Chapter 3

FUNCTIONAL REPRESENTATION OF COMBAT

1.0 PURPOSE OF THE DESCRIPTIVE MODEL

Hardware systems for military use are designed by groups of technical specialists integrated by some system engineer. The process of design involves a very large number of qualitative and quantitative decisions; a frequently used criterion for decision is some measure of operational utility or *combat effectiveness*.

Force designers construct a larger system, integrating people and hardware into a military force tailored to support national objectives. Force designers are also concerned with combat effectiveness, but must balance overall combat effectiveness against budgetary and political constraints.

Tactical commanders must employ the military forces, including the hardware systems, to support the national objectives in various conflict situations. Tactical Commanders properly are interested only in combat effectiveness.

The degree to which these three classes of people - system engineers, force designers, and tactical commanders - can communicate and cooperate has major impact on the success of the military forces of the United States. Successful communication, a prerequisite to cooperation, requires a common language, including common units of measurement.

Dollar cost, often expressed in the form of *cost effectiveness*, has frequently been used as a unit of measurement. One of the major drawbacks to this unit is that it is meaningless to a tactical commander who, in combat, is the most important member of the trio described above.

The needs of the Tactical Commander are recognized by the issuance to the developer of some Statement of Operational Requirements (SOR) to serve as a basis of design. The SOR is based on some consensus of informed military opinion and is expressed in military terminology. Typically, the SOR contains quantitative specification of desired performance characteristics but does not assign relative importance of these goals; thus it does not form a good basis for the trade-off studies by the System Engineer. Because *requirements* are stated rather than *benefits*, the Force

Designer has no quantitative basis for assigning relative priorities among SOR's. Thus, informed military opinion does not actually have the influence it should on the design of hardware and forces.

To bridge this communication gap is the primary task of the operations analyst; a mathematical model of combat can form the bridge. However, all combat situations, and especially ground combat situations, are so complex (due to numbers of variables) as to defy modeling which is both true to the real phenomena and practicable in terms of computation.

The objective of this chapter is to provide a Descriptive Model of Combat and thus improve the utility as a communication tool of mathematical models of combat. The emphasis is on describing, as accurately as possible and in quantifiable terms, the totality of land combat, rather than on achieving immediately useful but less meaningful computational models. Although land combat is the vehicle for development, analysis of sea, air and unified combat may require only specialized versions of the same model.

Four significant concepts described herein provide a general overall sketch of the Descriptive Model of Combat:

1. The use of human effort, expressed in man-days, as a common unit of measure. This makes it possible to represent time as being of value in conflict situations.

2. The mechanistic model of battle as a process involving military elements, interrelated and affected by the performance of certain specified functions. This basic concept is not, of course, unique; however, the explicit scheme of interrelations between functional performance and combat potential is believed to be unique.

3. The definitions of Capability, Potential, Performance, Efficiency, and Pace. These concepts bridge the gap between simulation models and more generalized, Lanchester-like models employing performance rate relationships among the several functions.

4. The identification and modeling of the continuous Command processes of planning and decision which trigger all other functions to produce events.

In principle, the above concepts make it possible to quantitatively relate system characteristics to the probability of success in a specified conflict. In practice, any such answer would be so affected by assumptions, sensitivities to input data, and computational approximations as to be useless, or even delusive. Creation of a single monstrous quantitative model incorporating all aspects of conflict is not a goal.

It is intended, however, that this descriptive model of land conflict will be extended and detailed to the point that it can:

1. Rationally interconnect existing and future models of battle phenomena (e.g., Capability Model, Engagement Model, etc.).

2. In particular, standardize symbology and terminology among these existing and future models.

3. Be utilized to produce evidence regarding the relative desirability of various system characteristics, and the relative desirability (or inventory fraction) of various systems in a force mix.

The third listed purpose requires extension of the concepts from elemental[1] to unit phenomena.

2.0 A COMMON UNIT OF MEASUREMENT

The procurement and employment of military hardware systems and military forces involves people and agencies of varying primary concerns. These[2] include force designers, tactical commanders, and system engineers involved in the total process of procurement and employment of military systems. Budgetary and Procurement levels continuously interface in the justification and execution of the defense budget and quite naturally communicate in the language of dollars. As we have mentioned, however, the *dollar* value of a system is meaningless to tactical and strategic commanders.

At the Budgetary level, defense dollars are allocated by the Department of Defense (DOD) to provide military forces which are then incorporated in the national military strategy formulated by the Joint Chiefs of Staff (JCS). Superior strength in manpower and equipment will decide the outcome of military operations in many, perhaps most, cases; however, there is no favorable ratio which will guarantee victory, due to the imponderables of human performance. Since the

[1] See Section 7.0 for definition.
[2] Refer to Figure 1-6. Model Recognizes Budgetary, Procurement, Strategic & Tactical Considerations.

uncertainty as to requirements for each threat situation is compounded by diverse world-wide political-military commitments, it is small wonder that the JCS military planners never feel they have enough resources.

Other national projects, both internal and external, rightfully compete for a share of the budget; and of course the individual wants his share of the gross national product impacted as little as possible by taxes. Thus, the DOD force designer must procure a suitable mix of men and material within some fluctuating budgetary limit which he is inclined to regard as hopelessly inadequate.

The dollar language used for discussion of this problem tends to obscure the fact that a much more important investment is being made --- the time, and in many cases the lives, of a generation of young men and women committed to implement the military strategy. Effective use of this manpower, assisted by the previously procured equipment, and of time, determines the outcome in the theater of conflict. Man-days are the common unit of measurement in the model developed in succeeding paragraphs.

It is suggested that man-days are also a suitable unit for budgetary considerations as shown in Figure 3-1. The cost of an item in man-days fluctuates only with productivity. When the same calculation is made in dollars, *price* rather than *cost* is often the output, and extraneous factors such as profit, overhead rate, and inflation obscure the issues. *Contracting Officers* must be concerned with *price* comparisons, *developers* should attempt to identify true *cost*.

At the Procurement level, the system engineer is concerned with cost, which is naturally expressed in dollars. He is also concerned with schedule, total effort, critical tasks, and skilled manpower - all better expressed in man-days than in dollars. The system engineer is also concerned with combat effectiveness, but must be informed on this subject by representatives of the Military user. Combat effectiveness is produced by some combination of a great many system qualities and performance variables. Quantitative measures are available for some, but not all, of these variables; these measures are incommensurable. There is no way to establish the ideal balance among the variables except in the context of some specific combat situation. However, various situations produce different answers.

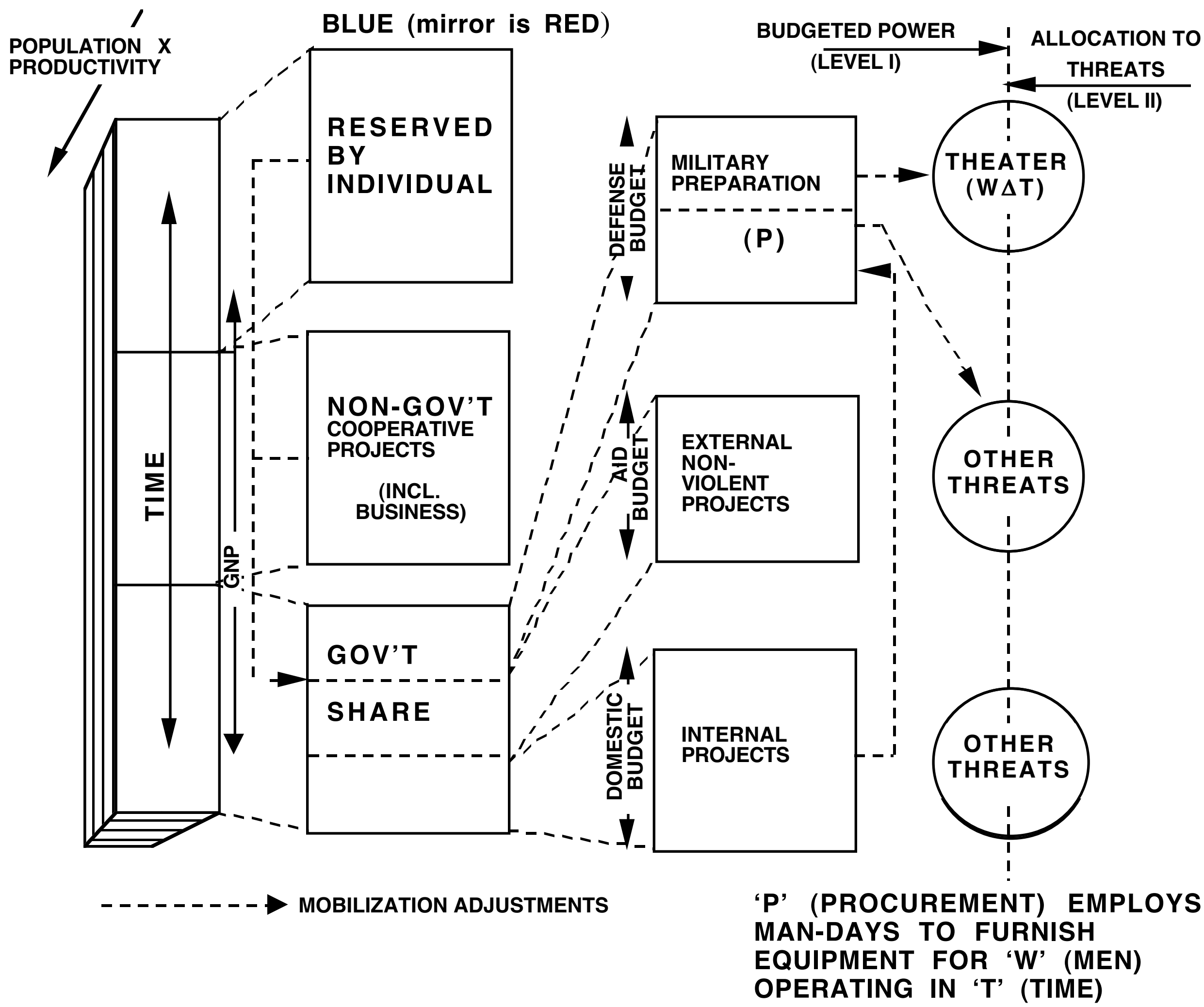


Figure 3-1 - Manpower and Time Meaningful at all Levels

The use of man-days, as described hereafter, to compare input with output in a scenario context produces useful evidence regarding the best balance of system qualities.

