the advantage that aggregated battalion scores are provided and the chart is simpler than the

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[14]The U.S. Army Command and General Staff College, War Gaming, ST 105-5, p. 44.

tote board. On the other hand, the current method does not allow dimensional adjustment of these firepower scores to more realistically simulate company position within the battalion. Nor does it facilitate the simulation of variance in firepower score to the same degree as the proposed method. Additionally, there is no prescribed methodology for tailoring the battalions into tank-infantry task forces. Admittedly this could be done by extracting firepower scores on a company basis. Should this be done from the table, it would require manual recording of each company score and addition of these scores into a composite battalion score. Since the proposed method prescribes tailoring as a matter of course, provides a more detailed and complete variance of firepower with range, and allows dimensional positioning within the battalion, it is selected as an appropriate modification for the current game.

Now that firepower methodology is established, it is appropriate to investigate its interrelationship with unit strength and rates of advance. As will be shown next, these interrelationships may be tied together in a relatively simple manner.

CHAPTER IV

COMBAT POWER RATIOS AND MANEUVER RATES

Basic Considerations

The ratio of opposing unit firepower scores attenuated by the percentage difference between actual strength and authorized strength, must be further modified by such influences as direction of attack, mobility, and type of terrain traversed to provide a realistic determination of combat power ratios and maneuver rates between units. In the Leavenworth game, these movement rates are computed by hand, based on the data from a series of tables. For the game, the necessary tables are extracted from the USAC&GSC war game manual[1] and furnished in a control pamphlet.

Considerable simplification occurs when the mathematical factors envolved and the tables used are brought together on a calculator similar to a circular slide rule.

The Combat Power Calculator

In the process of originating such a calculator for the divisional game, a simpler one that satisfies the criteria for movement found in FM 105-5, "Maneuver Control",

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Ibid., pp. 19, 21, 22, 44, 45.

was first devised. [It is to be annotated on the reverse side as Rate of Movement Calculator No. 1.] As it turned out, this simplified calculator is similar in most respects to the more complex calculators later developed. It provided a good first start upon which to build and it should provide a good beginning for explanation of the series of calculators devised. On this simplified calculator, the method of modifying firepower ratios between opposing forces by their strength ratio; the method of converting these ratios to combat power ratios; and rate of movement determinations are exactly the same as the methods used later. Besides simplifying the evolution of these devices, combination of measurement techniques between the Army Field Manual, "Maneuver Control" and the Leavenworth text, "War Gaming", is valuable from the standpoint of standardization of training doctrine, just as is the previous use of firepower scores from the same Department of Army manual. The combat power calculator is based on the tables of Appendices VII and VIII[2] of that manual and standard logarithm tables.

The first thing to be determined in developing the calculator, is the range of firepower scores that should be included. Using the methodology for aggregating battalion

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[2]U.S. Department of the Army, Maneuver Control, FM 105-5, pp. 142 and 146.

task force firepower scores on the brigade tote boards, a range of firepower scores for attacking and defending battalion task forces may be determined. Exceptionally, when the division commander and his staff have found occasion to designate armored cavalry troops or separate companies on flank protection, general outpost, or other separate missions, company level firepower scores are needed. And even more rarely, perhaps during counterattack play, when a whole brigade is advancing on one direction of attack and it is unnecessary to separate out individual battalion task forces, brigade firepower scores will be necessary. With these things in mind, examination of appendix VII of FM 105-5 shows company firepower scores in the hundreds and those for battalions in the thousands. The aggregates for a brigade could range up to 10,000 and in some cases, a bit higher.

To properly deal with this range of values and give the calculator enough versatility to be useful for computing the foreseeable full range of divisional problems, a firepower scale of from 10 to 30,000 should be selected. This range of values is easily accommodated using a series of logarithmic scales, which in any case is necessary for the calculator.

A review of logarithms show that they are exponents of some fixed number which is referred to in the language of

logarithms as the number base, or base. When this fixed number or log base is raised to the power of a certain exponent, a given number results. Consequently, any given number; 1, 2 . . ., 105, ... 2369, . . . etc. has a logarithm which when used as an exponent of a common base[3] such as 10, and 10 is then raised (or lowered) to the power represented by the logarithm, the given number; 1, 2, . . ., 105, . . ., 2369, . . . etc. results. Any given number, A, may be represented as $A=10^B$, where B is the logarithm of A. Similarly $C=10^D$ and $E=10^F$.

Now $AxCxE=10^B x10^D x10^F=10^{B+D+E}=ACE$. By adding the exponents B, D, and E and raising ten to the power represented by this addition, the product ACE may be computed. By adding B, D, and E as logarithms and looking up the antilogarithm of this sum in standard tables, the product ACE is similarly found. This may also be done graphically using logarithmic scales. As on a standard slide rule, by sliding such scales along each other, logarithms may be added. The antilog values written on the face of the scales are simply the original numbers such as A, C, or E, that were represented by the logarithms. The consequence of adding on such scales is the desired multiplication.

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[3]10 is a common base. See M. Wiles Keller, College Algebra (Cambridge, Mass: Houghton Mifflin Co., 1946) p. 245.

Division follows just as simply. Consider A/C. $A/C=D^B/10^D=10^{B-D}$. To divide one number by another, the logarithms are subtracted. This too is easily done graphically using logarithmic scaling.

The task of developing the combat power calculator then is essentially that of providing a graphical method of multiplying and dividing the essential elements of combat power to yield an attacker to defender combat power ratio. These elements are firepower scores and strengths of opposing sides. These initial firepower scores must be adjusted if opposing units are not at 100 percent strength (TO&E). They must also be adjusted during the course of battle to account for attrition. To do this on the calculator, the ratio of opposing unit firepower scores is multiplied by the ratio of opposing unit strengths. This produces the combat power or force ratio. Table XXVI of FM 105-5 is then used to match the rate of advance to the force or combat power ratio.

Mathematically all that must be done is a multiplication and a division using the logarithm principles just reviewed in graphical form on a circular slide rule.[4]

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[4]The combat power calculator developed is found in the jacket of appendix IX. The discussion of its construction is more easily followed if it is available. It is annotated on the back as Rate of Movement Calculator No. 1.

The circular slide rule may be constructed from disks of cardboard and fogged acetate. First an outer scale series is constructed on the circumference of a cardboard disk that has a diameter of about nine inches. (This is not a restrictive dimension.) To do this, first divide the circular disk into 360 equal parts with a protractor. Each division represents one unit. Next using a table of common logarithms, the log scales are constructed. For example the log of 10 is 1.0000 to four places. The characteristic, 1, of this log indicates the first scale. The mantissa 0000 indicates the starting point for this first scale. This point is marked and it becomes the origin of reference for constructing the rest of the scales. To find 20, the log indicated from the tables is 1.3010. The characteristic, 1, indicates the first scale again. The mantissa 3010 indicates 30.1 units. At 30.1 units to the right of the origin, 2 is marked. To find 95, the log indicated is 1.9777. Ninety-five is then marked 97.77 units to the right of the origin. The second scale begins one hundred units to the right of the origin. The log of one hundred is 2.0000. The characteristic two (2) might be said to indicate the second scale. The second scale runs from one hundred to two hundred units to the right of the origin. The third scale starting point represents 1000, the logarithm of which is 3.0000. The third scale includes 1000

to 9999 and is marked off between 200 and 300 units to the right of the origin. To find 30,000, the log 4.4771 is indicated. The characteristic 4 indicates the fourth scale up the series, the mantissa indicates 47.71 units to the right along this fourth scale, where 30,000 is marked. The log scales are stopped at 30,000. This outer scale series represents attacker firepower. On this same cardboard disk and interior to the log scale just constructed on the periphery, a second scale is constructed. This scale will represent combat ratio. It should be circular, and of about four and one-half inches diameter. If a radial line is drafted to each log value marked on the outer scale that lies within the range four hundred to ten thousand, the intersection of these lines and the interior circle will provide the second set of log scales sought. To mark this second scale, ten is marked below ten thousand. Nine falls directly below nine thousand and so on down to one which falls below one thousand. Below one, nine tenths falls below nine hundred. In similar manner, scale division continues until four tenths is reached. This is the stopping point, as it is deemed unnecessary to provide combat ratios of less than four tenths.

Below this interior scale representing combat power, rates of advance for the various types of terrain are printed.

No computation is envolved here, only a comparison between the combat ratio values and the rate of advance values given in table XXVI of appendix VIII of FM 105-5. Therefore, immediately below the proper combat ratio value on the cardboard disk, the proper values for rate of advance depending upon terrain type listed are printed in sequence.

The terrain types are defined as: (1) Open - open, flat, slightly rolling terrain, (2) Median - rolling, lightly covered with trees, (3) Close - rough, heavily wooded, mountainous, swamps, or jungle. Although it is not included on the calculator, a fourth terrain type completely impassable to mechanized or armored forces should be added. The umpire must be prepared to recognize this latter classification and disallow vehicular movement over terrain bearing this classification.

Terrain classification is not detailed in the maneuver control manual. It is detailed in the CONARC[5] manual. So that the responsible controller or umpire may firmly grasp what is meant in the terrain types given, further discussion of terrain is found in appendix II. A necessary adjunct to the controller's or umpire's equipment is a terrain classification overlay which identifies and segments the various

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[5]United States Continental Army Command, War Gaming Handbook (U), pp. 9-5, 9-6, 9-10, 13-14, 15, 16.

terrain types on the battle map over which the war game is being fought. The various terrain types should be compartimentalized and cross-hatched on the overlay. With such an overlay available, rulings may be quickly made and indecision avoided.

With the attacker firepower score log scale constructed on the periphery of the cardboard disk, the combat ratio log scale constructed interior to it, and the graphics for rate of advance depending upon terrain type completed, attention may be turned to construction of the intermediate disk. This is made of fogged acetate. The outer scale series is a replica of the logarithmic scales on the circumference of the cardboard disk. These scales represent defender firepower. A second logarithmic scale is constructed interior to this outer scale. This scale represents attacker strength. Construction is facilitated in the same manner that it was on the cardboard disk. The second scale is constructed by using radial lines from the outer log scale to the center of the disk. Their intersection with the arc of the attacker strength scale mark off the proper logarithmic scale values. The intermediate disk is completed with the construction of the attacker strength scale.

The third and smallest disk is the final construction item. It too is of fogged acetate. On this, a replica of

the attacker strength scale is constructed. This is the defender strength scale. Interior to this log scale, arrow indicators are marked directly under the 100% defender strength index to provide indices by which combat ratio and rate of advance may be read through the two acetate disks at the proper place on the face of the cardboard outer disk. This is easily seen, if in retrospect it is deduced that all that has been constructed is a method of multiplying a firepower ratio by a unit percentage strength ratio. Should the firepower ratio be 1:1, and the percentage strength ratio 1:1; it follows that the combat power ratio [other elements of combat power not considered] should be 1:1. Therefore if the scales on the cardboard and acetate disks are exactly aligned with like values in opposition, the arrow index for combat ratio must be placed on the outer acetate disk to read 1 [1:1]. Likewise the arrow indicators for rate of advance will fall below the combat ratio indicator since the values that must be read through the acetate disks were simply extracted from FM 105-5 and placed below the proper combat ratio value. It might be noted that the values for rate of advance are separated into two graphic tables. The tables for INF and CAV&RECON are immediately below the combat ratio. The set for MECH & ARM are almost 180^{o} opposed. No matter, this set could be constructed anywhere on the cardboard disk

as long as the appropriate arrow indicators on the outside acetate disk are constructed when this outer disk is aligned to the proper combat ratio.

With this, the basic combat power calculator is completed.

While the construction of the calculator is still fresh in memory, rules for use of the calculator might be set down:

Step 1. Compute attacker firepower from the proper brigade tote board, adding direct support or reinforcing (category 1) artillery firepower values as appropriate. Set the value on the attacker firepower scale, outer disk.

Step 2. Compute defender firepower similarly, setting the value on the defender firepower scale, intermediate disk, against the attacker firepower score on the outer disk.

Step 3. Set defender strength on the inner disk opposite attacker strength on the intermediate disk.

Step 4. Opposite the proper arrow on the smaller acetate disk read combat ratio on the base cardboard disk through the acetate.

Step 5. Similarly, using the proper arrow indicator, read rate of advance for stated unit type and terrain type.

The combat power ratio may be used for casualty assessment which will be discussed in a later chapter. The rate

of advance is used to reposition the task forces on the battle map for the next play period.

For example, suppose a blue battalion is attacking a red battalion. At a game interval for a given assessment period, the blue firepower computer might determine that the blue battalion has a firepower score of 3010, and attrition from casualties has reduced the unit's strength to an actual strength of seventy eight percent authorized strength. The red firepower computer at the same time might announce that his defending red battalion has a firepower score of 1428 and a strength of eighty three per cent.

The rate of movement computer would receive this information, and on the Rate of Advance and Combat Power Calculator, set the value 1428 on the defender firepower scale opposite the value 3010 on the attacker firepower scale. (Note that the actual numerical values must be estimated as between the scaler values of 3000 and 3200 for the attacker and between 1400 and 1500 for the defender.) On the smaller fogged acetate disk, on the defender strength scale, eighty three per cent (estimated between eighty and eighty five per cent) would be set opposite seventy eight per cent (estimated between seventy five per cent and eighty per cent) on the attacker strength scale of the intermediate fogged acetate disk.

The rate of movement computer would now be ready to determine the attacker's rate of advance. The rate of movement computer would read a combat power ratio slightly greater than two favoring the attacker. Were the attacker an infantry battalion attacking over "median" terrain, a rate of advance of three hundred meters per hour would be judged. Were the attacker an armored or mechanized force, a rate of advance of four hundred meters per hour would be allowed. Similarly maneuver rates over other terrain types could be found reading the approprate indices.

Figure 4 shows the calculator with scales set to solve this problem.

Now as stated previously, this calculator was developed to demonstrate that the principle of the circular slide rule could be used in rate of movement calculation. It was developed for use with the Department of Army "Maneuver Control" field manual. It was described in detail so that its basic principles and method of construction would be understood.

It may be used with FM 105-5, in either field maneuvers or simplified war gaming. However, with its description complete, it is discarded forthwith from further consideration so that using the same basic principles a more complex calculator may be developed specifically for use with the divisional war game.

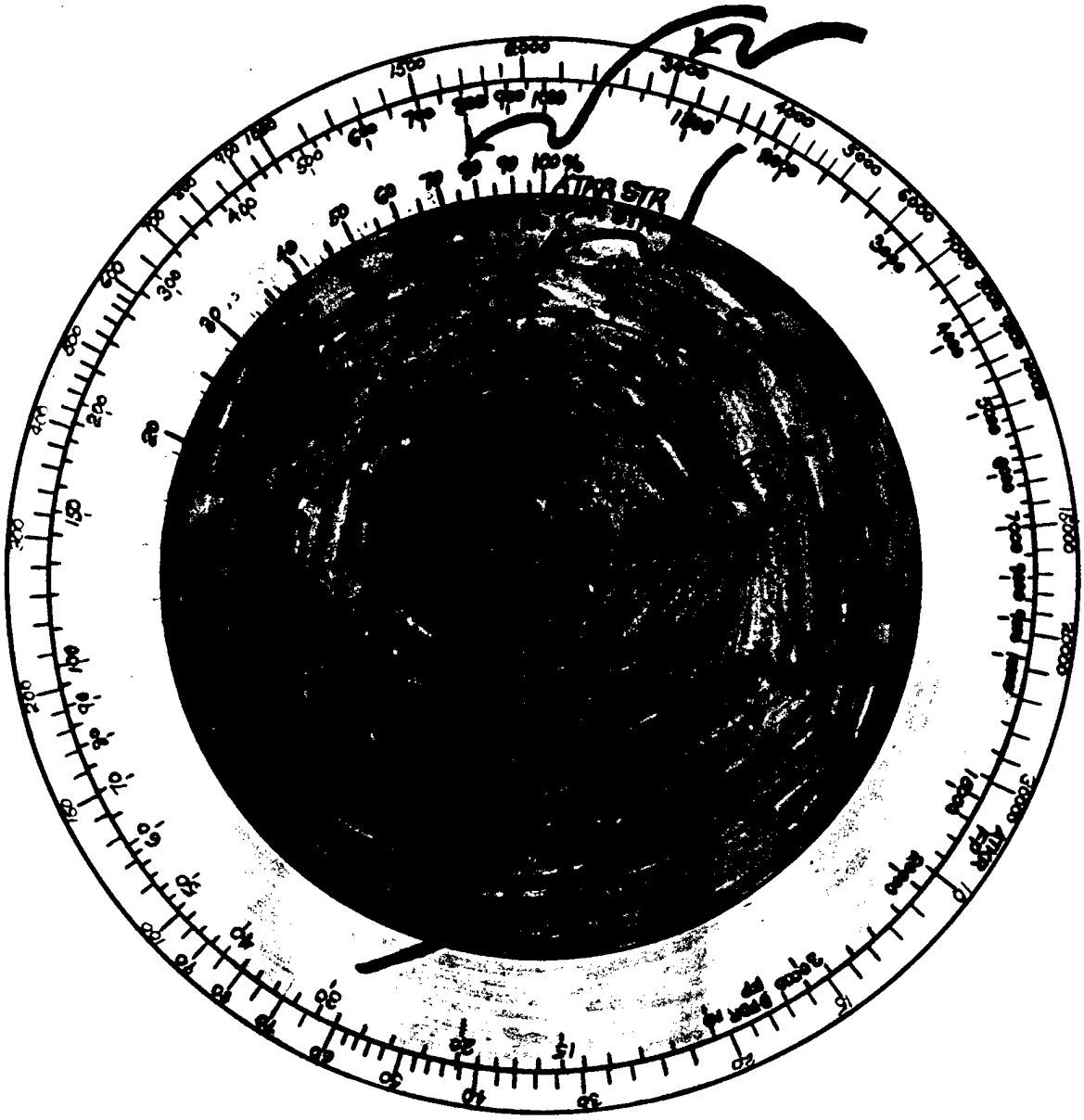

FIGURE 4

The Combat Power Calculator for the Divisional War Game

A more complex combat power and rate of advance calculator may be developed for divisional war gaming using additional tabular information taken from the Command and General Staff College special text "War Gaming". [This calculator is to be annotated on the back as Rate of Movement calculator No. 2. It may be found in the jacket of Appendix X.] Tables of interest are found on pages 19, 21, 22, 44, and 45 of the C&GSC text. These tables allow the umpire assessors to assess rates of advance based on firepower and strength, as with the calculator just developed [No. 1]. Additionally, they not only measure variation due to type force and terrain type, but also include consideration of direction of attack and defender defensive posture. The additional tables that address direction of attack and defensive fortification implications[6] may be included in the tabular graphics of the divisional calculator [No. 2]. The log scales for attacker and defender firepower and strengths duplicate those of the simpler model [No. 1].

This being the case, it is unnecessary to describe in detail the complete construction of the calculator. It is

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[6]A discussion of defender posture concerning time required to construct a "hasty defense" or a "fortified position" is found in Appendix III.

only necessary to explain the positioning of the tables and show their use.

The tables relate directly to the basic combat power ratio between attacker and defender. Recall that the firepower scores of opposing units is calculated based upon the weaponry available to the units. The firepower of the attacker is compared to that of the defender. The resultant firepower ratio is then reduced by the unit strength ratios on the calculator. This yields the basic combat ratio between forces. By setting this ratio on the calculator, the tables that have been added automatically read out proper rates of advance.

As will be noted on examination of the tables, the rates of advance of foot infantry, of mechanized and armored forces differ by the nature of their differing mobilities. The rate of advance of cavalry and reconnaissance forces differ by the nature of their mission.

This set of influences or factors is first categorized and then graphically displayed on the base cardboard disk of the calculator. The display chosen is the result of several trials wherein readability was the primary consideration. To read the proper value, defender posture is first selected. Is he in the open, in a hasty defense, or in a fortified position? Next the attacking force is considered. Is it an

infantry unit, a cavalry or reconnaissance unit, or a mechanized or armored force? Finally, direction of attack and type terrain are considered. Values representing a flank attack are given in red. As the ratio of firepower scores originally computed will rarely be in even integers, likewise the combat power ratios will rarely come out even. Consequently the arrow indicators will normally point out some value between extracted tabular values. This being the case, the control computer merely estimates or interpolates a value between the tabular values given to use.

