PROLOGUE

In 1832 Carl von Clausewitz wrote:

> "But the first business of every theory (ON WAR) is to clear up conceptions and ideas which have been jumbled together, and, we may say, entangled and confused; and only when a right understanding is established, as to names and conceptions, can we hope to progress with clearness and facility, and be certain that author and reader will always see things from the same point of view. Tactics and strategy are two activities mutually permeating each other in time and space, at the same time essentially different activities, the inner laws and mutual relations of which cannot be intelligible at all to the mind until a clear conception of the nature of each activity is established.
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> He to whom all this is nothing, must either repudiate all theoretical consideration, or his understanding has not as yet been pained by the confused and perplexing ideas resting on no fixed point of view, leading to no satisfactory result, sometimes dull, sometimes fantastic, sometimes floating in vague generalities, which we are often obliged to hear and read on the conduct of War, owing to the spirit of scientific investigation having hitherto been little directed to these subjects."
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> --- Clausewitz "On War"

There has long been general interest in quantifying various aspects of combat effectiveness, with the objective of *predicting*, prior to actual employment in combat, the contribution to success made by some force, force component, or weapon system. Insight is always desired into the comparative behavior of forces, where the local contribution of a particular weapon system may have only a relatively small payoff when compared to the force as a whole. The complexity of this problem is further increased by acknowledged sensitivity to factors relating to the environment and tactical employment of the forces. It is this complexity that has led to the development of analytical war games -- truly vast simulations where many aspects of combat are in some manner introduced so that questions may be examined in a nearly complete tactical context.

War gaming is a tedious and expensive methodology. If satisfactory mathematical techniques existed which could comprehend directly problems of the complexity and scope of those posed today, they would surely be employed in preference to war games.

In the past efforts have been undertaken to examine direct mathematical approaches to developing measures of effectiveness for large composite forces. This came about because of the continuing needs of planners for quantitative tools for use in establishing force structures, compositions, and levels.

An excellent assessment of the state of the art was presented in a paper[1] which first comments on existing methods of computing indices of combat effectiveness, to indicate both their military content and mathematical nature. Next, it examines the question of what such measures should contain if they are to be applied legitimately to problems of force structure and composition. Finally, it describes the necessary mathematical properties of a workable measure.

An aggregate measure of effectiveness of a combat unit should represent a collection of properties over a collection of objects, within an organizational structure.

All existing methods of derivation of aggregate measures of combat effectiveness depend largely on numerical properties of weapons and equipment. They also depend on a certain amount of military hypothesis and history of performance of combat units. They deal almost entirely with the casualty producing capabilities of weapons; and they reflect few, if any, of the attributes of the organization containing the weapons. They ignore the vast amount of resources contained in the combat organization which has nothing to do directly with inflicting casualties on the enemy, but without which the combat task could not be performed. These two omissions, the inherent nature of the fighting organization and proper accounting for non-weapon equipments, are not the result of oversight; they result simply from an inability to handle the complexity that arises with their inclusion.

There are two general uses to which aggregate effectiveness measures of ground combat are put. These are (1) assessment of small unit battles and (2) static force comparisons. In the first application the numbers used represent total capability of small units engaged in combat, to resolve battle situations in larger simulations or war games. In the second application the numbers used represent the total capability of large units (usually division or larger) by which static force comparisons can be made. These two uses, and certain models developed for application to them, are discussed.

In the assessment of small-unit engagements the aggregation of unit capabilities extends fundamentally over the unit of resolution for the war game; or often over a small group of small units considered as involved in the same engagement. For instance, the fundamental aggregate could be the company; but two or three companies on one side might be engaged with a comparable enemy force.

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[1] Paul F. Dunn and Col. Harold C. Brown: The Nature and Application of Aggregate Measures of Combat Effectiveness. dtd 28 Oct. 1965.

The basic measure should represent all important internal properties of the aggregated unit which bear on its capability to deliver effective fire. We are now in a position to anticipate an important (and often overlooked) distinction in the nature of a measure to be used in game assessment, and one which is to be used for out-of-context comparisons. An aggregated unit in a game operates within a system of rules governing its employment by the player, and describing both the tactical and physical environment. The unit is also small compared to the size of the game. Hence, there is little requirement for explicit modeling of many combat function, especially those which come into play principally at higher levels. Most of these functions may be accounted for adequately by modifiers on basic firepower capabilities. On the other hand, if aggregate measures are to be used for direct comparison of forces, there must be further mathematical formulations to replace the dynamics provided by the game.

There are several approaches to development of the aggregate small unit scores, but they all depend primarily on establishing the relative lethality of all weapons found in the unit. One such method[2], calculated a combat potential consisting of a sum for all weapons over a single *microscopic* engagement, with each weapon considered only in its primary role. For example, antitank weapons are counted only for their capability against tanks, and mortars against personnel. Specific supply limitations are not considered. However, posture and mission are encompassed in a set of tactical modifiers which account for hardness of defensive positions, terrain, and an inherent numerical advantage to units in the defense.