In summary: Man-days are used in the model described hereafter as a common unit interconnecting the concerns of the military levels from the JCS to the tactical user. It is suggested that they are also of meaning at the Budgetary (DOD) and Procurement levels, and when used will clarify procurement and design alternatives.

3.0 THE UTILIZATION OF SCENARIOS

The Budgetary planner (Level I in Figure 3-1) procures and/or modifies on some time schedule, a force of trained men (W) and a set of equipment (P -- the result of man-days invested in Procurement). The Level II (JCS) planner must provide for the use of these assets in attaining the political goals of the nation. To do this, he visualizes various *threats* - - situations in which military force may possibly be employed. In our terminology , these individual threat situations are *scenarios*, which are briefly discussed in this section.

The Joint Chiefs of Staff planner, based on intelligence of the plans and intentions of potential enemies, may be able to *predict* upcoming threat situations, especially near-term ones. To guard against the unpleasant surprises of an unpredictable world, he should also *assume* threat situations, rejecting only those which can be labeled incredible . Some combination of predicted and assumed scenarios can then be selected as a basis for formulation of national military strategy.

The set of scenarios used by Level II planners should be quite large, since they must specifically provide for all reasonable contingencies during the time-span of the plan. The set of scenarios used by force designers and system engineers cannot be as complete; the much greater detail required to model the interplay of a system with its environment limits the number of differing scenarios that can be developed and utilized. The set should be selected to incorporate the credible extremes of scenario variables, testing against such a set will develop understanding of both capabilities and limitations of systems and forces being considered for acquisition.

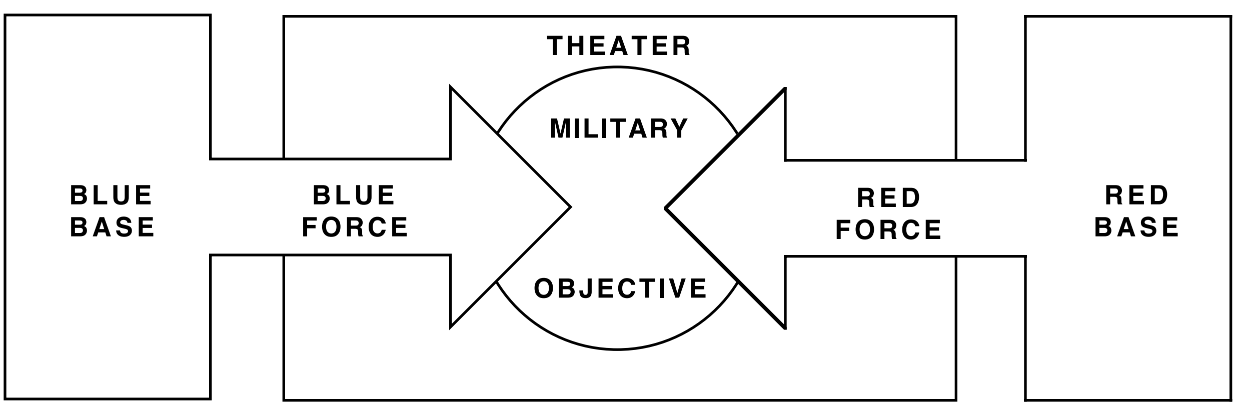


Figure 3-2 - The Anatomy of a Military Force Should Suit its Environment.

The scenario describes the circumstances of a conflict and the three-part environment -- natural, enemy, and friendly -- in which the military system under design must operate. The environment (scenario) variables are:

- Natural Environment
- Enemy (Red) Force
- Political Constraints
    - Sanctuary
    - Time Pressures
    - Limits on Methods
- Military Objectives

These variables characterize a scenario to be used for force development; for hardware system development, another variable - Friendly (Blue) Force - would be used. It is omitted for force development scenarios because the Blue Force is the system being designed.

If a scenario is to be used with the modeling approach described herein, certain prescriptions are made as to its construction; these are described as follows in the order Natural Environment, Enemy (Red) Force, Political Constraints, and Military Objectives.

The Natural Environment is described by specifying a Theater of Conflict and a starting date. This identifies a store of terrain and seasonal climate information which can be utilized to the level of detail required. The forces placed within the theater are constrained to operate entirely within the theater -- only a specified flow of supplies and replacements enters the theater. This constraint isolates the problem for study -- if matters outside the theater are of interest, they must be studied in a different scenario, perhaps placed in a larger theater.

A charge of *scenario dependence* may be laid against this very specific approach. However, if it is conceded that the effectiveness of a system (to include a military force) may be affected by the circumstances and environment of its employment, then obviously the system must be analyzed in various circumstances and environments. *Scenario dependence* is avoided not by generalization but by study in various scenarios and combination (*NOT* averaging) of the conclusions.

The Red Force is also to be described very specifically, and in particular to be limited to some total manpower Input. This permits assessment of the impact (in man-days) of a Blue action relative to the total resources of the opposition. Comparison of this impact with the fraction of Blue resources expended then gives a measure of the worth of the action.

For analysis of non-nuclear warfare, the postulated ratio of Red to Blue forces should not be so large as to drive the solution to an inescapable conclusion, for example, nuclear weapons. The scenarios being discussed here are the set used for force and hardware system design, not necessarily those to be used by Level II (JCS) planners. If one pictures the enemy as ten feet tall, one makes a desperation effort with a sling shot; while for a smaller and less ungainly opponent, a sword and buckler may be indicated.

Political constraints should be introduced into the scenarios as required for the study of special problems. As an example, Figure 3-2 represents a situation in which both sides can introduce supplies and replacements into the theater from an inviolable sanctuary, and can withdraw forces into that sanctuary at will. Force design answers, and even those of hardware systems, may differ in this case from that where either or both bases are within the defined theater. It may be that such analysis would demonstrate the exorbitant cost, in time, lives, and deployed forces, of political constraints which afford the enemy a military sanctuary.

Another type of political constraint which may be considered is one which places some time pressure on military operations. Time pressures develop within theater strategies, as discussed in section 5.0 of this chapter, due to the necessities for coordination of forces and for timely response to hostile moves. A time pressure imposed from outside the theater has somewhat different results, since it tends to remove flexibility from the theater strategy.

Finally, assumed political constraints on methods used (e.g., banning of nuclear or chemical weapons) enable consideration of specialized problems (e.g., How would a *limited* war in Europe be fought?).

There should be a recognized difference between the set of at least partially predictive scenarios used by Level II Strategic planners and the spectrum of scenarios used as tools by systems analysts. So long as conditions and environments postulated in the latter spectrum are not incredible, their use may unearth valuable information.

4.0 MILITARY OBJECTIVES

Wars arise when two political entities, or two groups of political entities, resort to violence for the resolution of conflicting political objectives. Wars end and peace is restored normally after some alteration of the military situation, when the conflicting political objectives are reconciled sufficiently that violence is no longer the most promising method of solution for either side.

A war would be completely successful, from a unilateral view point, if one side succeeded, by the application of violence, in arriving at a status vis-a-vis the enemy where its political objectives could no longer be opposed. Such an accomplishment might be termed a *military victory*. However, in most practical instances, the military achievements will have been accompanied by modification and accommodation of political objectives, so that the outcome of the war is a joint product of political and military developments. Unconditional surrender or unacceptable attrition of the enemy forces has seldom been the actual outcome of warfare; under the shadow of massive nuclear deterrents, such a military objective is less realistic than ever before.

Analysis should be directed toward the attainment of military objectives other than indiscriminate attrition of the enemy forces. In fact, to measure the utility to the military force of various component elements one must be aware that:

- A *MILITARY FORCE* IS DESIGNED TO CONDUCT MILITARY OPERATIONS
- *MILITARY OPERATIONS* ARE A PLANNED USE OF VIOLENCE TO ACHIEVE A POLITICAL OBJECTIVE
- A *POLITICAL OBJECTIVE*, IF ACHIEVED, WILL CHANGE THE ENEMY'S BEHAVIOR
- BUT *MILITARY OBJECTIVES* ARE: TO OCCUPY OR CONTROL AREAS; TO DO VIOLENCE TO PEOPLE OR PROPERTY.

This model deals with MILITARY forces seeking MILITARY OBJECTIVES.

Valid military objectives can be stated for some political objectives, but not all. To expel the enemy's military forces from a certain area (e.g., South Vietnam) is a valid military objective. To "win the hearts and minds of the people", though a praiseworthy aim, is definitely a political and

NOT a military objective. The concurrent military objective can only be to establish a level of security which protects non-violent agencies for the duration of their task. To cause the enemy to desist from attacking from some sanctuary is in fact a political objective. Possibly, there is some level of violence (a military objective) which will accomplish this end; it obviously was not reached in Vietnam.

A confusion of political and military objectives can have very adverse effects on national policy decisions and on the conduct of military operations. In addition, political objectives are a poor starting point for analysis, being generally rather imprecise and difficult to translate into material terms.

Military objectives are of two types -- the first an expression of the Maneuver function, the second of the Fire function as discussed in Section 7.0 of this chapter. Military forces can occupy and/or control terrain features; they can also do violence to (deliver Fire against) people or property. In most wars, all sides have both types of objective. In guerrilla wars, one side places small and transient reliance on in-country terrain features (objectives) using violence against opposing forces and the civil population as its principal method for realizing political objectives.

