**STUDY PROJECT**

# MODELING COMBAT FATIGUE IN THE JOINT THEATER LEVEL SIMULATION MODEL

BY

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USAWC MILITARY STUDIES PROGRAM PAPER



# MODELING COMBAT FATIGUE IN

# THE JOINT THEATER LEVEL SIMULATION MODEL

AN INDIVIDUAL STUDY PROJECT

by

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## ABSTRACT

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# MODELING COMBAT FATIGUE IN THE JOINT THEATER LEVEL SIMULATION MODEL

## CHAPTER I

## INTRODUCTION

> Friction is the only concept that more or less corresponds to the factors that distinguish real war from war on paper. The military machine — the army and everything related to it -- is basically very simple and therefore seems easy to manage. But we should bear in mind that none of its components is of one piece: each part is composed of individuals, every one of whom retains his own potential of friction.[1]

Human participation and influence dominate combat, but the effects of human factors or performance are frequently neglected in the Army's combat models. The need for better representation of the human dimension of combat in our combat simulation models has been recognized for many years, but the current suite of combat models continues to represent equipment capabilities much better than human aspects. This chapter introduces the subject of modeling soldier performance in combat simulation models. It describes this study's background, purpose, and scope. Combat stress, battle fatigue, and combat fatigue are also described.

### Background

In 1986, a workshop sponsored by the Military Operations Research Society (MORS) was held to seek "More Operational Realism in Modeling of Combat (MORIMOC)." Every subgroup at that workshop identified human factors as one of the most serious problems in modeling today. This included the lack of attention to modeling human factors and the lack of data to support this modeling area. The human side of combat is all too often neglected in our models. For example, weapon systems modeling often reflects equipment capabilities and does not consider the limitations imposed on the equipment by the crew that operates it. Units are sometimes able to remain in combat for weeks without relief, or they are attrited to low levels without breaking.

This project is an extension of the work that is currently under way within the Army modeling community. Ms. Sally Van Nostrand of the U.S. Army Concepts Analysis Agency has written two reports on this subject. The first report, "Model Effectiveness As a Function of Personnel [ME = f(PER)]," identified areas in which modeling of battlefield processes could and should be modified to include the effects of human factors and human performance.[2] The second report, a research project for the Industrial College of the Armed Forces titled "Including the Soldier In Combat Models" described a classification system by which soldier factors could be grouped and incorporated into combat models. This report also developed estimates on how much sleep soldiers would get during combat.[3]

In February 1989, a second MORIMOC mini-symposium was conducted with the purpose of establishing an information base in order to define the present status of modeling human performance and behavior and their effects on the conduct and outcome of combat. This workshop included 34 presentations concerning various aspects of modeling human actions. The presentations ranged from discussions of taxonomy, data base developments, human factors research and modeling, to applications of combat and other simulations.

## Purpose and Scope

There are many aspects of combat which are heavily influenced by human performance. Defeat criteria (breakpoint); command, control, communications, and intelligence ($C^3I$); suppression, and movement are just four such examples.

The purpose of this study is to outline a procedure for incorporating the effects of combat fatigue in the ground combat portion of the Joint Theater Level Simulation (JTLS) model. This report also addresses the requirements for, and availability of, data to implement this concept in JTLS. It also assesses how this approach could be applied to other combat functions in JTLS, to other combat simulation models, and to other soldier performance factors.

The objective of this analysis is to incorporate into JTLS some, but not all, of the factors that are associated with combat fatigue. In particular, this analysis attempts to capture the main parameters that affect the "physical" aspects of combat fatigue: sleep loss, type of operation, battle intensity, and time in combat. On the other hand, this analysis does not address "individual" factors such as a soldier's personal situation, belief in the cause, combat experience, or isolation. Also, it does not include "morale" factors such as unit cohesion, training proficiency, leadership, or confidence. This does not imply that these factors are unimportant. Rather, these factors represent areas that are highly subjective or lack sufficient data. Finally, this report does not address the influence of "environmental" effects (terrain and weather) as it impacts on soldier performance.

## Combat Fatigue

Battle fatigue is a subset of combat stress. Field Manual 26-2, "Management of Stress in Army Operations," defines combat stress and battle fatigue.

> Combat stress is the sum of all internal stress reactions to the conditions on the AirLand Battlefield and all stressors that result in reduced soldier performance. The term combat stress reaction covers all types of reactions to the stresses related to combat. Combat stress reac-

tions are observable behaviors which soldiers show as a result of internal stress.

Battle fatigue is the broad "umbrella" label for the physical, mental and emotional signs that result naturally from the heavy mental and emotional work involved in facing danger and/or performing demanding missions under difficult conditions.[4]

Combat stress causes battle fatigue. Battle fatigue covers a broad range of symptoms. These symptoms range from normal but uncomfortable emotions and physical complaints that do not impair performance, through symptoms which slightly interfere with performance, to reactions which make soldiers dysfunctional.

Battle fatigue is a negative combat stress reaction. The evidence of battle fatigue may show up as reduced alertness, attention, perception, reasoning, comprehension, and motor responses as well as memory loss, and difficulty with oral and written communication, self-control, and interpersonal relations.[5]

FM 26-2 provides some insight on the strong relationship between battle intensity and stress casualties. In World War II and Korea, there was an average of one battle fatigue casualty to every four or five wounded in action. In an extremely intense battle, the ratio commonly reached one to three. In desperate situations, battle fatigue casualties have reached one to one ratios.[6]

Similar results also apply to other armies. For example, the overall battlefield stress rate for the U.S. was 23 percent when expressed as a percentage of wounded in action. The percentage for the Israelis in the 1973 Arab-Israeli War was 30 percent. In the Lebanon crisis in 1982, the Israeli rate was also 23 percent.[7]

The definition of battle fatigue used by FM 26-2 is very broad. To narrow this definition, this study uses the term "combat fatigue" to mean the combined effects of psychological and physical stressors that affect soldiers when they are engaged in combat, or are performing under combat conditions.* This research concentrates on the effects of combat fatigue -- the degradations to unit operational effectiveness as they relate to battle intensity and combat duration. As indicated in this study's scope, this analysis attempts to capture the stress vulnerabilities that result from sleep loss, type of operation, battle intensity, and time in combat. The term "combat fatigue" excludes the performance degradations associated with individual factors such as new combatants, age, education, fear, etc. It also excludes morale factors such as unit cohesion, leadership, and training.

*This is essentially the same definition of combat fatigue used by the ME=f(PER) study.

## ENDNOTES

1. Carl von Clausewitz, On War, translated by Michael Howard and Peter Paret, p. 119.

2. Sally Van Nostrand, Model Effectiveness as a Function of Personnel, [ME=f(PER)], September, 1986 (hereafter referred to a "ME=f(PER)".

3. Sally Van Nostrand, Including the Soldier in Combat Models, 1988.

4. U.S. Department of the Army, Field Manual 26-2, p. 4 (hereafter referred to as "FM 26-2").

5. Ibid., p. 5.

6. Ibid., p. 19.

7. Dale B. Flora, Battlefield Stress: Causes, Cures, and Countermeasures, p. 30.

## CHAPTER II

## JOINT THEATER LEVEL SIMULATION (JTLS) MODEL

This chapter provides an overview of the JTLS model. Additional information on JTLS is provided in the Appendix to this report. This chapter also describes in further detail the ground combat and logistics activities in JTLS. This background is essential for understanding the rationale behind the approach for incorporating combat fatigue in JTLS. This concept, approach, and method will be described in Chapter III.

