Chapter 9

SUMMARY

Throughout military history Intelligence regarding enemy capabilities and intentions, decisions made by Command, and Communication between echelons of Command, have profoundly influenced the outcome of combat. In recent years technological developments have vastly increased the capability to acquire, store, and transmit data, yet it is extremely doubtful that these capabilities have produced a commensurate increase in combat effectiveness. The mass of data flooding the information-handling systems may even be producing the opposite effect.

Research and development of a Combat Model concentrating on the effects of information flow and information-handling processes may help solve this dilemma.

A theory of combat has been developed herein which is embodied in a descriptive model of selected military functions and battle processes. This model is quite detailed with respect to the information-handling functions of Command, Intelligence, and Signal and represents an excellent starting-point for incorporation of these functions into some form of a Theater Combat Model.

It is the purpose of this summary to present an overview of the total problem and the soundness of the technical approach.

A methodology for the study of requirements *For* and *On* tactical weapon systems has been developed in *The Anatomy of Combat*. In the process, a basis has been provided for evaluating candidate concepts against such requirements. For the sake of clarity and convenience, the overall tactical problem has been broken down into the basic combat functions (Direct Fire, Support Fire, Interdiction Fire, Strategic Fire, Air Defense, Defense Suppression, Air Superiority, Naval Surface Combat, Anti-Submarine Warfare, and Intelligence) and studies have been undertaken of several of these functions. In order to study force-mix questions, it is necessary to net these functions together to establish their relative utility under varying scenario conditions. Quantification is possible only through some rational, logical method of assigning values to targets. A simple method of valuing targets has been hypothesized and applied in the study of Interdiction Fire and Defense Suppression with promising results.

As weapon lethality has increased, tactical warfare has increasingly emphasized maneuver and suppressive fire (i.e., time and situational factors). This necessitates careful integration of the closely related combat and support functions in some form of target value that reflects the effects of maneuver and disruption of enemy courses of action as well as the time-honored effect of physical damage or destruction.

An approach to quantifiable values for military elements is developed in Chapter 5 wherein military elemental values are pictured as a process of adding on to *Residual Values*, furnished by the next higher command, a *Situational Value* derived from the element's contribution to combat potential for a chosen course of action. This method appears applicable for practical analysis of system effectiveness; however, there remain several areas in which simplified and approximate computational methods must be developed. At this point, a sound basis exists for undertaking the design and development of a methodology for relating the effects of Intelligence, Communication, Command and Control system/resources, including counter measures, to combat activity and outcomes for a theater level Army force.

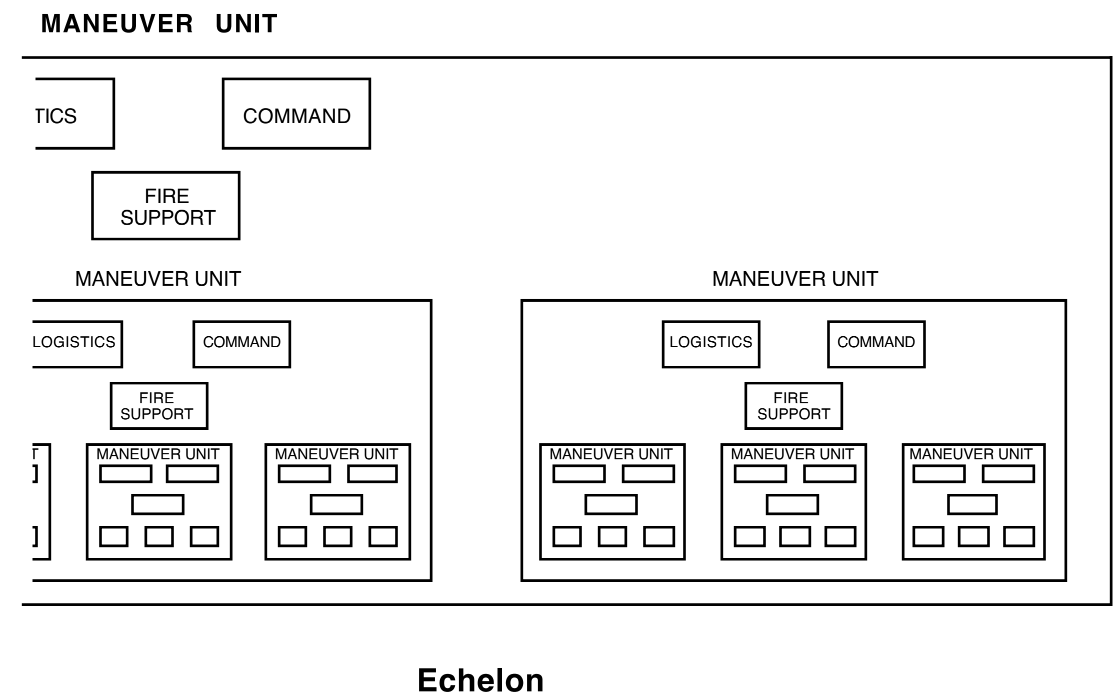
In the functional description of combat, the conflict is represented as a set of battles defined as to Space, Time, and Opposing Forces. In space, large battles are divided into concurrent smaller battles, these into still smaller ones, down to element versus element duels. Each side pursues some strategy which calls for time-phased accomplishment of certain objectives (to take or hold terrain and/or inflict damage on the opponent), thus at each tactical level each *battle* end state is the initial state for the next. Each side (Blue or Red) has a theater-level strategy which allocates resources and assigns objectives and control directives to its major subordinate commands. These in turn formulate subordinate strategies of their own and pass similar but more detailed *directive* information to the next lower echelon, and so on down to the level of the combat element - the rifleman, tank and crew, etc. This flow of orders affects the efficiency and the pace of the battle.

This model views the battle as decided by the relative strength of the opponents <u>and</u> their relative effectiveness in performance of nine military functions. These are the Combat Functions of FIRE, MANEUVER, and INTELLIGENCE which are linked to the Combat Support Functions of SUPPLY, MAINTENANCE, TRANSPORTATION, CONSTRUCTION, and SIGNAL through the COMMAND Function which continuously plans and triggers functional performances. The functional potentials are quantitatively linked into an expression of *Combat Potential* . Relative Combat Potential is considered a major determinant of battle outcome. In addition, Command decisions are represented as guided by an Objective Function to be maximized; the Objective Function is Combat Potential relative to that of the enemy. Of course, the battle is not isolated; the combat inside the *battle-ground* is influenced by the combat in adjacent battlegrounds and also by performance of support functions from outside.

2.1 THEORY OF COMBAT

2.1.1 Functional Description of Combat

The conflict is represented as a set of battles defined as to space, time and opposing forces as indicated in Figure 9-1.