If neither side has a terrain objective, or if no terrain objectives are contested, a logical model of land combat breaks down. Within the model neither side moves because movement from a position of good cover and concealment results in heightened vulnerability and loss in a game of self-preservation or relative attrition. The real-life analog may be the "Phony War" of early 1940, in which the French did not choose to advance and the Germans were not yet ready to strike. (N.B., It has been pointed out that feints or sacrifices designed to entrap the reacting forces are possible. This is true, but within the model the feinting force must be represented as having some temporary objective in order to force its movement.)

Political objectives and political developments often put time pressure on one of the opponents. This time pressure may not be apparent at the start of the conflict; it sometimes grows because of war-weariness or is produced by a requirement to attend to internal problems or other external threats. Usually one side is in a greater hurry than the other and is therefore forced onto the offensive. The offensive has great advantages in terms of initiative, but usually requires a preponderance of force and the acceptance of higher initial losses.

Based on these considerations, objectives are defined within this model as follows:

- For at least one side, a certain set of terrain features is given a value in terms of manpower. This value is not explained; it is considered to derive from the significance of the terrain features to the political objectives of that side. These features are termed *final* objectives for that side.

- If politically-inspired time pressure is to be modeled, the value assigned to final objectives is made *time-dependent*.

- Features which derive value from their contribution to a strategy for achieving final objectives are termed *intermediate* objectives.

- For both sides, enemy elements are made objectives by assignment of a *residual* value beyond a certain time.

See Section 8.0 of this chapter for further explanation and illustration.

5.0 THEATER STRATEGY

In order to study the contribution to combat effectiveness of alternative systems, system concepts, organizations or doctrines, we propose to define for analysis a phenomenon called a *battle*.

Figure 3-3 illustrates a rationale as to how battles occur. Two sets of military elements (Blue and Red) have been introduced into some terrain area (theater) to accomplish certain military objectives. The final objectives (Δ_B Blue and Δ_R Red) are valuable in themselves because their occupation will assist in accomplishment of the political objectives for which the war is being fought. The intermediate objectives (Δ) are valuable only to the extent that they improve combat potential for further operations.

A strategy is a plan - a set of current and intended future decisions for the allocation of resources to attain the military objectives of the planner (Blue or Red). Initial manpower resource allocations by Blue and by Red forces are also indicated in figure 3-3, together with a timed plan for attainment of objectives. This results in an allocation of man-days to each objective. Where the two strategies call for possession of the same objective during overlapping time periods, a battle (Δ_X) will result.

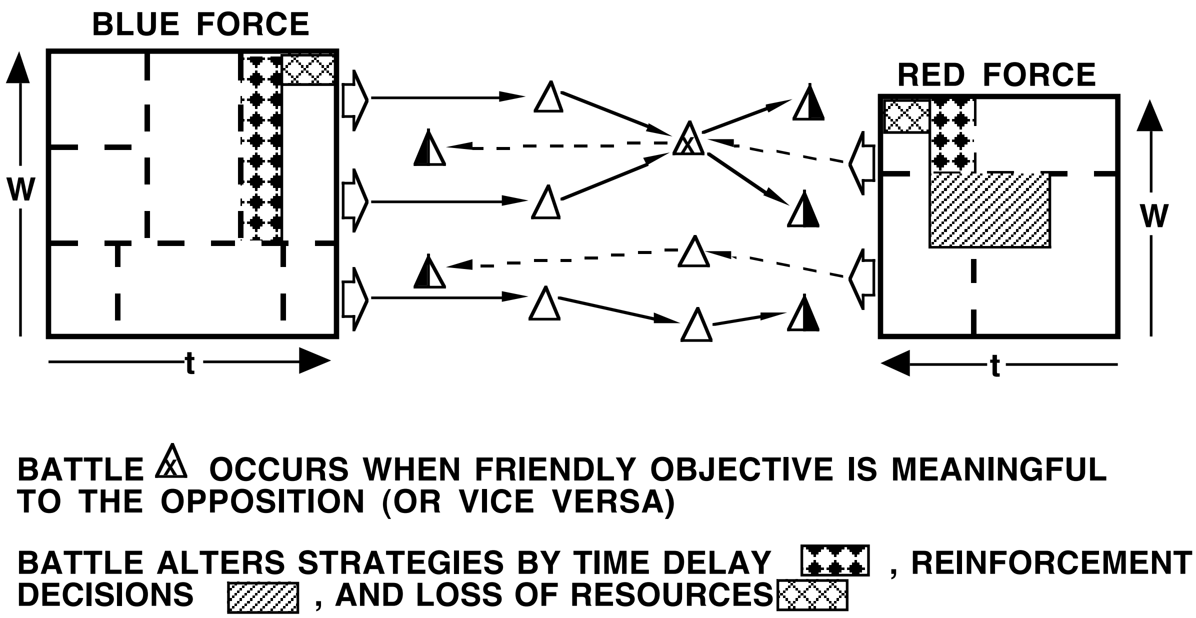


Figure 3-3 - Theater Strategy Involves Terrain, Time and Manpower.

Figure 3-3 illustrates a situation in which Blue and Red forces (W) have selected differing final objectives and the strategies result in only one battle. If the terrain objectives of one side are correctly chosen to assist in the accomplishment of its political objective, then the strategy of the opposite side must include opposition to these objectives. In such a case, battles will be frequent. Note that the peculiar strength of insurgency movements is that they have few, small, and relatively transient terrain objectives in early phases, and that they are not forced to oppose any single particular objective of the other side.

Referring again to Figure 3-3, it will be noted that both Blue and Red forces have subdivided forces and assigned to each subdivision both interim and final objectives. The commanders of the subdivisions now each have an assigned area, objectives, and a force (W). They can thus develop a resource allocation and a strategy, which will usually involve additional interim objectives and probably a shorter time span before revision. This process is repeated down the chain of command, terminating at the platoon or squad level. The objectives at lower level derive their value from their contribution to the attainment of overall theater objectives; the final theater objectives derive their value from a contribution to attainment of political objectives.

Both sides, being realistic, expect to lose strength in the process of fighting for objectives. This has not been represented as a part of the strategy, since nobody actually plans on losses of a definite magnitude. However, there is an understood and sometimes stated *limit* of loss. One must accomplish each objective with sufficient remaining strength, both absolute and relative to the enemy, to proceed to the next objective.

As illustrated in figure 3-3, a battle alters previous strategies in three different ways. A major battle usually forces a revision of the strategy of the losing side. A revision of strategy may also occur without battle as a consequence of maneuver developments.

6.0 THE BATTLE

Figure 3-3 above, in its simplified presentation of strategy, seems to imply that the battle is an isolated phenomenon. The pitched battle between limited forces has gone out of style, perhaps starting with Braddock's defeat [3]. Analysis now must concern itself with battles which are not isolated as shown in Figure 3-4.

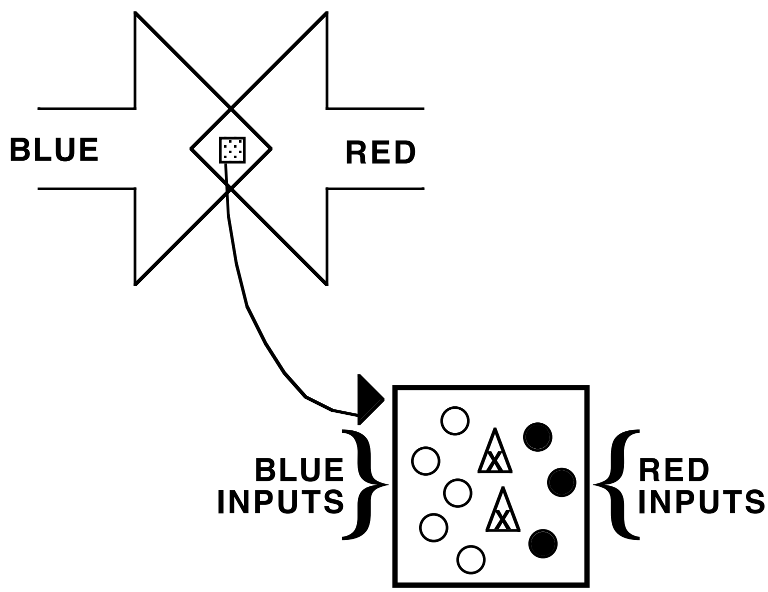


Figure 3-4 - The Battle is Not Isolated.

[3] 9 July 1755. Battle of the Monongahela. As his force approached Ft. Duquesne, Braddock was surprised and routed by 900 French and Indians. He was killed with more than half of his force.

What is done in the analytic approach being described herein is to isolate a small section of the conflict and examine it first without input from outside the *battlefield*. Inputs to be modeled are:

INFORMATION
- ORDERS
- INTELLIGENCE

REINFORCEMENTS

SUPPORT FIRE

SERVICE SUPPORT
- SUPPLY
- MAINTENANCE
- CONSTRUCTION
- TRANSPORTATION
- SIGNAL

Then selected inputs are introduced singly and in combinations, with study of interrelations and effects. The Service Support input categorys selected are those believed to have major effect on the battle.

Battles have three hierarchical aspects - in force organization (echelon), in geography, and in time as demonstrated by Figures 3-5, 3-6, and 3-7, respectively.

On each side the engaged units or elements are a part of a parent organization which furnishes the inputs from outside the battlefield, Figure 3-5. The units may not be as stylized as shown, and the organization may be flexible and informal, but the listed inputs are available from somewhere at some time.