### JTLS Model Overview

JTLS development began in 1982 as a result of a demonstration of an enhanced McClintic Theater Model. This initial development was sponsored by U.S. Readiness Command, the U.S. Army War College, and the U.S. Army Concepts Analysis Agency. Jet Propulsion Laboratory was the original system development contractor. Management configuration control was later transferred to the Office of the Joint Chiefs of Staff (J-8) under the terms of the Modern Aids to Planning Program (MAPP). The current JTLS baseline (version 1.65) was released in September 1988 by the system contractor, SYSCON Corporation.*

JTLS is an interactive, computer-assisted war simulation. Its primary purpose is to provide unified and specified commands a war plan analysis tool. This theater-level model is designed for use in analysis, development, and evaluation of contingency plans and joint tactics; in evaluation of alternative military strategies; and in analysis of combat systems. It simulates the

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*This overview of JTLS was developed by synthesis of the JTLS documentation published by the Office of the Joint Chiefs of Staff. This documentation consists of 13 volumes. The main volume used in this research is the JTLS Analyst Guide, version 1.65, September 1988.

interaction of five functions -- ground, air, naval, logistics, and intelligence activities -- in a strategic, two-sided, player-interactive, event-driven wargame. Players provide the command and control function to the model via assigning missions or issuing orders.

JTLS is designed with "open architecture." It is completely database dependent. That is, no numbers or data are embedded in the source code. JTLS was originally envisioned to model roughly 300 individual units, 20 combat systems, 1,000 targets, and a terrain area of 1,000 by 1,000 nautical miles. The model also tracks individual aircraft and naval platforms. Developing a database for JTLS may require nine or more months.

JTLS is designed to play brigade/regiment-sized units or higher, but it is dependent on the size of the hexagonal terrain grid selected. A hex size of 14-17 km (face to face) is recommended for brigade-size resolution. (Separate battalions are sometimes identified to round out the force structure.) The attributes of each hex can be divided into two categories: attributes inside the hex (such as terrain) and attributes on each of the six edges of the hex (such as barriers).

Through its various model components, the design of JTLS allows for control of the model; interface to input weapon system capability, scenario, and other data; and interface between players and the model. The model has two basic modules or programs. The first basic module is the Model Interface Program (MIP) -- the "brain" of the model. The MIP provides the means by which players interact with the second basic module, the Combat Events Program (CEP). Players use the MIP to issue directives to create missions and to issue queries to obtain specific reports. The CEP is the "heart" of the model. The CEP simulates the execution of ground, naval, air, logistics, and intelligence activities.

JTLS is a discrete-event simulation. That is, the model updates the game clock to the next event after it has performed the actions required of the current event. The model can also synchronize game time to real time or slower when necessary (to allow for player interactions). There are three types of events of primary concern in the ground combat function — a player-initiated event, a ASSESS COMBAT event, and a ADJUST SUPPLIES event. A player-initiated event is the method by which the player interacts (schedules events) in JTLS. For example, a Red player orders a unit to attack at 0530 hours, or a Blue player assigns a delay mission to a unit at 1432 hours. An ASSESS COMBAT event is a model-controlled (not player-initiated) event used to compute ground combat between units in contact and to update the status of every unit. The model initiates this event, nominally, once every game hour. Similarly, the model uses the ADJUST SUPPLIES event to perform logistics functions such as replacing personnel and weapon systems in every unit. This event is nominally initiated once every 24 game hours.

## JTLS Ground Combat and Logistics

Due to the close interrelationship between functional activities in JTLS, this section includes a description of ground combat, ground combat attrition, and logistics.

### Ground Combat

Ground combat in JTLS performs the following activities: (1) management of combat unit missions and postures, (2) unit movements, (3) distribution of combat power, (4) fire and maneuver, (5) attrition, (6) nuclear and chemical effects, (7) consumption, (8) mine effects, and (8) combat engineer functions.

Maneuver units in the order of battle are ground units. Wargame players assign missions to these units via orders. Orders can be to move, attack, defend, delay, withdraw, fire, mine, or engineer. A ground unit has both a mission and a posture. Mission describes what wargame players want the unit to do whereas posture describes what the unit is actually doing. There are ten postures that relate to ground combat: moving, attacking, defending, defending (hasty), delaying, withdrawing, incapable, wiped out, air operations, and amphibious operations.* A unit's posture depends on wargame play. A unit's posture affects its movement, attrition, and supply consumption.

In ground combat, players control three basic assets -- units, combat systems, and supplies. JTLS recognizes seven ground unit subtypes: infantry, armor, mechanized, cavalry, light artillery, heavy artillery, and engineer. Each unit is characterized by its attributes -- its capabilities or constraints (e.g., combat systems they possess and the supplies they consume). For example, an infantry division may possess combat systems such as combat personnel, tanks, 155-mm artillery, 4.2 mortars, support personnel, other end items, and command, control, and communications.

Units can maintain tactical postures (attack, defend, delay, withdraw) only if they are at or above a specified combat strength called UT WEIGHTED STRENGTH, or sometimes referred to as "fractional strength." This combat strength is defined as a ratio -- ranging between zero and one -- of a unit's current weighted strength to its authorized strength called UT FULL UP

*Air and amphibious operations are addressed as air and naval activities in JTLS, respectively. Therefore, the remaining eight postures are considered to be ground combat postures in this analysis.

STRENGTH. In JTLS, this combat strength (UT WEIGHTED STRENGTH) is checked against specific thresholds (e.g., attack to defend, defend to delay, delay to withdraw, breakpoint, and wiped out) to determine if the unit can maintain or assume a specific posture.

Ground Combat Attrition

JTLS uses two schemes for attrition in ground combat. The first scheme is a deterministic, mixed, heterogeneous, time-stepped Lanchester model. It is used to simulate direct fire and organic indirect fire between units in combat. A database of coefficients is used as input to the Lanchester equations. The coefficient database considers such factors as day/night, weather, side, attritor posture, and attritee posture. Hence, there are many possible combinations that influence the selection of individual coefficients from the database for each engagement. The second attrition scheme is a discrete probability-of-kill (pK) mechanism. This method is used to simulate the effects of explicit artillery fires, air defense artillery effects, ground damage from air attack, and attrition to convoys by ground units.

Logistics

The JTLS logistics function includes initial issue, consumption, and resupply; the requisition and adjust supplies processes; Class VII replacements; and maintenance and return to duty processes.

JTLS treats personnel as a special supply category (for issuing replacement personnel). The model issues personnel when they are available and the unit is understrength. The number of personnel to be issued cannot exceed the number authorized for the unit. The ADJUST SUPPLIES event also manages the evacuation and return-to-duty procedures. Medical support uses the same procedures of Class VII maintenance algorithms.

# CHAPTER III

# INCORPORATING COMBAT FATIGUE IN JTLS

This chapter turns to the aspects of modeling combat fatigue. First, it describes some general considerations that should be acknowledged when incorporating human performance in combat simulation models. Second, it describes a method of classifying soldier performance in combat models and indicates how this taxonomy influences the JTLS modeling approach. Finally, this chapter describes a concept, assumptions, approach, and methodology for incorporating combat fatigue in JTLS.

## Modeling Considerations

While human performance is an important element of combat, the value of incorporating all elements of soldier actions in combat simulations must be weighed against a model's purpose, scope, and resolution. For example, if a model simulates one-on-one duels, it may be important to model as many aspects of human performance as possible. These may include such traits as visual acuity, intelligence, education, or level of training. As one moves up the Army's hierarchy to models which simulate few-on-few interactions, these individual traits are still important, but they may not be as relevant as in the case of a high-resolution model. The focus usually shifts from individual or equipment performance to crew and weapons effectiveness.

As one moves further up the hierarchy to models which simulate many-on-many interactions (such as in JTLS), the necessity to model many of these individual traits becomes even less important. The focus at this level is usually on force-on-force attrition and movement. Some may argue that if low-resolution models use results (in the form of input data) from higher-resolution models which incorporated human interactions, it may be unnecessary to include any additional human factors. If this is not the case, then human performance factors should be incorporated by other means. Hence, it is important to know and understand the source of data used in a model.