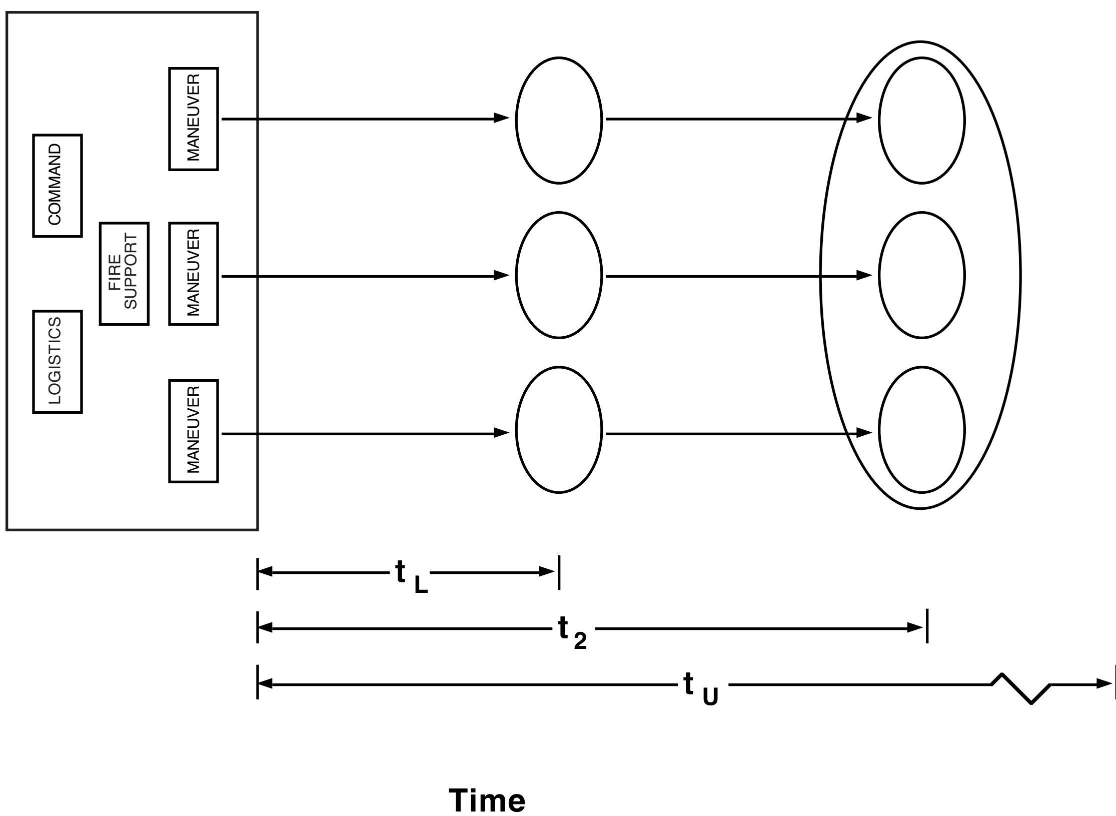
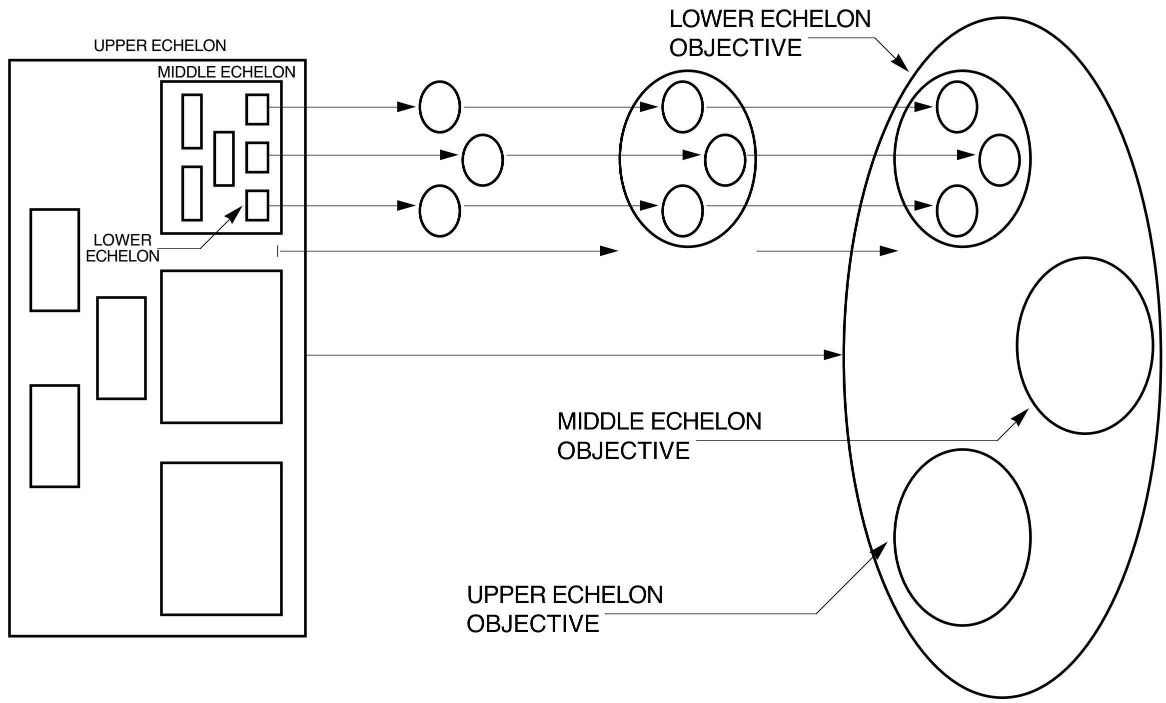


Figure 9-1 - Essentials of Battle are Forces, Space, Time, and Success Criteria (continues).



Geographic

- SECURE OBJECTIVE
- ACCOMPLISH WITHIN TIME t_2
- ACCOMPLISH WITH EXPENDITURE OF FINITE RESOURCES

Success Criteria

Figure 9-1 - Essentials of Battle are Forces, Space, Time, and Success Criteria.

In space, large battles are divided into concurrent smaller battles, these into still smaller ones, down to element [1] versus element duels. Each side pursues some strategy which calls for time-phased accomplishment of certain objectives (to take or hold terrain and/or inflict damage on the opponent), thus at each tactical level each battle end state is the initial state for the next. Each side (Blue or Red) has a theater-level strategy which allocates resources and assigns objectives and control directives to its major subordinate commands. These in turn formulate subordinate strategies of

[1] Element - A military entity which cannot be subdivided without loss of function (e.g., a rifleman, a weapons crew, a tank and crew, etc.).

their own and pass similar but more detailed directive information to the next lower echelon, and so on down to the level of the combat element. This flow of orders (*directive information* described in Paragraph 2.1.2 below) affects the efficiency (η) (see Paragraph 2.1.3) and the pace of the battle which is designated by τ .

The model views the battle as decided by the relative strength of the opponents *and* their relative effectiveness in performance of the nine functions shown in Figure 9-2.

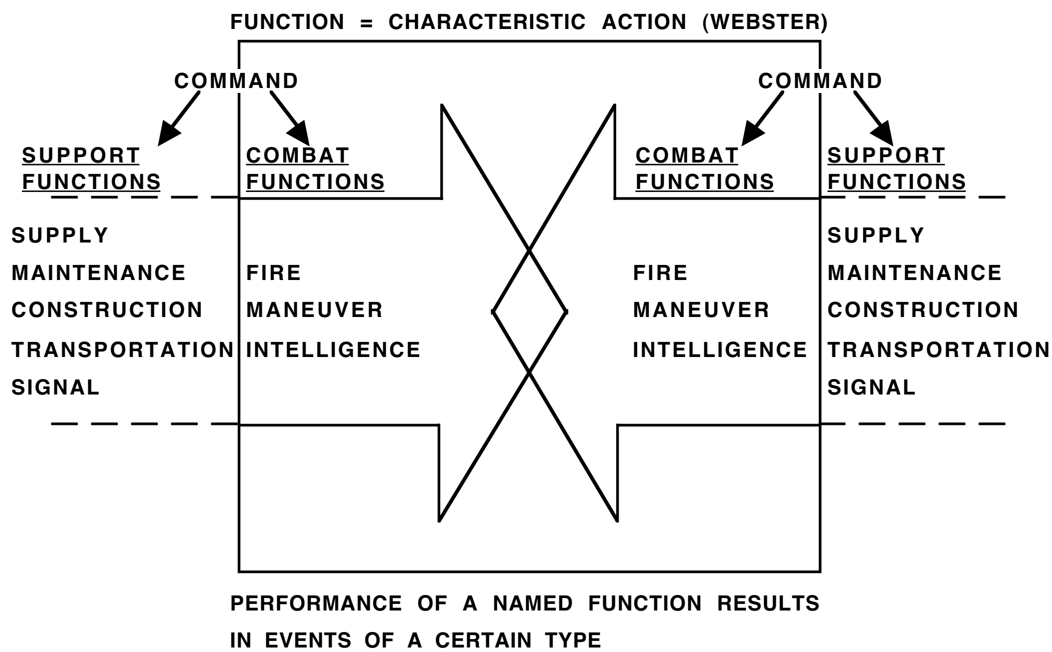


Figure 9-2 - Combat Potential Derives From Functional Performance.

Each functional performance alters the potential of other functions as indicated in Section 2.1.3. The battle is not isolated; the combat inside the *battleground* is influenced by the combat in adjacent battlegrounds and also by performance of support functions from outside.

The list of nine functions could be expanded; e.g., psychological warfare can be very important. However, these nine have been selected as those very important combat functions which are reasonably tractable for analysis.

2.1.2 Concept of Combat Potential

In the theory of combat, Combat Potential (π) represents the ability of a combatant element or unit to take or hold terrain and to inflict damage on the opponent.