For example, suppose that a blue battalion of firepower score 2000 and strength of 80 per cent is attacking a red infantry battalion of firepower score 1000 and strength of 90 per cent. The firepower ratio 2000:1000 is set on the firepower scales. The strength ratio 80:90 is set on the ATKR and DFDR STR scales. This is the same procedure that was used with Calculator No. 1. If the blue battalion is attacking over open terrain in a frontal attack against red defending in the open, a combat ratio of 2.7:1 [estimated between 2 and 3] should be read. The proper arrow indicator for rate of advance would read between 450 and 550 meters per hour. Since the indicator is about three quarters of the way to the value 550, a proper rate of advance would be chosen as 525 meters per hour.

As well as interpolations of this type, the umpire would normally reduce or increase this value in accordance with his judgment of the effect of such influences as weather, time of day, or the attainment of surprise by the attacker. Proper multiplicands to account for these factors and insure uniformity should be made available for the war game in the control pamphlet issued.

Assume that in a divisional war game, a blue battalion task force with a firepower score of 3600 is assaulting a red battalion that has a firepower score of 1300. The blue force is armored and is attacking frontally over "close" terrain. Blue strength is eighty per cent and red strength is ninety five per cent. Red is defending from "a fortified position".

Solution of the problem calls for first setting the red firepower score of 1300 opposite the blue attacker score of 3600. The strength ratio is next established on the intermediate and inner disks. With this done, go to the index for mechanized and armored forces over "close" terrain that is found on the smallest disk under the indices column headed "CBT/RATIO ATKR/DKDR DFDR IN FORT. PSN". Note that the combat ratio reads about 2.4. The arrow index is advanced a bit beyond 250 meters per hour and well short of 300 meters per hour. An estimated rate of advance for the armored force of

270 meters per hour would be assigned. Since 250 meters per hour is the tabular value for a combat ratio of 2 to 1 and 300 the value of 3 to 1, and the combat ratio is about 2.4 [:1].Interpolation between 2 and 3 would also yield 270 meters per hour as the rate of advance. Note again the red figured rates of advance. These are used only when the direction of attack is on a flank! Figure 5 shows the problem set up.

A more difficult problem might be solved with the calculator and also serve to introduce a final modification. Suppose two blue mechanized battalions are attacking a red battalion of infantry. One blue battalion has a firepower score of 3000 and a strength of eighty per cent; the other, a score of 2000 and a strength of ninety per cent. The red battalion has a firepower score of 1500 and a strength of ninety five per cent. The difficulty is immediately apparent. Should the blue firepower scores be added and their strengths averaged so that a composite firepower score and strength may be used for blue? Were this done, some accuracy would be lost. The composite firepower score would be 5000 and the average blue strength would be eighty five per cent. In the firepower and strength ratio comparison, this would give blue an adjusted firepower score of (.85 x 5000 = 4250) 4250. If the blue battalion of score 3000 and strength eighty per cent was first adjusted to a score of

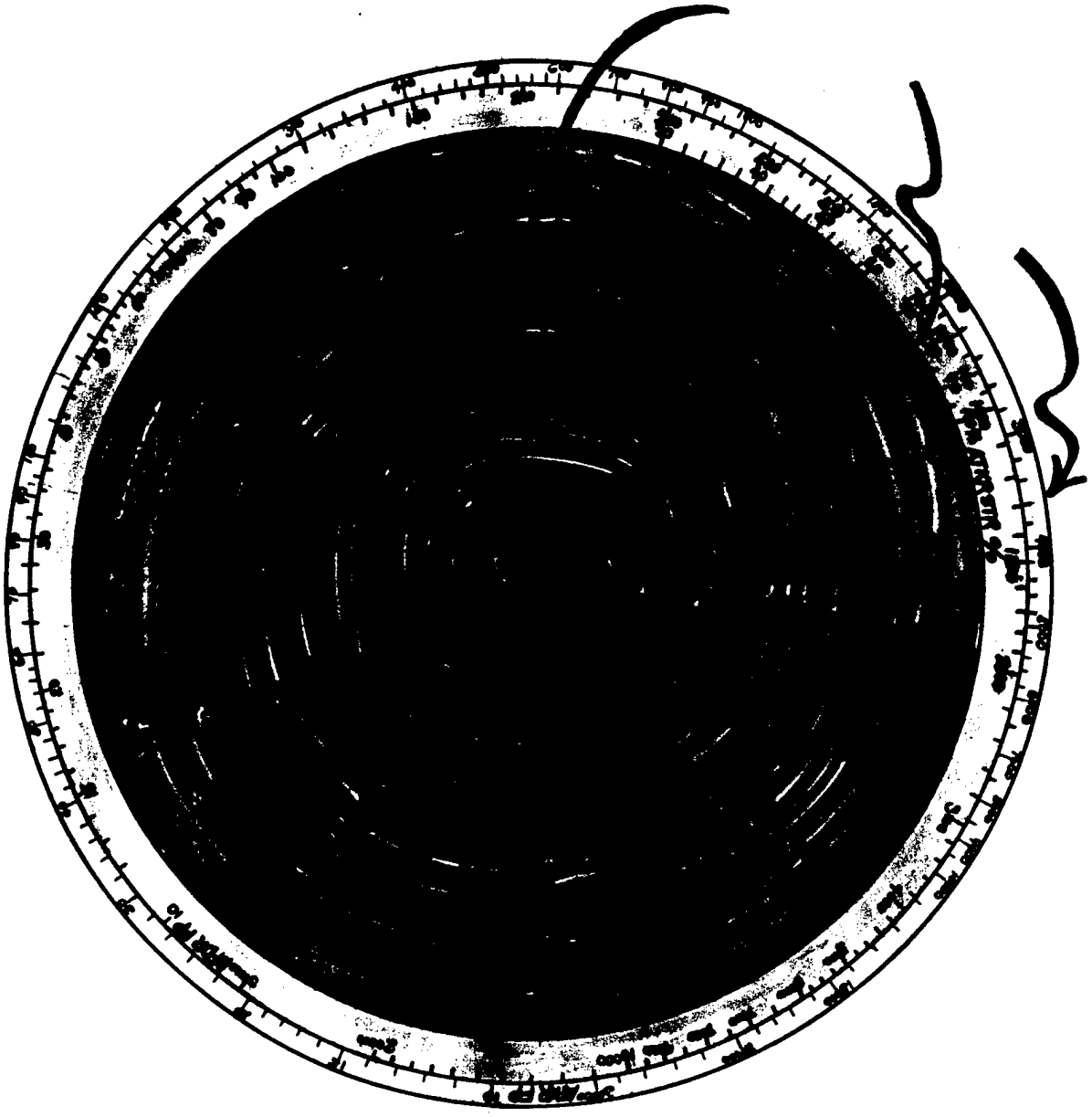

FIGURE 5

(.80 x 3000 = 2400) 2400 and the other blue battalion (.90 x 2000 = 1800) to 1800, the composite score would be 4200. A difference of fifty points would exist. The second method is proper. However, this part of the problem cannot be computed on the calculator [No. 2]. For blue, the composite score adjusted by task force strength would have to be worked out first. The composite score for blue would then be set on the attacker firepower scale against the red strength of 1500. The attacker strength would be set at one hundred per cent against the red strength of ninety five per cent because the blue strength has already been accounted for. If the blue battalions were advancing in a frontal attack over "close" terrain against defending red in a fortified position, the rate of advance would be three hundred meters per hour.

The problem may be solved, but not completely on the calculator. This difficulty may be eliminated by considering each blue battalion to attack only a certain percentage of red's front. The percentage each blue battalion would be attacking should be estimated from the war game battle map. By adding a fourth disk to the calculator the problem may be overcome. Consider what is done on the calculator in another light. Mathematically, it is:

$$\frac{\text{attacker fire power}}{\text{defender fire power}} \times \frac{\text{attacker strength}}{\text{defender strength}}$$

$$= \text{combat ratio} \quad \begin{matrix}(\text{modified by terrain, type force,}) \\ (\quad \text{direction of attack} \quad)\end{matrix}$$

If red must divide his combat power to fend off two blue battalions, mathematically examining red's relation with each blue battalion separately; the following may be written:

$$\frac{\text{Attacker}_1 \text{ firepower x attacker}_1 \text{ strength}}{\text{Defender firepower x Defender strength x \% Defender frontage}}$$

= combat ratio, blue_1 to red (modified as above)

and

$$\frac{\text{Attacker}_2 \text{ fire power x Attacker}_2 \text{ strength}}{\text{Defender firepower x Defender strength x \% Defender frontage}}$$

= combat ratio, blue_2 to red (modified as above).

Now per cent defender disposed against blue_1, assuming homogeneity of force within red's area is:

$$\text{Percent Red} = \frac{\text{Attacker}_1 \text{ frontage}}{\text{Defender frontage}}$$

and against blue_2:

$$\text{Percent Red} = \frac{\text{Attacker}_2 \text{ frontage}}{\text{Defender frontage}}$$

substituting into the original equations for blue_1 or blue_2:

$$\frac{\text{Attacker fire power}}{\text{Defender firepower}} \times \frac{\text{Attacker strength}}{\text{Defender strength}} \times \frac{\text{Defender frontage}}{\text{Attacker frontage}}$$

= combat ratio, blue to red (modified).

More concisely, the combat power red brings to bear on blue is inversely proportional to the ratio, blue frontage to red frontage.

By adding a fourth disk to the divisional combat power calculator, it takes its final form. [This final calculator is to be annotated on the rear as Rate of Movement Calculator No. 3. It may be found in the jacket insert of Appendix XI.] First the present smallest disk is modified.

To this third [second acetate] disk, an additional logarithmic scale series is added below the defender strength scale which would represent defender frontage. On the new [fourth but third acetate] disk, opposite the defender frontage scale, an attacker frontage scale would be constructed. The indices to the tabular values found on the base cardboard disk would be transferred in proper position to the fourth disk. This would not add much additional complexity. It would require one move each of three acetate disks to set up the ratio that positions the proper index over the appropriate rate of movement value. This compares to two moves required previously.

Returning to the sample problem that generated this final modification, it may be solved as two problems with relative ease.

The blue battalion (mechanized) with a firepower score of 3000 and strength of eighty per cent, is discerned from the war game battle map to be disposed across eight hundred meters of red's 1500 meter front. The second blue

mechanized battalion keeps red occupied on the other seven hundred meters. To find $blue_1$'s rate of advance, the firepower ratio 3000 to 1500 [red's firepower] is set on the first and second disks of the calculator; the strength ratio eighty to ninety five per cent is set on the second and third disk in, and the defender to attacker frontage ratio 1500 to 800 meters is set on the third and fourth disk. Blue, in a frontal attack over "close" terrain against red's fortified position advances at a rate of about three hundred meters per hour. See figure 6.

Similarly, $blue_2$'s rate of advance may be found. He has a firepower score of 2000 and strength of ninety per cent. He opposes red along 700 meters of red's total front of 1500 meters. The problem is set remembering red's firepower score of 1500 and strength of ninety five per cent. Defender red's firepower of 1500 is set opposite attacker blue's firepower of 2000. Defender red's strength of ninety five per cent is set opposite attacker blue's ninety per cent. Attacker frontage of 700 meters is brought opposite defender's frontage of 1500 meters. $Blue_2$, being mechanized, advances in this frontal attack over "close" terrain against red's fortified position at approximately 280 meters per hour. Comparing these answers with that of three hundred meters per hour obtained as an average for both battalions before shows that

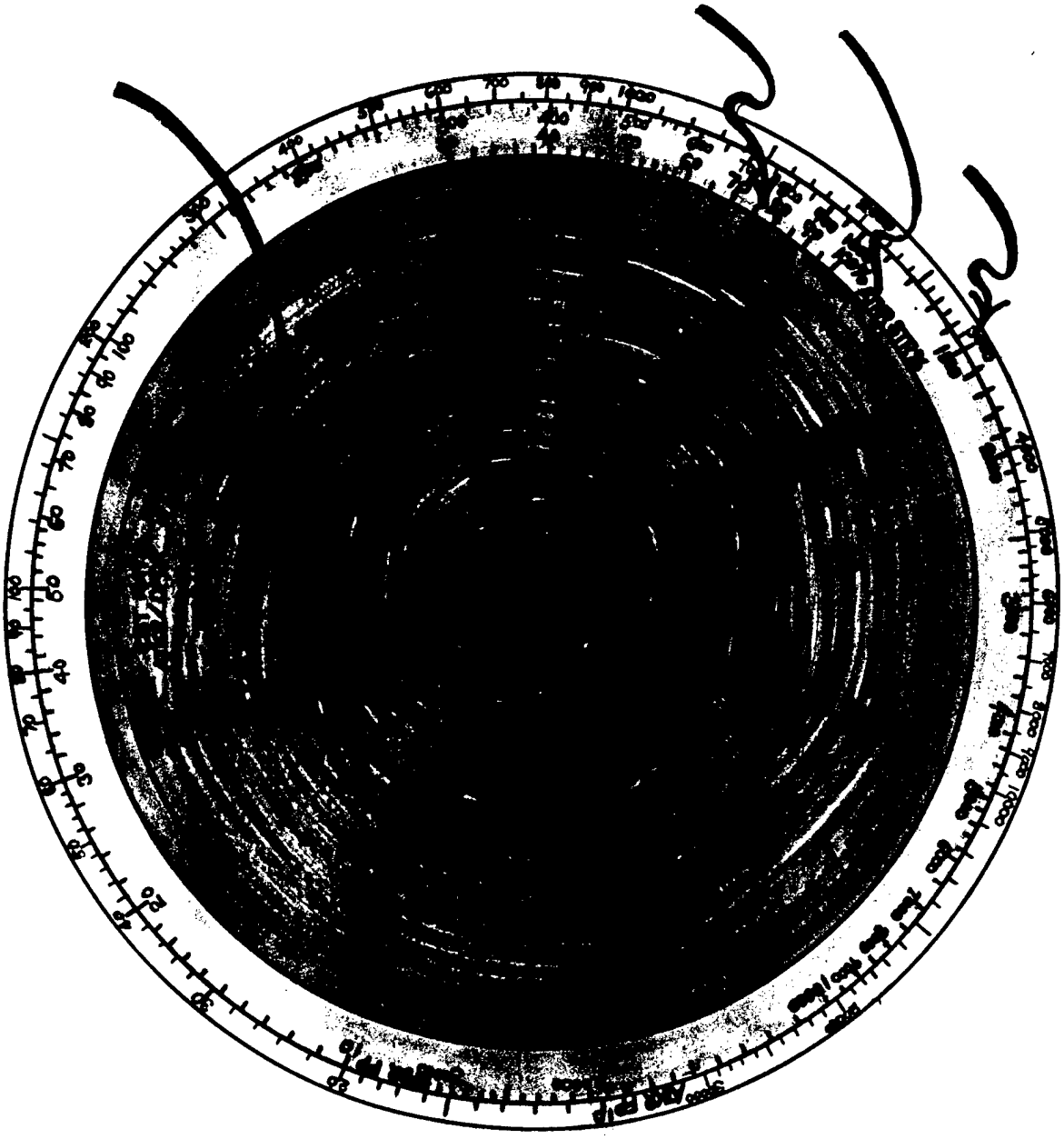

FIGURE 6

the new average of 290 meters per hour, is but slightly different, within acceptable tolerance for war game purpose. The additional ratio on the calculator [No. 3] does allow solution of the complete problem, and allows separation of rates of advance between task forces.

Additional Attempts at Improvement

The divisional combat power calculator is a pilot model. Only limited effort has been devoted to reducing or codifying the information found on its face to increase readability. The reason for this is twofold. First, in its present format, by comparison with the aforementioned tables in ST 105-5, the origin of the tabular values and their meaning becomes immediately discernable. Secondly, the objective of devising the calculator was to demonstrate a principle of simplification of divisional war gaming procedure. By coding the various scales alphabetically and providing an index either in the center of the calculator or on back; much of the information adjacent to the scales could be eliminated and easier read through achieved.

On the other hand, considerable effort went into attempts to simplify the tables on the calculator. Should additional efforts of simplification be attempted, it would be of value to know the direction of this previous work.

Examination of the tabular values show that the rates of advance are number sequences that increase in value as the attacker to defender combat power ratio increases. One such number sequence (it doesn't matter which) is: 450, 550, 700, 1100, 4600. This is transformed into a number series by adding values: 450 + 550 + 700 + 1100 + 4600. In turn, various power series, such as $ax + ax^2 + ax^3 + ax^4 + \ldots$ or $ax^0 + ax^n + an^{2n} + \ldots$ where n is either an integer or noninteger, were tried by curve fitting process, in an attempt to replace the tabular values with curves that would closely approximate them. Finally, the numbers themselves were graphed on the face of the calculator. The attempts at finding power series that would provide suitable curves were fruitless. The numbers themselves could be plotted by logarithmic polar plot, but the resultant curves did not simplify the calculator to any noticeable degree. Arbitrary linearization between end values of each number sequence would provide simplification, but the values would differ considerably from the ones found in the Leavenworth war gaming manual. Since it has been assumed that these are the most realistic rate of advance values that present experience can provide (they are the same as the Department of Army values), such linearization would run contrary to the objective of increasing realism. Therefore this possibility

of modification for the sake of simplification was cast aside.

In résumé, the divisional combat power calculator [No. 3] in three movements sets off three ratios which automatically produces a combat power ratio and appropriate rates of advance. It eliminates repetitive referral to three separate tables by combining them into one display. It eliminates two multiplications of three factors each and one division each time combat power is recomputed. During the course of a war game wherein many recomputations of combat power and rate of advance occur; the calculator should save a considerable amount of time.

Time savings of this nature are possible elsewhere in the divisional training game. The necessity for movement rate computations are not confined to maneuver units going across country. As shall be shown next, a march calculator may be devised to aid in solution of this war game problem.

CHAPTER V

THE MARCH CALCULATOR

March Computations

To keep the various maneuver units actively engaged in battle, continuous reprovision of the substance of combat power is necessary. Supply convoys continuously move up toward the front. Reserves are brought up. Road nets are normally used for these quasi-administrative moves. FM 101-10 devotes a whole section of chapter four to troop movements.[1]

The detailed computations required to compute columnar vehicle densities, road space, time length, and time distance are "old hat" to the competent staff officer. The detailed computations are necessary to coordinate movements of enormous numbers of vehicles over limited road nets; so that tactical columns and convoys will not be split and control lost. They are necessary to prevent massive road jams. They are therefore an integral part of divisional operations and a proper subject for continuous training, if the "old hat" kind of competence in march computations is to be provided

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[1]U.S. Department of Army, Staff Officer's Field Manual: Organization, Technical, and Logistical Data, Part 1 (Washington: U.S. Government Printing Office, October, 1961), pp. 120-170.

the commander from within his staff. Consequently the divisional war game may provide a vehicle for this training. Staff estimates of column movements may be required as part of the training game.

The work required to formulate estimates of column movement may be simplified in a variety of ways. FM 101-10 provides a list of aids that simplify the calculations.[2] These aids include simplified formulas, road movement graphs and tables, nomographs, and a march rate calculator similar to a common slide rule. A complete explanation of each aid is given in the FM. All might be adapted to the divisional war game. Whether they should, or some portion should, depends upon the training objective of the game. If orientation only on detailed march calculations is desired, and the division G3 required to prepare only general estimates of movement times; the simplified formulas given in the FM may be used, or the fold out march calculator opposite page 140 may be constructed to do the job. This calculator is quite simple and because of its simplicity, highly recommended.

As an alternative, a circular calculator similar to the combat power calculator may be devised that makes use of logarithmic scales. One is easily constructed. Figure 7 shows such a device. It has some advantage as a divisional

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[2] Ibid., p. 127.