A second combat potential method [3] accounts in great detail for specific weapons capabilities; including, in addition to direct lethalities, multipliers accounting for available ammunition supply for each weapon. Separate potential apply to units found in various postures and terrain.

Still another approach to a model of small unit combat involves a set of Lanchester-type equations using a matrix of effectiveness coefficient, one for each weapon against each target class. Target class is usually also defined as a weapon class. An example of this type of model was developed in connection with the FAME war game.

The use of aggregated firepower potentials for battle assessment in war games requires the development of attrition equations and sometimes expressions for probability of success for the combatants. In addition, special combining rules for the individual small unit potentials are

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[2] FAME, A War Game for Testing Division Organization (U), Tech Memo ORO-T-383, Res. Analysis Corp., McLean, Va.
[3] Interim Report: Measuring Firepower Potential and Combat Effectiveness (U), USArmy Combat Developments Command, Adv. Tactics Proj., Fort Belvoir, Va.

sometimes provided so that artillery fire support can be better accounted for, and units committed late or withdrawn from the battle can have their proper effect.

Regardless of the method used in these various developments, there are many similarities, especially in mathematical structure and in areas where far-reaching military assumptions have to be made. Some of these basic similarities are described as follows.

All are linear combinations of a fundamental lethality per weapon or lethality per round per weapon

No account is taken of mutual support of weapons of like kind; except as might be buried in the average casualty payoff per round as shown by historical data.

No proper account is taken of mutual support of weapons of unlike kind.

Equivalence ratios of point and area fire weapon potentials are inferred from the analysis of certain historical campaigns -- examples of which show a wide disparity according to theater.

The equivalence ratio of tanks and infantry is established through arbitrary -- more or less elaborate -- procedures, in which the actual combinations of tank and infantry teams are not considered. Either a direct relationship is assumed or a dubious mathematical system of inequalities is used (none involving tank-infantry teams) to place armor and infantry on a summable basis.

It should be noted that all methods, including those likely to be developed, in order to accomplish assessment of small unit actions, finally require the selection of real-time rates of attrition -- whether as personnel attrition directly, or as the relative attrition of combat potential. This means that absolute casualty rates have to be inferred, or that acceptable casualty levels for type operations must be determined, in which case battle times have to be assumed.

This is a resume of the general structure and military content of several types of aggregate scores, and the models of small unit combat in which they are incorporated. Although the tone of the description just given is critical, this does not mean that any great improvement can be offered at present. Furthermore the errors contained in the very small unit aggregates are compounded when similar methods are used to compile scores representing the capability of units of division size or larger. What we will have to say in the latter part of this book is offered in the hope that workers in this field will recognize that there exist certain logical and mathematical attributes of military reality that, to an extent, conflict with the requirements implied by the applications. This implies far more complicated models than any thus far proposed. If this be the case, so be it; the recent applications to the analysis of static forces, or the comparison of structures and composition, present far more serious problems than that of war game assessment.

The application of aggregate measures in static force comparisons to problems of force structure involves the development of a number, or small set of numbers, which completely characterizes the combat organization in regard to its ability to undertake various combat missions under specified circumstances. When a larger organization is involved, these numbers must comprehend far more obscure phenomena than the mere casualty production potential of the totality of weapons in the unit. Some operational properties of large units arising purely from size and structure may equal or exceed in importance the properties of the weapons themselves.

The story of development of aggregate scores for application to force comparisons of this sort is distressingly brief. The fact of the matter is that almost no actual development has occurred. On each occasion in which aggregate scores for division-size units have been needed, the procedure has been to select what was considered to be the most adequate of the firepower scoring systems and to apply the same methodology to the larger organization. Sometimes care is taken to reduce (albeit arbitrarily) the scores awarded to weapons belonging to headquarters and rear echelon elements which are not often involved in direct combat. This negative consideration is not offset by any real credit for the tasks that service support and other rear area elements do perform.

As far as numerical procedure is concerned, a total score is obtained by summing firepower scores or combat potentials for all units contained in the larger organization; a similar total firepower score is obtained for some reference organization and divided into the former. This yields an Index of Combat Effectiveness. Such indices may be calculated for any of several overall mission situations for more detailed comparisons.