The general formula for calculation of Combat Potential is

$$\pi_{C,B}\Big]_{t1}^{t2} = \sum_{\ell} Q_{\ell} \Delta t_{\ell} \Bigg]_{t1}^{t2} + \sum_{j} p_{R,j} \Bigg]_{t1}^{t2} V_{R,j} \Big]_{t2} \qquad (1)$$

where π represents potential; $\pi_{C,B}$ represents the Combat Potential of a Blue unit or element. The combat potential is measured in units of mandays, and is always evaluated for some specific future period represented here by time t_1 to time t_2 . It is a measure of what the unit can be expected to accomplish during that period.

The first term on the right quantifies the maneuver function - the ability to take and/or hold terrain objectives. Q_{ℓ} represents the assigned value (in equivalent men) of the ℓ^{th} terrain feature; Δt_{ℓ} represents the period of Blue occupation of that feature.

The second term on the right quantifies the Fire function - the ability to destroy, or otherwise put out of action, Red elements. $p_{R,j}$ is the probability that the j^{th} Red element will be *killed* during the period t_1 to t_2; $V_{R,j}$ is the value to Blue of having that Red element out of action for the phase of operations beginning at t_2. Characteristic incremental times of interest $(t_1 - t_2)$ lengthen as higher echelons are considered. The battalion plans strategy from day to day, the theater will use a " t_2" of a week to a month.

This concept of combat potential is similar to the frequently-used umpiring tool of firepower score. It differs in that maneuver potential is explicitly included and that the support functions can be directly and quantitatively related to the combat potential.

Relative combat potential determines the outcome of combat. Very infrequently is a conflict decided by attrition, usually one side or the other decides at some point that it can no longer achieve its objectives in the face of the enemy potential to negate them. At that point it retreats, sues for peace or otherwise changes its objectives. No model can predict this occurrence.

The two most fundamental problems of combat analysis are:

a) The *Umpiring* problem - How are the results of combat dependent on strength and performance of combatants and on other factors?

b) The *Aggregation* problem - How to represent strength and performance of composite units of varying sizes?

Combat performance is Potential modified by an operator τ (the *pace* of operations) which is determined by the functions of Intelligence, Command and Communications. Combat Potential is released only by Command action at some level down to and including the individual rifleman selecting his own course of action. Combat Potential can be used as an umpiring algorithm by application of the following Lanchester-like equations:

$$\Delta\pi_{C,R}\Big]_{t_1}^{t_2} = \tau_B \pi_{C,B}\Big]_{t_1}^{t} (t - t_1) \quad , \ t_1 \leq t \leq t_2$$

and

$$\Delta\pi_{C,B}\Big]_{t}^{t_2} = \tau_R \pi_{C,R}\Big]_{t_1}^{t} (t - t_1) \qquad (2)$$

Red Combat Potential for the time period t to t_2 is degraded by Blue combat performance during the period t_1 to t, and vice-versa. When the potential of either side has been degraded to the point that it can no longer expect to accomplish its objectives, the conflict ends. It is conjectured that the pace of the battle, τ, may represent the most important influence of command upon military operations.

The concept of Combat Potential also assists in solution of the *aggregation* problem, because it uses a unit of measure (man-days) common to all echelons. The effect of each of the nine listed military functions on Combat Potential can be traced. For some functions (e.g., Construction) the relationship is quite complex; a complete solution to the aggregation problem is not yet in hand.

Since Combat Potential will decide the conflict, it is represented as determining the decisions of both sides (see Equation 3 for Blue). The Blue Objective Function to be maximized by choice of course of action is his combat potential relative to Red:

$$\pi^{B}_{C,B} \; - \; \pi^{B}_{C,R}$$

or (3)

$$\sum_{\ell} \mathrm{Q}^{\mathrm{B}}_{\ell} \; \Delta t_{\ell} \Big]_{t_1}^{t_2} + \sum_{j} p_{R,j} \Big]_{t_1}^{t_2} V^{B}_{R,j} \Big]_{t_2} - \sum_{i} p_{B,i} \Big]_{t_1}^{t_2} V^{B}_{B,i} \Big]_{t_2}$$

This is simply Blue Combat potential minus Red Combat potential; only one term is used for maneuver since occupation of a feature by Blue means denial to Red. The superscript B's mean *according to Blue valuation* - the directive values for Q^{B}_{ℓ}, $V^{B}_{R,j}$, and $\mathrm{V}^{\mathrm{B}}_{\mathrm{B,i}}$ are assigned by the next higher headquarters in implementation of its strategy, which extends beyond the t_2 assigned the lower echelon. The values assigned by Red - Q^{R}_{ℓ}, $V^{R}_{R,j}$, and $\mathrm{V}^{\mathrm{R}}_{\mathrm{B,i}}$ - may be quite different - in which case the local battle is not *zero-sum* .

This general formula for the Objective Function applies at all levels from element to theater. It also applies to air and naval forces - though the Q's must be omitted, since holding terrain is not an applicable mission. Other means can supply the Q value for naval missions (See Chapter 8.8).

2.1.3 Functional Potentials and Capabilities

The Combat Potential of an element or unit is determined by its potentials in one or more of the nine functions listed in Figure 9-2. Fire and Maneuver enter directly into the equation for combat potential; the Support Functions contribute indirectly, e.g., ammunition *supply* may limit the number of targets which can be engaged in the period from t_1 to t_2 and thus affect Fire Potential.

Each element has a *Capability* (κ) for performance of its functions, which is determined by its configuration and performance variables. The basic Capability of the men operating and supporting a piece of equipment is amplified by an operator μ (the *Productivity* of the equipment). Thus $\kappa = \mu W$, where W is the manpower investment. The units of measure differ according to function. Fire is measured by probable removal of Value ($V_{R,j}$) from enemy elements. Transportation is measured by ton-miles/day.

However, the Potential (π) very seldom approaches the Capability (κ) because of a situational efficiency factor, η. For Fire the degrading factors can be such as: 1) Shortage of Targets, 2) Lack of Target Information, 3) Shortage of ammunition, 4) State of Maintenance, 5) Darkness.

Thus, in general

$$\tau = \eta\kappa = \eta\mu W$$

where η's vary drastically with time and selected course of action.

To summarize the theory to this point: The effect of each military element on the outcome of combat is determined by its contribution in one or more of the nine previously-listed functions (Figure 9-2). The contribution can be measured and influences other potentials in the following ways:

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.

These functional contributions determine Combat Potential. Fire potential directly establishes $p_{R,j}$ (attrition of Red) and Maneuver potential directly affects Δt_ℓ (terrain occupation). The other functional potentials contribute indirectly. When expressed as an Objective Function, relative

Combat potential forms a basis for tactical decisions for both sides. Relative Combat Potential, after alteration by the performance of both sides, eventually determines the outcome of the conflict.

Both the research into assessment factors (paragraph 2.2.3.3) and the use of Combat Potential as an umpiring tool in a Theater Combat Model require the employment of factors modifying the manpower ratio between the combatants. In the Theory of Combat these factors are of three types: μ's representing hardware-connected productivity, η's representing situational efficiencies, and τ's representing the influence of the information-handling functions.

2.1.4 Command Function

Command controls and *triggers* the performance of all other functions. For simplicity, only the Command of Combat functions (Fire and Maneuver) is discussed below.