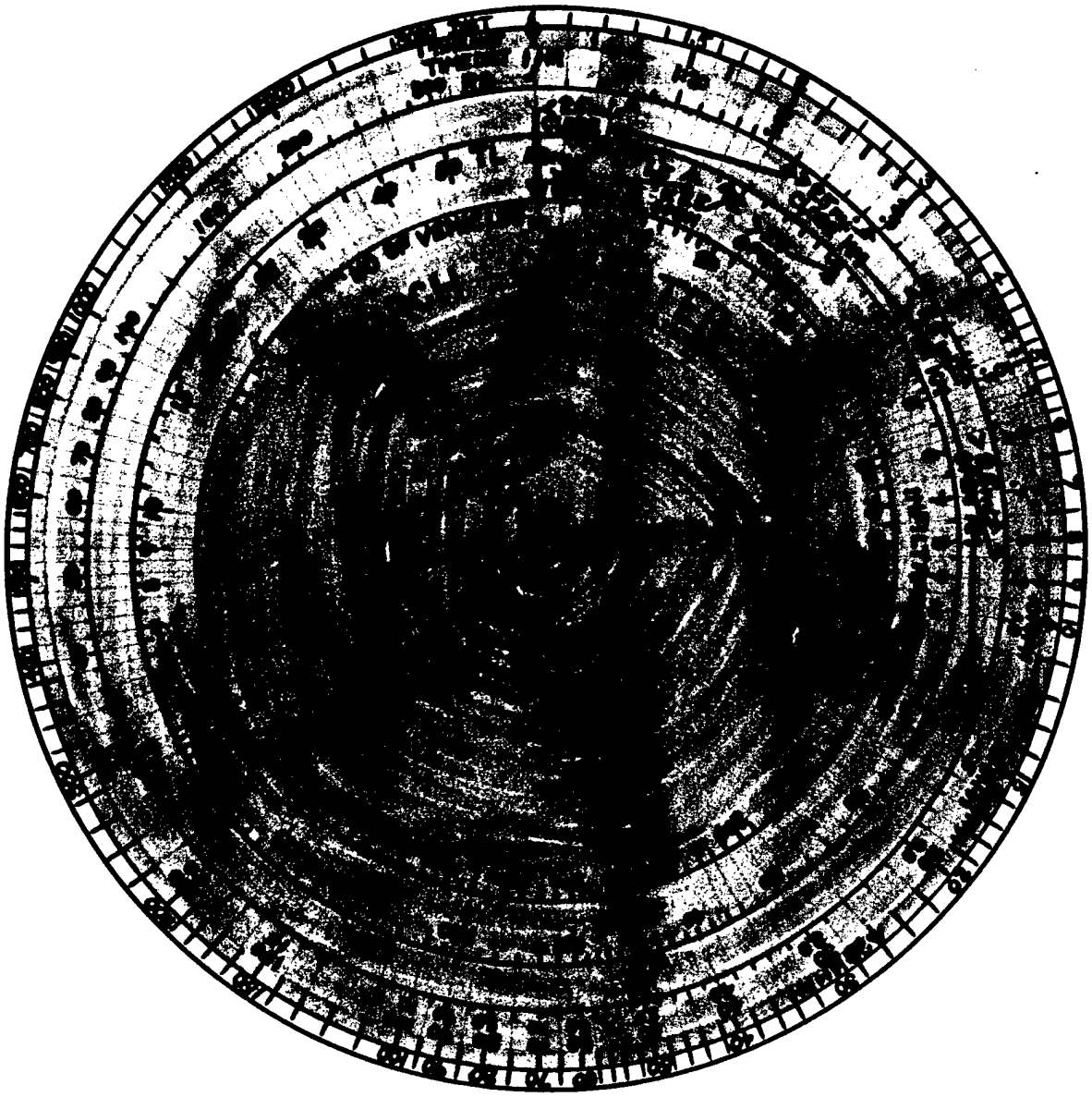

FIGURE 7

war game tool when march formations are aggregated into company, battalion and brigade formations and march rates are constricted to standard values of 15 mph during the day and 10 mph at night.

A series of log scales are drafted on a base or inner cardboard disk. Several trials at construction established that the most usable form for the calculator included four separate scales. These from the outside in on the base disk, graphically display distance and time distance, road space (RS) and time length (TL), and number of vehicles in column.

A second disk of fogged acetate, of somewhat smaller diameter than the base disk is used to calculate values. Marked on this disk, and based on logarithmic scalar distance are indices to use with the scales of the base disk and arrow indicators that point respectively to appropriate values of time distance, road space and time length. These arrow indicators produce values that are based on the simplified formulas given on page 128 of the field manual. Distances may be read in either miles or kilometers.

To find the road space occupied by a column, the lower index is set opposite number of vehicles (in the column) on the innermost scale. If it is a daylight march of a column of less than twenty five vehicles; proceed to the scale marked RS (Road Space). Find the answer at the index

marked: $\underset{\text{OPEN}}{<}25$. At that index find arrow indicators for either miles or kilometers. OPEN in the index symbology stands for an open column which is used for daylight marches.

To find the road space occupied by a column of more than twenty five vehicles on a night march, once again set the lower index opposite the number of vehicles in the column. Proceed to the RS scale. Find the answer in either miles or kilometers at the index marked: $\underset{\text{CLOSE}}{>}25$. The word CLOSE indicates a closed column which is normally used for night marches. Similarly road space may be found for columns of greater than twenty five vehicles on night marches or columns of less than twenty five vehicles on daylight marches.

To find the time length of a column, with the index set on number of vehicles; proceed to the TL (Time Length) scale and find the answer at the arrow indicator marked for greater or less than twenty five vehicles, open or closed column. The time length of a column of vehicles infiltrating at a standard rate of three vehicles per mile may also be found at the infiltration index.

To find the time distance of a column, set the rate of march index (10 mph for night marches and 15 mph for daylight marches) on the outer edge of the fogged acetate scale opposite the march distance on the outer scale of the

cardboard base disk, and read the answer under the time distance index, also located on the outer edge of the fogged acetate disk.

Certain cautions must be noted. First, while this march calculator includes road space and time interval between march units, it does not include road space and time intervals between march serials of battalion or brigade size. When using the calculator to determine time length of columns of battalions of greater than one serial, add five minutes for each additional serial of battalion size. Add 15 minutes for each additional brigade size serial greater than one. Additional road space varies depending upon rate of march (ten or fifteen miles per hour, night and day marches respectively), but may be found by multiplying the additional time interval by the rate of march.

The second caution is that the march rate calculator was devised to compute only road space, time length, and time distance. The G3's troop movement job also includes preparation times, loading times, detrucking times, authorized halts and a number of other factors that must be considered in his troop movement planning. He must not leave these out of his estimates. A discussion of these is available in chapter four of FM 101-10.

The march rate calculator included in the jacket of appendix XII is a prototype, devised to demonstrate feasibility

only. Therefore it has not been developed in final form. It could be improved from the standpoint of readibility by coding the scales and indices as necessary, and providing an explanatory table at the center of the base disk.

The primary differences between it and the one illustrated in FM 101-10 is that (1) it does the same job with fewer scales, (2) it provides a greater range of values, and (3) it allows computation of time distance, as well as time length and road space. It provides another aid for computing movement. Whether or not it should be used for a particular divisional training game ultimately rests on the training objectives of that game.

With the development of this variation from the standard march rate calculator, investigation of combat power as it effects maneuver and investigation of movement may be concluded. But as was stated in chapter two, the many factors in war gaming are interrelated. Consequently, combat power will continue in the theme, as attention is turned to casualties and materiel attrition.

CHAPTER VI

CASUALTIES

Casualty Sources

Casualties and destruction of equipment are caused by opposing combat forces in direct encounter. The maneuver units move first to position their inherent firepower to best advantage upon the terrain over which the battle is being fought. Each combatant maneuvers to optimize his combat power so that he may inflict maximum damage on his enemy. The resultant attrition in men and equipment reduces the combat power of each. Because of this attrition, eventually the attacker may advance, close with and destroy his enemy, seizing his position and resources, or forcing his retreat. Or the defender may hold his position, forcing the attacker's withdrawal, or opportunely counterattack and destroy his adversary.

The maneuver unit's combat power is augmented by supporting fires. Primary among the support rendered is artillery and air. The destructive power inherent to the maneuver units must be measured along with the destructive power of these supporting fires to determine which opponent gains the upper hand and wins the days. The choice was made in Chapter

III to base this determination on the casualties incurred by each force. Therefore, the battlefield effects in terms of casualties inflicted by; (1) the maneuver units with their small arms, crew served weapons, mine fields, direct-support and reinforcing (category I) artillery; (2) artillery not yet accounted for (category II); and (3) tactical air support, must be measured. Also, today, nuclear weapons are part of the means afforded each of these casualty producers. Because of the tremendous impact of nuclear weapons on the battlefield and because of the unique attention that has been paid to these weapons in developing methods of estimating their effects, they will be segregated into a separate casualty source.

Devising methods of measuring casualties, explaining their validity, and the limits of this validity is the intention of this chapter. To do this, it is appropriate to first review historical and present methods of casualty determination. Following this, the rationale for determining casualties produced by the casualty sources will be developed. Along with this, reduction of each rationale into a mathematical formulation adaptable to presentation on simple calculators will take place.

Lanchester's Law

In beginning, no historical review of battlefield attrition would be complete without consideration of Lanchester's

classic work on the subject. Frederick William Lanchester,[1] an Englishman, was primarily interested in the consequence to warfare that the introduction of the airplane would bring. He was convinced that it would assume an overwhelming dominance. To prove his point, he found it necessary to make a mathematical analysis of the relationship in battle of type opposing forces; air, sea, and land. For this analysis, he devised a series of simple equations to describe this relationship.

Addressed to the land battle, his fundamental equations in their simplest form described the rates by which the troop strengths of opposing forces in battle are dissipated with time. These equations are:

$$(1)\ \frac{db}{dt} = -r \times c$$

and

$$(2)\ \frac{dr}{dt} = -b \times k$$

Where the letter "b" represents the numerical strength of the blue force and "r" that of the red, "t" stands for time and "c" and "k" are constants.[2] The calculus symbology $\frac{d(\ )}{dt}$ describes rate of change of strength with respect to time.

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[1]James R. Newman, The World of Mathematics, "commentary on Frederick William Lanchester" (New York: Simon and Schuster, 1956), Vol IV, pp. 2136-2137.

[2]Frederick William Lanchester, Mathematics in Warfare, Vol IV of The World of Mathematics, ed. James R. Newman (New York: Simon and Schuster, 1956), p. 2140.

Lanchester developed these basic equations further by stating:-

> In the equations (1) and (2), two constants were given c and k, which . . . were taken as equal; the meaning of this is that the fighting strength of the individual units has been assumed equal. This condition is not necessarily fulfilled if the combatants be unequally trained, or of different morale. Neither is it fulfilled if their weapons are of unequal efficiency. The first two of these, together with a host of other factors too numerous to mention, cannot be accounted for in any equation any more than can the quality of wine or steel be estimated from the weight. The question of weapons is, however, eminently suited to theoretical discussion.
>
> . . . . . .
>
> Any difference in the efficiency of the weapons - for example the accuracy or rapidity of rifle fire may be represented by a disparity in the constants c and k in equations (1) and (2). The case of the rifle or machine-gun is a simple example to take, inasmuch as comparative figures are easily obtained which may be said fairly to represent the fighting efficiency of the weapon. Now numerically equal forces will no longer be forces of equal strength; . . .[3]

To account for such possible fighting inequality between forces caused by, as in Lanchester's example, one side having more efficient weapons than the other, Lanchester modified his original equations by multiplying the force numerical strengths, "r" and "b" of each side, by the constants "N" and "M". These are coefficients that modify the strength of each side in accordance with its fighting efficiency.

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[3] Ibid., p. 2144.

Lanchester continues:-

Rate of reduction of "Blue" force:-

$$\frac{db}{dt} = -Nr \times \text{constant} \quad . \quad . \quad . \quad (3)$$

and "Red",

$$\frac{dr}{dt} = -Mb \times \text{constant} \quad . \quad . \quad . \quad (4)$$

and for the condition of equality,

$$\frac{db}{bdt} = \frac{dr}{rdt},$$

or

$$\frac{-Nr}{b} = \frac{-Mb}{r},$$

or

$$Nr^2 = Mb^2 \quad . \quad . \quad . \qquad (5)$$

> In other words, the fighting strengths of the two forces are equal when the square of the numerical strength multiplied by the fighting value of the individual units are equal.[4]

Lanchester then broadened this conclusion into a general law: ". . . the fighting strength of a force may be broadly defined as proportional to the square of its numerical strength multiplied by the fighting value of its individual units."[5]

By continuing his treatment with further manipulation of his modified equations, he also showed that under certain

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[4] Ibid., p. 2145.

[5] Ibid., p. 2145.

circumstances the rate of loss could be independent of the numbers of troops engaged but would be directly proportional to the efficiency of the weapons. He indicated that this is an unexpected result but "probably" correct.[6]

He then went on to prove his thesis with a general graphical solution. This proof included brief reference to the defeat of the Austrians near Verona, by Napoleon in his Italian campaign and the defeat of Jourdan and Moreau on the Danube by the Archduke Charles in 1796. It also included a more detailed examination of Nelson's naval strategy against the French and Spanish.[7]

He concluded that in a general sense the n-square law was an important truth. He also stated that it could be more easily applied to naval and air strategems and battles than to land battles. His rationale was:-

> We have already seen that the n-square law applies broadly, if imperfectly, to military operations; on land, however, there sometimes exist special conditions and a multitude of factors extraneaous to the hypothesis whereby its operation may be suspended or masked. In the case of naval warfare, however, the conditions more strictly conform to our basic factors. Thus, when battle fleet meets battle fleet there is no advantage to the defender analogous to that secured by the entrenchment of infantry.[8]

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[6] Ibid., p. 2148.

[7] Ibid., pp. 2148, 2153-2157.

[8] Ibid., p. 2151.

Now before concluding this analysis of the implication of the Lanchester equations on force strengths and their relation to battlefield attrition, it is appropriate to consider their present day applications along with other recent casualty studies, as these studies will bear upon the conclusions reached.

Present Day Casualty Treatment

The fundamental law of the Lanchester equations were introduced into certain FAME war games. The equations themselves were modified so that certain battlefield influences on losses were a function of time.[9] This approach differed from other FAME games which were based on combat potentials modified by judgment.

Even with certain basic modifications to the Lanchester equations, the equations were found unsuitable because losses were always unrealistically high.

Other investigators have pursued Lanchester's parameters. R. L. Helmbold had some interesting points to make from his study. He begins by stating:

> Since their enunciation in 1916 Lanchester's models of combat (or modifications of same) have been used by many investigators and for many purposes. Surprisingly enough few serious attempts (other than Lanchester's qualitative discussion) to test these models by an appeal to data seem to have appeared in the literature.

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[9]Richard E. Zimmerman et al., FAME, p. 215.

> On the other hand, there does exist a fair amount of data in sufficient detail to permit estimation of some or all of the parameters related to Lanchester's square law attrition model.[10]

In his study, Helmbold investigated twenty seven battles which spanned the years 1759 to 1945. Troops engaged varied from two thousand to two hundred thousand, casualties from three hundred to more than forty two thousand, and duration of combat from four hours to thirty days.

He identified the following sources of error and data weaknesses.

(1) Positive identification of attacker and defender with respect to time. This was hindered by spoiling attacks, counterattacks, counter-counterattacks and unclear combatant intentions.

(2) Initial strengths, reliability of data gleaned from the smoke of battle, failure of portions of the total forces to engage, and difficulties in assessing when reserves and reinforcements were committed were problematical in this respect.

(3) Casualty assessment. Old accounts, reports, and narratives either failed to identify loss sources or distinguish between them. Some included the whole gamut, killed-

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[10]R. L. Helmbold, "Lanchester Parameters for some Battles of the Last Two Hundred Years," CORG-SP-122-122 (Fort Monroe, Va: USCONARC, February 14, 1961) p. iii.

in-action, wounded-in-action, missing-in-action, prisoner of war, and non-battle losses. Others included only portions.

(4) Duration of engagement. Error sources here are based on narratives such as . . . the battle opened on the day of . . . or ended on the day of . . .. Accounts rarely specified when the initial artillery preparation began.[11]

Working through these difficulties, Helmbold showed by means of statistical analysis that the initial force ratio, attacker to defender, had a significant positive correlation to the defender to attacker casualty production ratio.

He hypothesized that the equation

$$D/A = 3/2\ x_o/Y_o$$

(where "D" is defender casualty production, "A" is attacker casualty production, and "x_o" and "y_o" are respectively attacker and defender initial strengths), is a universal relation between initial strengths and casualties.[12]

Be it so that this hypothesis were true, and the initial force ratio were three to one favoring an attacker. Helmbold then showed mathematically that if the attacker is assumed to break off his attack only after enduring about thirty per cent casualties, with that force ratio, he would prevail over even the most determined enemy.

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[11] Ibid., pp. 4-5.

[12] Ibid., p. 7.

Progressing further, and developing additional equations from Lanchester's square law, he showed that for these additional equations Lanchester's equations forecast victory rather well only at extreme values. That is, interpreted in a broad sense, they forecast victory rather well when there was gross disparity between attacker and defender combat power. On the other hand, for intermediate force ratios, mathematical descriptions of combat power differences and predictions of victory for one side or the other did not correlate well with past combat reality.

From this, Helmbold suggested:-

> It may be that a skillful tactician is able to overcome modest disadvantages, but not a heavy disadvantage, although in the present state of knowledge this can only be a bit of speculation.[13]

In contrast to Helmbold's study, Dorothy Kneeland Clark took a different view after research into the following problem:-

> To investigate from actual combat data the validity of the statement that a unit may be considered no longer combat effective when it has suffered N per cent casualties.[14]

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[13] Ibid., p. 10.

[14] Dorothy Kneeland Clark, Casualties as a Measure of the Loss of Combat Effectiveness of an Infantry Battalion (Chevy Chase, Maryland: Operations Research Office, The John Hopkins University, August 1954), p. 1.

Clark begins with the supposition that it is a gross over-simplification not supported by combat data to state that a unit looses its combat effectiveness after suffering N per cent casualties (usually given as between twenty and thirty per cent). She recognizes that of the many variables which may affect the fighting performance of a military unit, only daily variations in numerical strength can be quanitified;this data being available from historical morning reports.

Her detailed conclusions cite that only ranges of loss percentage can give any accurate description of what happens in combat. The loss of combat effectiveness taken as a unit's inability to perform its mission is, in turn, dependent on the mission itself. She says that widely different loss percentages are, for instance, associated with a breakpoint from attack to defense and a breakpoint from defense to withdrawal. Duration of combat and arrival of replacements too have their influence.[15]

The range of loss percentage must be used because from her study the very wide individual differences in the ability of infantry battalions to carry out a given mission could not be accounted for in terms of casualties alone, no matter how the data might be presented.

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[15] Ibid., pp. 34, 35.

She believes that the most frequent and powerful influences on mission failure are breakdowns in leadership, fire support, reinforcement and communications, rather than loss rates.

Her study cites that records include instances in which prompt and vigorous action particularly by officers at company level or below prevented unauthorized withdrawal and stimulated troops in the attack. The records described other situations wherein battalion officers rallied and reorganized demoralized units as they fled to the rear.[16]

It appeared certain from other battle descriptions that fire support was a major influence on infantry action. Discouragingly though, it was almost impossible to determine what types of fires and how much were provided at a given time.[17]

In discussing reinforcements she stated that a breakpoint might be avoided by the timely arrival of reinforcements. She described one action in which one battalion coming up saved the day for two which were heavily engaged just holding onto their position. Shortly thereafter, however, all three were again in offensive combat.[18]

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[16] Ibid., p. 31.

[17] Ibid., p. 32.

[18] Ibid., p. 32.

In regard to communication failure, she stated:-

> More or less drastic failure in communications marked all the breakpoints studied, usually preceding and often contributive but apparently never the decisive factor.[19]

In another casualty study, Robert J. Best, of the Operations Research Office, had this to say concerning the influence of casualties on battlefield actions:-

> . . . Study of data from ordinary sources can yield only suggestive results on the dependence of casualties on the tactical situation and on their influence on the outcome of an action . . .[20]

A number of other studies concerning various military problems such as when reserves should be committed or what formation should maneuver units take may be found in war gaming archives.[21] A number of these studies reduce these problems to mathematical formulations based on the Lanchester equations. Because of the simplicity of Lanchester's equations, many of these problems are readily solved mathematically. The two problems cited above have such solutions. However, of the problems reviewed, unless they are tactically obvious, their

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[19] Ibid., p. 33.

[20] Robert J. Best, Analysis of Personnel Casualties in the 25th Infantry Division, 26-31 July, 1950 (Chevy Chase Md: Operations Research Office, The John Hopkins University, April 14, 1952), p. 3.

[21] George A. Gamow and Richard E. Zimmerman, Mathematical Models for Ground Combat (Chevy Chase, Md: Operations Research Office The John Hopkins University, April, 1957).

solutions remain suspect. For instance, the general solution to the formation of maneuver units problem when Blue is defending, and Red attacking; is that Blue keep the bulk of his forces in reserve. In fairness to the authors of this solution, it must be pointed out that they suggest any conclusion is dangerous, and that the model may better describe the relation of the general outpost line (GOP) and combat outpost line (COP) to the FEBA than the FEBA to the reserves. Again they recognize that the simplicity of their model may omit certain essential elements.