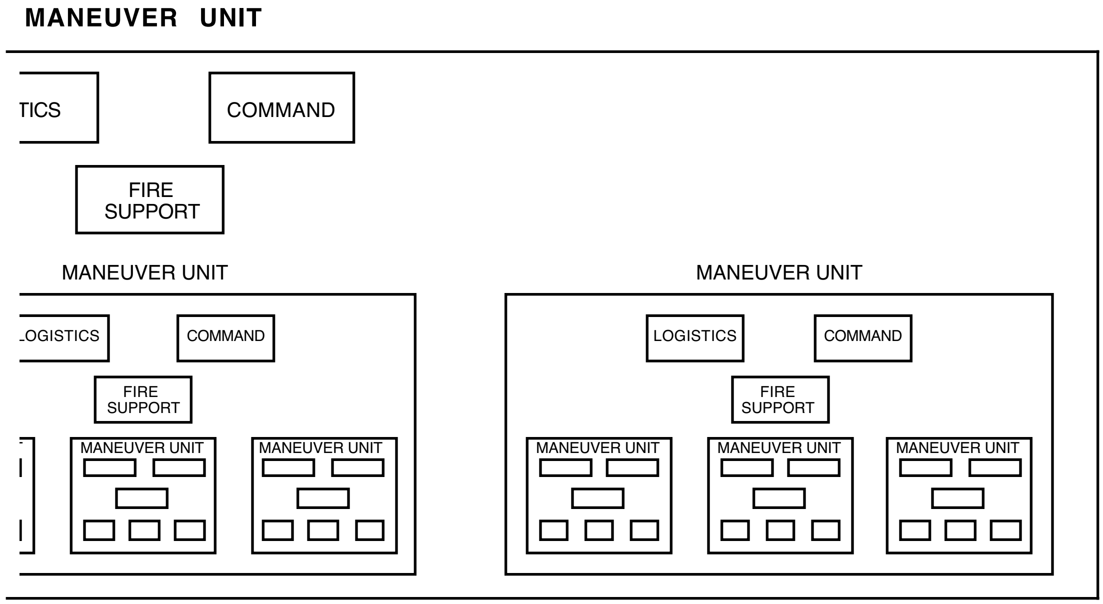


Figure 3-5 - Echelon Organization

Figure 3-6 reflects what has been previously stated; each terrain objective is considered as a step in the execution of some strategy. The strategies are peculiar to the echelon devising them, but each lower-echelon strategy is designed to achieve objectives assigned by the next higher echelon. As previously noted, in the use of this model one side will always be assigned terrain objectives, the other side may or may not be.

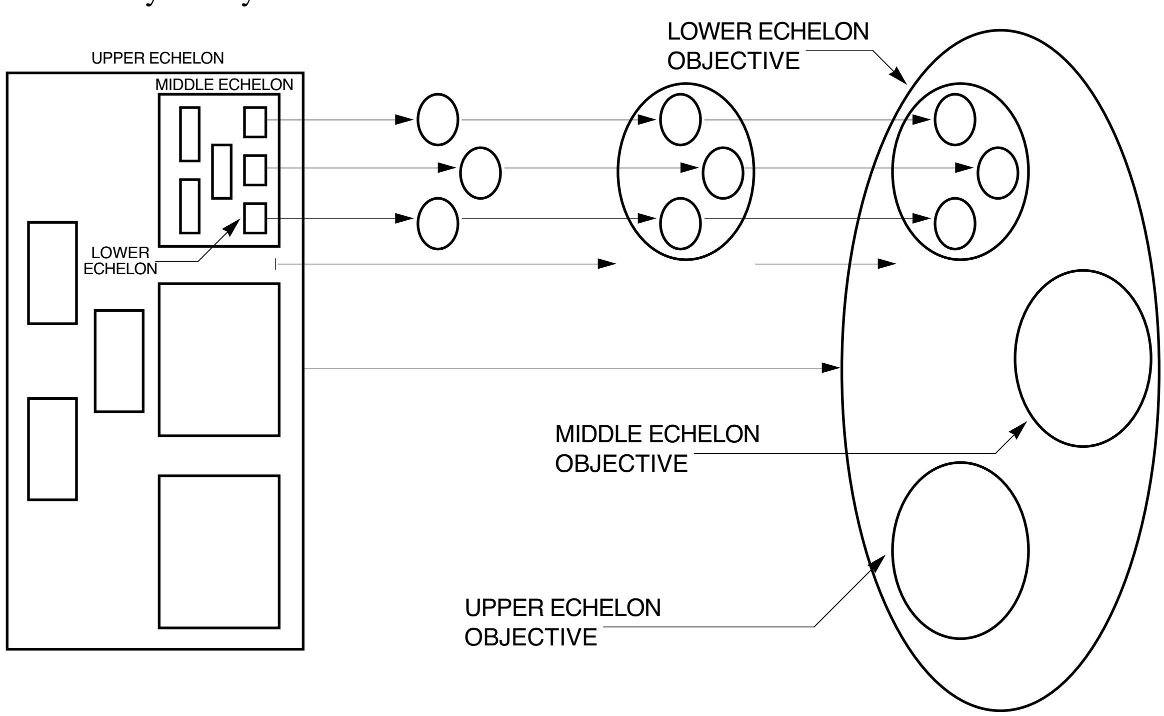


Figure 3-6 - Geographic Regime.

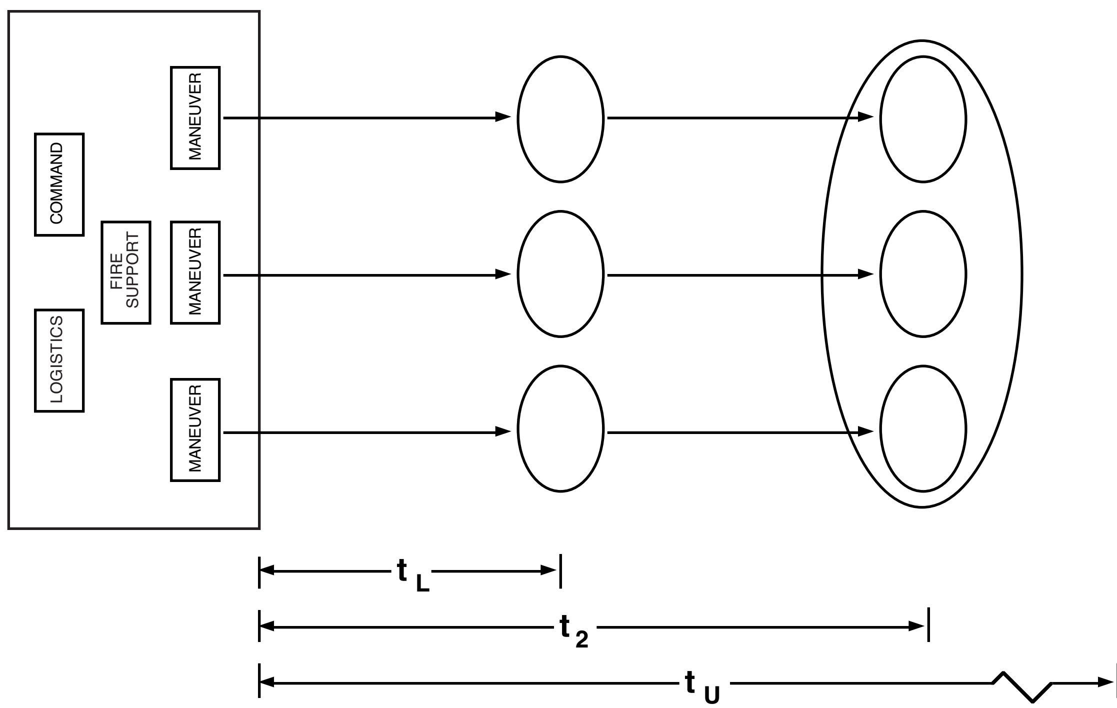


Figure 3-7 - Time Regime.

Since the objectives are a part of a coordinated strategy, they must have a value which varies with time. Figure 3-7 presents conventions of nomenclature for time: t_2 is the planned time of arrival on objective of the echelon being analyzed, t_L is the same time for a lower echelon and t_U for a higher echelon.

To measure contributions to success in battle, one must have a definition of success in battle.

BATTLE SUCCESS CRITERIA ARE TO --

- SECURE OBJECTIVE
- ACCOMPLISH WITHIN TIME t_2
- ACCOMPLISH WITH EXPENDITURE

The criteria expressed above are obvious and will be discussed further in Section 8.0.

7.0 COMBAT AND SUPPORT FUNCTIONS

The mechanism of battle modeled herein can be simply described:

> Command triggers functional performance by elements; the performance results in events which change potentials for further performance; the changed potentials alter available courses of action; the altered situation results in further command triggering.

An element, in our terminology, is an entity performing one or more military functions, and which cannot be subdivided without qualitative loss of functional capability. Examples: A rifleman; A tank with crew; A truck with driver. The analysis starts with elements, progressing to units at a later time. A unit is a collection of elements under the direction of a single command element.