Command of course operates through a *chain* or net. Figure 9-3 illustrates one command element operating between a superior command and subordinate elements or units.[2]

The superior command issues orders in consonance with its chosen strategy. These orders (Directive Information) consist of:

t_1, t_2	-	The Directed Period Of Operation
$(\cdots, B_i, \cdots)$	-	Assigned Elements (Often Pre-Established And Unchanging)
$[\underline{\bar{A}}]$	-	Bounds Of Area Of Operation
Q's	-	Values Of Terrain Objectives
$V_{R,j}$'s	-	Values Of Attrition Of Red Elements
$V_{B,i}$'s	`-	Values Of Conservation Of Blue Elements
V_S's	-	Controls On Supply Expenditures

[2] The Command function is the same from squad leader to theater headquarters

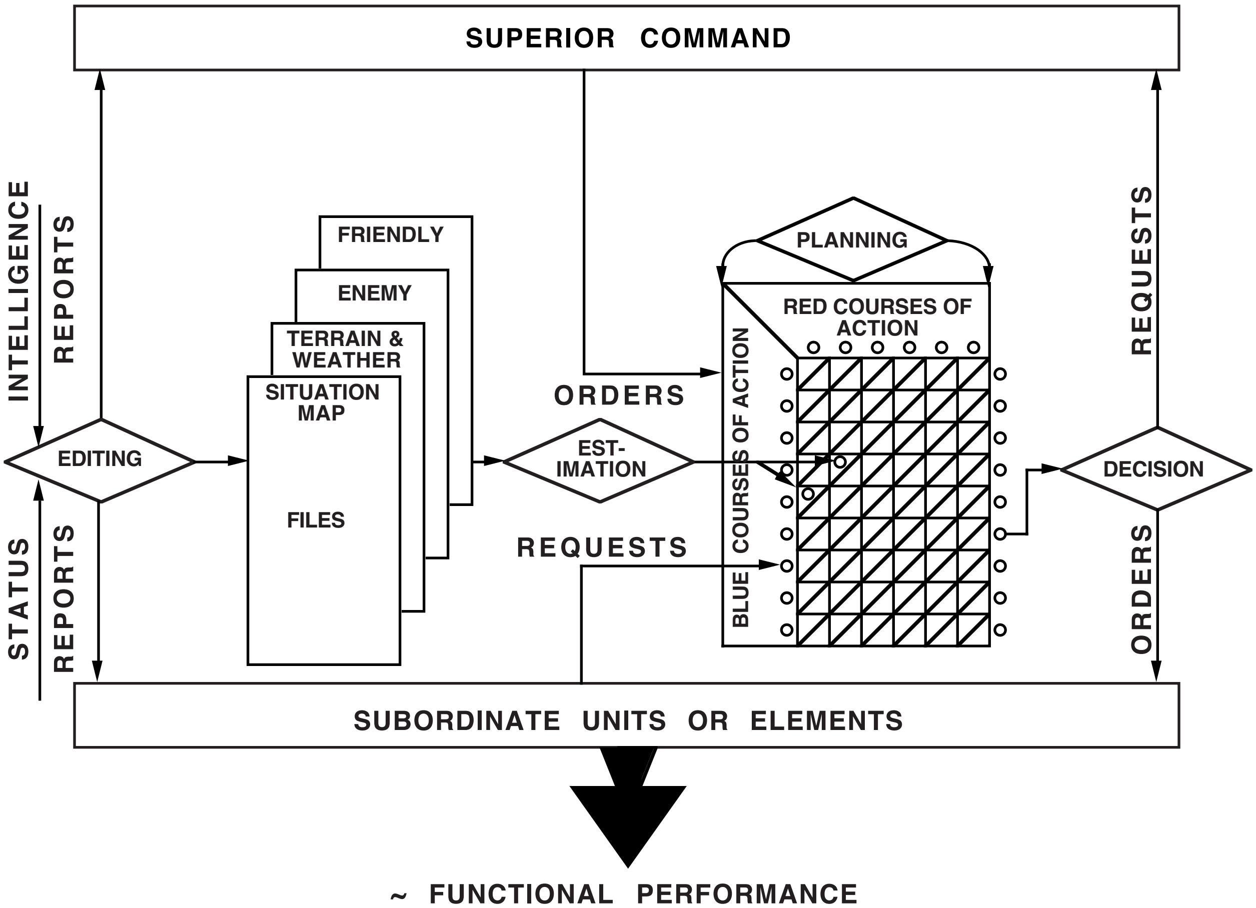


Figure 9-3 - Command Continuously Plans and Triggers Functional Performance.

The underlying theory for quantification of the Q's and the V's is covered in Chapter 5. The unit of measure for both Combat Potential and the Objective Function which guides decision for each side is the man-day. National defense and the conduct of war are regarded as the expenditure of national effort (measured in man-days) to attain certain political objectives. For analysis at the theater level, it is often sufficient to compute *in-theater* man-days rather than total national effort.

A well balanced military force in the combat area is composed of men of various talents and machines capable of various functions. By analysis of maintenance and operations required for all these machines, it is possible to apportion a value of man-days to each machine (weapon or vehicle or system). Destruction of the machine (or delaying its entrance at its assigned point in the battlefield) would render its apportion of man-day value unproductive to the enemy. If all machines were rendered unproductive, the military force ceases to exist. If some of the machines were rendered unproductive, the military force capability would be degraded.

The value of man-days for Blue Machines can be used as a measure of cost to Blue of operating and maintaining his machines; the ability of Blue machines to render Red machines unproductive (measured in cost to Red to operate and maintain his machines) can be used as a measure of effectiveness of the Blue machines.

There are two additional reasons for the use of man-days:

- The procedure introduces the vital factor of *time* into combat considerations.

- The man-day unit allows comparison of widely different military functions; for example. What is the comparative utility of a fund of man-days used for supply delivery, versus the same amount expended in Interdiction ?

The Q's used in the model are of three kinds:

a) Q_S's represent the final terrain objectives of the theater strategy, with value established by the political objectives of the conflict.

b) Q_I's represent time-phased intermediate objectives implementing a time-phased plan for maneuver in the final objective.

c) Q_T's represent the tactical value of temporary occupation of terrain; they furnish a mechanism for insuring coordination among lower-echelon strategies. E.g., a Q_T assigned to a base of fire directs its positioning to support a maneuver element.

Q_I's and Q_T's are time-dependent; Q_S's are treated as constant-value independent of time. They are probably in fact time-dependent, since national will and political objectives do change with time. The variable value of Q (in men) is integrated over time of occupation to produce man-days.

The $V_{B,i}$'s, $V_{R,j}$'s, and V_S's are expressed in man-days. Conceptually all these values can be derived from the political objectives and overall theater strategy. In practical analysis, however, they are usually assigned on a relative basis.

For example:

$V^B_{B,i} / V^B_{R,j}$ Represents the attrition ratio Blue will accept.

$Q_T \Delta t / V_{R,i}$ Represents the risk that Blue will take to occupy a given terrain feature.

In addition to Directive Information, the Command element has two other flows of incoming information - Intelligence of enemy units and *Status Reports* of friendly units. This information is edited for pertinence and placed in continuously-updated files.[3]

The Command Plans by postulating Blue courses of action consonant with its directive information and Red courses of action consonant with known or assumed Red capabilities. It Estimates in terms of Objective Function value (see Paragraph 2.1.2 and Eqation 3) the probable outcome of each pair of opposed courses of action, using information drawn from the Files. The Decision is then extracted as the maximin of the game matrix and communicated as Orders. If no positive Objective Function value is attainable, a Request (for change of Directive Information) flows back up the chain of command.

This rather mechanical view of the decision process leaves out at least two important attributes of a good commander - Leadership and Generalship, Both of these can be modeled within this system.

Leadership is the capability to have Directive Information (Orders) accepted and carried out by the subordinates. Defective leadership can be modeled by picturing subordinate Command elements as substituting their own Q's and V's for those received (with bad results for the overall strategy).

Generalship is the capability to out-think and out-wit the opposing commander. This can be modeled by weighting the feasible Red courses of action according to an estimate of Red's intent (or past practice, etc.). The result is better or worse than the maximin, according to the Generalship of the commander.

Decision must be a dynamic process; any decision is completely valid only for a relatively brief period. Moves by the combatants then alter the state on which the decision was based, eliminating

[3] The word *files* is used to connote an organized mass of data, continually updated. It includes, for instance the current situation map.

some of the original courses of action as no longer feasible, and sometimes opening up new courses of action. In addition, as the opponent makes moves new intelligence may replace old intelligence or assumptions regarding the enemy.[4]

However, there is always a lag (Δt_D) between the analysis of a situation and the communication of orders designed to cope with it. The characteristic length of this lag is considered one measure of the effect of Command on Combat Potential. Another effect of Command is the Objective Function value realized by decision, as compared to that realizable by a *perfect* decision-maker (the maximin). This ratio is defined as Command Efficiency (η_D).