Now we have gone full circle. Lanchester's work has been discussed. Modern treatment of his equations with respect to combat power or force ratios and casualties has been considered. Other approaches to casualty investigations have been reviewed. And finally, Lanchester's equations in relation to other military problems that bear more remotely on battle casualties have been considered. What conclusions may be drawn and how do they bear on the divisional training game problem in so far as casualty treatment is concerned?

Inferences with Respect to Casualty Measurement

Without a doubt, Lanchester was a pioneer. He was the first man bold enough to attempt to reduce the implications of battle to scientific formulation. Before him, tactical deduction was strictly empirical, truly an art and hardly a science.

His own admissions of weaknesses should be noted. His own admonition that his equations fit the naval or air engagement where the variables are fewer than in the ground battle is in itself suggestive.

Perhaps his equations describe two robot armies fighting to the finish on a bounded flat plain. Each mechanical man would be programmed electronically and equipped to destroy his adversary at a certain rate; and continue to do this until he himself was put out of commission. There would be no effects of weather, terrain, or the human spirit. No variables such as holding out reserves would exist.

It may be though, that as state of the art is advanced, some mathematician will be able to describe the ground battle with a general equation such as

$$\frac{d(b,r)}{dt} = F\ (B_1,R_1,B_2,R_2,\ldots B_n,R_n)$$

based on Lanchester's equations. He might show that the loss rates, $\frac{db}{dt}$ and $\frac{dr}{dt}$, are functionally related to definite numbers of variables that completely encompass the Blue and Red situations.

On the other hand, even if this is never done, Lanchester's equations, because of their general insight into the events of battle, have had great hueristic importance, and will probably continue to have. This is obvious from Helmbold's

study. His suggestion, mathematically derived from a modified Lanchester equation, that a three to one combat power ratio massed by an attacker will always allow the attacker to win, should be most interesting to divisional planners. On the other hand, Helmbold's statement that a skillful tactician may be able to overcome modest disadvantages in so far as unfavorable force ratios are concerned, but not major ones, will probably surprise only a few. The important result here though is that for intermediate force ratio values, when theoretical victory predictions were compared to actual battlefield results, correlation did not exist.

Clark's study reinforces the importance of such variables as leadership, fire support, reinforcement, and communications on the outcome of battle. These make no discrete appearance in Lanchester's equations, but certainly if they influence battle outcome itself, they should effect casualty rates.

At any rate, imperfect as they are, the Lanchester equations continue to draw attention. They have provided the impetus for a great deal of thinking. Many people are today attempting to coalesce tactics, strategy and what happens in battle itself to mathematics. And paralleling the pure sciences, even physics, when simple differential equations are found inadequate to describe phenomena; investigators turn

to more sophisticated methods. In physics, when physicists found Newtonian dynamics inadequate to describe the atom and its internal mechanics, they turned to statistical probabilities and developed quantum mechanics. War gamers and operations analysts likewise have turned to statistical probability.

Divisional Casualty Estimate

Now certainly the divisional training game need not make exhaustive use of such tools as these, even though today's analytical games do. But as stated at the very outset of this investigation, it would be useful to find ways to pull the rigid, tedious but realistic analytical methodology closer to the free, fast but less accurate training methodology. As far as casualty computation is concerned, this may be done in a gross but logical way using the simpler principles of statistics and probability theory. These principles may be oriented around the G1 casualty statistics found in FM 101-10.

Chapter Two, "Personnel" of FM 101-10 includes casualty estimates based upon World War II and Korean War experience.[22] Short period estimates, that is estimates for

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[22]U. S. Department of Army, Staff Officer's Field Manual: Organization, Technical, and Logistical Data, FM 101-10 (Part 1), p. 46.

periods not exceeding five days, reflect the following daily personnel battle casualties as percentage of strength.

(1)	Covering and security force action	0.9%
(2)	Attack:	
	(a) Meeting engagement.	2.4%
	(b) Of a position, first day.	3.8%
	(c) Succeeding days.	1.9%
	(d) Of a fortified zone, first day.	6.3%
	(e) Succeeding days	3.2%

(Percentage values given in the table for defensive casualties need not be included here as they will be based on percentage attacker casualties in the manner presently practiced in the Fort Leavenworth divisional war games.)[23] The percentages listed above are based on total divisional strength. No estimates are given for smaller units, therefore these must be generated from available data.

One method of making casualty estimates for battalion size maneuver units reduces these divisional statistics from a daily division wide estimate to an hourly committed battalion estimate. A range of hourly battalion casualty percentage figures may be deduced which should closely match the divisional statistics over the course of a war game. This

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[23]U. S. Army Command and General Staff College, War Gaming, ST 105-5-1, p. 25.

requires adapting the hourly range of values that may be selected to probability statistics. It requires an estimate of that proportion of troops within the division that will be committed to the maneuver battle and an estimate of how long they would be committed during a twenty four hour period. Only gross accuracy is required in these estimates because a range of casualty rates wide enough to include most "real world" rates (that could be experienced in battle) may be selected. Selection of specific rates for each hourly battle increment is based on normal probability and random numbers.

This method of making casualty estimates for battalion size maneuver units requires that three main assumptions and several others of less importance be made. The primary assumptions are:

(1) Over a long term average, only personnel of the maneuver units suffer significant casualties from catagory I artillery, mortars, direct fire weapons, and small arms including automatic weapons.

(2) The average battle day will have a duration of eight hours.

(3) During this battle day, only one-half of the personnel of the division assigned to maneuver elements will be fully exposed to the effects of the weapons listed above. (This latter assumption is made to account for uncommitted reserves and brigade and lower maneuver unit personnel such as

headquarters troops who, even in the heat of battle, remain fairly well protected.)

Using these assumptions and the short period divisional casualty estimates, conversion may be made to average hourly casualty rates among committed maneuver battalion task forces. Before making this conversion, percentage of maneuver unit (infantry and armor) casualties should be separated from those taken by combat support and combat service support troops. FM 101-10[24] reflect that past wars show that the infantry division experiences 95.4 per cent of the casualties taken among combat troops and 4.6 per cent among all others. Armored divisions have experienced 85.1 per cent of casualties taken in the maneuver units and 14.9 per cent for all others. Mechanized divisions are new and no combat experience data exists for them, therefore, it might be assumed that they will average half way between the infantry and armored divisions in casualty distribution.

A gross estimate of casualties in all three type divisions could be made by averaging the percentages found in each division. Doing this, ninety per cent of the short period casualties could be anticipated in the maneuver units

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[24]U.S. Department of Army, Staff Officer's Field Manual: Organization, Technical and Logistic Data, FM 101-10 (Part 1), p. 46.

and ten per cent in all others, for an "averaged" division. This is predicated on equal time in combat of relatively the same intensity for all three type division.

This analysis is continued by turning to personnel distribution by type in a ROAD division. Type ROAD division strengths are computed from page two of the Leavenworth manual, "The Division", RB61-1. Strengths are:

(1) Infantry Division:

(a) Maneuver unit strength, all ranks, excluding armored cavalry.- 7790

(b) Other, aggregate.- 7816

(2) Mechanized division:

(a) Maneuver unit strength, all ranks, excluding armored cavalry.- 8032

(b) Other, aggregate.- 8328

(3) Armored division:

(a) Maneuver unit strength, all ranks, excluding armored cavalry.- 7955

(b) Other, aggregate.- 8395.

When the maneuver unit strengths for the three type divisions are averaged and the supporting unit strength is averaged:

(1) Maneuver unit strength is.- 7925

(2) Supporting divisional strength is.- 8179

and average division strength is 16,104, or

(3) Percent maneuver troops is, - 49.2%

(4) Percent supporting strength is,- 50.8%

Since this is a gross estimate, a fifty-fifty strength distribution between maneuver unit and support strength is acceptable for the division.

Now reviewing short period estimates from FM 101-10 given earlier, the short period estimate for daily personnel loss as percentage of strength is:

(1) For a meeting engagement,- 2.4%

therefore, computed casualties for an "averaged" division for one day could be forecast as:

(a) .024 x 16,104 = 386 casualties,

and from the given assumptions, maneuver troops receive 90 per cent of these casualties, or

(b) .9 x 386 = 347 casualties.

To compute divisional troops engaged and fully exposed during the battle, it has been assumed that 50 per cent of the maneuver unit troops would be fully exposed during the battle day, and maneuver unit troops comprise 50 per cent of the division strength. Therefore:

(c) .5 x .5 x 16104 = 4026

or 4026 troops would be fully exposed and engaged.

Continuing by computing the percentage casualties among these troops, there would be:

(d) $\frac{347 \text{ casualties}}{4026 \text{ troops exposed}} = 8.16\%$

or 8.16 per cent casualties among the exposed battalion task force personnel for the battle day. Since it has been assumed that the average battle day will last eight hours, the hourly casualty rate would be:

(e) $\frac{8.16}{8}$ 1.02% casualties per hour.

However, 1.00 per cent will be used, as the .02 per cent is hardly significant.

Similarly, casualties on an hourly basis for other offensive actions would be:

(2) Attack of a position, first day,- 1.75%

(3) Attack of a position, succeeding days,- .85%

(4) Attack of a fortified zone, first day,- 3.2 %

(5) Attack of a fortified zone, succeeding days,- 1.45%

Casualties computed for a covering and security force action differ in only one respect from the computations completed above. It would be unrealistic to assume that the same number of divisional troops would be engaged and fully exposed. It might be assumed that the normal distribution of troops for a divisional covering force would be the armored cavalry battalion and a tank battalion. (Again, supporting troops are not considered exposed to the small arms,

infantry or armor, crew served weapons, casualty risk.)

The strength of this force would approximate 1400.

Average division casualties for the daily short period estimate would be:

(6) Covering and security force action. 0.9%

(a) .009 x 16104 = 145 divisional casualties.

(b) 0.9 x 145 = 130 casualties among the troops engaged and exposed.

(c) $\frac{130 \text{ casualties}}{1400 \text{ troops exposed}} = 9.3\%$

(d) $\frac{9.3\%}{8 \text{ hours}} = 1.15\%$ casualties per hour.

Such computations of hourly battle casualty rates are acceptable only on a gross basis. Should the assumptions made be proven correct over a long term, battle casualties for the given type actions would average to the percentage values computed. But even then, they could hardly be applied to individual engagements with the expectation of achieving credible casualty distributions. Numbers of troops engaged varies. Intensity of combat varies. The length of the battle varies. Since it has been concluded that other mathematical procedures such as Lanchester's laws are not very helpful, the only simple mathematical method left that will lend credibility to casualty computations appears to be a combination of statistical analysis and probability theory.

Casualty Computation Based on Statistical Probability

This method is very useful if we assume that the hourly casualty rates computed are correctly an average for the different types of combat over a long period of time. If they are accepted, the normal distribution curve and random numbers afford a method of introducing random probabilities whereby "chance" itself will determine hourly casualty rates. Chance selection of casualty rates means that presently unmeasurable variability among such factors as morale, training, leadership, weather, etc., that play in combination to effect casualty rates during battle and in turn effect its outcome are indirectly taken into account.

Explanation of the methodology to be developed requires that certain statistical terms and operations be understood. First of all the normal curve or normal distribution is a bell-shaped curve which extends infinitely far in both the positive and negative direction. Plotted as a graph on which the y axis is chosen to represent ordinate values and the x axis abscissa values, the curve would appear as in Figure 8 below.

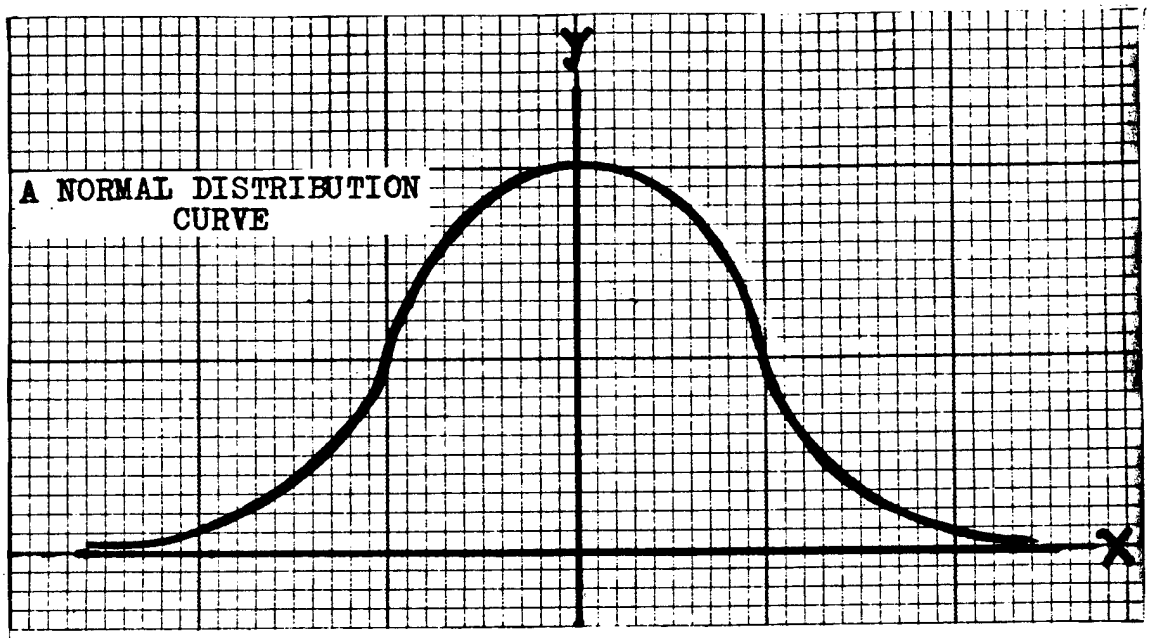

FIGURE 8

It may be noted that the curve shown is a symmetrical bell-shaped curve. Should the curve shown be defined as the curve of a normal distribution of total area unity, it will have certain useful properties.[25] One of these is that the mean, median and modal values are the same. The mean value is the average value. The median value is the middle value when all values are arranged according to absolute size. The modal value is the most frequent or common value. In other words, the mean value is an arithmetic average; the median value is

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[25]Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis (New York: McGraw-Hill Book Company, 1951), pp. 47-49.

an average of position on the graph; and the mode is the most frequent or common value. The second of these properties is the sigma, σ, a standard deviation left or right, is defined to always inclose 34.13 per cent of the area under the curve. This is shown below in Figure 9.

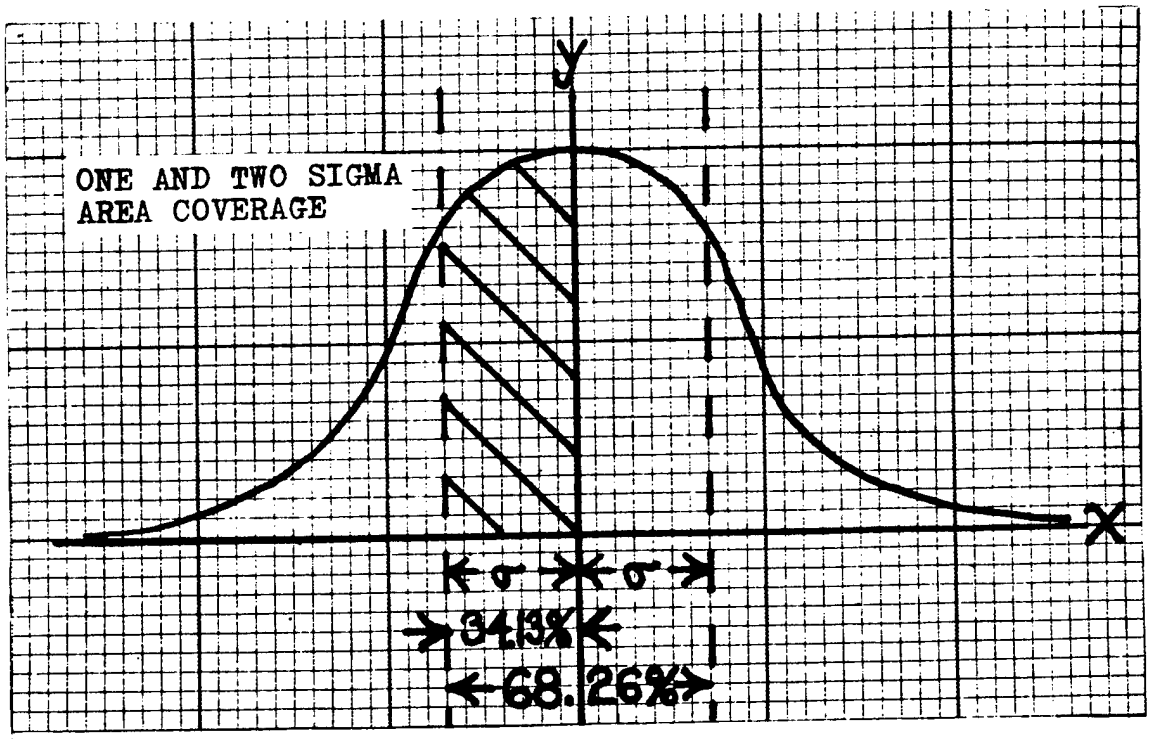

FIGURE 9

Now there are many normal curves of unity value. Some of these are shown in Figure 10. The important thing

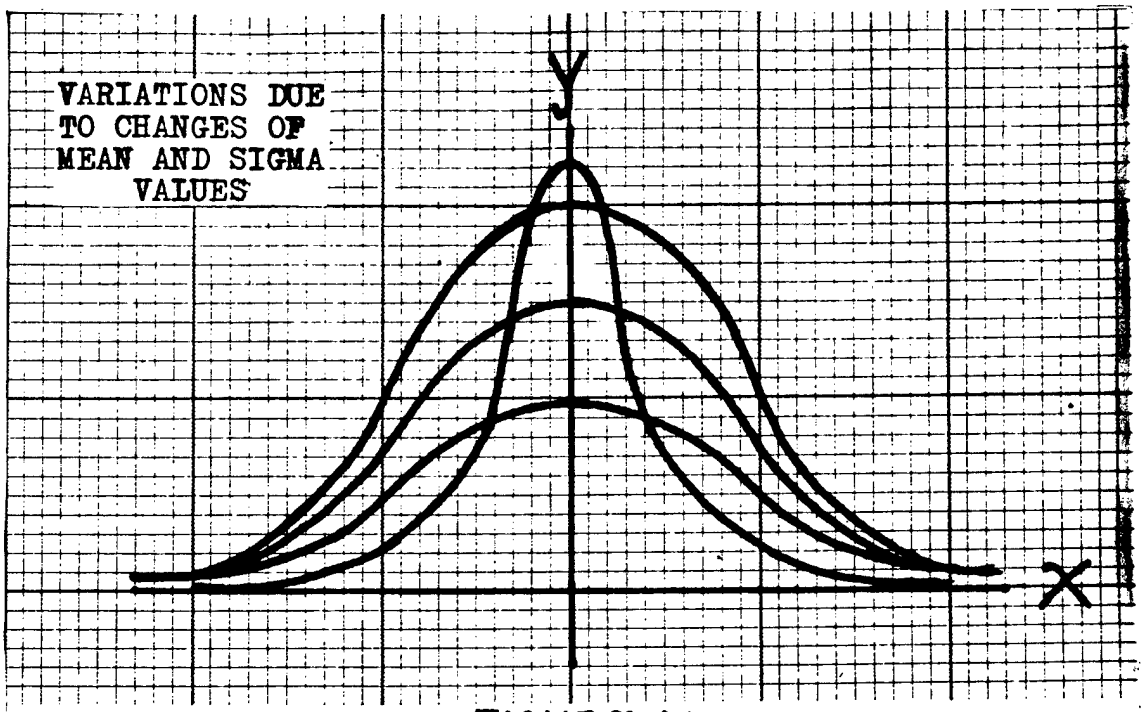

FIGURE 10

in this discussion is that the average or normal value can be defined and an appropriate standard deviation (sigma) be chosen for the curve that will be used. For each type combat action from security and covering force action thru attack of a fortified position these average values have been defined. What remains is selection of an appropriate sigma, or deviation from average. The Leavenworth manual states: "Assess casualties in battalions in contact caused by small-arms and automatic weapon fires at the rate of 1 to 3 per cent per hour.[26] It also states:-

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[26]U.S. Army Command and General Staff College, War Gaming, p. 48.