Finally, one may argue that it may not be important to model the human dimension of combat in a two-sided model because, like weather, it affects both sides. This is not a valid argument. The effects of human performance can be asymmetric. Qualities such as education, national characteristics, or belief in the cause can favor one side over the other. Training and doctrine may also have an important influence. For example, the Red side's doctrine may indicate that it intends to commit units in the attack for 48 hours. By that time, it expects those units to be exhausted and replaced by units from a follow-on echelon. The Blue side may not follow such doctrine. Instead it may intend to keep units committed to the point of exhaustion. Blue may rely on leadership of individual commanders to enforce unit rest periods or unit rotations to get rest. Replacement of exhausted units will be handled on a case-by-case basis. The effects of these two contrasting doctrines can be significant on overall combat results.

## Taxonomy for Soldier Actions

In 1988, Ms. Sally Van Nostrand described four major categories for soldier factors that should be included in combat models. These categories also may have different modeling requirements or techniques.[1]

The first category is Maximum System Capability. This category includes soldier factors which affect equipment capabilities. All too often, equipment specifications, such as maximum effective range and hit probabilities, are used in combat models. This implies that soldiers are "perfect" when the influence of human performance is not included. For example, all targets are not engaged at distances of maximum effective range. Indeed, results from the National Training Center indicate that this is often not the case. Also, there may be other circumstances which influence equipment capabilities. The soldier may not want to reveal his position by firing too soon, or he has difficulty identifying the target as friend or foe. Data should reflect the limitations of soldier performance -- not merely maximum capabilities of equipment. This category of soldier factors can be implemented in combat models usually by adjusting input data to reflect the nominal performance of combat systems -- including soldier influences -- rather than maximum equipment capabilities.

The next category is called Static Soldier Quality. It includes soldier factors that do not appreciably change during combat. The factors that are included in this category depend on the resolution of the model and the time span that it simulates. Education and training levels and national characteristics are examples of factors that fall in this category. Since these factors do not appreciably change during the conflict, they do not normally require explicit representation in the model. Instead, these considerations may be included via preprocessing or including an additional factor to influence the appropriate interactions.

The next category is called Dynamic Soldier State. This category includes soldier performance factors that vary over time. The category covers factors such as leadership, morale, cohesion, combat experience, weather, terrain, intensity of preceding battles, sleep loss, physical fatigue, fear, etc. To incorporate these soldier factors could require model changes. Van

Nostrand defines these changes as "pergorithms," personnel performance algorithms. The reason for the slow progress in modeling these influences is attributed to the difficulties in obtaining a consensus on the need for specific model changes and the lack of data to support such improvements.

The fourth category is called Event Timing. This category acknowledges the fact that soldiers cannot fight (or perform other tasks) continuously over extended periods. Therefore, equipment and units cannot be totally effective 24 hours a day. This category can be incorporated by modifying soldier/-equipment/unit availabilities. Van Nostrand states that this category can be easily modeled by removing an appropriate number of soldiers and equipment. Alternatively, it could be modeled by factoring model results.

## Modeling Concept and Approach

The objective of this research is to incorporate the effects of combat fatigue in JTLS. This goal must be balanced against considerations for the model's purpose, design, data availability, and resources. The modeling concept and approach uses Van Nostrand's taxonomy. This analysis concentrates on methods to incorporate soldier performance that changes during combat (the Dynamic Soldier State) and that modifies the soldier availability for combat (Event Timing).

### Concept

The modeling concept underlying this initiative is to affect unit performance -- to degrade unit operational effectiveness. A unit that is fresh and at full strength represents its maximum unit capability. Combat fatigue degrades this overall capability. The rate of degradation is a function of what type of unit it is, what tactical posture it is in, and the battle intensity it has undergone. The rate of combat fatigue (unit degradation/improvement) also implies time variation. While combat weary soldiers degrade unit effectiveness, replacements or unit rest periods can improve overall operational effectiveness.

For example, Figure 1 describes an armor unit that, initially, is not in contact with the enemy and moving for 12 hours; then attacking for 12 hours and withdrawing for 18 more hours while in contact; and finally defending for 12 hours while not in contact. The top curve (no combat fatigue) describes this unit's operational effectiveness without consideration for combat fatigue. The unit suffers casualties and equipment losses while in contact,

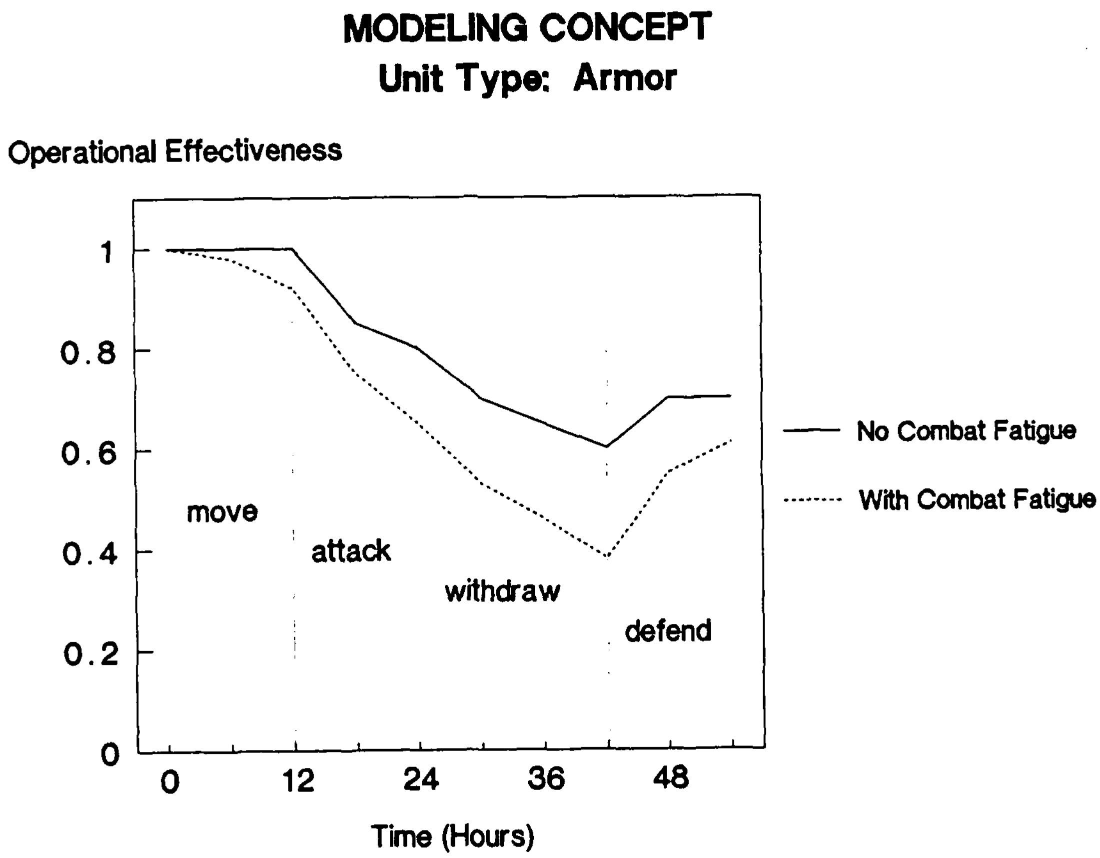


Figure 1

and its effectiveness is therefore reduced. On the other hand, operational effectiveness is improved by the arrival of replacement personnel beginning at the 42nd hour.

In contrast, the bottom curve (with combat fatigue) in Figure 1 describes, conceptually, the additional influence when combat fatigue is incorporated. Combat fatigue degrades operational effectiveness even when a unit in not in contact. In this conceptual example, this armor unit's operational effectiveness is degraded about 8 percent after moving while not in contact for 12 hours. Operational effectiveness is degraded at a greater rate when a unit is in contact. On the other hand, effectiveness can improve when soldiers have an opportunity to rest -- and by virtue of fresh personnel arriving in the unit.