2.1.5 Intelligence Function

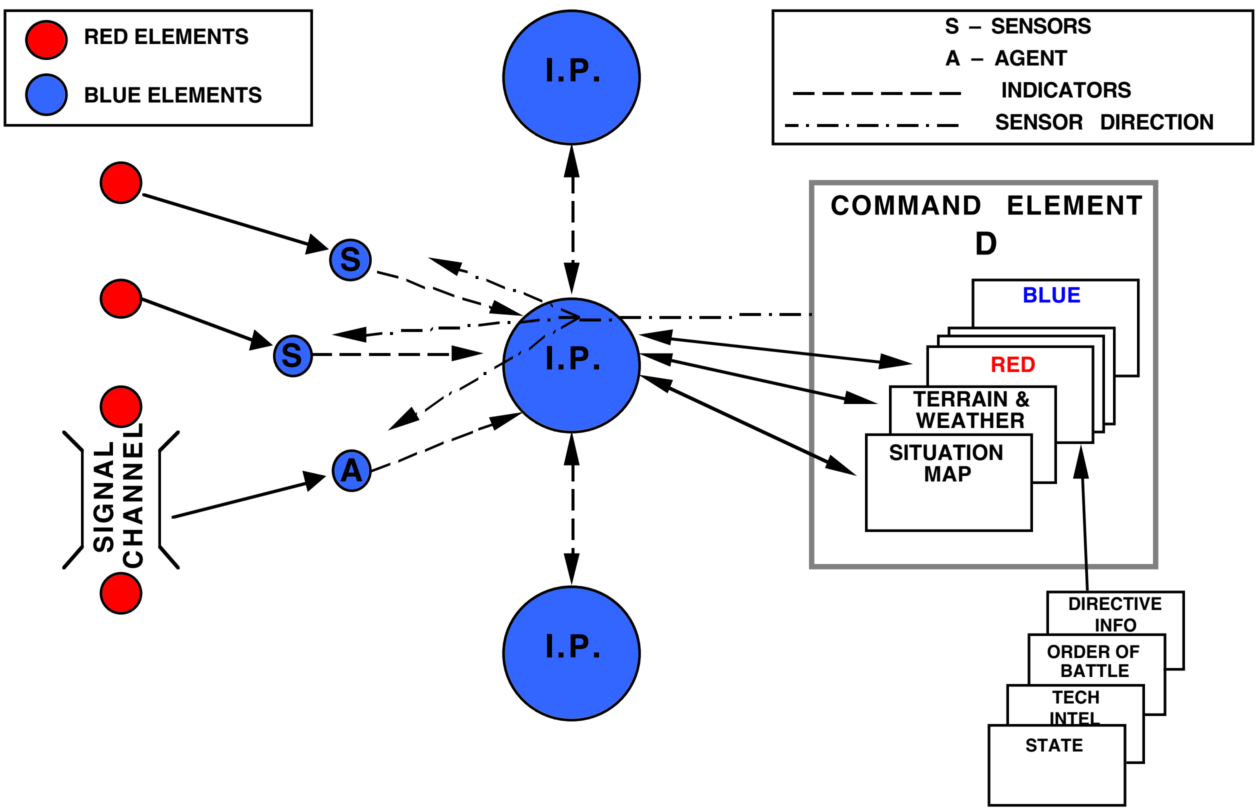


Figure 9-4 - An Intelligence Processor Modeled.

As illustrated in Figure 9-4, information concerning the enemy is collected by two classes of elements - Sensors and Agents. A sensor operates by Observation and often receives only

4 Reserves are held in reserve in order to cope with the emergence of new intelligence and to capitalize on any flaws in the enemy strategy as these are revealed by his actual movements.

indicators, which must be interpreted by an Intelligence Processor (IP) to produce Intelligence items. An Agent operates directly in enemy information channels and thus picks up Intelligence items directly.

Under each heading, Sensor and Agent, is a wide variety of intelligence collection devices. A Sensor may represent anything from a single scout to a SLAR (Side Looking Aperture Radar) or satellites; an Agent extends from POW interrogation through a spy to signal intercept devices. The basic distinction is in type of information gathered, rather than technology.

Intelligence Processors (from an individual's brain to a Theater Intelligence section, G-2) furnish *sensor direction* [5] and also process the incoming information for inclusion in the command files.

The files regarding Red are organized as follows:

a) Red directive information (orders and plans, which can be acquired only by agents)

b) Order of battle (partially available before the conflict, and constantly updated). Order of battle is important for sensor direction, and also because assumptions must be made regarding any unlocated unit *known* to be part of the order of battle.

c) Technical Intelligence regarding the capabilities of Red elements. With complete technical intelligence, identification of an enemy element releases all necessary information about that element.

d) State (including location) which determines the current functional efficiency (η) of the element. State includes such information as posture (firing, moving, etc.), state of repair, availability of supply. It is improbable that a complete description of enemy State will be attained by intelligence operations.

The Intelligence Processor creates the intelligence items from indicators or other intelligence items by the process of inference.

The efficiency of Sensors and Agents is established by the amount of indicators or intelligence items acquired; the efficiency of the Intelligence Processor is established by the amount and

[5] It is important to model *surveillance* as a Directed search for information, directed by what is already known, and by the information needs of the command.

correctness of inferences drawn from information furnished by sensors and agents. The efficiency, (η_I), of Intelligence activities as a whole is a function of the potentials of Sensors, Agents, and Processors, and directly affects the attainable (η_D) - Command Efficiency.

2.1.6 Signal (Communication) Function

Information must be passed between Intelligence Processors and Command elements as indicated in Figure 9-5.

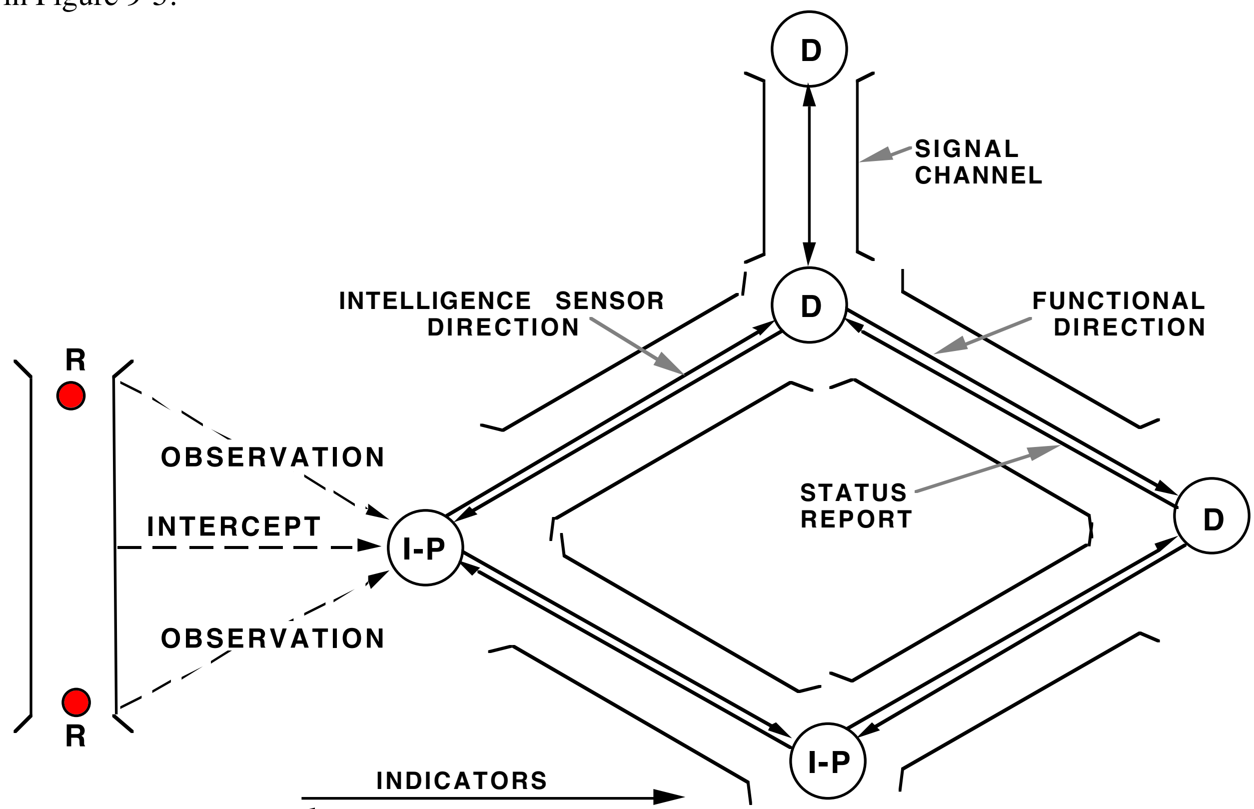


Figure 9-5 - Information Handling Loops.