> . . . Division casualties suffered by an attacker during the assault are assessed between 1 and 7 per cent per day. (Nonnuclear battle casualties in a brigade seldom exceed 15 per cent per day.)[27]

Since no other data is available to dispute these figures, care must be taken to stay within this guidance. Yet in attempting to improve methodology, the methodology selected must be compatible with the statistical experience provided by FM 101-10's short period casualty tables.

One sigma distance left and right from the mean along the normal curve includes 68.28 per cent of the area under the curve. Two sigma, left and right, from the mean along the normal curve contains over 95 per cent of the area under the curve. A sigma, $\bar{\sigma}$, of 0.5 per cent provides a variance of one per cent right and left for the two sigma deviation range. This means that if average hourly attack casualty rates were centered about two per cent on this normal curve and exact values chosen in some random fashion, ninety five per cent of the time they would range between one per cent and three per cent per hour. This range lies within the ranges prescribed in the Leavenworth manual. There will be deviation beyond these values depending upon type action, but normally these limits will not be exceeded. Therefore a sigma of 0.5 per cent is prescribed. The mean value will be that value computed for each type combat action, attack

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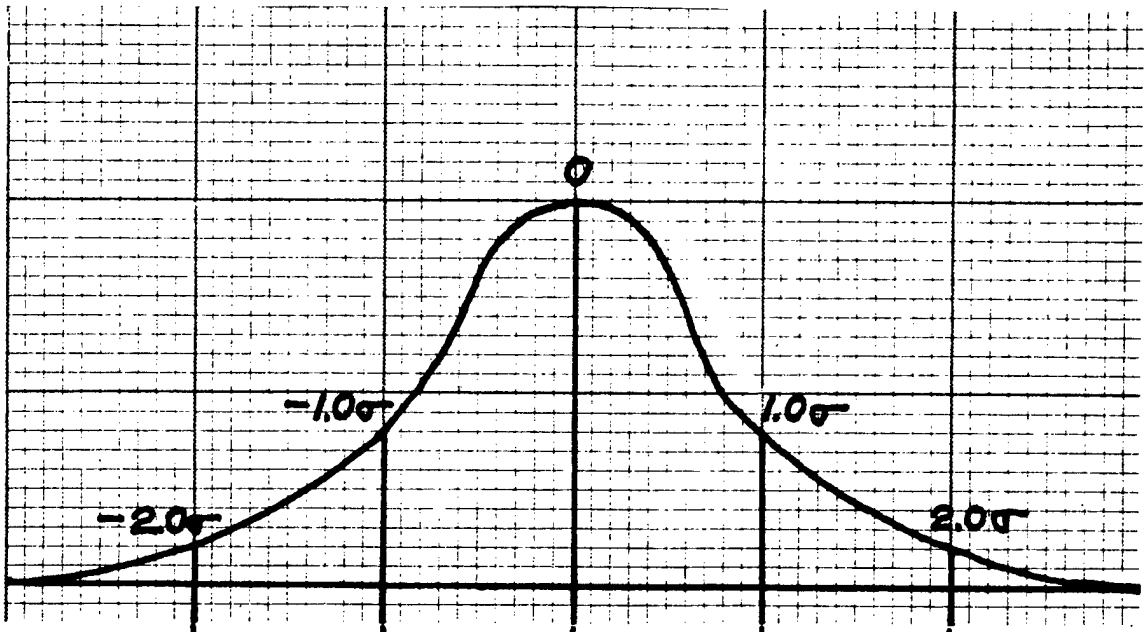
[27] Ibid., p. 25.

of a position, attack of a fortified zone and so forth. Figure 11 below shows how these casualty values fit the normal distribution curve.



0 .15 .40 .60 .90 1.15 1.40 1.65 1.90 2.15 2.40 2.65
SECURITY AND COVERING FORCE ACTION % CASUALTIES

0 .25 .50 .75 1.0 1.25 1.5 1.75 2.0 2.25 2.50
MEETING ENGAGEMENT % CASUALTIES

.25 .75 1.0 1.25 1.5 1.75 2.0 2.25 2.50 2.75 3.0 3.25
ATTACK OF POSITION * 1ST DAY % CASUALTIES

0 .10 .35 .60 .85 1.10 1.35 1.6 1.85 2.1 2.35
ATTACK OF POSITION * SUCCEEDING DAYS % CASUALTIES

1.7 2.2 2.45 2.7 2.95 3.2 3.45 3.7 3.95 4.2 4.45 4.7
ATTACK OF FORTIFIED ZONE * 1ST DAY % CASUALTIES

0 .2 .45 .7 .95 1.2 1.45 1.7 1.95 2.2 2.45 2.7 2.95
ATTACK OF A FORTIFIED ZONE * SUCCEEDING DAYS % CASUALTIES

FIGURE 11

Since the desire expressed earlier is to allow "chance" to operate in selection of casualty rates, this is all that remains to be done. In doing this, use is made of the idea that the area under the normal curve may represent the probability that a certain casualty rate would occur. To describe this idea, assume that a number of war games have been played during which the casualty computer has been required to judge casualty rates within the prescribed percentages many thousands of times. If the frequencies that his selected values occurred matched the area under the normal distribution curve, they would be said to have a normal distribution. If the y axis were designated to represent frequency of selection, that is the number of times a certain casualty rate would be selected, and the x axis the casualty rate itself, approximately sixty eight per cent of the selections could be expected to fall within one sigma deviation from the average casualty rate value. Ninety five per cent should be within a plus or minus two sigma (standard deviation) range. More than ninety nine per cent of the selected casualty rates should lie within a three sigma range. For instance, as shown in Figure 12, with an average casualty rate of two per cent and a standard deviation of one half per cent out of one hundred chance selections, a casualty rate of 1.5 per cent per hour or lower could be expected

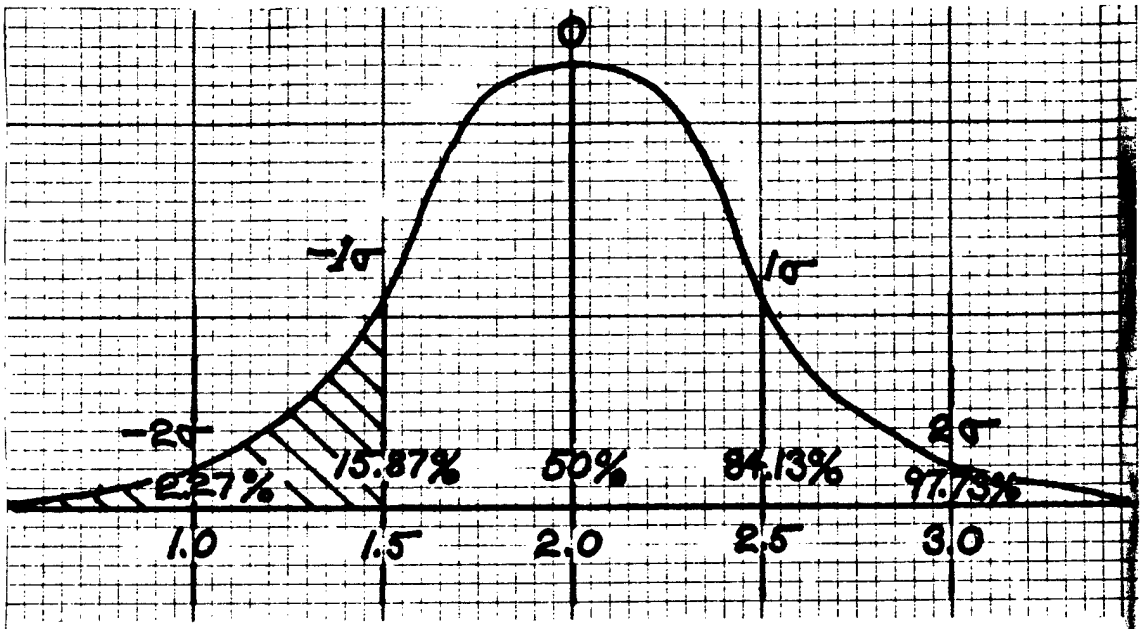


FIGURE 12

in about sixteen selections. Similarly, a casualty rate of three and one-half per cent or less, could be expected in all selections. There would be less than two tenths of one per cent chance that a rate higher than three and one-half per cent would occur.

How then, may it be assured that the casualty computer select values that stay within the desired percentage deviation from the average value? He would by using a random number table containing values zero to ninety nine. Each value would represent a percentage occurring on the normal distribution curve. The random numbers are assigned to the normal distribution curve as shown in Figure 13 below. Note that they are assigned for each one-half standard deviation. They represent the approximate percentage

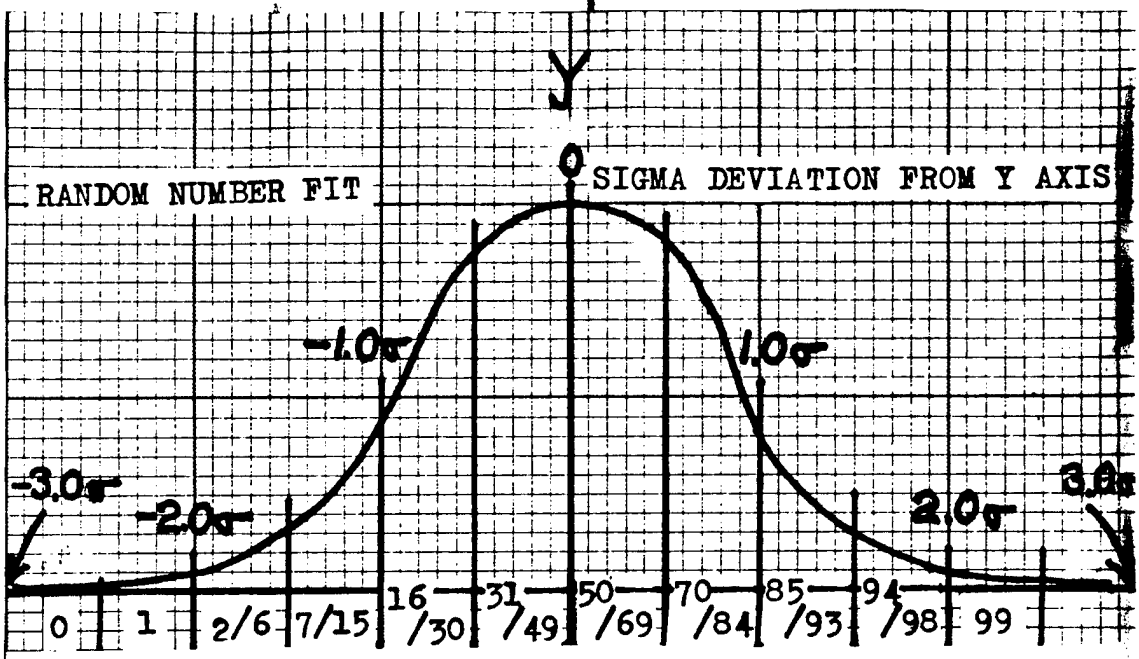


FIGURE 13

area under the curve measured from the minus three sigma intercept. They were computed from a standard normal curve area table which may be found in almost any statistics text of book of engineer tables.[28]

The Small Arms Casualty Calculator

It is a simple matter then to shift the random values to fit the casualty percentages shown in Figure 11. This is what is done in devising a circular calculator for the casualty computer. On a cardboard disk similar to the others that have been described, on the outer circumference a logarithm scale is inscribed. This represents hourly casualty rates. Interior to this, a series of random number tables are drawn

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[28]Herbert Arkin and Raymond R. Colton, Statistical Methods (4th ed.; New York: Barnes and Noble, Inc., 1950) p. 110.

so that the casualty computer upon selecting a random number may read up to the proper hourly casualty percentage rate. This casualty calculator is completed with an outer cardboard disk of slightly larger diameter. On the outer circumference of this disk, another logarithm scale is inscribed. This log scale is so constructed that defender casualty rates may be immediately found. As stated earlier, defender casualty rates in the divisional war game have been made dependent upon attacker casualties. (Although no reason for this is given, this dependency may be a concession to Lanchester's ideas.) Table XIV, "Defender's Casualties", found on page 25 of the Leavenworth war gaming manual prescribed how defender casualties should be assessed.[29] Attacker casualties are simply multiplied by some factor which is in turn dependent upon the combat ratio between attacker and defender. These values are shown in table III below. The logarithmic scale of the outer cardboard disk is so constructed that by placing the index found at the three to one combat ratio value (which has a prescribed multiplier of one), over attacker casualty rate, the defender rate may be read

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[29]U.S. Army Command and General Staff College, War Gaming, p. 25.

TABLE III

Defender Casualties

Combat Ratio Attacker to Defender	Attacker Casualty Multiplier
1 : 1	0.33
2 : 1	0.66
3 : 1	1.00
4 : 1	1.33
5 : 1	1.66
6 : 1	2.00
7 : 1	2.33
8 : 1	2.66
9 : 1	3.00

directly. It is read on the cardboard disk underneath the proper combat ratio value. This casualty calculator may be found in the jacket, appendix XIII.

An example should suffice to demonstrate the process that the casualty computer follows to compute attacker and defender casualties. Assume that a battalion task force is making a first day attack against a fortified zone defended by an estimated aggressor company. A combat ratio of four to one has been previously determined. An assessment time interval is called. The first thing the casualty computer must do is select a random number. He would go to the random number table provided in the control manual and select

a number. Suppose that the number selected was eighty four. Going to his casualty computer, he would find that eighty four prescribed an attacker casualty rate of between 3.58 and 3.7 per cent. The random number block containing this number is seventy to eighty four. Since his number is at the extreme end of the block, he should select a casualty rate of 3.7 per cent. However, he is not bound to this figure. He must stay within the percentage range indicated by the random number block, but, if from his knowledge of the situation this rate appeared high, he would have the authority to select some other rate within the limits of the block. Should he select 3.7 per cent, he would then place the index of the acetate disk over this figure. He would determine that for a four to one combat ratio the defender would suffer:

$$3.7 \times 1.33 = 4.92$$

about 4.9 per cent casualties. These then are the rates that would be assessed.

One final note on small arms casualty assessment based on this method. The method has growth potential. Without dwelling on the thought some reflection on the process should make this apparent. For instance, suppose some factor that effects the small arms maneuver battle, such as terrain or weather variation could be isolated in its effect. This effect could be plotted on a graph. It would probably change

the shape of the normal distribution were it incorporated into that curve. It might cause the mean, median, and modal values to differ. No matter, as long as the percentage area under the curve can be determined, the method of assigning random numbers based on area may still be used. Therefore, as war gaming state of art progresses in the future and more is determined about casualty assessment, the method suggested should still be useful and could provide even greater realism.

Category II Artillery and Airstrike Casualty Assessment

As indicated at the beginning of this chapter, casualties are produced not only through the direct confrontation of maneuver units but also by artillery and airstrikes. A technique for assessing these casualties that varies but little from present methodology is next to be discussed. Beforehand though, it is appropriate to review current techniques, and the discussion will begin with those pertaining to artillery.

Chapter III discussed category I artillery. Recall that this is the direct support and reinforcing artillery immediately available to the maneuver unit commander. Since these fires are immediately available, they were included in the overall firepower score assigned to the maneuver unit. All other artillery fire support is designated as category

II artillery. It is general support or general support-reinforcing artillery which is controlled by the division artillery commander for the good of the entire division. Hence it is not immediately responsive to an individual battalion task force. For this reason, the casualty producing effects of category II fires are computed separately.

The current methodology used at the Command and General Staff College[30] requires that casualties be determined on a per volley basis. This is done by comparing the size of the area covered by a category II volley with the size of the area occupied by the unit bombarded. Troop distribution within battalions or companies is considered uniform. The percentage of the area occupied by troops that is covered by the volley is then multiplied by a per volley casualty percentage. Tables in the Leavenworth manual give the size of a battalion volley depending upon calibre weapon and the per volley casualty percentage depending upon troop posture.[31]

A portion of these are extracted below for reference.

TABLE IV

Conventional Artillery Area Coverage

Unit	Area covered in square meters
105 Bn	125,600
155 Bn	125,600
155/8-in Bn	138,500

[30] Ibid., pp. 48-49.

[31] Ibid., p. 49.

TABLE V

Casualties per Battalion Volley,
Conventional Artillery

Troop Posture	Percentage
Erect	10
Prone	6
Entrenched	1
In trucks	6

Exactly how the casualty computer determines the percentage of a troop occupied area that is covered by a battalion volley may be left for him to decide. However, as a suggestion, he could provide himself acetate cutouts sized to the area of the respective type battalion volley and scaled to the map scale of his battle map. On the other hand, it appears to be rather tedious to compute casualties from artillery on a per volley basis since artillery concentrations are quite often three to five volleys and may run considerably higher. A method to speed up this computation would be very helpful.

First, reflect on the table that gives casualty percentages for the various troop postures. It is logical to expect that those troops surprised by artillery fire in an erect posture would either quickly "hit the dirt" or move out of the area. It would probably be impossible to predict

exactly which course of action they would take as it would depend entirely on the situation at hand. If they were attacking, either course of action would be logical. If they were defending, or in an assembly area, they would most likely go prone, and probably seek entrenchment (if they were not already entrenched). The action they might take if they were traveling entrucked would also depend upon the immediate situation. Were the road blocked or congested, they would probably disperse off the road and seek shelter. Were it open, they would probably stay entrucked and move beyond the area of shellfire as rapidly as possible.

It may be assumed though that they either take protection within the impact area or disperse beyond it as rapidly as possible. It is not logical then to assess casualties based on an "erect" troop posture after the first volley. This should be kept in mind in assessing casualties from artillery fire.

Three categories (1) prone, (2) entrenched, and (3) in trucks, are then left to consider. It might be stated immediately that it must be left to the casualty computer who is familiar with the existing situation to judge the troop posture on which he would base his assessment. To help him after he has decided this, a calculator based on a graphic display of increasing casualties with increasing

numbers of volleys may be constructed. The FAME war game provides the necessary mathematical expression upon which the calculator graphics will depend. Therefore FAME'S evolution of this expression should be noted:-

> . . . Since a target consists of personnel uniformly distributed in a target area, a round having a lethal area covering the fraction α of the total target area causes a fraction of casualties that is also α. The number of personnel remaining are then $1-\alpha$ times the original number. On the second round the fraction who become casualties is $(1-\alpha)$. The sum of the casualties for the first and second rounds then is $\alpha + (1-\alpha)$ or $2\alpha - \alpha^2$. This suggests reexpressing the total casualties after two rounds as $1-(1-2\alpha+\alpha^2)$ or as $1-(1-\alpha)^2$ In turn the total fraction of casualties after n rounds becomes $1-(1-\alpha)^n$. When values of α suitable to conventional area-fire weapons and their targets are to be used, this multiplier may be rewritten with neglible error as $1-e^{-n\alpha}$.[32]

Figure 14 shows the cumulative casualties that would result from increasing numbers of volleys according to the FAME expression. It should be noted that two curves represent attacking troops. The casualty computer would pick the far right curve if, on the first volley, he determined the troops to be erect. This would allow a first volley assessment of ten per cent casualties. The middle curve also represents troops attacking and would be chosen by the casualty computer if he determined that the troops were advancing in a posture more cautious than erect. The left hand curve gives cumulative assessment against entrenched defending troops.

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[32]Richard E. Zimmerman et. al., p. 238.