This is a brief outline of the state of efforts to describe numerically the effectiveness of combat organizations. If direct comparison of large organizations is to be made it must be remembered that the large aggregate index will contain all the flaws of the compounds from which it is built, and -- in fact -- even more. Proper consideration of virtually all high-level command and support functions is omitted in the aggregation process. The same error is not made to the same extent if aggregates at low levels are used in war games, because at least some of the high-level functions are included in the body of game rules governing the manipulation of the small units; and, of course, a certain amount of tactics is brought in through the player's skills. In addition, the pseudo-dynamical employment of the force imposes natural limitations on its payoff in attrition on the opposing force, so that to some extent at least, comparisons by this means are more believable than those of indices of total combat effectiveness.

The favorable vote made above for simulation comparisons of effectiveness should not be construed as an opinion that games and simulations are the final answer. There is no doubt that the gaming technique itself needs much improvement. Furthermore, it is time-consuming and expensive and suffers to some extent from many of the same omissions as the indices of combat effectiveness. It is scarcely a facile tool for force comparisons, especially where organizational structure or design of forces is the contemplated objective. Hence the search for analytical methods giving a satisfactory description of force capabilities is mandatory and should be pursued most energetically.

There are three attributes of the combat organization which must be treated in any model in order that it be sufficiently complete to deal with problems of composition and structure of military forces. These are: (1) the structure, (2) the functions, and (3) the means. A few remarks on each of these should clarify the scope of the problem.

All models so far developed relate almost exclusively to the resources of the combat organization and, in particular to personnel resources (when considering losses or cost of achieving an objective) and weapon resources (when considering payoff in enemy casualties). The structure or morphology of the unit is never really examined. As with any other kind of large task-oriented organization, the way the parts are interconnected has much to do with the efficiency of operation. Problems of communication and control prescribe the nature of the command hierarchy: the span of control is related to the branching ratio of the hierarchy, and its tactical responsiveness is related to the number of echelons or vertical height of the organization. All aspects of operations that depend on the flow of information or instructions, or upon processing and planning, depend on both these geometrical properties of the hierarchy. Thus it is obvious that pure organizational structure plays a role in overall combat effectiveness.

The principal functions of a combat organization have been identified as firepower, mobility, command and control, intelligence and service support. (Firepower and mobility should be replaced with *fire* and *maneuver* to distinguish the processes of delivery of fire or the actual tactical maneuver from the physical capabilities therefor.) Actually these might be better thought of as functional areas than as functions themselves. Each of these areas consists of numerous more or less clear-cut (but usually not independent) functions. It is also important to distinguish equipment from functions because the equipment exists as a means to the accomplishment of a function: weapons exist as means of destroying or threatening destruction of enemy personnel and materiel;

communications hardware exists as a means of transmission of information; and target acquisition equipment exists for the purpose of gaining knowledge of location or type of enemy resources.

It is tempting to measure the ability of an organization to perform a military function by a simple mathematical function of numbers and kinds of equipment available to support that function. However, this is probably not sufficient. We need absolute models of processes that include equipment properties as an important, but not the only ingredient.

The means to accomplish a function are all the personnel and equipment resources operating in support of that function. It must be recognized that a particular function may be supported by another function as well as by its own resources. For example, the transportation function is supported by its vehicles; the maintenance and repair function supports it also, and, in addition, is itself supported by certain physical means for accomplishing that service. The reason for stressing this sequential structure of support is to assure that the model exacts penalties as well as bonuses for including support functions. All functions require, as well as provide, support.

No existing mathematical model of the aggregate effectiveness of a large combat organization even approaches the quality necessary for confident application to problems of force structure or composition. Nor is it possible at this time to provide much more than a mere prescription for such a model. Although this offers little by way of solution of the problem, some benefit may accrue if workers in the field are encouraged to face up to the difficulties, and abandon the search for quick and easy methods. *The Anatomy of Combat* is the reaction to this challenge.

In closing, we discuss some general mathematical attributes of measures of effectiveness to determine their relevance.

A complete description of military reality by mathematical methods appears to imply mathematical properties such that the product could be a difficult tool to apply, and hence of limited utility. We recognize that some compromise of reality for the sake of utility may well be necessary. However, the present Index of Combat Effectiveness or firepower scoring systems reflect so little reality that their utility is negligible for want of a problem to which they may be confidently applied. In future developments any such compromise should be made reluctantly and knowledgeably, with careful consideration of effects on the applicability of the model. The properties we now discuss are consequences of what is believed to be military reality, and we make no effort to anticipate to what extent they must be relaxed for the sake of utility or for sake of making any progress at all.

To be of sufficient scope to meet requirements the model should: (1) Reflect those structural features of the combat organization which have an important bearing on the performance of represented functions, whether primary or supporting; (2) Model each represented function in the absolute sense of epitomizing a process for achieving a specified purpose; (3) Consider weapons and equipment as tools contributing to the performance of particular functions; and (4) Contain both functional and organizational aspects which are brought together in an objective function depending on variables which define the purposes of the unit, and which contain at least parametric reference to enemy and environment.