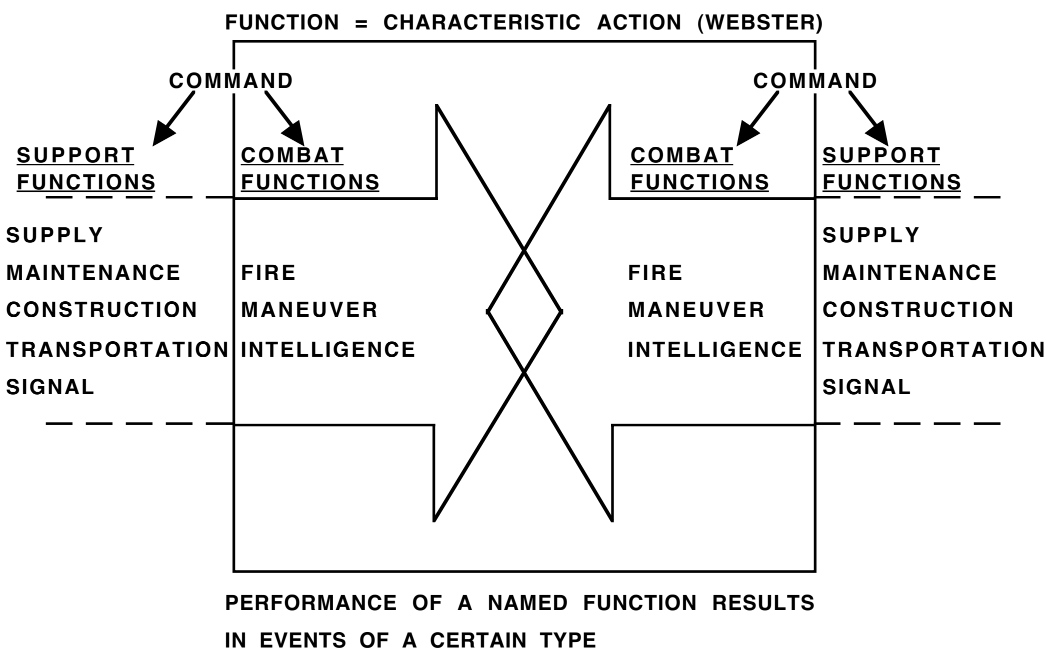


Figure 3-8 - The Battle is Decided by Functional Performance.

A function is a relationship between two elements or between an element and a terrain feature; performance of the function (a *characteristic action* or event) results in alteration of one or more potentials for future performance. The nine functions from each side (including command) selected for modeling are represented in Figure 3-8. Performance of a named function results in events of a certain type as follows:

EACH FUNCTIONAL PERFORMANCE ALTERS POTENTIAL

- *FIRE* REDUCES POTENTIAL OF TARGET.
- *MANEUVER* ALTERS PATTERN OF FIRE/INTELLIGENCE POTENTIAL
- *INTELLIGENCE* IMPROVES COMMAND POTENTIAL
- *SUPPLY* INCREASES ALL POTENTIALS
- *MAINTENANCE* RESTORES ANY LOST OR DAMAGED POTENTIAL
- *CONSTRUCTION* ALTERS TERRAIN AND THENCE OTHER POTENTIALS.
- *TRANSPORTATION* INCREASES MANEUVER POTENTIAL
- *SIGNAL* INCREASES COMMAND POTENTIAL
- *COMMAND* TRIGGERS EVENTS, RELEASING POTENTIAL

It is reasonable to believe that the same functional definitions will cover interactions among units; this awaits verification in later chapters.

Each of the functions listed can be divided into sub-functions -- in some cases at progressively finer levels of detail. Each function depends on the performance of internal processes. Figure 3-9 illustrates these points: interrelating the command *processes* of planning, decision, estimation and editing and the command *sub-functions* of order, request, and status report. (A status report concerns friendly units, an intelligence report concerns enemy units.) Planning is modeled as a continuous process; it triggers everything else. Decision continuously monitors the planning matrix, translating each newly-preferred course of action into orders or requests.

As will be illustrated in Section 9.0, the process of planning can be modeled as a continuous generation and modification of a game matrix. Decision is modeled as the automatic selection of that Course of Action which gives the highest expectation of profit. But since the game is two-sided and non-zero sum, the selection can be improved by knowledge or estimation of the enemy commander's objectives and his degree of optimism. The degree of success in such estimation will depend on the skill or *Generalship* of the commander, as well as on his own degree of optimism.

Skill is a characteristic of the individual concerned -- a characteristic determined by inherent ability, training, experience and other circumstances. Differentials in capability of human elements of a common type, or of units identical in manning and equipment, can be attributed to *human factors*.

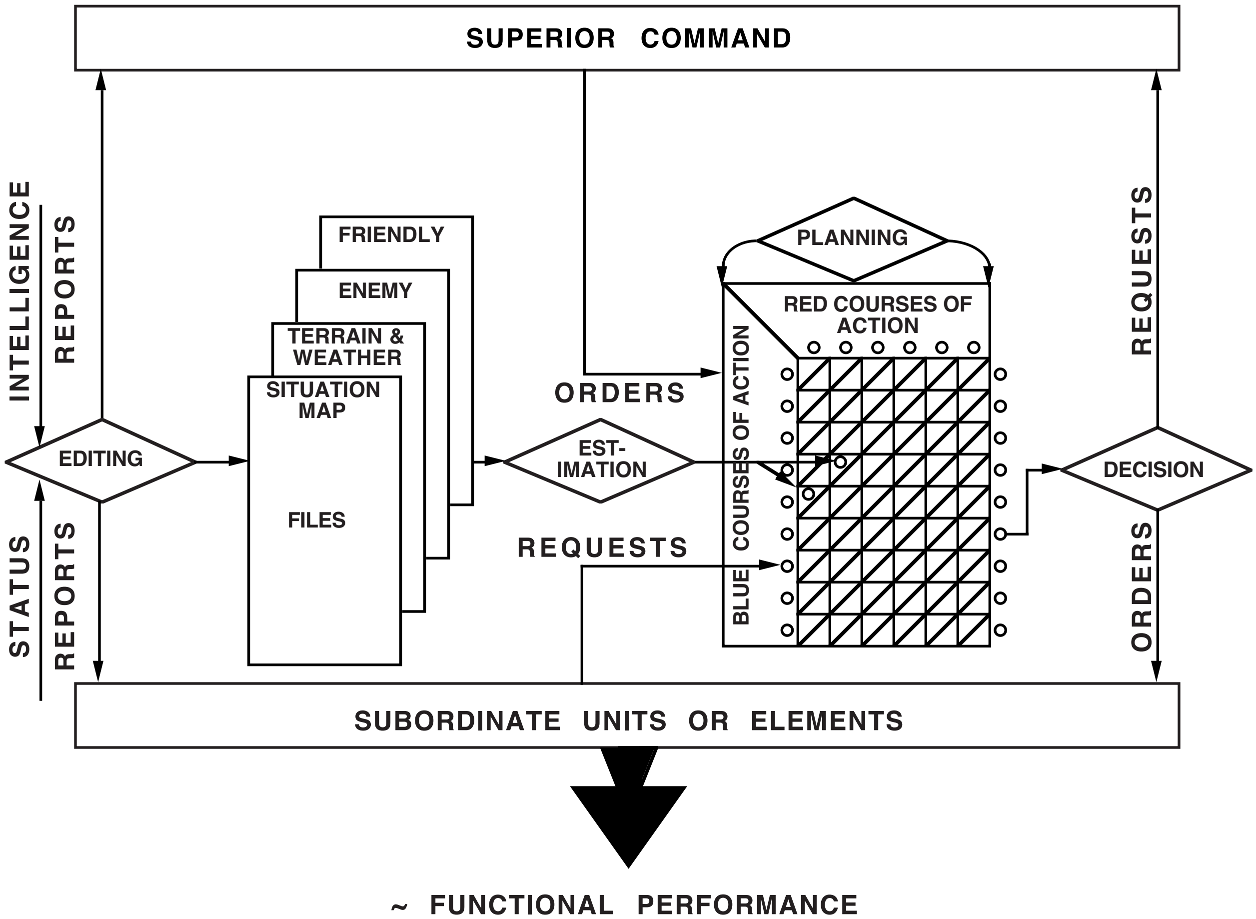


Figure 3-9 - Command Continuously Plans & Triggers Functional Performance.

Military opinion, supported by many instances recorded in military history, holds that the individual and collective performance of the human beings involved is by far the most determinative single factor affecting the outcome of any military conflict. Napoleon, for instance, stated that human factors outweighed materiel factors as three is to one in determining the outcome. It is interesting to speculate whether increased mechanization of combat has altered this factor, and if so in which direction.

The introduction of human factors into a model results in much greater complexity of computation. Further, the generation of useful units of measure and credible input values for human characteristics is a forbidding problem.

The modeling approach being described, however, does present many opportunities for the definition of human factors and indication of their effect (*Generalship* is one example). The following policies in this regard have been used to further model development:

- Wherever possible, human factors are carefully defined and incorporated into the logical-mathematical formulations.

- Calculations based on parametric variations of human factors are employed in an attempt to establish their importance.

- For problems involving hardware systems, human factors are *zeroed out*.

At present, the human factors being considered are limited to:

- SKILL -- which affects the rate or quality of any functional performance by a human element.

- MOTIVATION- -- which affects the response to orders.

- PHYSICAL CONDITION -- which affects skill and motivation.

The unit equivalent of the elemental characteristic of MOTIVATION is *ESPRIT*.

8.0 MEASUREMENT OF PERFORMANCE

Both force planners and system engineers are concerned with measurement of the functional performance of elements. As described in Section 3.0, measurements of system performance in various scenarios will produce evidence as to the most suitable combination of system characteristics. The approach to such measurement follows.

Now each Function has various measures 1) CHARACTERISTICS, 2) CAPABILITY, 3) POTENTIAL, and 4) PERFORMANCE and defined as:

- CHARACTERISTICS measure facets of performance; e.g., rate of fire, lethality, vehicle capacity.

- CAPABILITY measures maximum rate of performance in some defined, idealized situation.

- POTENTIAL measures attainable performance in actual situation in specified time interval.

- PERFORMANCE measures effect of POTENTIAL during specified time interval as triggered by COMMAND function.

In other words, military elements have certain CHARACTERISTICS which combine to produce some CAPABILITY for performance of one or more of the functions. This CAPABILITY expresses the manner and rate at which the element, in some defined *standard* state, can alter the functional potential of other elements in some standard state and relationship to the element being defined.