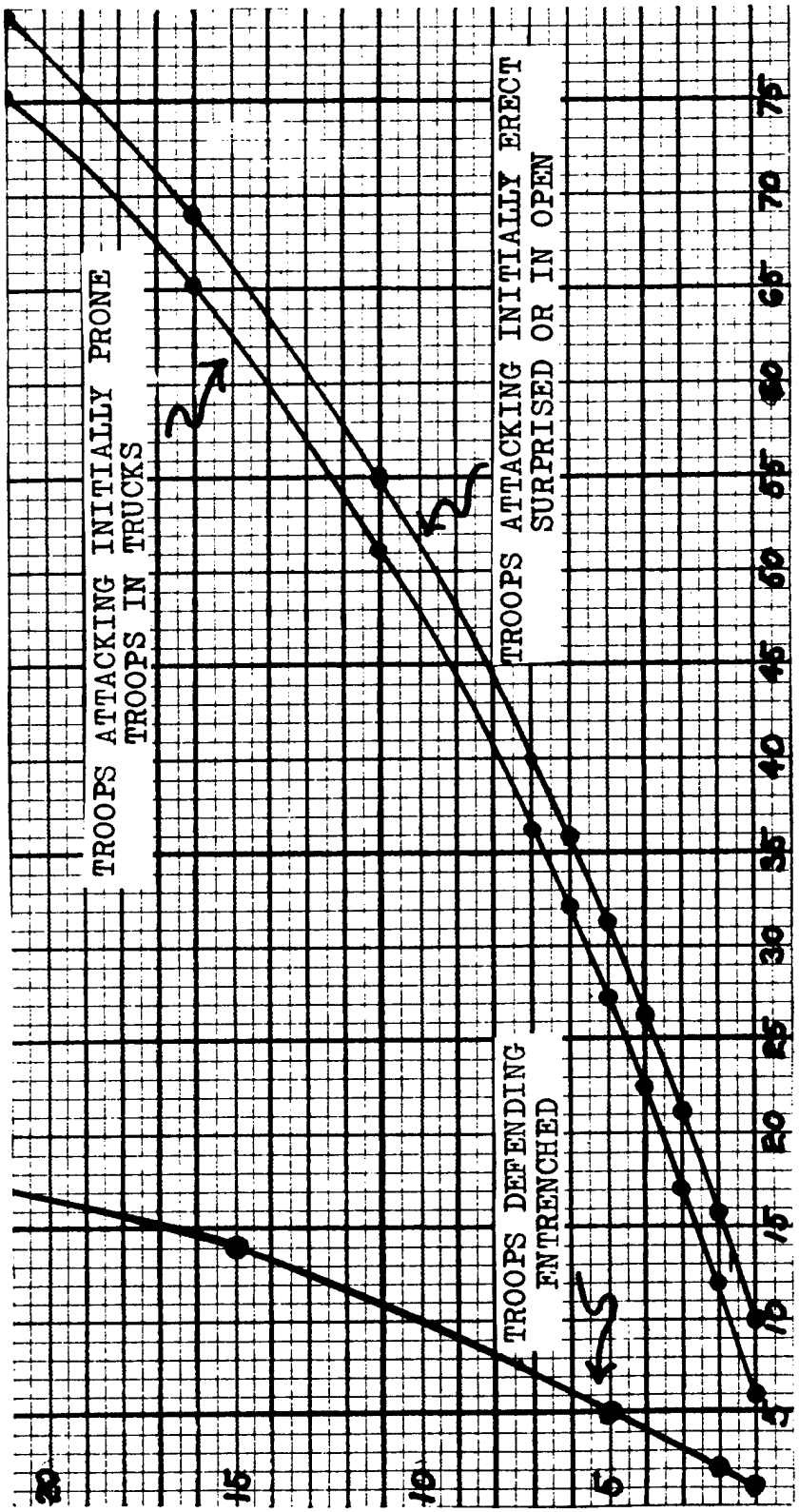
TROOPS ATTACKING INITIALLY PRONE
TROOPS IN TRUCKS
TROOPS ATTACKING INITIALLY ERECT
SURPRISED OR IN OPEN
TROOPS DEFENDING
ENTRENCHED
NUMBER OF VOLLEYS
PERCENTAGE CASUALTIES

FIGURE 14

Some notes on these curves are appropriate, Numerical investigation of the FAME expression shows that it does nothing more than assess the percentage casualties given in the foregoing casualty table. However it does this on a cumulative basis making the assessment against remaining strength. This is to say that if the first volley caused ten per cent casualties and the second six per cent and the third six per cent, strength remaining or cumulative casualties would be:

(1) (1 - .1) (100% strength) = 90% strength

(2) (1 - .06) (90% strength) = 84.6% strength

(3) (1 - .06) (84.6%) = 79.5% strength

(4) 100% - 79.5% = 21.5% cumulative casualties.

It may be seen now that if the casualty computer made this computation on a volley for volley basis, results would be the same. He should save considerable time however, by using the graph because it eliminates a number of computations. It should be remembered that these casualties are assessed only within the lethal area of the volley, and not against the entire unit! As well the graphical values should be used as a guide. Occasions may arise whereby it is tactically obvious that greater or fewer casualty percentages should be assessed. The chief umpire should instruct his casualty computers in how to deal with such situations. Finally, a question might be posed as to why twenty volleys was chosen as an

upper limit on the graph. Actually, on the calculator to be devised, fifteen volleys will be the upper limit. The answer follows; first, rarely will the occasion arise during which more than fifteen volleys are fired. Secondly, it may be assumed that a saturation point would somewhere be reached; that a greater number of volleys would have no greater effect because the target has either dissipated or the remaining troop elements are so well protected that area fire is ineffective against them.

For the moment, so much for artillery. Before continuing with the construction of the calculator, casualties from air-strikes should be investigated because criteria for determining these is similar to that just discussed for artillery. In fact, they will be graphed with category II artillery on the calculator.

The Leavenworth manual includes a table that may be used as a guide for assessing casualties inflicted by one aircraft making one pass, or combinations of aircraft passes up to a total of four.

A portion of the data is extracted in Table VI.[33]

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[33]U.S. Army Command and General Staff College, War Gaming, p. 51.

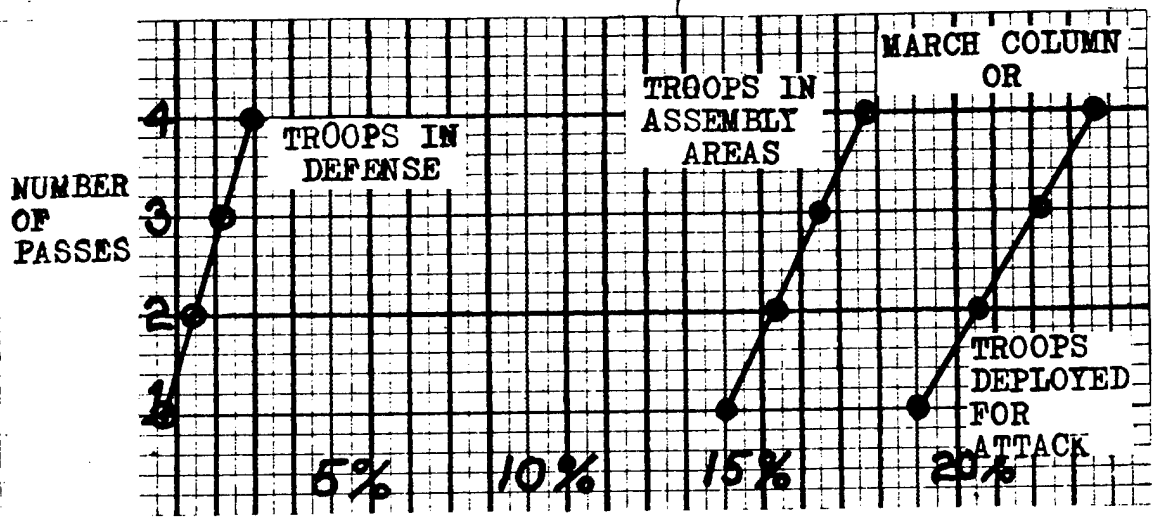
TABLE VI

CONVENTIONAL AIRSTRIKE CASUALTIES

Personnel targets	Casualties for Initial Pass	Casualties for Each Additional Pass to a maximum of three
March column (dismounted)	20 per cent	2 per cent
In assembly areas	15 per cent	1.5 per cent
Deployed for attack	20 per cent	2 per cent
In defense (fox holes)	0.7 per cent	0.7 per cent

Criteria for damage assessment against other type personnel targets is also given. However, it is not amenable to handling on a cumulative loss basis. Consequently airstrikes measured against personnel targets in postures other than those given above must be assessed on a per pass basis.

The data presented in Table VI may be plotted on a graph such as that depicted below.



CUMULATIVE CASUALTY PERCENTAGES

FIGURE 15

The cumulative percentages shown were computed in the same manner as those for artillery casualty cumulative percentages. As with the artillery loss figures, the percentages shown may only be assessed against troops in the area of the airstrike pass. The Leavenworth manual states that this is assumed to be about fifty by eight hundred meters or 40,000 square meters.

This graph and the one previously given for artillery are used together to form the basis of the artillery/airstrike casualty calculator. As with the small arms casualty calculator, only a cardboard base disk and a larger cardboard outside disk is needed. Construction is simple and quite similar to that prescribed for the other calculators. Log scales representing casualty percentages are

constructed on the periphery of both cardboard disks. The graph representing artillery casualties and the graph representing airstrike casualties are inscribed opposite each other immediately below the log scales on the smaller disk. They are arranged so that cumulative casualty percentages for the number of volleys or airstrike passes may be read directly above the intersection of the cumulative percentage curve and the radial line representing volley or pass numbers.

The outer disk also contains a log scale. Remember that cumulative casualties are assessed only against the troops in the artillery volley lethal area and the airstrike lethal area. The casualty computer must estimate this percentage from his battle map. The log scale on the outer disk provides him with the means to multiply this later percentage by the cumulative casualty percentage determined from the graphs. This will give him actual percentage loss that would be assessed against the unit attacked. These two disks complete the artillery and airstrike casualty calculator. For convenience this calculator forms the reverse side of the Small Arms Casualty Calculator. It may be found in the jacket of Appendix XIII.

The artillery and airstrike calculator is simple to use. During a divisional war game, the casualty computer would determine from Blue or Red's fire support plan and its

appendices how many volleys or tactical air sorties up to four have been directed against specified target coordinates. Suppose that Blue has fired six volleys against Red at coordinates xxyy. The casualty computer would first determine what troops are located in the target area. Suppose that from his battle map he estimates that thirty per cent of an entrenched Red battalion has been hit by the Blue concentration. After determining this percentage unit coverage, he would locate cumulative casualty percentage for six volleys on the curve for troops defending, entrenched. This would be determined reading up from the graph as six per cent. Multiplying six per cent by thirty per cent on the acetate disk, he would assess 1.8 per cent casualties against this Red battalion.

Casualty Determination for Nuclear Weapons

This completes the methodology for determining casualties from major conventional sources. Nuclear, biological and chemical weapons have been left out purposely. These weapons are available for delivery by maneuver units, artillery, and aircraft. However, because of their great influence on modern warfare, they are separated in a special category. Training doctrine, though still evolving, is fully developed for these weapons. Because of the special impact of these weapons upon fire support concepts, it is firmly believed

that the methodology for forecasting and assessing the effects of these weapons should be rigidly followed during the divisional training game. Therefore nothing different is to be proposed. Nevertheless they do enter into the scheme of casualty assessment. Therefore cognizance of this should be made. Nuclear, biological, and chemical casualty assessment is made on a percentage basis, and the percentage loss is multiplied right into the combined casualty assessment from all other sources.

Combined Casualty Assessment

First off, casualties should be assessed as they occur. Maximum realism would obtain if this were done. Force ratios and movement rates could then be incrementally adjusted and allow close simulation of the battle as it progressed. However this would be time consuming to the point of absurdity in the manual training game. Therefore casualties are normally assessed at hourly intervals. An easy way to do this is to first subtract each assessed casualty percentage from one hundred per cent, then multiply the remainder together.

Then multiply that percentage figure by the starting strength or the "percentage of authorized" starting strength of the force being assessed. The order of multiplication does not effect the combined assessment figure. Another

specially constructed circular calculator could be provided to accomplish this chore. It is so simply done on a military slide rule though, that it would not be worth the investment. Thus casualty assessment may end with one final note.

That is, while the calculators developed to aid the casualty computer are perhaps more complex in concept than those developed for the rate of movement computer, they should be simpler to operate. As with the other calculators, their primary advantage is that they should speed up the divisional training game. The ultimate proof of this claim is testing. A test of these devices plus an overview of their relation to the elements of the training game along with general conclusions will be presented in chapter seven.

CHAPTER VII

SUMMARY OF RESEARCH, TEST, AND CONCLUSIONS

Graphic Aid Integration into Present Methodology

The investigation into improving techniques employed during the division level manual war game is now complete. It is intended that the graphic aids developed be superimposed on current methodology; and that this methodology change only so much as was described in the chapters that developed the graphic aids themselves. The Brigade Tote Board changes this methodology by requiring maneuver company firepower score aggregation into battalion task force firepower scores rather than initial acceptance of battalion scores provided in an umpire/control pamphlet. The Force Ratio and Rate of Movement Calculator [final model] does not change methodology. It changes only computational technique. Nor does the March Computor change methodology. It provides an alternative to the methods described in FM 101-10 for making march calculations. The Small Arms Casualty Calculator changes methodology to a small degree by requiring random selection of hourly battalion casualty rates rather than an arbitrary selection between one and three percent. The Airstrike and Artillery

Casualty Calculator expands present techniques of assessment so that casualties may be computed for multiple airstrikes or artillery battalion volleys in one computation rather than by a series of successive computations. Consequently use of these new aids should not require any detailed or major revision of the division level war game described in the U. S. Army Command and General Staff College War Gaming manual.

Summary of Research

Three essential tasks remain. The relationship between the proposed aids and the elements of the war game set forth in Chapter II should be discussed to clarify the impact of the graphic aids on these game elements. The proposed devices must be tested to ascertain, [as well as may be done at this stage of development] if they do achieve the objectives initially set forth of simplifying, speeding up, or providing additional war game realism. Finally conclusions based on test results should be reached as to the usefulness of the aids.

To dispatch the first task, review of Table II, reproduced below from Chapter II, is in order.

TABLE II

ELEMENTS OF THE DIVISIONAL GAME

UNITS		
COMBAT	COMBAT SUPPORT	COMBAT SERVICE SUPPORT
Troop List Strengths a) initial b) casualties c) replacements Firepower Unit effectiveness	Troop List Strengths a) initial b) casualties c) replacements Unit effectiveness	
MANEUVER		
Combat Power) mobility) terrain) weather)	Rate of movement	
FIRES		
Integral	Supporting	
(firepower score)	Direct Support Artillery other arty) conventional air support) chemical missiles) biological Nuclear	
Air Defense Barriers and Obstacles Communications Fortifications Intelligence		

As stated in Chapter II, the war game elements are interrelated to a considerable degree. The Brigade Tote Board and The Combat Power and Rate of Movement Calculator together impinge upon and overlap the techniques used to assess factors

related to these war game elements. Therefore, it is appropriate that they be considered together. These graphic aids deal with assessing the factors related to the game elements listed in Table II under "Units", "Combat" and "Maneuver". The tote board firepower cards facilitate accounting for initial task force strengths and indirectly for required replacements. Together with the tote board, the cards provide a method for organizing tailored battalion task forces and introduce a technique for detailed firepower assessment which takes into account the weapon's range and positional depth as firepower builds up from initial engagement until opposing forces close in battle. Firepower is related to unit effectiveness through the "raw score" firepower reduction that takes place on the combat power and rate of movement calculator. This calculator first reduces the firepower ratio by the opposing force [attacker and defender] strength ratio, and then accounts for the lateral firepower distribution by taking into account the attacker and defender frontages. The calculator provides a combat power read out and by tabular display connects rate of movement to terrain and mobility. It does not account directly for weather but does make allowance for the additional element "type defense" or "fortifications". The effect of weather on mobility may be accounted for indirectly if the criteria for wet and dry soil conditions

given in Appendix II are used. The control or movement computer of the umpire staff may reclassify "open" to "median" and "median" to "close" terrain by using this criteria when weather conditions so dictate during a war game. The March Computor calculates reinforcement and resupply times and therefore may assist unit effectiveness assessment of all [type] troop units.

The Small Arms Casualty Calculator provides casualty assessment within combat units. The Airstrike and Artillery Calculator provides for casualty assessment from those sources in all type units.

It may be seen that the proposed graphic aids provide new techniques that aid in assessing factors integral to almost all of the war game elements of the first three subgroups of Table II. Notable exceptions in the subgroup entitled "Fires" are "Chemical", "Biological", and "Nuclear". These fires may be delivered by conventional or missile artillery. Detailed assessment doctrine for these fires exists today. It was decided after review of these assessment techniques that they should be used in the divisional war game in their present form. Therefore no new proposals have been made.

The remaining elements are included in the fourth subgroup of Table II. These include Intelligence, Communications, Barriers and Obstacles, and Air Defense. Research was stopped

short of the war game techniques that deal with these elements for several reasons. Review of current techniques for playing intelligence led to an early conclusion that the present techniques were not adaptable to any new simplified or more realistic approach. Review of communications gaming led to the same conclusion.

Research was stopped short of techniques dealing with Barriers and Obstacles and Air Defense because primary staff planning involving these elements occurs at headquarters higher than division level. The division staff must deal with these elements to be sure; but compared to other planning operations at division level, much of the planning for barriers and obstacles, and for air defense may be reduced to standard operating procedure. Therefore emphasis on these elements at divisional level during a war game is variable. It will depend upon the objective of a particular divisional game. Should the author of a particular game desire to emphasize play in these areas, he is limited to present techniques. However, the successful development of a number of aids that may improve techniques for dealing with other game elements suggests that research into barrier and air defense play might prove fruitful. Now that these graphic aids have been related to the listed war game elements, it may be seen that they tie a majority of these elements together in new assessment techniques.

Testing

With the proposed graphic aids now related to the game elements, it is appropriate to investigate by test whether or not the aids themselves are valid and will in fact fulfill the objectives of adding realism or simplifying and speeding up the divisional game. To do this, test objectives were established. In establishing these objectives, limitations on test resources and the limitations of the aids in their present form were recognized.

As brought out previously, all the proposed aids are prototypes. The originals were constructed by hand and reproduced by photographic process. Except for the firepower cards, professional draftsmanship was not used.

The construction of the logarithmic scales on the various calculators requires a knowledge of mathematics outside the professional acumen of the average draftsman. This construction would require detailed explanation on how to read tabular log values, and then measure and mark these values at the proper place on the circular scales. Thereafter close supervision of a draftsman doing this work would be required. Such a draftsman and such drafting services were not available for the construction of the first models. Fine draftsmanship would enhance readability considerably.

Secondly, recognizing the prototype nature of the calculators, only limited effort was devoted to reducing the mass

of data presently incorporated into the graphics. Such reduction could be accomplished by color coding and by the use of coded symbology that could be explained in a table placed in the center or on the back of each calculator. Codification that would reduce the data on the calculator disks would also enhance readability to a considerable degree. In their present form, the calculators, although suitable for testing purposes, are difficult to read.

Consequently a test that would require quantitative analysis of time savings or accrued simplification is not presently a valid objective and in fact could do a disservice to the ultimate value of the calculators. This leads to a test objective that is limited to a less refined appraisal of the validity of the devices insofar as speed of play and simplification is concerned.

This limitation applies only indirectly to the objective of increasing realism. As realism depends primarily on level of aggregation, if it can be demonstrated that aggregation at lower levels may be made without seriously constraining speed of play or adding unacceptable complication, the objective may be considered fulfilled.

Turning attention now to human resources available at the U. S. Army Command and General Staff College for testing, certain additional limitations become apparent. The

student body is available on a voluntary basis. Because of normal study requirements and other demands on the student's time, it was ascertained that the maximum time that could be requested was about three hours. Along with this time limitation, sample size of the student group is limited by the number of copies of available graphic aids. Three tote boards with sufficient maneuver company cards and six copies of the calculators have been produced. This limits the sample size of officers taking the test to twelve.

Finally, of the three hours alloted to the test, since the graphic aids would be completely new to the test group, a certain amount of time would have to be devoted to an explanation of their function. This would reduce the available testing time and reduce the sample size of the number of problems on the test.

With the foregoing limitations in mind, test objectives were established to determine the following by comparison between a control group and a test group.

(1) Whether or not increased assessment speeds were probable using the calculators. This would require a coarse test completion time comparison between the control and test groups.

(2) Whether or not simplification of assessment computations was probable using the calculators. This would require comparison of the accuracy of answers.

(3) Whether or not increased realism would be achieved by introducing the tote board method of firepower assessment and the Small Arms Calculator. This would require analysis of answers to problems concerning battalion task force firepower rating's and problems dealing with this calculator.

Again, in recognition of the imposed limitations, a critique sheet would be issued to the students which would query on a qualitative basis whether or not the new graphic aid techniques would fulfill the foregoing objectives.

With the test objectives established, the next step was to devise appropriate instruction in the use of the aids and a test from which data sufficient to answer the test objectives could be extracted.