Assumptions

Combat fatigue affects individual soldiers and their subsequent capability to conduct combat operations. Therefore, the model must incorporate the dynamics of soldier characteristics to some appropriate level of detail. It follows that the combat fatigue these individual soldiers undergo also impacts their unit's operational effectiveness. This analysis assumes that the combat fatigue an individual soldier suffers contributes to the overall degradation of the unit to which he belongs. That is, there is a direct relationship between an individual soldier's degradation to his unit's degradation. A unit with its authorized equipment which has soldiers that are 80 percent effective is also operationally effective at 80 percent. Similarly, if five percent of the soldiers in a unit are medically evacuated due to combat fatigue, the unit's effectiveness is also reduced by this event. However, the potential aggregation and synergistic interactions that could occur in this translation are not addressed in this analysis.

Next, the inability of soldiers to obtain sleep is a major contributor to combat fatigue. Due to model resolution in JTLS, an assumption must be made concerning sleep. The level of resolution in JTLS for theater-level modeling (brigades, divisions) is too coarse to detail the capacity of subordinate units to obtain rest or to implement unit rotations so that units on alert can rest. Therefore, it is assumed that units in contact with the enemy operate under the conditions of continuous operations.* It is further assumed that units which are not in contact are able to at least partially recover from the degradation suffered previously.

Finally, it is assumed that the intensity of battle over a period of time is quantified by the rate of combat losses (attrition rate) in JTLS. This attrition rate is directly related to the rate of combat fatigue a unit endures.

Approach

Since combat and support personnel are modeled by JTLS, the modeling approach proposes to modify the ground combat function in two ways: (1) affect personnel effectiveness and availability due to combat fatigue, and (2) affect weapon system capability to perform attrition when soldiers are fatigued.

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*Continuous operations are continuous land combat operations where there is opportunity for brief or fragmented sleep. In contrast, the term sustained operations are continuous land combat operations where there is no opportunity for sleep.

## Methodology

Implementing this approach in the ground combat function of JTLS is based on the introduction of a new parameter called DEGRADATION FACTOR (DF). This factor will affect two modeling areas. First, DF is used to modify personnel availability. Second, DF is used to modify attrition. These modifications have the overall effect of degrading operational effectiveness (combat strength).

### Degradation Factor

In JTLS, unit operational effectiveness is measured by combat strength. Combat strength (referred to as UT WEIGHTED STRENGTH in JTLS) is defined as a fraction -- ranging between zero and one -- of the combat strength at which a unit would be if it had all of its authorized systems operational. That is:

$$\text{COMBAT STRENGTH} = \text{SUM } (i=1,N) \text{ [ON HAND COMBAT SYSTEMS}_i \times \text{COMBAT VALUE}_i] \;/\; \text{SUM } (i=1,N) \text{ [AUTHORIZED COMBAT SYSTEMS}_i \times \text{COMBAT VALUE}_i]$$

where i is summed over the unit's combat system types. The proposed method modifies this equation by introducing the parameter DF:

$$\text{COMBAT STRENGTH (with DF)} = \text{DF} \times \text{[SUM } (i=1,N) \text{ [ON HAND COMBAT SYSTEMS}_i \times \text{COMBAT VALUE}_i]] \;/\; \text{SUM } (i=1,N) \text{ [AUTHORIZED COMBAT SYSTEMS}_i \times \text{COMBAT VALUE}_i]$$

where DF is the degradation factor, ranging between zero and one, that represents the fraction of unit operational effectiveness when combat fatigue is included. A unit's initial DF is assumed to have a value of one. The combination of variables [DF x ON HAND COMBAT SYSTEMS] represents a reduction, due to combat fatigue, in the number of available weapon systems or personnel -- assuming that the degradation factor can be applied across all combat system types.

The relationship of the degradation factor DF to the combat fatigue parameters of unit type, posture, battle intensity, and time is illustrated in Figure 2. This conceptual example displays the degradation of a cavalry unit in the defense under continuous operations conditions. The curve set indicates levels of possible battle intensity (average loss rate percentage). For example, this unit suffers a combat fatigue degradation of 0.50 after 72 hours in the defense if it suffered 18 percent losses (an average loss rate of 6 percent per day). Similar graphs could be developed for other unit types and for other unit postures. If this unit's operational effectiveness was 0.90 without considering combat fatigue, then its operational effectiveness with consideration for combat fatigue is 0.45 (0.50 x 0.90 = 0.45).

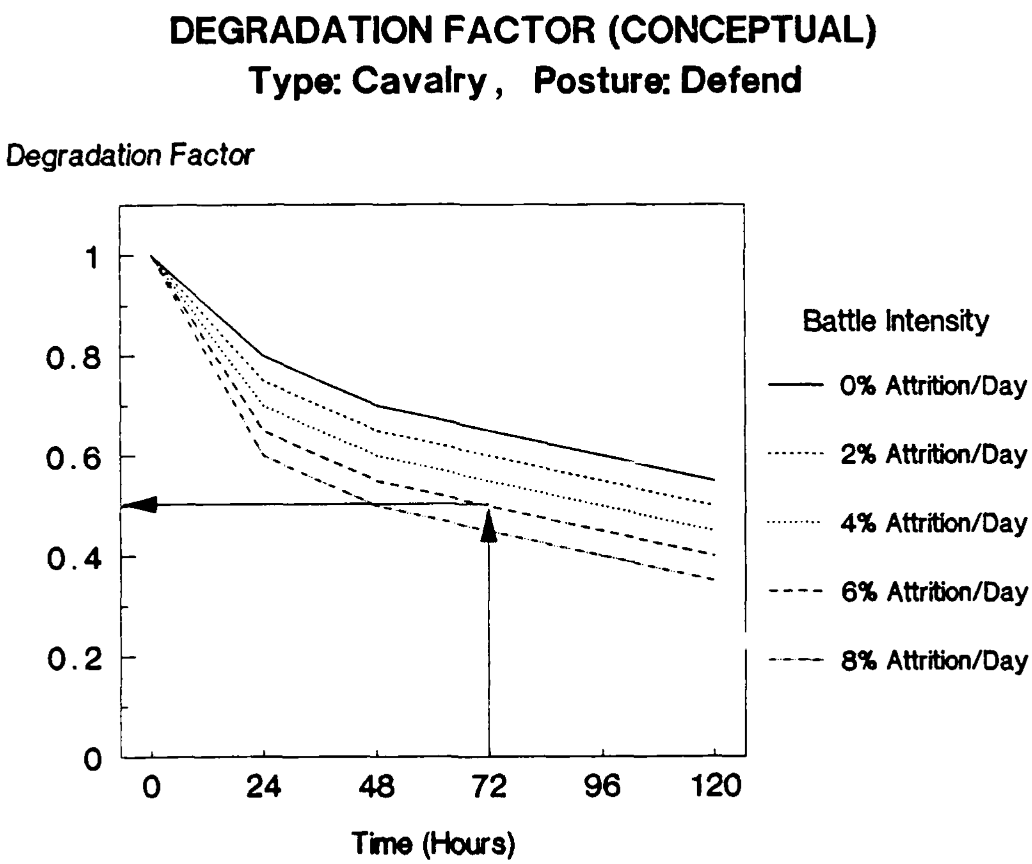


Figure 2

If a unit changes posture, the change in degradation can be obtained from the new posture's degradation curve set. Using the appropriate attrition rate curve, its degradation can be determined from its current degradation factor and the length of the time period.