When the element is placed in some model situation, its CAPABILITY is modified to a POTENTIAL because of the non-standard state of either itself or the element on which it is to act, and because of the surrounding circumstances (environment).

The POTENTIAL is turned into PERFORMANCE of the function only by decisions issued by the COMMAND function.

To illustrate by means of a weapon, as in Figure 3-10, an element whose function is FIRE. The CAPABILITY of the weapon is expressed as the rate at which it can deny functional performance to standard opposing elements within range, given a perfect state of maintenance, and a continuous supply of ammunition.

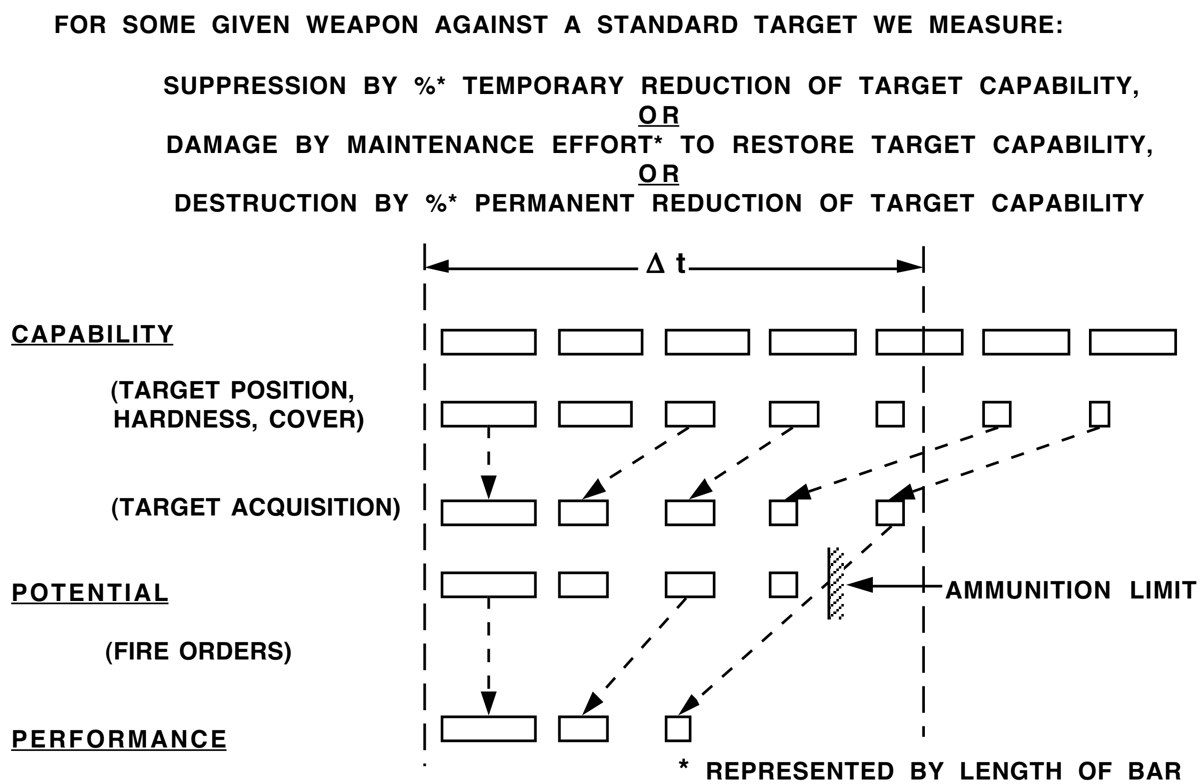


Figure 3-10 - An Example of the Measurement of Function.

When this weapon is placed at some location in an actual situation, its POTENTIAL can never exceed its CAPABILITY. The potential is usually considerably less than capability for the following reasons:

1. Potential is considered only within some Δt.

2. The number of targets available within range may be limited.

3. The targets may be less profitable than the standard (nominal) target, due to greater inherent hardness, or to use of cover.

4. Some targets may be unknown due to deficiencies in intelligence.

5. The available ammunition may be inadequate to cover even the known targets.

6. The weapon's potential may have been reduced by damage or suppression by enemy Fire.

POTENTIAL is turned into PERFORMANCE by a series of decisions. Even though the full POTENTIAL may be utilized during the course of an engagement, its rate of release cannot exceed, and is normally less than; that which its POTENTIAL would support.

Now let us define:

EFFICIENCY $$\eta = \frac{\text{POTENTIAL IN } \Delta t}{\text{CAPABILITY} \times \Delta t}$$

PACE $$\tau = \frac{\text{PERFORMANCE IN } \Delta t}{\text{POTENTIAL IN } \Delta t}$$

W (MANPOWER INVESTMENT) is used as one measure of capability.

Then

$W \eta \tau$ IS PERFORMANCE

Note that this defines W, η, and τ as promised earlier. The *macroscopic* expressions, referred to earlier, are now simply expressed: within any arbitrary Δt the POTENTIAL for future action by either side is reduced by the PERFORMANCE of the other side.

These are truly abbreviated statements. The formulations must be improved to include the increase in potential derived from maneuver and the form of interaction of the potentials deriving from each function.

9.0 AN ILLUSTRATIVE PROBLEM

The very simple *element* problem described here is used to illustrate some of the principles outlined in preceding Sections. We start with an explanation of the initial situation as shown in Figure 3-11.

The battlefield has eight terrain features, shown by numbered triangles. Terrain features l and 2 are occupied by identical Blue elements, Feature 3 is the Blue objective; feature 8 is occupied by a single Red element. The status of features 4, 5, 6, and 7 is not observed by Blue forces, but since it is assumed for this example that he knows the Red Order of Battle to be only one element, he can deduce that they are unoccupied. Routes connect the features as shown.

The terrain of the battlefield is visualized as consisting of features (Δ), obstructions (∩), and routes (----). The scale of the representation depends on the level of analysis; each feature is large enough to contain any *one* of the elements or units being considered in the analysis. Features may have an intrinsic value if they are designated as military objectives for the battle in question. Whether or not they have such a value, they have a certain capability to furnish either cover, concealment, or both for elements which occupy them. Occupation of a terrain feature by an element also modifies the element's potential for fire, intelligence, or both, according to the pattern of obstructions surrounding the feature, and according to the number and type of enemy elements within range of the feature.

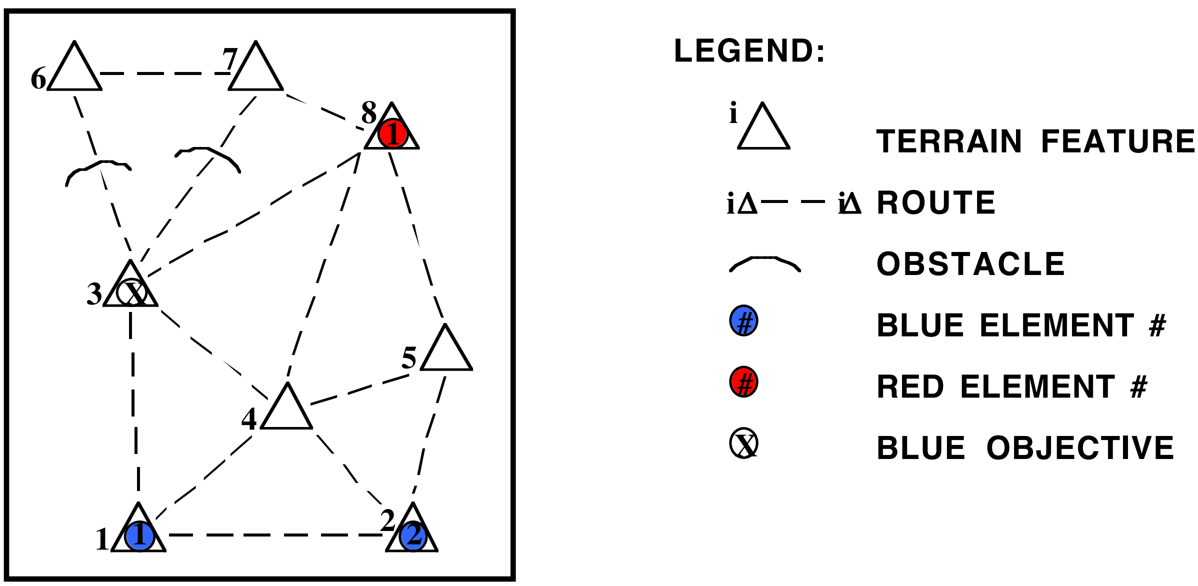


Figure 3-11 - A Type Problem is Defined for Analysis.

When a commander looks at terrain, he sees it in terms of possibilities for the fire and maneuver elements under his command. They are pictured as executing some course of action which is a schedule of time intervals spent at points and time intervals spent moving between points. A moving target is harder to hit than the same target at rest unless the latter is partially or totally covered and/or concealed. (For clarification, cover provides concealment unless it is hastily or clumsily constructed cover, rather than natural cover. Concealment does not necessarily provide cover.) Thus, when the commander examines the terrain, he identifies those points at which his elements will have the best cover and/or concealment and as a minimum will be less vulnerable than if they simply kept moving.

Terrain features are also characterized by fields of fire and fields of view. It may be that certain features will be chosen for superiority in these regards, though somewhat deficient in terms of cover and concealment.

The commander, or his intelligence specialist, is also examining the terrain to determine points which might be occupied by the enemy - in general, these will also be characterized by a higher degree of concealment or cover than their surroundings. The merged sets of points selected from operational and intelligence points of view are what we designate as terrain features and represent them by Δ.

The Blue identification of terrain features is not necessarily the same as that of the Red, although it is suspected that they will normally overlap to a large extent. Whichever commander has greater skill in terrain appreciation (a sub-process of Estimation) will enjoy some advantage. A larger number of feasible courses of action can be developed, and the best course of action may present itself to the more skillful commander and be overlooked by his opponent. Since we are not at this point proposing to evaluate the effect of human skill, the set of features presented in this example is considered to be a complete set identified both by Red and by Blue.