Each such transfer of information is accomplished through a communication channel (Figure 9-6).

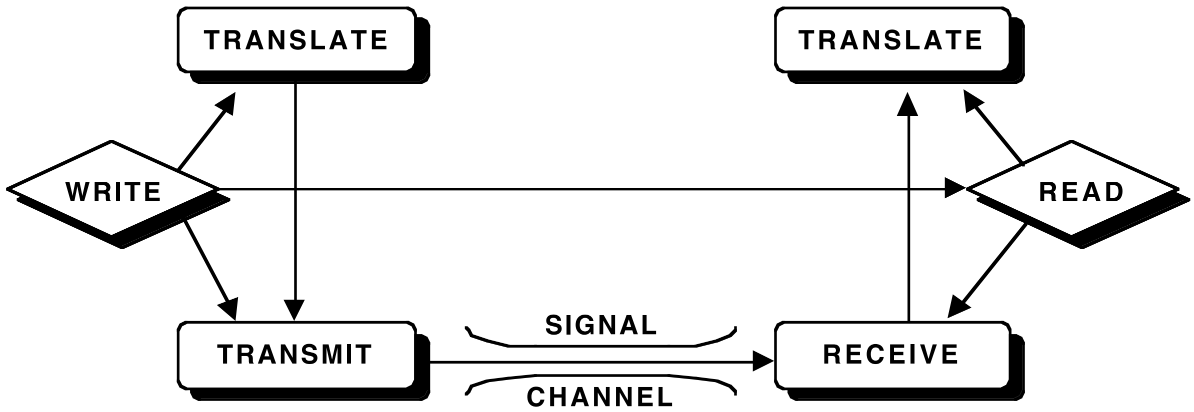


Figure 9-6 - A Communication Channel Defined.

The *signal* channel is considered to involve only the transmitting and receiving *hardware* the communication channel includes the language processes Read, Write, and Translate (including encoding). Analysis of communications extends to questions of understanding between Writer and Reader.

The signal channel may of course be a net rather than a single channel, but the communication channel is always two-party, a Reader and a Writer.

Signal can add nothing to the information flow; it can only detract by time delay (Δt_X) or the introduction of error, bias, or distortion. The extent to which information is transmitted and received correctly can be represented as an efficiency η_X which directly affects command efficiency.

2.1.7 Effect of Information-Handling Functions

In execution of any proposed study, the attempt will be to define and evaluate the following performance variables:

η_D The extent to which command chooses the optimum course of action.

Δt_D Command reaction time.

η_I The extent to which intelligence files contain complete and correct information of the enemy.

Δt_I Lag time in update of intelligence files.

η_X Accuracy of signal transmission.

Δt_X Signal transmission time.

It is considered that relative combat potential and therefore the outcome of battle is affected in a very major way by the quality (η_D) of the orders issued and by the lag-time ($\Delta t_I + \Delta t_D + \Delta t_X$) between the existence of a situation and formulation and issuance of a decision as to what is to be done about it.

η_I determines the extent to which the commander has a correct picture of enemy capabilities and therefore limits his achievable η_D

η_X further limits η_D to the extent that error, bias or distortion is introduced in the communication/signal channels transmitting intelligence, directive information, or status (friendly situation and capabilities) information.

Effectiveness in Information-handling functions (Command, Intelligence, and Signal) probably determines the outcome of combat to a much greater extent than firepower, mobility, or the other hardware-dependent functions. There is no doubt that it is important to introduce these functions into a theater-level model; there is much room for discussion as to *how* and *how much*.

To illustrate:

Commanders perform three major function:

- Leadership - training and motivating the command
- Generalship - out-thinking and out-witting the opponent (or vice-versa)
- Decision - allocating resources, assigning objectives, establishing necessary controls

Conceptually, each of these functions can be modeled and quantified. In each case (perhaps more so for Leadership and Generalship) it will be quite difficult to establish appropriate input and assessment data (see Paragraph 2.2.3, below). It probably will be best to concentrate effort on the Decision aspect of Command as most tractable and relevant to the immediate objective of the study.

Another decision should be the extent to which a Theater Combat Model will model Communication (language-connected) as opposed to Signal. The Read-Write aspects of Communication, as opposed to the Transmit-Receive aspects of Signal, would bring semantics into the analysis. Semantics are very important - misunderstood orders have cause several military debacles - but it may be unwise to design misunderstood orders into a Theater Combat Model.

It is felt that decisions of the type described above bear more on the purpose and use of a Theater Combat Model than they do on the detailed construction thereof.

2.2.3 Acquisition of Input/Assessment Data

The data which must be acquired falls into three classes:

a) Performance variables of hardware/software systems.

b) Performance data for human elements/units.

c) Assessment factors/algorithms to interrelate functional performance and combat results.

These are discussed in turn.

2.2.3.1 Performance Variables of Hardware/Software Systems

For example, under the class Sensor we must eventually have data as to the specific performance of these equipments eventually to be introduced into the model - be the Sensor an eyeball, a radar, a camera, or a *sniffer*.

The following work should be accomplished:

a) Specification of the Classes and Species of hardware for which input data are needed (this effort guided by results of the first two areas of work discussed above). The Classes and an example of Species are as follow:

CLASSES:

1) Command Elements (e.g., TACFIRE)
2) Intelligence Processor (e.g., Photo-interpretation Equipment)
3) Sensors (e.g., SIGINT, ELINT equipment)
4) Agents
5) Signal Channels

Example:

Class: Sensors

Species:
Camera
Radar
Infrared
Sniffers
Low-Light Level Television
Enemy Counter Measure (ECM) Equipment
etc.

b) Specification of the quantifiable performance variables required as input for modeling of each Species. E.g., Radar -peak power, p.r.f., scan rate, resolution, etc.

c) Identification for each Species of a principal source from which this data can be obtained and liaison with this source to ensure it is available in the form specified (e.g., Military Electronics Commands for Radars).

d) Algorithms/models for translation of this performance data into Capability and Potential. E.g., for the radar we must derive or obtain from a qualified source the probability that *IF* placed in surveillance over a suspect area, it will detect some specified enemy element (as a function of range, element motion, clutter, countermeasures, etc.).

2.2.3.2 Performance Data for Human Elements/Systems:

In the Information-Handling functions people are at the same time a drawback and an indispensable asset. People are error-prone, fatigue-prone, and of non-uniform skill and motivation. Machines are faster and practically error-free, but (at least so far) incapable of the imagination required to postulate varying courses of action, to draw all appropriate inferences from intelligence indicators, or to ensure complete mutual understanding in a communications process.

It will probably be non-pertinent to reflect varying human performance in a Theater Combat Model (though modules which permit this may enable addressing some rather interesting questions) but it is important to understand how human limitations affect Combat Potential. No combat system ever realizes its full capability in battle, in part because of the situational efficiency (η), but even more so because of the Pace of the Battle (τ). The latter is attributable entirely to delays and errors in the information-handling functions, and these are attributable to human performance.

If a Theater Combat Model is to reflect *reality*, an operator (τ) must be introduced. It may be that this will remain an undifferentiated factor drawn from historical data (see Paragraph 2.2.3.3), but some effort should be devoted to attempting to isolate its constituents.

Specifically, data will be needed on the performance of humans, singly or in groups, and with varying levels (including none) of information-processing equipment, in the following processes:

a) Planning (postulation of opposing courses of action)

b) Estimation

c) Decision

d) Editing (Routing and File-keeping)

e) Inference

f) Assumption

g) Communication (ensuring understanding)

h) Status Reporting

2.2.3.3 Assessment Factors/Algorithms

It is clear that the utility of all work described herein will be ultimately measured by the ability to relate Information-Handling performance to combat outcome. Combat modeling is based upon an assumption that there is some functional connection between the relative strengths (however measured) of two adversaries and their respective success in attaining opposed objectives. As implemented in combat models, this assumption usually takes the form of curves interrelating rates of progress, rates of attrition, and relative strength.