Even a casual awareness of military organizations or operations indicates that a satisfactory model cannot be a linear combination of numerical resources. This is well recognized for combinations of highly dissimilar weapons, but not usually appreciated for combinations of like weapons. The non-linearity would extend likewise to dependencies on enemy resources. Therefore, *non-linearity* seems to be a natural requirement on the model.

It cannot be expected that any *values* provided by the model will be meaningful unless the local environment, including the opposing forces, is specified and held constant. For this reason current Indices of Combat Effectiveness are suspect because they depend both on an historical organization and some unspecified set of local circumstances. Comparison of two or more new organizations by taking ratios of total firepower scores to that of some common historical reference organization is not legitimate since both tactical and environmental context are lost. We thus require that the model contain an explicit dependence on reference.

It is assumed in applications of present scoring systems that the set of indices describing a variety of organizations possess a transitive relationship of inequality. That is, if $A > B$ and $B > C$, then also $A > C$. This clearly cannot be true, in view of the previous remarks regarding dependence on reference, and nonlinear dependencies. Hence, inequalities determined to hold in one context may not hold in another.

Linearity arguments and dependence on reference lead to the conclusion that a model cannot permit the unlimited substitution of one weapon for another, for this would imply that a sufficient number of any weapon, regardless of its individual effectiveness (other than zero), could defeat any target array. This is surely not true.

Many military functions very likely will prove, on close examination, to be processes which possess critical thresholds or saturation tendencies. For example, fire suppression exhibits both characteristics; a unit attacking would derive little payoff from very thin supporting artillery fire. As the density of fire increases and the enemy is forced to keep under cover, the attacker derives a rapidly increasing benefit (in the form of casualties he does not lose) until at higher fire densities his marginal benefit diminishes to almost nothing.

The nature and uses of aggregate effectiveness measures for ground forces have been presented. It has been shown that there is a difference in the requirements on the measures depending on whether it is to be applied as an assessment tool in war games or as a tool for abstract comparisons of the overall combat capability of two organizations. The latter imposes a much more stringent requirement on the model, since it must contain specific reference to many of the non-weapon properties of the organization.

It is believed that a model of a large combat organization must be constructed along functional lines, and allow for the structure of the organization as it affects function performance. Similarly, materiel resources should be treated as tools that aid in the accomplishment of the function. This is an inversion of the order of emphasis customarily taken in the construction of such models.

An attempt has been made to demonstrate why this approach is necessary, and some very general necessary properties of a satisfactory model have been specified. These properties are viewed as military realities, rather than *nice-to-have* , and it is realized that some compromise of reality for the sake of utility will undoubtedly have to be made.

The above assessment provided the spring board for the subsequent research that is the subject of The Anatomy of Combat. In the course of studying requirements *FOR* and *ON* tactical systems. We have striven for the clarity advocated by von Clausewitz by breaking down the overall tactical war into basic combat functions for the purpose of individual analysis. These are identified and discussed in Chapter 2. In order to study force mix questions, it is essential to net these functions together to establish their relative utility under varying scenario conditions. This necessitates some rational, logical method of assigning values to targets. Chapter 3 points out that the closely related combat and support functions must be carefully integrated in some manner to provide useful and credible results in the understanding of tactical warfare.

Military system evaluation criteria are addressed in Chapter 4 and military element value theory is further developed in Chapter 5. Validation of the approach is demonstrated by a simplified method of valuing targets for Interdiction Fire in Chapter 6 and its use is verified in Chapter 8.1 wherein it is shown that Interdiction Fire targets are very much time dependent; therefore, target values for the study of Support Fire are substantially more so.

The concept and design of scenarios for utilization in operations analyses is treated in Chapter 7 and demonstrated in detail for the Suez Crossing Concept in Chapter 7.4 and for a Central European Scenario in Chapter 8.5.

Other diverse applications of the theory are treated in Chapter 8. Descriptive models for studies of Modular Weapons Concepts, the Selection of Guidance Systems for Air-to-Surface Weapons and the Value of Mine Warfare are designed in Chapters 8.2, 8.3, and 8.4, respectively. A detailed study of the tactical Utility of Anti-Radiation Missiles in suppression of ground defenses is designed and tested in Chapter 8.5, and the unique applicability of the methodology is demonstrated by establishing the military value to be gained from an attack on the anti-aircraft defense command and control nets in Chapter 8.6. Although most of the discussions have been addressed to land warfare, the applicability of the descriptive model for Sea Control Requirements is described in Chapter 8.7 and the basis for establishing the value of Resupply Requirements for a European scenario is addressed in Chapter 8.8.

For the reader who is appalled at the size of the book, Chapter 1 provides a brief introduction to the Concept for Analysis of Warfare. Chapter 9 summarizes the major aspects of the methodology.

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