As a convention to simplify analysis, an assumption is made that a terrain feature can be occupied by only one Fire, Maneuver, Command, Intelligence, or Construction element at a time. This reflects the desirable principle of dispersion of assets, and closely contiguous points can be defined if desired. Supply, Maintenance, Transportation, or Signal elements can be collocated with the earlier-named types or each other at a single feature; in fact, they often must be so collocated to perform their function.

Routes are distinguished by length and by trafficability; the two characteristics combine to determine the time which any given element requires to traverse the route. Routes throughout their length present no advantage to vulnerability or potential of the traversing element; if they did, additional features would be defined for analysis and the route would become two or more shorter routes.

The routes indicated as connecting features are presumed to be the best available in the speed of traverse. The routes between widely separated features are pictured as deviating to pass through features close to a direct line connecting the points. This reflects sound maneuver tactics; whether or not a stop is planned, it is normal to take maximum advantage of cover and concealment.

Obstacles to movement do not preclude use of a route; they do impose a delay time for passage. Obstacles to flat-trajectory fire or line-of-sight (not used in the type problem) absolutely preclude these operations between the two points at the end of a route so marked. If the most direct route between two points is so marked on all segments, there is no line-of-sight between the points.

Blue has been assigned a terrain objective in this type problem; Red has not. For Blue Forces to accomplish their military objective, they must place one element on the objective 3 by time t_I and maintain it there and functioning until some later time t_F. To accomplish this, he is given resources in the form of a number of elements - in this case, two. He is also given such information as is available about his opposition and the terrain. This may include: occupied features, features known to be unoccupied at the time of the information, and information about the local enemy order of battle (one Red element in this example) - from which he can deduce the number of enemy elements which must be paired with unresolved features to construct a complete map of the enemy situation.

The value of occupancy of the objective by a Blue element, derived from some higher level of strategy, is as shown in Figure 3-12.

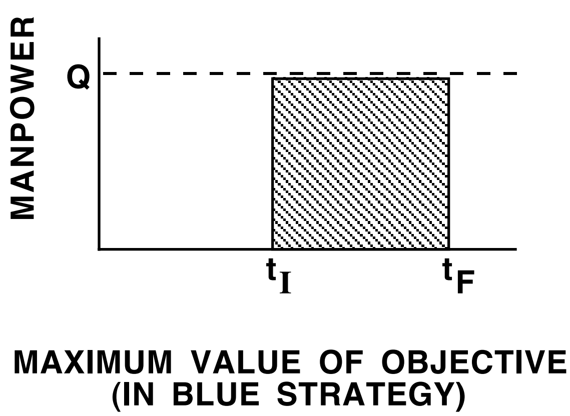


Figure 3-12 - Blue's Payoff is Defined.

Q is expressed in terms of Blue elements, and thus time on the objective between t_I and t_F is worth Q times the duration of functioning occupation. The Blue and Red elements each have a residual value for operations beyond t_F and, therefore, the net profit to Blue Forces of any operation is determined as follows.

Defining:

Δt = BLUE TIME ON OBJECTIVE BETWEEN t_I and t_F

P_{K_i} = PROBABILITY OF KILL OF i^{th} ELEMENT BEFORE t_F

V_i = RESIDUAL VALUE OF i^{th} ELEMENT AFTER t_F

Then Blue's payoff formula is:

$$Q = \Delta T + P_{K_R} V_R - P_{K_{B1}} V_{B1} - P_{K_{B2}} V_{B2}$$

and Red's payoff formula is:

$$P_{K_{B1}} V_{B1} + P_{K_{B2}} V_{B2} - P_{K_R} V_R$$

Δt is the time between t_I and t_F during which a functioning Blue element occupies the objective. P_{K_i} and V_i are the probabilities of kill prior to t_F and the residual values after t_F of the indicated elements, respectively. The best plan from Blue's viewpoint is that which maximizes his profit .

A similar payoff formula is drawn up for Red. Since we assume that the objective has no value for him, his criterion for profit is one of relative attrition.

Each command element is pictured as continuously planning: constructing alternate courses of action and evaluating them according to his own payoff formula by the estimation process. The construction of one Blue course of action is now described in Figure 3-13

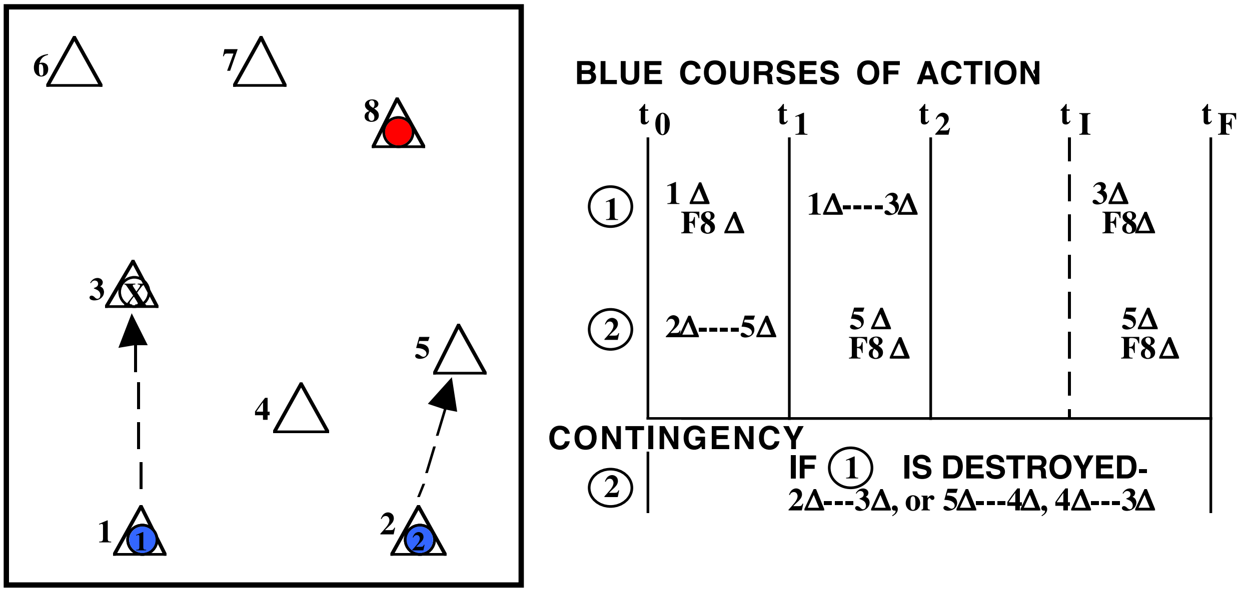


Figure 3-13 - The Value of each Course of Action can be Calculated.

- P_K's and therefore Blue's payoff can be calculated as a function of FIRE and MANEUVER POTENTIAL

- Accuracy of calculation by Blue depends on completeness of INTELLIGENCE and STATUS reports

- Estimation (a COMMAND process) can substitute for incompleteness of reports

- Red's course of action also affects payoff

1) Since the two Blue elements are identical, it makes no difference which one occupies terrain feature 3.

2) Either Blue element is more vulnerable to fire while on a route than while at a terrain feature. The vulnerability while on a route is determined by the position with respect to enemy elements, the time spent in traversing the route, and the speed while enroute (speed of a moving target increases errors of fire). Although the diagram appears to favor element B_1 on route 1---3, if feature 4 masks fire from 8, the preferred solution may be element B_1 on routes 1---4, 4---3. On the other hand, if route 2---4 has a great edge in trafficability one might favor element B_2 on routes 2---4, 4---3.

Trafficability is measured by the decimal fraction of maximum element speed which is average for traverse of the route. It has a different specific value for each type element, and will be zero for those elements for which a route is impractical at any speed.

Let us assume that element B_1 on route 1---3 has the greatest probability of survival en route. A timed plan of maneuver for element B_1 now emerges. Since the hazard on route 1---3 does not exist if the Red element R_1 is non-functional, it may be profitable for element B_1 to deliver fire against element R_1 until time $t_I - (t_2 - t_1)$, creating some probability that the travel will be completely safe (given that B_1's ammunition plan will permit). On the other hand, feature 3 may offer much better cover than 1, and equal or better fire potential against feature 8. In this case, it is desirable to move t_1 back to t_0. The question as to element B_1's timing is tentatively decided by the relative kill potentials of B_1 on 1 versus R_1 on 8 and B_1 on 3 versus R_1 on terrain feature 8. Let us assume that B_1's best procedure is to travel immediately to point 3.

Note that calculations to this point may-show the enterprise to be unprofitable for Blue Forces. Whether it is or not, we go on to examine possibilities for making it more so. Since B_1's course is tentatively decided, we now examine what B_2 may do to help. He can, of course, deliver fire from point 2 against point 8, constantly if ammunition permits. If ammunition is limited, it should be expended during the time of B_1's greatest exposure; R_1's function may be impaired by the suppressive effect of B_2's fire, even if it is not prevented by kill. In addition, R_1 will have to make a decision as to his delivery of fire (he could afford to ignore B_2 if he were inactive); R_1's best decision depends on the relative vulnerability of B_1 and B_2, and B_1 is moving, so that his logical decision is probably to shoot at B_1 and deal with B_2 later.

It appears possible that B_2 will have more suppression potential from 5 than from 2 and so we may refine the course of action by having B-2 move to 5, B_1, of course, can probably deliver suppressive fire during the period $(t_0 - t_1)$. The profitability of this plan may be compared with one that leaves B_2 at 2. Note that it can conceivably be more profitable even if t_2 comes after t_I. The loss of time on the objective may be offset by less expected loss in resources. Note that under this course of action feature 5 has become an intermediate objective for B_2, having a value to the larger operation.