Figure 3 illustrates this case. Suppose a mechanized infantry unit has a combat strength of 0.85 and a degradation factor of 0.60 after attacking. It current operational effectiveness (with DF influences) is 0.51 (0.60 x 0.85 = 0.51). The unit withdraws in the next period (8 hours), and suffers losses at a rate of four percent per day with a combat strength (without combat fatigue) of 0.837 (0.85 - [.04 x 8/24]). The unit's new degradation factor is

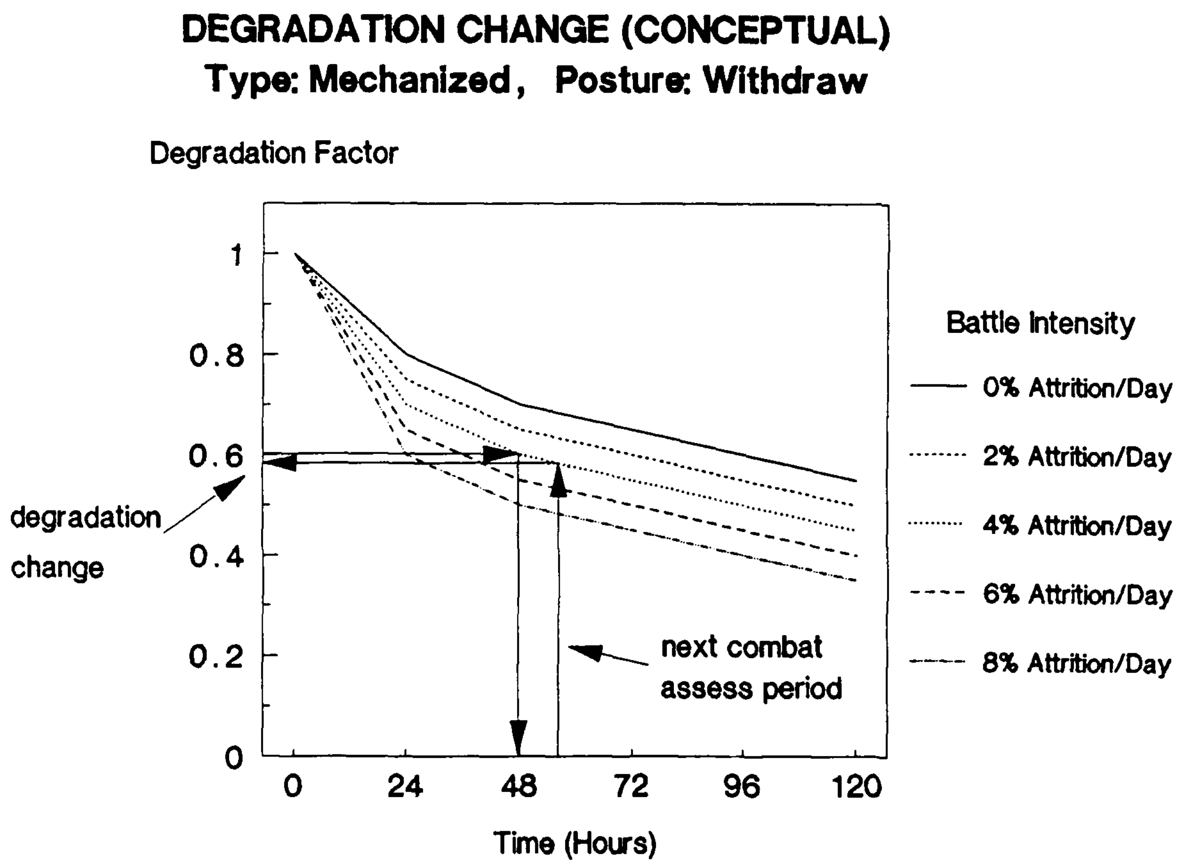


Figure 3

found by entering the four percent per day attrition curve at a DF of 0.60, moving along the curve for the length of the time period, and reading the new DF of 0.58. Therefore, the unit's combat strength when combat fatigue is included is 0.485 (0.837 x 0.58 = 0.485).

Personnel Effectiveness and Availability

JTLS models personnel as a combat system. Therefore, personnel strength can be degraded by application of the degradation factor to personnel similar to any other weapon system. This will affect a unit's operational effectiveness by degrading its combat strength.* In turn, it could influence what tactical posture a unit can assume in JTLS. For example, if a unit's combat strength is too low, it cannot attack in JTLS. In addition to the overall degradation to the unit, combat fatigue in some soldiers may be serious enough to cause medical evacuations. The loss of these soldiers will reduce unit strength and will have the additional benefit of creating more demands on the medical/return-to-duty function in JTLS.

The arrival of replacement personnel, theoretically, should offset the degradation to unit operational effectiveness. These replacements are handled as a normal logistics function in JTLS. The arrival of new personnel in a unit will increase its personnel strength (up to its authorized strength) and

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*A unit's combat strength may be further degraded if a link existed between a weapon system and its crew. If a crew (or portion thereof) is unavailable due to combat fatigue, then its weapon system capability should be degraded accordingly. Conversely, if a weapon system is attrited, then its crew (or portion thereof) should also become a casualty and impose demands on the medical and personnel replacement systems in JTLS. (However, this also opens another dimension as to what portion of the crew are casualties. Are they killed or wounded? If wounded, what is their return-to-duty cycle?)

will, consequently, increase its operational effectiveness as reflected in its combat strength equation.*

Additionally, when a unit has an opportunity to recover from battle fatigue, there should be a corresponding increase in operational effectiveness. When the conditions for recovery are appropriate, a nominal value of, say, six percent per day (see data discussion in Chapter IV) could be added to its degradation factor (up to its initial combat strength) to compensate for this recovery.

Lanchester Ground Attrition

The second major thrust for incorporating combat fatigue in JTLS is to influence ground attrition computations. JTLS uses two attrition schemes for ground combat: Lanchester coefficients for aimed and area fires, and pK for explicit fire missions such as an artillery unit directed to fire on a second-echelon unit. The current method of Lanchester coefficient attrition for combat system type j is, for example:

RED COMBAT $\text{SYSTEMS}_j$ ATTRITED = MIN [(# ATTRITED FROM BLUE AIMED FIRE + # ATTRITED FROM BLUE AREA FIRE), (# RED COMBAT $\text{SYSTEMS}_j$ AVAILABLE FOR ATTRITION)]

where

# ATTRITED FROM BLUE AIMED FIRE = SUM (i=1,N) [# BLUE $\text{SYSTEMS}_i$ x ALLOCATION $\text{FACTOR}_{ij}$ x LANCHESTER $\text{COEFFICIENT}_{ij}$]

where i is summed over Blue's direct fire systems, and

*To be accurate, new personnel in a unit do not suffer combat fatigue at the same rate as the rest of the unit. Therefore, a unit's personnel pool could be segregated into groups according to length of time in the unit. If this is done, a more appropriate degradation factor could be determined by computing a "weighted DF" based on personnel pools representing time in the unit.

$$\text{\# ATTRITED FROM BLUE AREA FIRE} = \text{SUM } (i=1,N) \; [\text{\# BLUE SYSTEMS}_i \times \text{ALLOCATION FACTOR}_{ij} \times \text{LANCHESTER COEFFICIENT}_{ij} \times \text{\# AVAILABLE RED COMBAT SYSTEMS}_j]$$

where i is summed over Blue's area fire systems.

The proposed methodology modifies this equation by adding the DF factor so that:

$$\text{\# ATTRITED FROM BLUE AIMED FIRE (with DF)} = \text{SUM } (k=1,M) \; [\text{SUM } (i=1,N) \; [\mathbf{DF}_k \times \text{\# BLUE SYSTEMS}_i \times \text{ALLOCATION FACTOR}_{ij} \times \text{LANCHESTER COEFFICIENT}_{ij}]$$

where i is summed over Blue's direct fire systems, and

$$\text{\# ATTRITED FROM BLUE AREA FIRE (with DF)} = \text{SUM } (k=1,M) \; [\text{SUM } (i=1,N) \; [\mathbf{DF}_k \times \text{\# BLUE SYSTEMS}_i \times \text{ALLOCATION FACTOR}_{ij} \times \text{LANCHESTER COEFFICIENT}_{ij} \times \text{\# AVAILABLE RED COMBAT SYSTEMS}_j]$$

where k is summed over Blue's participating units and i is summed over Blue's area fire systems. The combination of variables [DF x # BLUE SYSTEMS] represents a reduction in the number of Blue weapon systems available to attrite the enemy.