This instruction would necessarily review present techniques and cover the purpose and usage of the proposed aids. Sample problems would be used to demonstrate the aids. Time would also be required for a general orientation on the purpose and organization of the test. One and one-half hours would be alloted to this test phase. Upon completion, the student officers would be divided by random process into a test and a control group of six officers each. The test group would be required to solve thirteen problems covering the full range of graphic aids usage. The control group would solve the same problems by current techniques using the Leavenworth

war gaming manual and slide rules. A number of college faculty members familiar with the thesis project would be invited to attend.

The test was conducted from 0930 hours, 30 April, 1966 until 1300 hours. It went as planned except the instruction required a bit more time than originally scheduled. The group of twelve student officers was oriented and received instruction for two hours and thirty minutes. The test required a maximum time of one hour. [The sample problems, test problems, answers, and critique may be found in the jackets of Appendices IV through VII respectively.] The mathematical background of the twelve officers tested included algebra, use of the military slide rule, and logarithms. Five officers had studied mathematics through calculus. The group included two allied officers, one marine officer, and nine army officers of different branches.

Test Results

Analysis of test results fulfilled expectations. The Brigade Tote Board problems concerning firepower were most readily solved by the test group. Ninety five per cent correct answers were achieved. The control group necessarily used Table X of ST 105-5-1 [page 44] which does not provide sufficient firepower data to completely solve the problems presented. Consequently this group was asked to make estimates

when tabular data was incomplete. These estimates caused variation in their answers which ranged from sixty to one hundred twenty per cent of the nominally "correct" answers.

The test group successfully solved eighty three per cent of the Combat Ratio and Rate of Movement problems with that calculator. The control group, using ST 105-5-1 and slide rules, solved seventy five per cent. Ninety per cent correct solutions were achieved by both groups for the March Computor problems. The test group bettered the control group in solving the small arms, airstrike, and artillery casualty assessment problems by a score of eighty per cent correct solutions compared to fifty five per cent. The average test completion time for the test group was 43.5 minutes. For the control group, it was forty four minutes.

The test was followed by the critique. At this time the twelve test officers answered the questions issued and provided additional comments if they desired to do so.

Ten of the twelve officers indicated that the aids were not difficult to understand. Two U. S. Army officers indicated that the Combat Ratio and Rate of Movement Calculators were difficult. But they also indicated by additional comment that this was due to the prototype nature of these aids. They did not feel they would be difficult after being drafted into final form. One officer indicated that the March

Computor was difficult to understand for the same reason. He also indicated that he felt a nomograph would more readily solve march problems. None of the officers felt that a mathematical background beyond algebra was needed to understand the graphic aids. Three felt that even algebra was not required. The majority of officers tested indicated that they felt the aids could be mastered in three hours. Two felt four or more hours would be required. All of the officers indicated that they would rather use the graphic aids to make war game assessments than continue to use present methods. All indicated that they believed the objectives of either increasing realism or simplifying and speeding up divisional war gaming assessment had been achieved.

Additional ideas for improvement of the graphic aids were solicited primarily as an answer to question three of the critique sheet. Generally the tested group agreed that codification and draftsmanship would improve the final models. Other comments of interest included the following:

(1) That officers could be replaced by trained enlisted teams for making repetitious war game assessments using these aids.

(2) That other variables could be added to the calculators.

(3) That repetitious practice using the aids would cut war game assessment times in half.

Conclusions

From analysis of the test results and student officer comments, the following conclusions were drawn in reference to the divisional training game.

(1) The Brigade Tote Board provides a technique whereby increased realism may be obtained in firepower computations and assessments.

(2) Fair assurance exists that should the Combat Ratio and Rate of Movement Calculator be engineered into final form, through codification of the information contained on its face and professional draftsmanship, it would both simplify and speed up making the war game computations for which it was designed.

(3) The March Computor does provide an alternate method of computing time length, road space, and time distance of military columns of battalion size or less traveling on road nets. Whether or not this method is superior to those described in FM 101-10 requires additional testing.

(4) The Small Arms Calculator which provides a technique whereby more realistic casualty rates may be assessed during a war game in which repetitious casualty assessment is required, is easy to understand and does not appreciably increase assessment time. Further improvement by professional draftsmanship would enhance its readability.

(5) Fair assurance exists that should the Airstrike and Artillery Calculator be engineered into final form, through codification of the information contained on its face and professional draftsmanship, it would both simplify and speed up the computations it was designed to make.

(6) Fair assurance exists that the average officer could learn to use the graphic aids in less than four hours and become increasingly skillful upon working with them.

(7) Further development of the aids would be profitable to the Army if the divisional training game is practiced or contemplated for practice sufficiently to offset the cost of further development efforts and the cost of subsequent training in using the aids.

TABLE VII

WEAPONS, MANEUVER UNITS

Weapon	Points/Range in Meters (less than 300)	500	500	700	1000	Maximum Effective Range
Rifle, 7.62mm	1	1	.5	0		500
Rifle (M) 7.62mm	4	4	2	1		700
Pistol 45 cal	1	0				25
Submachine gun 45 cal	1.5	.5	0			300
Grenade launcher 40mm	5	5	0			420
Rocket launcher 3.5 inch	10	10	5	0		500
Machinegun 7.62mm	6	6	6	6	4	1100
Machinegun 30 cal	6	6	6	6	4	1100
Machinegun 50 cal	10	10	10	10	10	1900
Mortar 81mm	12	12	12	12	12	3650
Mortar 4.2 inch	15	15	15	15	15	5500
Rifle Recoilless 90mm	15	15	15	7	0	800
Rifle Recoilless 106mm	20	20	20	20	20	1100
Gun, tank, 76mm	28	28	28	28	26	4400
Gun, tank, 90mm	30	30	30	30	28	4400
Gun, tank, 105mm	32	32	32	32	30	4400
Kit, machinegun, dual	12	12	12	12	8	1900
Kit, machinegun, quad	24	24	24	24	16	1100
Kit, rocket, 2.75 inch	10	10	10	10	10	2000
SS-11	0	0	20	20	20	2000
Entac	0	0	20	20	20	2000

NOTE:- The weapon point score values used in this table and Tables VIII thru XVI were extracted from FM 105-5, "Maneuver Control." Maximum effective ranges were extracted or calculated from the specific weapons characteristics given in the Department of Army 17 and 23 series of field manuals.

TABLE VIII

FIREPOWER, HEADQUARTERS AND HEADQUARTERS COMPANY, TANK BATTALION

Weapons	Nr	Pts	Range (100's of meters) 0 2 4 6 8 10 12 14 16 18 20 42 44		54 56
Rfl 7.62mm	230* 244	1	230 (115) (0)		
Rfl (M) 7.62	2	4	8 (4) (2) (0)		
Pistol	76	1	76/0		
Subm. Gun	16	1.5	24 (12) (0)		
Gren. Lchr	12	5	60 (0)		
M. Gun 7.62	13	6	78 (52) (0)		
M. Gun 30 cal	2	6	12 (8) (0)		
M. Gun 50 cal	45 46*	10	450 (0)		
Mort. 4.2 in	4	15	60		(0)
Gun. Tk 76mm	2	28**	56 (0)		
Gun. Tk 105mm	3	32**	64 (0)		
TOTAL			1118 1042 1018 724 720 690 630 630 180 60		60
			1042 1030 839 722 180		0

*When augmented, augmentation not incl in totals

**Incl secondary armament

TABLE IX

FIREPOWER, TANK COMPANY, TANK BATTALION

Weapons	Nr	Pts	Range (100's of meters)															
			0	2	4	6	8	10	12	14	16	18	20			42	44	46
Rfl 7.62mm	6 13*	1	6		(3) (0)													
Pistol	84 87*	1	84/0															
Subm. Gun	36	1.5	54	(27) (0)														
Gren. Lchr	1 3*	5	5		(0)													
M. Gun 7.62	17	6	102					(68)	(0)									
M. Gun 50 cal	20 21*	10	200										(0)					
Gun, tank, 105	17	32**	544															(0)
TOTAL			995	911	857	846		812	744			744						
			911	884	849		846	795				544				544	0	

*When augmented, augmentation not incl in totals
**Includes secondary armament

TABLE X

FIREPOWER, HEADQUARTERS AND HEADQUARTERS TROOP, ARMORED CAVALRY SQUADRON

Weapons	Nr	Pts	Range (100's of meters)										
			0	2	4	6	8	10	12	14	16	18	20
Rfl 7.62mm	175 178*	1	175		(88) (0)								
Pistol	46	1	46										
Subm. Gun	2	1.5	3	(2) (0)									
Gren. Lchr	6	5	30		(0)								
M. Gun 7.62	2	6	12					(8)	(0)				
M. Gun 50 cal	30	10	300									(0)	
TOTAL			566		517	312		308	300			300	
			520	519	400		312						0

*When augmented, augmentation not included in totals

TABLE XI

FIREPOWER, ARMORED CAVALRY TROOP, ARMORED CAVALRY SQUADRON

Weapons	Nr	Pts	Range (100's of meters)																				
			0	2	4	6	8	10	12	14	16	18	20		42	44		54	56
Rfl 7.62mm	87	1	87		(44)	(0)													
Rfl (M) 7.62	6	4	24		(12)	(6)	(0)												
Pistol	64	1	64/0																
Subm. Gun	15	1.5	23	(12)	(0)														
Gren. Lchr	22	5	110		(0)														
M. Gun 7.62	19	6	114					(76)	(0)										
M. Gun 30 cal	6	6	36																
M. Gun 50 cal	34	10	340										(0)						
Mort. 4.2 in	3	15	45															(0)	
Gun. Tk. 76	6	28**	168													(0)			
TOTAL			1011		924	715	703	653	553				553			45		45	
				947	936	759	709						213		213			0	

**Includes secondary armament

TABLE XII

FIREPOWER, AIR CAVALRY TROOP, ARMORED CAVALRY SQUADRON

Weapons	Nr	Pts	Range (100's of meters) 0	2	4	6	8	10	12	14	16	18	20
Rfl 7.62mm	77	1	77			(39)	(0)						
Rfl (M) 7.62	8	4	32			(16)	(8)	(0)					
Pistol	66	1	66/0										
Gren. Lchr	9	5	45			(0)							
M. Gun 7.62	4	6	24					(16)	(0)				
M. Gun 50 cal	7	10	70									(0)	
M. Gun. Dual	9	12	108					(72)				(0)	
M.G.Quad 7.62	9	24	216					(144)	(0)				
SS-11	4	20	0			(80)							(0)
Kit, 2.75 Rkt	4	20	80										(0)
TOTAL			718	652		594	578		462	302	302		0
			652			633	586					160	

TABLE XIII

FIREPOWER, HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION (MECHANIZED)

Weapons	Nr	Pts	Range (100's of meters) 0 2 4 6 8 10 12 14 16 18 20	42 44 54 56
Rfl 7.62mm	228 * 241	1	228 (114) (0)	
Rfl (M) 7.62	2	4	(2) (4) (0)	
Pistol	76 * 79	1	76 / 0	
Subm. Gun	8	1.5	12 (6) (0)	
Gren. Lchr	17	5	85 (0)	
Rkt Lchr 3.5	7	10	70 (35) (0)	
M. Gun 7.62	16	6	96 (64) (0)	
M. Gun 30 cal	2	6	12 (8) (0)	
M. Gun 50 cal	39	10	390 (0)	
Mort 4.2 in	4	15	60	(0)
Gun Tank 76	2	28**	56	(0)
Entac	3	20	0 (60) (0)	
TOTAL			1093 1017 1005 678 674 638 566 566 116	60 60
			1017 1011 827 676 176	116 0

*When augmented, augmentation not incl in total

**Incl secondary armament

TABLE XIV

FIREPOWER, RIFLE COMPANY, INFANTRY BATTALION, (MECHANIZED)

Weapons	Nr	Pts	Range (100's of meters)																
			0	2	4	6	8	10	12	14	16	18	20			36	38	40	
Rfl 7.62mm	138	1	138			(69) (0)													
Rfl (M) 7.62	18	4	72			(36)	(18) (0)												
Pistol	61	1	61/0																
Subm. Gun	2	1.5	3	(1.5)	(0)														
Gren. Lchr	24	5	120				(0)												
M. Gun 7.62	16	6	96						(64)	(0)									
Rkt Lehr 3.5	4	10	40			(20) (0)													
M. Gun 50 cal	21	10	210										(0)						
Mort. 81mm	3	12	36															(0)	
Rfl 90mm	6	15	90				(42) (0)												
Rfl 106mm	2	20	40							(0)									
TOTAL			906	845	842	528	382	350	246	246						36			
			845	843	597	442	382	350					36			0			

TABLE XV

FIREPOWER, HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION

Weapons	Nr	Pts	Range (100's of meters) 0 2 4 6 8 10 12 14 16 18 20		54 56 58
Rfl 7.62mm	225 * 238	1	228 (114) (0)		
Rfl (M) 7.62	2	4	8 (4) (2) (0)		
Pistol	65 * 68	1	65 / 0		
Gren, Lchr	16	5	80 (0)		
Rkt Lchr 3.5	8	10	80 (40) (0)		
M. Gun 7.62	7	6	42 (28) (0)		
M. Gun 50 cal	13	10	130 (0)		
Mort 4.2 in	4	15	60		(0)
Rfl 106	2	20	40 (0)		
Entac	3	20	0 (60) (0)		
TOTAL			733 668 336 332 318 250 60		60
			668 490 334 278 120		0

*When augmented, augmentation not incl in totals

TABLE XVI

FIREPOWER, RIFLE COMPANY, INFANTRY BATTALION

Weapons	Nr	Pts	Range (100's of meters) 0 2 4 6 8 10 12 14	36 38 40
Rfl 7.62mm	122	1	122 (61) (0)	
Rfl (M) 7.62	18	4	72 (36) (0) (18)	
Pistol	58	1	58 / 0	
Gren Lchr	23 23	5	115 (0)	
Rkt Lchr 3.5	3	10	30 (15) (0)	
M. Gun 7.62	6	6	36 (24) (0)	
Mort 81mm	3	12	36	(0)
Rfl 90mm	6	15	90 (0) (42)	
Rfl 106mm	2	20	40 (0)	
TOTAL			599 541 238 112 100 36 / 541 314 172 60	36 / 0

APPENDIX II

Terrain

The Leavenworth manual gives three classifications of terrain.[1] To these is added a fourth, which, though not listed, is obvious. This is, of course, that terrain which is impassable to mechanized and armored forces. A more detailed discussion of terrain is found in the CONARC "War Gaming Handbook".[2]

This manual identifies four types:

(1) Type A - Contour interval variation from 0 to 100 meters per kilometer, permitting maximum cross country movement.

(2) Type B - Contours varying from 100 to 200 meters per kilometer. Small hills with gentle slopes causing slight reduction in movement rates.

(3) Type C - Contour variation 200 to 400 meters per kilometer, sufficient variance to cause significant slowing down of cross-country movements.

(4) Type D - Contour variation 400 meters and over per kilometer. Not suitable for tracked or wheeled vehicles.[3]

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[1]U.S. Army Command and General Staff College, War Gaming, p. 45.

[2]U.S. Continental Army Command, War Gaming Handbook (U).

[3]Ibid., p. 13-15.

The movement rates associated with these terrain types are also restricted to the July-August period. This indicates that weather must be introduced as a factor. The rates themselves are classified and consequently can not be introduced here. This is unnecessary however, as the CONARC terrain types generally equate to those of the Leavenworth manual which values are given. Type A is equivalent to "open" terrain; type B, "median"; and type C, "close". There is no Leavenworth category equivalent to the CONARC type D. However, the controller or umpire has been admonished to disallow any vehicular movement over terrain fitting this category.

Along with this terrain classification based generally on land form, movement rates associated with vegetation are given. Vegetation that hinders cross-country movement are forests of various type which CONARC classifies as:

(1) Type L - Stands of pine and hardwood. One half of the area composed of seedlings and thickets 2 to 6 feet apart. One quarter covered with trees 6 to 12 inches in diameter, 6 to 9 feet apart. The remaining area covered with mature trees 10 to 30 feet apart. Cross-country movement rates are equated to type B terrain.

(2) Type M - Less mature, more closely spaced hardwoods of beech and oak, of sufficient diameter to prevent movement at rates greater than allowable over type C terrain.

(3) Type N - Areas of predominately pine forest. Trees are closely spaced and prevent movement at rates greater than allowable for type D. Impassable for wheeled and tracked vehicles except for roads and fire breaks.[4]

Finally, the CONARC manual distinguishes soil types in some depth.[5] These are:

(1) Class A - Coarse grained, cohesionless gravels and sands, with a subsurface of either dry or saturated soil. Absence of rocks or boulders in subsurface.

(2) Class B - Same as A except that the subsurface contains a rock underlay.

(3) Class C - Same as A, except for a very high water table.

(4) Class D - Inorganic soils of high plasticity, dry, with the absence of surface rocks and boulders.

(5) Class E - Inorganic clays of low to medium plasticity, clayey gravels and sands, dry.

(6) Class F - Low plasticity inorganic silts, silty gravels and sands. Dry.

These terrain, forest, and soil types may be grouped corresponding to the open, median, close, and impassable terrain definitions used in the Leavenworth division game. Wet

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[4] Ibid., p. 13-16.

[5] Ibid., p. 9-5.

and dry conditions must also be identified when this is done for the soil types.

Leavenworth Classification	CONARC Classification
(1) Open terrain	Type A terrain; soil classes A and B, soil class C when dry.
(2) Median terrain	Type B terrain; forest class L; soil class C when wet causes open terrain to become median.
(3) Close terrain	Type C terrain; class M forests; soil class C covering median terrain when wet causes movement restriction to that of "close" terrain. All terrain of soil class F when dry.
(4) Impassable to vehicles	Type D terrain; class N forests; wet soil class F.

TABLE

The CONARC manual does not equate soil classes D and E to any terrain type. Therefore, these soil classes are assumed to have negligible effect on terrain type classification and are consequently ignored. From their description, this appears proper.

APPENDIX III

Field Fortifications

Construction of a hasty defense is a time consuming task. Construction of field fortifications requires major effort. This becomes obvious upon examination of FM 5-15, the Army's field fortification manual. Table VI of this manual lists both the weight and volume of materials and man hours required to construct personnel and individual weapons emplacements.[1] Since the time required for such construction is of major concern in war game control; cursory review of the range of construction times involved is of interest. A skirmisher's trench which affords minimum hasty protection requires one-half hour's digging. An open one man foxhole requires between two and four and one-half hours to build depending upon the amount of revetment provided. A deepened two man foxhole or a two man foxhole completely reveted requires between eight and ten man hour's construction time. A fully covered twenty five foot fighting trench requires from thirty five to forty man hours.

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[1]U.S. Department of the Army, Field Fortifications, (Washington: U. S. Government Printing Office, October, 1959), p. 84.

Characteristics of crew served infantry and artillery weapon emplacements found in Table XVII of the manual show the same range of man hours.[2]

The effort required to clear fields' of fire, provide barbed wire entanglements, lay minefields, and camouflage must be added to these entrenchment times to get a clear picture of the work envolved. Man hour estimates for clearing fields of fire and providing barbed wire entanglements may be found in FM 101-10 (Part 1).[3]

Should a hasty defense be classified as that providing minimum cover for the rifleman and weapons crewman, that is, slit trenches and simple foxholes, four hours preparation time is credible. A fortified position would require at least twenty four hours to prepare, if reveted foxholes, covered fighting trenches, barbed wire entanglements, and camouflage are assumed as criteria for this classification.

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[2] Ibid., p. 124.

[3] U. S. Department of the Army, Staff Officers' Field Manual: Organization, Technical, and Logistical Data, Part 1 - Unclassified Data (Washington: U. S. Government Printing Office, October 1961), p. 211.

APPENDIX IV

GRAPHIC AIDS TEST

Part I

EXAMPLE 1 Initial BRIGADE TOTE BOARD Set Up

(a) Blue brigade commander has an infantry battalion, a mechanized battalon, and a tank battalion. Each conforms to current ROAD organization. For training purposes, the brigade commander desires to form three battalion task forces with maximum cross assignment of type maneuver companies.

(b) Organize the brigade on the TOTE BOARD

(c) The TOTE BOARD is set up to show three battalion task forces as follows:

(1) Hq & Hq Co; Inf. Bn.
Inf. Co.
Mech. Co.
Tank Co.

(2) Hq & Hq Co; Mech. Bn.
Inf. Co.
Mech. Co.
Tank Co.

(3) Hq & Hq Co; Tank Bn.
Inf. Co.
Mech. Co.
Tank Co.