Now if B_1 is rendered non-functional by enemy action at any time prior to t_F, B_2 may salvage mission value by proceeding from 5 via 4 to 3, granted that his expected loss does not outweigh the additional $Q\Delta t$ to be gained.

Obviously, the Blue course of action thus far described is only one of a large number which can be described. Profitability calculations can reveal which is the best, provided that R_1 remains at point 8 and fires so as to maximize *his* profit. However, the Blue commander has no way of knowing Red's objective or intentions. He must, therefore, postulate Red's courses of action based on Red potential as he sees it.

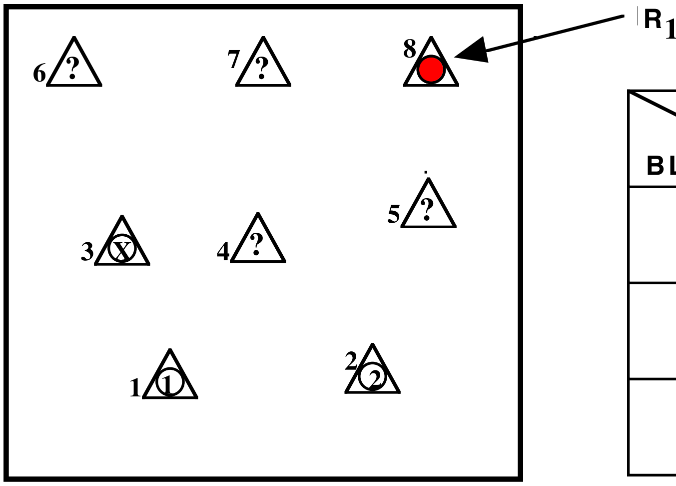
The result of this process is a large non-zero sum game matrix of Blue versus Red postulated courses of action wherein a saddle point would be a sound *average* decision (a command process); however, a saddle point usually does not exist. The quality of decision (generalship) dictates the result; however, we do not plan to analyze generalship, nor the other most important *human factors* such as Leadership, Motivation, Training, Skill, or Physical and Mental Condition.

As previously discussed in section 7.0 of this chapter, generalship may offset numerical and/or hardware superiority. This is a characteristic of the command element - a *human factor* or skill.

The game-matrix approach within the illustrative problem can assign a value to Blue's possession of certain items of intelligence.

Suppose Blue does not have perfect knowledge of the situation; either his Order of Battle File, or his Situation Map, or both, are incomplete. Suppose first that his Order of Battle information is perfect - he knows that the Red has two elements rather than one. He has located or been told about one element at terrain feature 8 and knows that 3 is unoccupied. However, the unlocated Red element R_2 may be at any one of features 4, 5, 6, or 7.

By a process similar to that already described, Blue can construct a pay-off matrix of opposing plans for each of the possible locations of R_2. Figure 3-14 represents an abbreviated matrix and a terrain map with known and unknown positions.



R_2 at / BLUE	4 ?	5 ?	6 ?	7 ?
CA 1	a	— —	— —	— —
CA 2	—	b	c	c
CA 3	—		d	e

Figure 3-14 - Intelligence Items can be Valued.

For the matrix shown, the values therein represent Blue's payoff for three courses of action (C/A) if the second Red element R_2 is at the terrain feature indicated. Let us assume that the values shown have the following relationship:

$$e > d > c > b > 0 > a$$

Then the value of knowing that:

R_2 is at terrain feature 4 = - a

R_2 is not at terrain feature 4 = b

R_2 is not at terrain feature 4 or 5 = c

R_2 is not at terrain feature 6 = 0

Each of these matrices will have a *best* decision point, but they may indicate different plans for Blue dependent on the location of R_2. Let us suppose that for R_2 at feature 4 the best plan for Blue shows negative profit; for R_2 at 5 Blue has a profitable plan available; for R_2 at either 6 or 7 Blue has a more profitable plan than for R_2 at 5 and one which involves different initial steps.

Now if R_2 is actually at feature 4, the payoff is less than zero. Hence Blue should not undertake any operation against the objective, but rather should report back for further instructions. The higher Blue echelon will have to re-examine its strategy and re-allocate resources. The Blue Forces in the battlefield may get reinforcements or fire support, or may be redirected to another objective, possibly in a different battlefield. Therefore, the knowledge that R_2 is at feature 4 prevents a loss (-a). The actual profit ultimately realized depends on the revised objective value.

If R_2 were known not to be at 4, Blue might elect to proceed as if he were at 5. In order to find out that R_2 is not at 4, Blue can afford to invest effort up to the positive value of the best Blue operation against Red elements at 5 and 8

If R_2 is known not to be at either feature 4 or 5, Blue can adopt a better plan with a higher pay-off. The investment is finding out that R_2 is not at either 4 or 5 can be equal to the additional profit of the better plan..

Since the same plan is adopted whether R_2 is at feature 6 or 7, there is no profit to finding out which. This is true, even though the profitability of the Blue operation may be different for the two cases. Actually, this assumption is rather artificial in order to illustrate a point. The plan is likely to involve placing fire on either 6 or 7, whichever is occupied, and probability of success will be lowered if the wrong one, or both, are taken under fire.

Thus, we have from our illustrative problem a plan for Sensor Direction (determine whether R_2 is at feature 4 , then whether at 5), and the value of two different items of information.

Now suppose that the Order of Battle information available to Blue is not specific as to the number of elements available to Red on the battlefield but does limit them as to type. Blue must examine the profitability of courses of action based on assumptions as to the tenancy of terrain features 4, 5, 6, and 7. (The Blue commander probably should investigate in descending order of optimism, to save effort, stopping when he comes to negative profit situations.) He may find, for instance, that his operation cannot be profitable if there is an R_2 at 4, or if there are an R_2 and R_3 at any two of 5, 6, or 7. He may then devote effort to finding out that 4, 5 and either 6 or 7 are unoccupied. A profit accrues if the effort devoted is less than the profit differential of a better plan.

If Order of Battle information does not limit the type of Red elements which may be present, Blue really should reconnoiter features 4, 5, 6, and 7 before proceeding with any plan.

Of course, this super-cautious attitude would not pay off on a real battlefield. Blue and Red Forces will both have to make risky decisions rather than wait for complete information. However, this analytic approach is intended to establish the value of intelligence both in maximizing payoff and in reducing risk.

10.0 SUMMARY

This Chapter has described the key concepts necessary for complete modeling of opposing military forces and their interaction within a scenario context. In Summary, these key concepts are as listed in section 1.0 :

- A Common Unit of Measure - MAN-DAYS.
- Battle as a process involving the performance of nine basic functions by each opposing force.
- CAPABILITY, POTENTIAL, PERFORMANCE, EFFICIENCY, and PACE - which are expected to enable useful calculational models of a Lanchester type.
- The identification of the COMMAND function as the driver of the situation, and its modeling as a continuously-updated game matrix.

Additional detailed work is required to complete a descriptive model; the major tasks presently defined are:

1. An explicit description of each of the nine functions, to include: type elements, their distinguishing characteristics, sub-functions, units of measure for performance of sub-function, and modification of capability by scenario factors.

2. For each of the nine functions, one or more (depending on sub-function identification) process charts carried to sufficient detail to identify all events requiring interface with other elements or units, This includes identification of interface variables which enable description of the effect of the functional performance.

3. Identification and description of some function called COMBAT which satisfactorily, though probably approximately, describes the result of combined performance of the nine functions currently identified. The unit of measure for this function is the man-day in theater, connecting terrain objectives and attrition as in the Blue Pay-Off value formulas associated with Figure 3-12.

4. Formulation of a macro-level equation (possibly more than one) in terms of either the combat function, or of the nine functions previously listed. In the latter case, it appears that MANEUVER and MAINTENANCE will contribute terms to the equations, though the other functions may possibly produce merely coefficients for the FIRE, MANEUVER, and MAINTENANCE terms.

5. Examination of the transition from elemental to unit potential for each function, including COMBAT.

6. Examination of the influence of scenario factors on each function at unit level.

7. Modification of the approach to permit application to tactical warfare at sea and in the air, and at air-sea, air-land, and sea-land interfaces. It is believed that the same functional approach CAN be applied, changed only by differences in the environment.

The above list of seven tasks describes a large amount of detailed work, much of which is covered in subsequent Chapters. Future effort may easily become over-theoretical and sterile unless an early attempt at quantitative application is made, as demonstrated by Chapters 6.0 and 8.2 for Interdiction Fire. If one wishes to undertake objective development of requirements FOR and ON Support Fire weapons systems. This would require completion of task a), and of tasks b), c), and d) for the Fire function. In addition, tasks c) and d) will have to be accomplished to the degree necessary to formulate a Support Fire Target Value.

The following possibilities for investigation exist (listed in order of increasing difficulty):

l) Methodology for Investigation of System Compatibility (as for Modular Weapons)

2) Methodology for Pre-acquisition Selection 0f Systems, to be Selected Based on Their Utility in a Spectrum of Level II Scenarios

3) Investigation of the Command Function (relevant to automated command systems, e. g., IBCS -- Integrated Battlefield Control System)

4) Investigation of the Intelligence Function

5) Qualitative Force Structuring Methods

Conceptually, at this point:

- We can logically and mathematically connect:

  COMMAND, INTELLIGENCE, FIRE, MANEUVER,
  SUPPLY, MAINTENANCE, CONSTRUCTION,
  TRANSPORTATION, and SIGNAL

- Using MAN-DAYS, we can trace national effort from budget to battlefield and determine output over input

- Practical results follow in subsequent Chapters.

For the moment, let us set aside the further development of target values, while we contemplate how we would use such methods in the establishment and verification of Requirements FOR and ON future military systems.

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