<u>pK Ground Attrition</u>

This attrition scheme involves explicit fires by artillery units. Unlike Lanchestrian equations, Red's pK attrition results are not a function of the number of Blue's participating artillery tubes. Hence, a different concept for incorporating combat fatigue is necessary. In JTLS, pK attrition uses three methodologies: fire-on-units, fire-on-point-targets, and fire-on-convoys. The measurement of pK attrition results varies among these three types of fire. Fire-on-units is measured by weapon system losses and casualties. Fire-on-point-targets is measured by reduction in target operational capability, and fire-on-convoys is measured by losses of trucks and tankers.

The degradation factor technique can also be used to integrate the influence of combat fatigue on the outcomes of these three cases. That is, fire-on-point-targets and fire-on-convoys use a "probability-of-kill" parameter to determine results. If an artillery unit's DF were applied against this probability, it would decrease -- due to combat fatigue -- its kill probability and, hence, its capacity to attrite the enemy.

Similarly, fire-on-units uses a "lethal area" parameter to determine results. "Lethal area" can be viewed as analogous to "probability-of-kill." If an artillery unit's DF were applied against this "lethal area" parameter, it would also decrease enemy attrition by reducing the effectiveness of its fires due to combat fatigue.

Requirement for New Unit Variable

JTLS updates each unit's count of operational combat systems and available personnel during the ADJUST SUPPLIES event. As part of the ASSESS COMBAT event, JTLS updates each unit's losses, combat strength, and posture. This information will be needed for the proposed concept. In addition to these, and other, unit characteristics, an additional unit data variable will be needed to properly assess changes in operational effectiveness due to combat fatigue. This variable, the degradation factor, will track each unit's degradation. A discussion of data requirements and availability to support the computation this degradation factor follows in Chapter IV.

## ENDNOTE

1. Sally Van Nostrand, Including the Soldier in Combat Models, pp. 6-13.

# CHAPTER IV

## ADDITIONAL MODELING IMPLICATIONS

This chapter discusses data requirements and the present availability of data. It also discusses the combat fatigue modeling approach's applicability to other JTLS functions, to other combat simulation models, and to other soldier performance factors.

### Data Requirements and Availability

This analysis proposes that soldier performance limits (degrades) unit operational effectiveness. The rate of degradation varies by unit type, by unit posture, battle intensity, and time in combat.

#### Scope of Requirements

There are four dimensions in the data needed to implement this methodology: unit type, posture, battle intensity, and time. Chapter III proposed a format and procedure for integrating these data dimensions into JTLS. There are seven unit subtypes in ground combat (infantry, armor, mechanized, cavalry, light artillery, heavy artillery, and engineer). These units can assume eight ground combat postures (move, attack, defend, hasty defend, delay, withdraw, incapable, and wiped out). Battle intensity is measured by unit attrition rates, and time in combat is measured in increments specified by the ASSESS COMBAT event interval.

#### Data Definition and Availability

The data to fully implement this methodology are not available. The required data set does not exist in form or substance today. Only limited portions are available in literature scattered throughout the behavioral, social, historical, and scientific fields. The following paragraphs highlight the status of current data.

There has been little scientific research conducted on soldiers in actual combat. Some data were collected in the Korean Conflict and the 1973 Arab-Israeli War. Most other research has been conducted in laboratory environments or in field experiments. Much of the pertinent literature is found under the heading of continuous operations. For example, there have been many reviews of the contribution of sleep loss, one of the most significant sources of combat fatigue, and its overall impact to combat effectiveness.

In 1987, the Walter Reed Army Institute of Research (WRAIR) and the Army Research Institute (ARI) for the Behavior and Social Sciences conducted a joint review of scientific and technical literature. This study determined what previous studies indicate about soldier and unit performance in continuous and sustained operations. Under sustained operations (SUSOPS), a variety of studies indicate that soldiers become militarily ineffective after two to three days without sleep. Mental abilities, along with initiative and motivation decline faster than physical abilities. Degradation in cognitive performance begins to occur as early as 18 hours into a SUSOPS. This decline is about 25 percent for every 24 hours of continuous work. This drop usually occurs in step-wise fashion in the early morning (0300-0600 hours).[1]

Under the conditions of continuous operations (CONOPS), a wide variation exists in the amount of sleep an individual needs. Some individuals need less than 3.5 hours sleep while others require as much as 10-12 hours. Most adults need between 6-8 hours sleep, but they can sustain a reduction of 1.0-2.5 hours for several months without affecting most tasks. The lower limit of sleep restriction for most individuals is 4.0-4.5 hours. Without this minimum amount of sleep, there is a rapid deterioration of mood, motivation, and performance. For CONOPS with minimal sleep (less than 3 hours per 24 hour period) the limit is several days to as much as a week. For CONOPS with moderate sleep (4 or more hours per 24 hour period) the limits are 2 or more weeks depending on actual amounts of sleep.[2]

Figure 2 on page 20 presented a format for the data required to calculate degradation factors by unit type and posture. This figure indicated a need to describe unit degradation as a function of battle intensity (attrition per day) and time. FM 22-9 describes, using performance curves, the types of performance degradations that can be expected during continuous operations. These curves suggest that degradation varies by: (1) mission hours, (2) unit type, (3) job specialty, and (4) combat activity. These curves describe degradations at task-level resolution. In addition to these curves, FM 22-9 also describes methods to combat this degradation.[3]

These effectiveness degradation curves in FM 22-9 were drawn from the Performance Effectiveness of Combat Troops (PERFECT) model developed for ARI.[4] The PERFECT model is a soldier performance model which projects degradations of individuals and small units during continuous operations. The model uses effectiveness values derived from previous ARI research projects. These estimates can be projected by type of unit, by composition of unit, by initial proficiency level, by total operation of all units, and by enemy/friendly strength ratios.

Specifically, the model included four types of small units: mechanized infantry, armor, fire support teams, and artillery. It encompassed, generally, three types of activities: sleep, deliberate defense, and hasty defense.

Finally, the model can vary eight parameters alone, or in combination. These parameters are unit proficiency, material strength ratio, personnel strength ratio, terrain advantage, light level, amount of platooning, and amount of continuous time in battle, and amount of sleep permitted.

Regarding data on battle intensity and large units, the ME=f(PER) research study indicated that the Historical Evaluation and Research Organization (HERO) derived fatigue factors based on analysis of World War II and the Arab and Israeli wars of 1967 and 1973.[5] HERO developed factors for division-level units when they are in contact with the enemy and when they are in recovery periods when there is no contact. HERO developed three intensity levels measured as a percentage of days when the division is in contact with the enemy. The factors represent degradations in effectiveness per day for each intensity level. These degradations are: 6.79 percent degradation per day when the intensity is 80 percent or more; 1.94 percent degradation per day when the intensity between 50 and 80 per cent; or 1.39 percent degradation per day if the intensity is less than 50 percent. The report also indicated other factors for larger formations such as corps or armies.

Data are also needed for the potential gain in operational effectiveness when units recover from combat fatigue. The HERO report also provided insights in this area. During lulls or when divisions are not committed to active combat, HERO indicated a "negative degradation" or increase of 5.94 percent per day recovery of lost combat effectiveness.

Finally, data are needed to determine the percentage of soldiers who are evacuated from the unit, as contrasted with those who remain in the unit and are less effective. The data for determining this ratio are not presently available.

## Application to Other Combat Processes in JTLS

### Air Combat

The JTLS air combat module performs air-to-air, air-to-ground, and ground-to-air combat functions of the CEP. These functions include the management of aircraft flights, their posture and movement, and interaction with and damage to other JTLS combat assets. Players control three basic air assets: airbases, squadrons, and air missions (flights of aircraft).

Air combat in JTLS has many similarities with its ground combat module. Airbases and squadrons are structured similar to ground combat units. There are 15 different types of air missions, almost as many different air mission postures, and four types of attrition methods. Therefore, the approach described for ground combat has some degree of application in the air combat module. However, the ground combat approach described for modeling combat fatigue must also consider the unique characteristics of the air combat activities in JTLS.