EXAMPLE 2 Battalion Initial Disposition Firepower Score

(a) A blue battalion task force composed of a Hq & Hq Co., Mechanized; two mech rifle co's.; and a tank co, is disposed 2000 meters from red position, preparing to attack. A mechanized company and the tank company are disposed along the FEBA. The second mechanized company is being held in reserve 1000 meters back. The center of mass of the support weapons (mortars, recoilless rifles, etc.) of the Hq & Hq Co. is also 1000 meters from the FEBA.

(b) Determine the firepower score of the blue task force.

(c) The firepower score is 732.

(d) The solution of this problem requires that the FIREPOWER CARDS representing the Hq & Hq Co., and the reserve co., be placed in the TOTE BOARD so that their center of mass scales read 1000 meters left of the Index. The attacking company FIREPOWER CARDS are placed in the TOTE BOARD so that their CENTER OF MASS scales read zero at the left index (since they are disposed along the FEBA). The battalion task force firepower score is added directly down from the 2000 meter mark on the DISTANCE BETWEEN OPPOSING FORCES scale at the top of the TOTE BOARD. Reading down at this point, the firepower scores are:

(1) Hq & Hq Co. - 116
(2) Tank Co. - 544
(3) Mech Co. - 36
(4) Res Mech Co - 36
732

EXAMPLE 3 BLUE TASK FORCE ASSAULT

(a) Three hours later, the blue battalion task force is closing with the enemy. The lead companies have overrun red's forward dispositions and blue's reserve company has been committed. The weapons platoon of the Hq & Hq Co. has repositioned itself forward to give maximum support. In this melee blue and red are intermingled.

(b) Determine blue's Firepower.

(c) Blue's Firepower is 3900.

(d) The solution of this problem requires that the TOTE BOARD be "closed"; that is all FIREPOWER CARDS be placed so that their left index is flush with the left index of the DISTANCE BETWEEN FORCES scale. The firepower score is added directly down the left index as follows:

(1)	Hq & Hq Co	- 1093
(2)	Tank Co	- 995
(3)	Mech Co	- 906
(4)	Res Mech Co	- 906
(5)	Total TF	- 3900

EXAMPLE 4 Rate of Advance and Force Ratio Problem

(a) A blue mech bn at 95% auth strength and firepower score of 2000 is making a frontal attack against a red inf bn in a fortified position over open terrain. The red infantry is at 65% strength and has a firepower score of 1200.

(b) What is the force ratio and blue's rate of advance?

(c) Force Ratio - 2.4:1
Rate of advance - 650 meters/hour.

(d) Set 2000 opposite 1200 on the firepower ratio scales on the rim of the calculator. Bring the defender strength of 65% opposite the attacker strength of 95%. On the inner disk for table marked DFDR IN FORT, PSN, OPEN terrain, FRONTAL ATTACK by MECH force interpolate at 650 between 600 and 1100 meters per hour. The force ratio is interpolated at 2.4:1 between 2:1 and 3:1.

(e) By current methods, the respective firepower scores of blue and red are first multiplied by their percent strength. The reduced firepower ratio is next established. Table X, page 19 of ST 105-5-1 is then used to determine the combat (or force) ratio. From the combat ratio, table XI, page 21 or table XII is used to determine rate of advance.

EXAMPLE 5 Illustration of insufficient combat power to advance.

(a) A blue tank bn is attacking frontally over median terrain along an 800 meter front. The bn firepower score is 3000; its strength is 90%. The defender red undergoing this attack is disposed along 1100 meters. Red has a firepower score of 2200 and is at 95% strength. Red is in a hasty position.

(b) Determine the force ratio and blue's rate of advance.

(c) Force ratio - 1.8:1
Rate of advance - blue does not advance as the force ratio is not sufficient to allow advance.

(d) Set 3000 opposite 2200 on the firepower ratio scales: Bring the defender strength of 95% opposite the attacker strength of 90%. Bring 800 meters on the inner disk opposite 1100 meters on the intermediate acetate disk. This represents the ratio DFDR FRONTAGE TO ATKR FRONTAGE. Read thru the acetate on the base disk on the table marked DFDR IN HASTY PSN for ARMOR in a FRONTAL attack over median terrain between - and 400 meters per hour. 400 meters per hour is the minimum rate of advance. Since the index does not reach this value, no advance is allowed. The combat ratio, read at the top of this scale, is between 1:1 and 2:1 and would be estimated at about 1.8 to 1.

(e) By current methods, the combat ratio would be determined on a slide rule by setting up:

$$\frac{3000}{2200} \times \frac{90\%}{95\%} \times \frac{1100}{800} = 1.77:1$$

Tables X and XII, pp. 19 and 22 of ST 105-5-1 would then be used to determine the rate of advance, in this case, less than minimum allowable.

EXAMPLE 6 Use of the calculator illustrating flank attack.

(a) A blue Mech bn is attacking the flank of a defending red infantry bn. The blue bn is disposed over 600 meters and the red bn over 2200 meters. The blue bn has a firepower score of 1500 and the red bn has a score of 2500. Both battalions are at authorized strength.
Terrain is open and red is defending in the open.

(b) Find the force ratio and blue's rate of advance.

(c) Force ratio 6.2:1, rate of advance 8000 meters per hour.

(d) This problem is solved in a manner similar to Example 5. However, since blue is attacking red's flank the red numbers are read on the table on the base disk.

EXAMPLE 7 Calculator use illustrating maximum values.

(a) A blue tank bn of firepower score 3500 at 95% strength is attacking a red bn which has been caught in the open. Red's strength is 75% and his firepower score is 2000. Blue is attacking forntally and is disposed over 1000 meters. Red is defending 3000 meters.
Terrain is close.

(b) Find the force ratio and blue's rate of advance.

(c) Force ratio - greater than 6:1, rate of advance - maximum rate of 1100 meters per hour allowed.

(d) This problem illustrates maximum allowable rates of advance. Note the arrow index is beyond the highest tabular value. This infers that the highest tabular value must be credited blue.

EXAMPLE 8 March computer use

(a) The brigade commander has ordered a reserve tank battalion to attack. Road distance from the reserve position to the line of departure is 30 km. There are 200 vehicles in the battalion. If the bn's lead vehicle has just crossed the start point, how soon will the full bn be available at the line of departure. Time is now 1400 hours.

(b) 2 hours and 10 minutes - at 1610.

(c) Solution is in two parts. First the time length of column is computed. The base index on the acetate disk is brought over 200 vehicles. Since the time 1400 indicates a daylight march, the arrow index for >25, OPEN is used. This symbology means the time scale was computed for a vehicular column of more than 25 vehicles marching in open column. One hour is read on the base disk under the arrow. The second part of the problem requires setting the arrow indicator for 26 Kmph (15 mph), the normal rate for a daylight march on the acetate disk opposite 30 on the base disk and reading 1 hr and 10 min (interpolation required) opposite the time disk arrow on the acetate disk.

(d) Solution of this problem by current war game methodology requires that the appropriate formulas and tables in FM 101-10. Part 1, page 128 and a slide rule be used.

EXAMPLE 9 March computer use

(a) An aggressor tank bn is located 200 km from a friendly airhead. It has an estimated 150 vehicles. What is its possible night time march closing time?

(b) 14 hours, 20 min estimated. Solution follows example 8.

EXAMPLE 10 Small Arms Casualty Calculator

(a) A blue battalion is in a first day attack against red who is defending a fortified position (zone). During an assessment period (hourly), you, as a casualty computer have selected at random, the number eighty five (85).

(b) What casualty percentage do you assess against blue for one hour of this attack?

(c) Assess 3.7%, 3.7% to 3.95% allowable.

(d) Upon selecting 85 from a random number table, move on the calculator table to ATTACK OF A FORTIFIED ZONE - 1st DAY. Tabular values of random numbers, in the table are found above the subtitle. The number, 85, lies in the BLACK random number block 85-93. Reading up to the BLACK log scale on the periphe using the accetate scale, percentage limits for each end of th block are found to be 3.7% to 3.95%. Since 85 is the lowest number within the block, 3.7% is the casualty assessment figu normally chosen. By the rules established, assessment to 3. is allowable, since it falls within block limits.

(e) If the blue to red force ratio was 6 to 1, what casualties should be assessed against red for this period? Assume 3.7% was assessed against blue.

(f) Assess red 7.4%.

(g) Place the index at the 3 to 1 force ratio over 3.7%. Read 7.4% opposite the 6:1 force ratio indicator.

(h) By current methods, casualty assessment against blue would be arbitrarily chosen as between 1 and 3 % per hour. (See par. 4.23, ST 105-5-1, War Gaming.) Table XIV, page 25, ST 105-5-1, gives the Defender Casualty multiplier. In this example, for a 6 to 1 force ratio, it is 2.

EXAMPLE 11 Small Arms Casualty Assessment

(a) A blue battalion is in a first day attack of position (hasty defense). If you have selected the random number 17, and the force ratio blue to red is 2 to 1, what hourly casualty percentage do you assess against blue and red.

(b) Blue 1.3%
Red .85%

(c) Values are acceptable from 1.25% to 1.5% for blue and .82 to .99 for red. This example shows that the red random numbers require reading the red log scale for percentage casualty assessment.

EXAMPLE 12 Category II Artillery Assessment

(a) Thirty five percent of a red reserve battalion is caught in the open by six volleys of blue Artillery.

(b) What percent casualties do the battalion suffer?

(c) 12.7%

(d) Using the Airstrike and Artillery Calculator, the intersection of 6 volleys and the graphic line for TROOPS ATTACKING SURPRISED OR IN OPEN, lies below 36%. This value must be multiplied by the area hit by the 6 volleys which was given as 35%. Placing the index of the outer log scale (at 100%) at 36%, read below 35% on the outer scale, 12.7% on the inner scale.

(e) Current methodology requires assessment according to the table XXXIV and par 4.25(b) of ST 105-5-1 on a volley for volley basis.

EXAMPLE 13 Airstrike Assessment

(a) Three blue aircraft strike the forward edge of a defending red battalion, about 25% of the battalion's positional depth.

(b) What percentage casualties occur in red ranks?

(c) .53%

(d) The mechanics of this solution are the same as those of the previous two examples. Note though that only the green radial lines are used for 1, 2, 3, or 4 aircraft. The intersection for three aircraft and the red graphic line labeled AIRSTRIKE TROOPS IN DEFENSE (FOXHOLES) yields the percentage casualty value on the RED log scale.

(e) Table XXXVI, page 51, ST 105-5-1 is used to solve this problem by current methodology.

APPENDIX V

GRAPHIC AIDS TEST

PART II

NAME_____

The Brigade Tote Board

PROBLEM 1 A blue brigade commander has 2 tank bns and 1 inf bn. He has cross assigned these into three tank inf task forces of two tank co's and one inf co. Set this up and determine the maximum firepower of each bn task force.

Answer _____ _____

_____

PROBLEM 2 (a) Within the brigade of problem 1, Task Force 1, (composed of HHC, tank, 2 tank co's, and an inf co) has been given the mission of seizing a hill mass 2000 meters in front of the present line of contact. This is the main red defense. The task force commander will attack with one tank and one inf co in tank inf teams. They are at the line of contact. He is keeping his second tank company in reserve 1200 meters to the rear. The support wpns of his HQ & HQ Co are located 1500 meters behind the LC.

(b) What is the firepower score of this TF in this initial disposition?

Answer _____

PROBLEM 3 (a) The two companies that form the lead elements of the task force of problem 2 advance to 500 meters of the enemy. The reserve co follows these lead elements 1000 meters back. The support wpns of the hq co are also 1000 meters to the rear of the lead elements.

(b) Determine the firepower score.

Answer_____

PROBLEM 4 (a) Task Force I is making the final assault and has closed with the enemy. The reserve co has been committed. The support weapons of the hq & hq co have been placed to put maximum firepower on the enemy. Blue and red forces may be considered intermingled.

(b) Determine blue's firepower?

Answer_____

Division Combat Power and Rate of Movement Computer
(Interim Model)

PROBLEM 5 (a) A blue mech bn is advancing over OPEN terrain against a red inf bn in HASTY POSITIONS. Blue is making a FRONTAL attack.

Blue Firepower - 3200
Blue Strength - 95% auth

Red Firepower - 2600
Red Strength - 90% auth

(b) Determine the combat ratio and blue's rate of advance.

Answer_____

PROBLEM 6 (a) Blue tank bn is advancing against a red bn over MEDIAN terrain. Red is in a FORTIFIED position. Blue is making a FLANK attack.

Blue Firepower - 4000
Blue Strength - 90%

Red Firepower - 3000
Red Strength - 90%

(b) Determine the combat ratio and blue's rate of advance.

Answer_____

Division Combat Power and Rate of Movement Calculator
(Final Model)

PROBLEM 7 (a) A blue mech bn is advancing FRONTALLY on an 800 meter front over OPEN terrain against red in a HASTY POSITION. Red is defending 1600 meters.

Blue Firepower - 2500
Blue strength - 90%

Red Firepower - 2200
Red Strength - 75%

(b) Determine the combat ratio and blue's rate of advance.

Answer _____

PROBLEM 8 (a) A blue tank bn is attacking the flank of a red mech bn which is in the OPEN. Blue is attacking along 500 meters, blue is disposed along 3000 meters. Terrain is OPEN.

Blue Firepower - 2500
Blue Strength - 85%

Red Firepower - 3000
Red Strength - 95%

(b) Determine the combat ratio and blue's rate of advance.

Answer _____

PROBLEM 9 (a) A blue inf bn is advancing FRONTALLY over CLOSE terrain against a red bn in a FORT PSN. Blue is attacking over 500 meters, red is disposed over 2000 meters.

Blue Firepower - 1500
Blue Strength - Auth

Red Firepower - 1200
Red Strength - 85%

(b) Determine the combat ratio and blue's rate of advance.

Answer _____

March Rate Calculator

PROBLEM 10 (a) An aggressor tank bn of 100 vehicles is located 125 km from a friendly airhead. How soon could it attack the air head?

(b) At night? Answer_____

(c) During daylight hours.

Answer_____

Small Arms Casualty Calculator

PROBLEM 11 Blue has been attacking red for three days. One blue battalion with a force ratio of 5 to 1 over red is making good headway. An hourly assessment period is called. You select the random number 65. What percent casualties do you assess against blue and red?

Answer blue_____

Answer red_____

PROBLEM 12 Category II Artillery Assessment

(a) A blue 155 battalion has fired 14 volleys against an attacking red battalion (in the open). You judge 50% coverage of red by blue's fire. What casualty percentage do you assess against red?

Answer_____

PROBLEM 13 (a) One blue aircraft strafes 50% of a red column of troops marching. What casualty percentage do you assess?

Answer_____

APPENDIX VI

GRAPHIC AIDS TEST

PART III

Answers

PROBLEM 1

(by Tote Board)

2 Bn T.F.s	Max firepower	
Hq & Hq Co, tank		1118
2 tank co's	2X995 =	1990
1 inf Co.		599
		3707

1 bn T.F.		
Hq & Hq Co inf		733
2 tank co's	2X995 =	1990
1 inf co		599
		3322

(by ST 105-5-1)

2 Bn T.F.		
Hq & Hq Co, Tank (est)-		700
2 tank co's	2X670 =	1340
1 inf co		630
		2670

1 Bn T.F.		
Hq & Hq inf (est) -		650
2 tank co's	2X670 =	1340
1 inf co		630
		2620

PROBLEM 2

(by Tote Board) 180 + 544 + 544 + 36 = 1304

(by ST 105-5-1) Any logical estimate

PROBLEM 3

(by tote board) 630 + 849 + 744 + 314 = 2537

(by ST 105-5-1) Any logical estimate

PROBLEM 4

(by Tote Board) 1118 + 995 + 995 + 599 = 3707

(by ST 105-5-1) Any logical estimate

PROBLEM 5 Combat ratio - 1.3:1, Rate of advance - blue cannot advance.

PROBLEM 6 Combat ratio - 2.3:1; rate of advance - 550 meters per hour (interpolation req'd)

PROBLEM 7 Combat ratio - 3:1, Rate of advance 750 meters per hour (interpolation req'd)

PROBLEM 8 Combat ratio ->16:1, Rate of advance, maximum allowable 8000 meters per hour

PROBLEM 9 Combat ratio - 5.9:1, Rate of advance max allowable 650 meters per hour.

PROBLEM 10 Night 7 hrs, 48 min. approx
Day 5 hrs, 10 min approx

PROBLEM 11 Blue .98%
Red 1.65%

PROBLEM 12 Red 32%

PROBLEM 13 Red 10%

APPENDIX VII

GRAPHIC AIDS TEST

PART IV

Critique

Please answer and comment as desired on the following questions.

1. Were these graphic aids difficult to understand? Yes ☐ No ☐

2. If your answer was yes, which ones?

   Please check.

   a. Tote Board ☐

   b. Division Combat Power and Rate of Movement Computor ☐

   c. March Rate Computor ☐

   d. Small Arms Casualty Computor ☐

   e. Airstrike and Artillery Casualty Computor ☐

3. How could they be improved?

4. a. Do you feel they achieve the objective of either increasing realism or simplifying and speeding up divisional wargaming assessment?

   Yes ☐ No ☐

   b. Comment

5. Would you rather make the divisional assessments given in the problems by the old methods?

   Yes ☐ No ☐

6. Does your mathematical background include

   Algebra ☐

   Logarithms ☐

   Slide Rule ☐

   Calculus ☐

   Beyond Calculus ☐

7. Do you feel that you need a mathematical background beyond algebra to work these devices?

   Yes ☐ No ☐

8. How long do you think would be required to fully master these graphic aids?

   One hour ☐

   Two hours ☐

   Three hours ☐

   Four or more hours ☐

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AIR CAVALRY TROOP, ARMORED CAVALRY SQUADRON

AGG AUTH STR

145

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

FIREPOWER SCORE

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

718 652 652 594 578 462 302 302 302 302 0

652 652 633 586 578 462 302 302 302 160

ARMORED CAVALRY TROOP, ARMORED CAVALRY SQUADRON

AGG AUTH STR

151

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
1011	947	924	715	703	653	553	553	553	553	213	213	213	213	213	213	213	213	213	213	213	213	45	45	45	45
947	936	759	709	703	653	553	553	553	213	213	213	213	213	213	213	213	213	213	213	213	213	45	45	45	45

RIFLE COMPANY, INFANTRY BATTALION

AGG AUTH STR

180

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
599	541	541	238	112	100	36	36	36	36	36	36	36	36	36	36	36	36	36							
541	541	314	172	112	60	36	36	36	36	36	36	36	36	36	36	36	36	0							

HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION

AGG AUTH STR

290

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
733	668	668	336	332	318	250	250	250	250	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
668	668	490	334	332	278	250	250	250	120	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60

TANK COMPANY, TANK BATTALION

AGG AUTH STR

90

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
995	911	857	846	846	812	744	744	744	744	544	544	544	544	544	544	544	544	544	544	544	0				
911	884	849	846	846	795	744	744	744	544	544	544	544	544	544	544	544	544	544	544	544	544				

HEADQUARTERS AND HEADQUARTERS COMPANY, TANK BATTALON

AGG AUTH STR

1305

CENTER OF MASS

DISTANCE FROM FEBA (100's of meters)

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

FIREPOWER SCORE

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

1118	1042	1018	724	720	690	630	630	630	630	180	180	180	180	180	180	180	180	180	180	180	180	60	60	60	60	
1042	1030	839	722	720	690	630	630	630	180	180	180	180	180	180	180	180	180	180	180	180	180	60	60	60	60	

RIFLE COMPANY, INFANTRY BATTALION (MECHANIZED)

AGG AUTH STR

199

CENTER OF MASS
DISTANCE FROM FEBA (100's of meters)

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
906	845	842	528	382	350	246	246	246	246	36	36	36	36	36	36	36	36	36							
845	843	597	442	382	350	246	246	246	36	36	36	36	36	36	36	36	36	0							

HEADQUARTERS AND HEADQUARTERS COMPANY, INFANTRY BATTALION (MECHANIZED)

AGG AUTH STR

304

CENTER OF MASS

DISTANCE FROM FEBA (100's of meters)

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

FIREPOWER SCORE

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
1093	1017	1005	678	674	638	566	566	566	566	116	116	116	116	116	116	116	116	116	116	116	116	60	60	60	60
1017	1011	827	676	674	638	566	566	566	176	116	116	116	116	116	116	116	116	116	116	116	116	60	60	60	60