Existing curves are certainly suspect; they tend to be drawn from World War II and Korean experience updated to reflect new technology, but updated by methods which are not well-documented. Thus, there would be a real utility in an update of this umpiring information, and in some deductions as to the influence of factors other than strength ratios or firepower scores (e.g., the degree to which advancing technology may have changed combat rates of movement and attrition). For this study, of course, what is needed is dependence of combat outcome on relative effectiveness of the opponents in Information-Handling functions. It is difficult to see how this can be extracted without reviewing all available data on this *umpiring* question.

Three general approaches to this area of research suggest themselves:

- Contact with the military Training Literature Branches to determine the source and quality of existing Field Manual data on movement and casualties.

- A polling of qualified military opinion.

- Historical research.

Historical research could be accomplished in the following steps:

- Contact Office of Military History, HQ U.S. Army to determine availability of relevant previously-collected data.

- Go into archives starting with the U.S. Army Library with the intent of collecting data on 100 to 200 historical conflicts. To the extent possible these will be similar, i.e. drawn from World War II and extended as necessary to conflicts similar in theater, and nature of opposing forces.

- Evaluate apparent Combat Potential of each side (basically strength, but modified by Productivity and Efficiency Factors (μ and η) where indicated.

- Plot the historical points as curves exhibiting movement and attrition as a function of Combat Potential.

- Employ mathematical correlation techniques to reduce the scatter (based on postulated functional dependence on variables other than relative strength). N.B. It is expected that the major difficulty will be to eliminate human performance *scatter* ; battles tend to be won by those who are most skillful and most highly motivated.[6]

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[6] Or, as one wag put it, "The winner is the one who made the next-to-the-last mistake!"

2.2.3.4 Priority in Research Program

The Importance of the three research efforts may be in inverse order of feasibility; priority should be assigned in the order: 1) Assessment factors, 2) Human performance data, and 3) Hardware performance data.

The following items should be investigated, as a minimum:

- *Assessment Factors:* Report on historical research effort, with assessment of feasibility and desirability of continuation.
- *Human Performance Data:* Report on availability of data, identification of sources, and digest of data collected.
- *Hardware Performance Data:* As described in Paragraph 2.2.3.1.

2.2.4 High-Resolution Models

High-resolution models applicable to any study fall into three general classes:

- Detailed models of the performance of specific or generic hardware systems.
- Models of combat interaction at levels lower than theater.
- Detailed models of the performance of human information-processing systems (with varying levels of machine assistance) - such as a headquarters, a signal net, or a G-2 (intelligence) section.

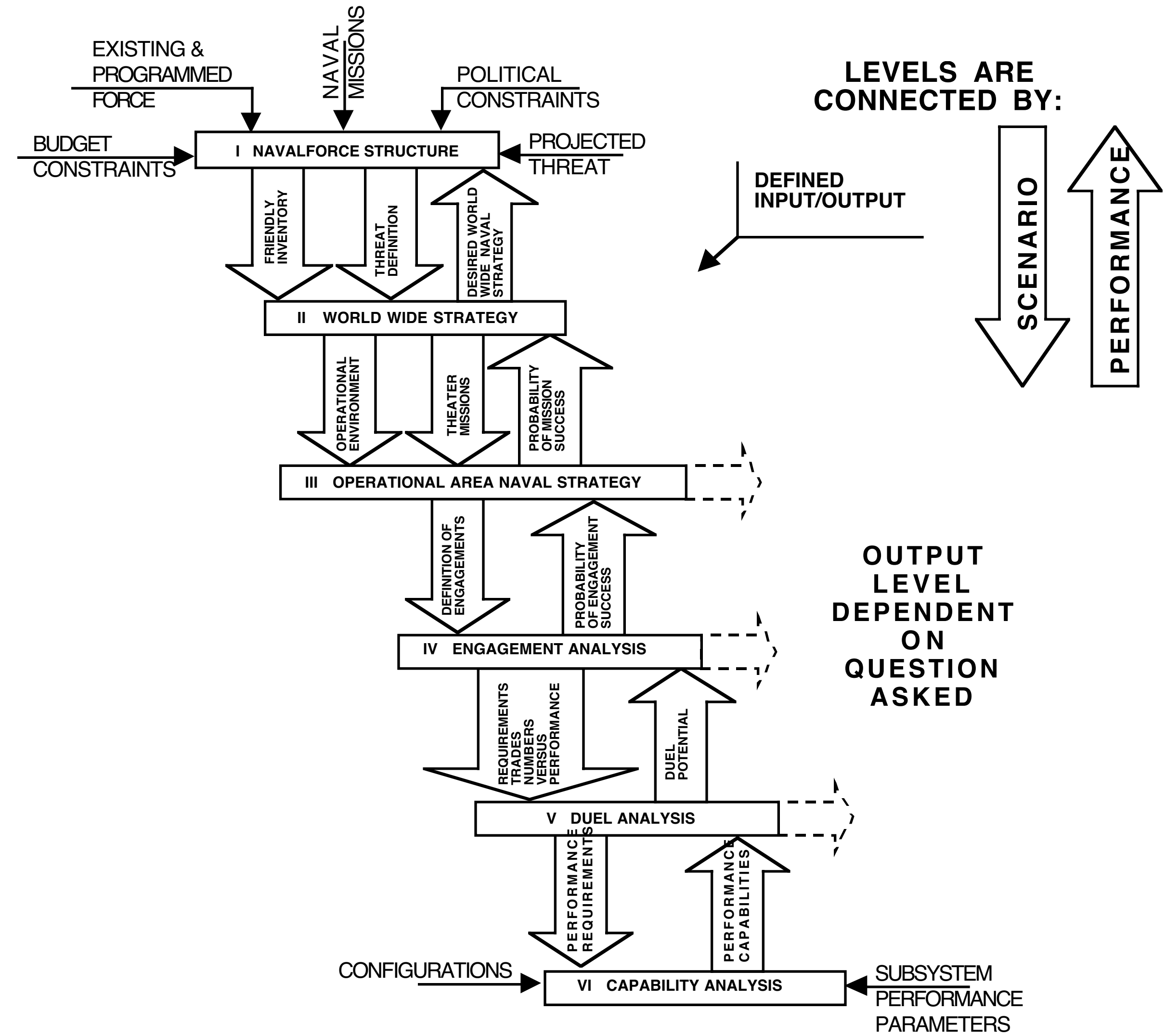

Figure 9-7 - Six Levels of Analysis.

In general a theater model should interact *scenario* information derived from Level II assumptions and analyses with performance information derived from Level IV models. If possible the Level IV results should be derived by operation of a separate model to produce input in a form acceptable by the theater model, as opposed to dynamic interface with the theater model. This will conserve machine capacity and time for detailed modeling of the theater-level processes. It is manifestly impossible to simultaneously play all levels down to squad (Level V); a cutoff must exist somewhere, and it may as well be at the first lower interface; however, this point of model structuring philosophy is certainly subject to further investigation.

The following models seem most likely to be needed:

- Headquarters Operations (Command Element)
- Command Net
- Intelligence Processor (e.g., G-2 section)
- Combat Intelligence Network
- Signal Net

The construction of any of these models must be contingent on results of the search for human element performance input. Although all the models will have definite utility as a research tool, priority should be given to those for which input drawn from experience data can eventually be provided.

The models will be constructed to enable analysis of specific questions; a list of such questions should be formulated as a first step and will guide both the construction of the model and the search for input data.

As an example, the following is a brief (and tentative) discussion of the probable shape of a Headquarters Operation Model.

The headquarters is to be presented as a system of sub-components, each consisting of one or more human beings, more or less machine-assisted, and performing (in some cases jointly) one or more of the processes shown in Figure 9-3. A minimum list might be:

- Command Group - Decision (and general supervision)
- AG (Adjutant Gen.) - Editing (Routing and Filing)
- G3 (Operations) - Planning (Postulation of Blue Courses of Action)
  - Estimation (of relative Combat Potential)
  - Communication (Issuance of Orders and receipt and interpretation of Requests)

- G2 (Intelligence) [7] - Planning (Postulation of Red Courses of Action)
  - Editing (with respect to Red and Terrain/Weather files [8])

It may be desirable to include G-4 and some members of Special Staff. They must, of course, prepare ancillary plans and orders for the support function.