For example, JTLS uses a CREW TIME constraint, an input parameter for aircraft characteristics, to check the amount of time the crew may fly. If a planned mission exceeds this time, the mission is cancelled and the player notified. A second example is airbase runway repair. Repairs are constrained by the number of repair crews, the amount of Class IV materiel, and the daily capacity of repair crews to repair runway cuts. Third, a squadron's maintenance capacity constrains aircraft sortie generation. There is a limit to the maximum number of aircraft that a squadron can fly per day. While it is possible to surge to a greater sortie rate, the maintenance time calculation in JTLS penalizes returning aircraft for exceeding the normal rate.

Each of these examples can be viewed as initial attempts at limiting operational effectiveness due to the availability of personnel. However, each does not fully consider the degradation in effectiveness due to combat fatigue. Therefore, the thrust for adding combat fatigue to air combat should be directed toward a dynamic degradation of these three static input parameters (crew time, runway repairs, aircraft maintenance capacity). This will influence the sortie generation capability of airbases.

Turning to air combat attrition, JTLS has four different methods: air-to-air, air-to-ground, ground-to-air (air defense), and other, miscellaneous mechanisms for attriting aircraft. Each of these attrition calculations has its unique set of algorithms. These computations are largely based on probabilities of kill. In general, the best approach for incorporating combat fatigue in these calculations is to modify these probabilities in a similar manner used for pK attrition in ground combat. Additionally, some of these calculations, such as in air-to-ground attrition, also consider target detection. Combat fatigue should also impact these detection probabilities.

Naval Combat

The JTLS naval combat module performs ship-to-ship, ship-to-shore, and fleet air defense functions of the CEP. These functions include the combat interfaces between naval forces and the ground, air, and logistics functions of JTLS. Players control naval combat through orders to naval units and naval formations.

Because the naval combat module has the same structure as ground combat, incorporating combat fatigue could follow a similar approach. Unfortunately, the naval combat module is not as mature as ground or air, and attempting a degradation of the personnel availability in naval operations may be premature. As an alternative, SHIP CLASS CHARACTERISTICS identifies several factors that are affected by combat fatigue (repair time, supplies onload and offload times). These repair and load factors could be degraded over time. Radar detection probabilities should be degraded as well.

Naval units may participate in five basic types of attrition: ship-to-ship, air-to-ship, ship-to-air, ship-to-shore, and shore-to-ship. Subsurface naval warfare is not modeled in JTLS. Ship-to-ship attrition is by cruise missiles only. There is no human interface. Impact probability is based on air-to-ground damage logic. The remaining types of attrition are similar to ground or air attrition schemes. Air-to-ship and ship-to-air attrition uses the same logic as air-ground or air defense attacks. Ship-to-shore and shore-to-ship attrition uses artillery or Lanchestrian-based calculations.

Logistics

As indicated in Chapter II, the logistics function in JTLS provides for initial issue, consumption, requisition, and resupply; Class VII replacements; and maintenance and return to duty processes. Logistics assets consist of support units and resupply assets. Ground units are primarily resupplied by these support units (but airlift and sealift may be used as well). Supply runs -- groups of cargo and tanker trucks carrying supplies -- are used for this purpose although there are situations when "implicit resupply" can occur. There is no tie between trucks and the soldiers who drive them in JTLS. Hence, the proposed methodology has only limited application. Personnel effectiveness can be degraded, but it will have only limited impact. In order to have significant impact, the capability of a support unit to move supplies should be degraded. One method is to apply a degradation factor -- similar to the method for ground combat units -- to the quantity of available trucks for transporting supplies. This will have the overall effect of reducing the capacity of the support unit and thereby reducing the capability of the unit receiving the supplies. Alternatively, the model design could be modified so that supply shipments are related to personnel. Then, if personnel are degraded due to combat fatigue, supply shipments will also be slowed.

Intelligence

The intelligence functions in JTLS provide information on the status of known enemy forces and their own forces. JTLS does not model individual intelligence functions. Instead, the model deals with processed, rather than raw, data. The reported intelligence is accurate, but this information is restricted in two ways. First, information is delayed. Therefore, it may be inaccurate by the time of receipt. Second, information is subject to probabilities of detection. Only objects detected are reported.

JTLS models six different intelligence assets — national, strategic, unit air and ground tactical gathering capabilities, human intelligence (HUMINT) teams, and air reconnaissance. National and strategic intelligence assets are not associated with any units. Tactical intelligence, HUMINT, and air reconnaissance assets collect intelligence by association with unit ground, air, or naval combat operations. Therefore, the influence of combat fatigue on these units could indirectly impact these intelligence gathering operations. In addition, combat fatigue should impact the probabilities of detection by these units over time.

## Application to Other Combat Models

Joint Chiefs of Staff Publication 1 defines a wargame as "a simulation, by whatever means, of a military operation involving two or more opposing forces, using rules, data, and procedures designed to depict an actual or assumed real life situation." There are many types of combat simulation models. The possibility that any individual wargaming model is identical to some other model is quite small, unless that model is a derivative of the first. Model purpose and construction decrease the likelihood that what presents a workable alternative in one model will not directly apply in another model.

While a comparison of specific interactions in distinct models may be dissimilar, some commonalities may exist in the general sense. For example, many combat simulations model attrition and use a form of combat strength to determine unit capabilities. Hence, incorporating combat fatigue by modifying these two areas, as suggested in the proposed concept for JTLS, may have widespread application.

## Application to Other Soldier Performance Factors

This research focuses on modeling the effects of combat fatigue in JTLS. As such, the methodology is unique to this soldier performance factor and to this model. In spite of this, some commonalities may exist with other soldier factors. Other soldier factors -- such as combat experience or wearing protective, chemical clothing -- are influenced by unit type, posture, battle intensity, the time. Therefore, adding more soldier factors such as these may be easier after implementing combat fatigue. On the other hand, there are soldier performance factors, such as breakpoints and suppression, in which the combat fatigue methodology may not directly apply. These two factors may be influenced by combat fatigue, however. Data requirements and availability may also continue to be a problem in these factors.

# ENDNOTES


1. Walter Reed Army Institute of Research, Effects of Continuous Operations (CONOPS) on Soldier and Unit Performance: Review of the Literature and Strategies for Sustaining the Soldier in CONOPS. p. 1-8.

2. Ibid., p. 1-17.

3. U.S. Department of the Army, Field Manual 22-9: Soldier Performance in Continuous Operations, December 1983.

4. Arthur I. Siegel, et al., Human Performance in Continuous Operations: Description of a Simulation Model and User's Manual for Evaluation of Performance Degradation, January 1981.

5. Trevor N. Dupuy, The Effects of Combat Losses and Fatigue on Combat Performance, Historical Evaluation and Research Organization, January 1979.

## CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

This chapter describes the conclusions and recommendations drawn from this research.

### Conclusions

Human performance dominates many aspects of combat and combat modeling.* This research examined only one element of the human dimension -- combat fatigue. The study proposes that combat fatigue in the ground combat function of JTLS can be modeled by influencing personnel effectiveness and availability and combat system attrition rates. The premise underlying this approach is that combat fatigue degrades unit operational effectiveness. The rate of combat fatigue varies over time. The rate of degradation is a function of unit type, its posture, and its battle intensity.

Because JTLS has the capacity to model personnel, the method for incorporating combat fatigue is to degrade its effectiveness and availability by unit type and posture. The proposed methodology introduces a new parameter called degradation factor, DF. The specific function or equation for this factor also depends on the unit's past degradation and attrition history (battle intensity).

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*Vector Research Incorporated (VRI), under contract to ARI, indicated that the most prevalent human factors in combat models involve decision making and performing tasks under adverse conditions. The areas which are most sensitive to changes in human factors assumptions are: (1) deployment and maneuver of maneuver unit weapons, (2 reserve commitment timing, (3) firing times in maneuver unit combat, and (4) suppression of maneuver unit forces. [George J. Miller, Human Factors Representations for Combat Models, ARI Technical Report 571, July 1982.]

Attrition is at the heart of any wargame. Therefore, the method also proposes to modify the ground aimed and area Lanchester attrition equations by using the DF to limit the availability of killer weapons systems. Attrition under the pK attrition methodology is also modified using a degradation factor.

Considerable data research has been performed on combat fatigue. Unfortunately, most of this research has been performed at the individual level. Very little research has been done concerning large units. If data from individual or small units are used, one must consider the relevance of this data. There are issues of aggregation and synergistic effects that apply.

Nevertheless, it is feasible, and important, to model the human dimension of combat. Soldiers are a major factor that contribute to the "fog and friction" of war. Indeed, it may help explain some of the differences in the comparison of computer model results with actual combat. This research was concerned with combat fatigue in a low-resolution combat model, but there is a need to apply the human dimension of combat in combat models at all levels. The specific methodology described in this paper is unique to JTLS. However, the general concept and approach could be applied to many combat models.

At present, there is insufficient data to fully implement this approach in JTLS. Some data exist for unit types, but it is useful for only four combat units. Data that indicate combat fatigue when units are in various postures are extremely limited. Some data exist on battle intensity, but they are scattered and aggregated. On the other hand, there is a wealth of information concerning sleep loss as it relates to small units in CONOPS and SUSOPS.

This analysis relied heavily on JTLS's use of combat strength to determine changes in operational effectiveness and postures. It is likely that other combat simulation models that use this method may also incorporate combat fatigue without major restructure.

## Recommendations

This research paper did not find the current existence of data to support this concept for incorporating combat fatigue in JTLS. With this background, there are two primary means of approach. The first approach is pessimistic and the second is optimistic.

The first alternative recommends further research into the data problem. Since it may be difficult to acquire the data, it would be wasteful to devote resources into modeling research at this time. No further investigations into modeling concepts would be conducted until data are acquired. The second alternative recommends further investigations into modeling concepts in spite of the absence of a fully complete data set. Data that is currently available would be used as surrogates until validated data are acquired. There is obviously a third alternative which is to implement simultaneous investigations in both data and modeling.

While it is appealing to recommend the third alternative, the second alternative is favored in this instance. Implementing the modifications would validate the premise that soldier performance factors are significant to model results. This would serve as proof of principle. It would also demonstrate feasibility and appropriateness. Finally, it would focus the research for specific human factors data.

Sufficient data exists to implement this alternative. Therefore, consistent with availability of resources, further research into the feasibility of modeling this concept is recommended. A version of JTLS should be modified and tested to determine the impact of the incorporation of combat fatigue on model results (sensitivity analysis). If model results do not change significantly, then combat fatigue should not be incorporated into the baseline JTLS model. However, it is anticipated that combat fatigue will have a significant impact on model results, and, therefore, the concept should be introduced into the baseline model.

Also, further work is needed to identify data sources (e.g., National Training Center, Simulation Network, history) and to complete and verify the data requirements described by this approach. One must continue to recognize that incorporating soldier performance in combat models can be grouped into the four categories identified in the ME=f(PER) report.

Human behavior is a significant contributor to the "fog and friction" of combat. Introducing the major aspects of soldier performance factors in our combat models to some degree will help them to achieve more realism.

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APPENDIX

## DESCRIPTION OF THE JOINT THEATER LEVEL SIMULATION MODEL*

[NOTE: This extract does not reflect model improvements made under the release of Version 1.65]

**TITLE:** Joint Theater Level Simulation (JTLS)

**DATE IMPLEMENTED:** 1983

**MODEL TYPE:** ANALYSIS (but has been used as an exercise driver/training model)

**PROPONENT:** Force Structure, Resource and Assessment Directorate (J-8), The Joint Staff, The Pentagon, Room 1D929, Washington, D.C. 20318-8000

**POINT OF CONTACT:** LCDR Nancy L. Deitch, AUTOVON: 225-1762, Commercial: (202) 695-1762

**PURPOSE:** JTLS is used primarily to analyze theater level operations plans. It is specifically designed to serve as both an operations support and force capability tool to assess the value of different mixes of forces or resources. The model also has been use as an exercise driver.

**DESCRIPTION:**

Domain: Land and air; limited naval operations.

Span: Accommodates any theater depending on data base; several theater data bases completed (Southwest Asia, Central Europe); others in preparation.

Environment: Hex-based. One of 15 discrete terrain transportation factors must be chosen for each hex. Models day and night operations and three different degrees of weather constant throughout the theater. Models roads, rivers, transportation barriers.

Force Composition: Joint and combined forces, Blue and Red.

Scope of Conflict: Primarily conventional warfare but some limited nuclear and chemical effects possible. Virtually all conventional weapons and their effects managed by model's Scenario Development System.

Mission Area: All conventional missions except unconventional warfare.

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*Sample entry for submission for the 11th edition of the Catalog of Wargaming and Military Simulation Models published by Office of the Joint Chiefs of Staff (J-8). Extracted from Phalanx, the Bulletin of Military Operations Research, Volume 21, Number 3, September 1988, pp. 15-17.

Level of Detail of Processes and Entities: Different for ground and air. Movement or attack/defend/withdraw/delay directives can be issued to ground units, usually brigade size (although size of entity is data base dependent). Can be up to 13 different levels in the same data base, but model runs more smoothly when all operational units are the same size. Ground attrition results, based on Lanchester Coefficients, are given down to single entities. Air operations treated with higher resolution. Can issue directives to individual aircraft and small package of aircraft jointed together for mission enhancement. Attrition for aircraft are probability of kill, Monte Carlo-based, and output single aircraft kills, Logistics modeled with high resolution. Intelligence operations also modeled.

**CONSTRUCTION:**

Human Participation: Required for decisions and processes.

Time Processing: Dynamic, time and event stepped model. Progresses through events at a user specified ratio of exercise time to real time.

Treatment of Randomness: Land attrition deterministically based on Lanchester Coefficients. Air attrition stochastically based on direct computation of probability of detection and probability of kill, with Monte Carlo determination of result.

Sidedness: Two-sided, symmetric, reactive model. Can be tested by a single operator and operated by as few as 2 or as many as 26 operators.

**LIMITATIONS:** Does not model all ship-to-ship fighting, naval mine warfare, or undersea operations.

**PLANNED IMPROVEMENTS AND MODIFICATIONS:** Naval module being enhanced. Intelligence and postprocessor will be enhanced in future versions.

**INPUT:** Scenario Development System takes as input relevant terrain, weapons, movement, attrition tables, characteristics of units, and arrival time in the theater.

**OUTPUT:** Produces printouts of movement, attrition, intelligence, and logistic data. Much material displayed symbolically on operational maps. Post processing helps analyze output.

**HARDWARE AND SOFTWARE:**

Computer: Designed to run on VAX computer with VMS operating system.

Storage: 240,000 blocks (122 megabytes) need before data base installed.

Peripherals: Minimum requirements: 1 printer, 1 graphics suite, 4 VT100 terminals.

Programming Languages: SIMSCRIPT II.5, "C", DCL, INGRES.

Documentation: Extensively documented with 11 published manuals.

**SECURITY CLASSIFICATION:** Unclassified, but data bases are often classified.

**GENERAL DATA:**

Data Base: Population of large data bases can take several man-years.

CPU Time Per Cycle: Dependent on data base size and player configuration. Large exercises can take hours of CPU time to process hours of combat.

Data Output Analysis: Post processor aids in analysis of output. Produces hard copies of raw data.

Frequency of Use: Varies by command, but is used at least several times per year by those listed below.

Users: CENTCOM, EUCOM, SOUTHCOM, Joint Warfare Center, Air University, Army War College, Combined Forces Command.

Comments: Managed through a configuration control board made up of representatives of all users. Continually upgraded based on priorities established by configuration control board.