The purpose of the model would be to determine how the performance variables of Command depend on the strength, organization, procedures, and machine-related Productivity (μ) of the headquarters organization. It is believed that these performance variables should be Δt_D - characteristic reaction time - and η_D - quality of decisions.

Among the questions which might be studied with the aid of such a model are:

1) What is the relationship between time required for decision (Δt_D) and η_D? (I.e., to what extent can expenditure of time improve the quality of the decision?)

2) How can file structuring and editing of incoming information expedite and improve the command process?

3) How will a machine-aided Tactical Operations System (TOS) improve command performance?

2.3 IMPLEMENTATION

Such work will implement the methodology and algorithms as computer subroutines and will develop the necessary interfaces to provide a complete Theater Combat Model, sensitive to the information-handling functions of Command, Intelligence and Signal.

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7 The G-2 also functions as a resident Intelligence Processor, but this aspect of G-2 duties should probably be studied in a separate model.

8 The word *files* is used to connote an organized mass of data, continually updated. It includes, for instance the current situation map.

In summary, the following tasks should be performed:

1) Derivation of Macro-Logic

2) Implementation of Information-Handling Methodology

3) Theater Combat Model Modification

4) Integration and Checkout

2.3.1 Derivation of Macro-Logic

A macro-flow logic diagram of the model should be prepared. Based on derived methodology, the macro-logic diagram will include operation of the information-handling functions and compatible with the Theory of Combat. The software design will be based on the macro-logic by determining those parameters required as input at each of the macro-module interfaces.

Interface parameters are those which directly interact with existing algorithms in the model. The form of these parameters may be vector-valued parameters. Thus, these parameters will introduce the functions of Intelligence, Command and Signal to the Theater Combat Model. The values assigned to the interface parameters will be determined by the macro-modules.

2.3.2 Implementation of Information-Handling Function Methodology

With the definition of the required interface parameters the procedural algorithms can be developed. These algorithms will model the defined information-handling functions.

The design and interplay of the algorithms will assure sensitivity to the activities of information processing. For clarity of understanding, it is possible to trace through the model structure the effects of changes in input of various kinds.

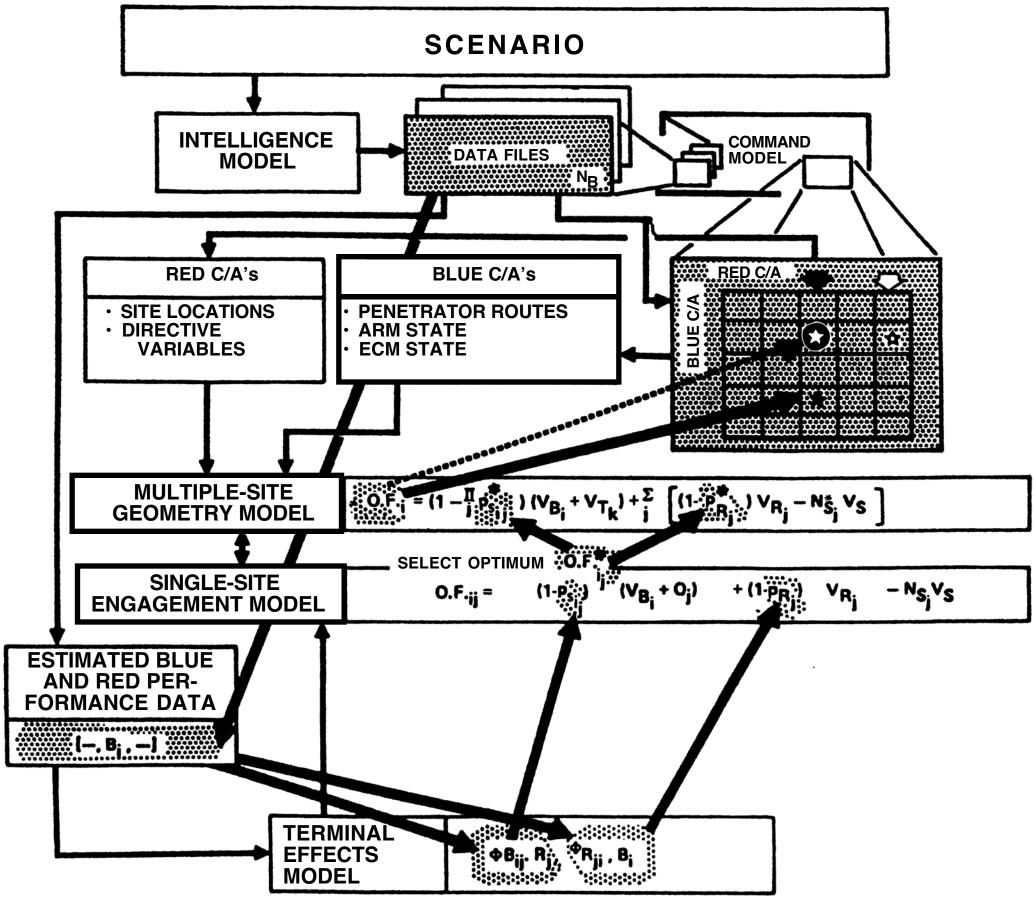

Figure 9-8 - Audit Chart Indicates Effect of Faulty Red Intelligence.

As an example, Figure 9-8, a simple *Audit Diagram*, illustrates this process for just one variable - the effect of faulty Red Intelligence processing on penetration of Red's air defense. Each of the individual boxes represents a macro-module and the interplay between the overall Objective Function (O.F.), the Intelligence Data Files, and the Command process is indicated by the lighter horizontal and vertical flow lines.

Now suppose the Command model is used to represent the Red planning process. One piece of intelligence of great importance to Red is N_B - the Blue Order of Battle - which establishes the number and strength of penetration attempts which Blue can make in any short period. In protecting his defense sites and prime targets (that are being defended), Red should initially be somewhat sparing of ammunition - issuing directive variables which cause individual sites to concentrate on self-protection and protection of assets, rather than pure attrition of Blue aircraft. However, once Red sees all Blue aircraft committed, these directive variables can be changed, by lowering the value of conserving defensive missile (V_S) for at least some unthreatened sites, to enable them to engage aircraft in the attrition mode of operations and thereby raise Red's Objective Function expectation.

For each pair (Blue/Red) of courses of action, duels are established which may take place between aircraft and individual defense sites. included in input information is the set $\left(\cdots, B_i ,\cdots\right)$ of Blue aircraft penetrating the site's defensive area. This number affects both the risk to individual Blue aircraft (Φ_{B_i,R_j}) and the risk to the site (Φ_{R_j,B_i}). These numbers in turn affect the probability of the i^{th} Blue aircraft survival against the j^{th} Red defense site ($p_{S_{i,j}}$) and the probability of kill of the j^{th} Red defense site (p_{R_j}). These terms appear in the defense site's computation of Objective Function, and thus establish the site's rules of engagement, which are determined by a maximin solution of the site's Objective Function.

In the block designated Multiple Site Geometry Model in Figure 9-8, adjustments to the directive variables issued to the various sites maximize the area-wide Objective Function, resulting in an area strategy for the defense.

Now suppose Red has incorrect information on the number of Blue aircraft (N_B) - he believes it to be lower than it actually is. Red is then unable to postulate some of the possible Blue courses of action - let a critical one of these be represented by the second row in the decision matrix of Figure 9-8. When the Command function examines the various alternatives without this row it selects a maximin value of the Objective Function represented by (solid black star) in the matrix; the selected Red course of action is marked by the arrow (solid black arrow).

The Objective function value attained by Red against the unforecast Blue course of action is denoted by (star in circle), a figure less than (solid black star). The difference (solid black star - star in circle) is not attributable to faulty intelligence, however, but merely to Blue capability. The proper Intelligence would have led Red to a different course of action marked by the arrow (white arrow). In this case, Red has lost (white star - star in circle) due to the faulty Intelligence.

It is expected that the macro-flow will exhibit a hierarchical structure (see Figure 9-7) so that several levels of combat can be simultaneously represented. Realizing that horizontal as well as vertical aggregation among modules is required for realism, "two-way" aggregation will be employed.

Since horizontal functional dependence is a difficult problem, the extent of horizontal interplay should be limited to the minimum amount necessary to achieve the expected sensitivity to the information-handling activities.

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