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OPERATIONS IMPLICATIONS OF
3X8 FIELD ARTILLERY BATTALIONS

by

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Operational Implications of 3x8 Field Artillery Battalions

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

A comparison is performed of battlefield effects of 3x8 field artillery cannon battalions using two different methods of employing battery fires. Battles conducted at the National Training Center are used as a basis for developing scenarios for analysis. The NTC Livefire OPFOR is replicated in Janus, and artillery missions from actual battles are fired against it. The two methods of artillery employment are platoon fires and battery fires. A statistical analysis is performed on the results, and the operational implications are presented. The findings indicate that the method of employing batteries, a unified battery versus independent platoons, does influence the number of kills obtained. But which method yields the best effects is highly dependent upon numerous, scenario related factors.

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I. INTRODUCTION

There has been a recently expressed concern within the Army about a possible decrease in the battlefield effects of field artillery battalions observed in training at the National Training Center in Fort Irwin, California. This thesis addresses one possible argument involved in the issue, by using the Janus combat simulation model to replicate portions of battles conducted for training. Two different methods of employing artillery fires are evaluated in the Janus model, using ten actual battle scenarios from the National Training Center. Analysis of Variance techniques are applied to two different methods of employment, and the results are analyzed for statistical significance, as well as the implied operational significance.

During the last decade, the force structure of the Armor and Mechanized Infantry Divisions in the United States Army has undergone several changes, some prominent, some subtle. Many of the changes have been a product of the "Division 86" (later, "Army of Excellence") revamp of Army Heavy Division force structure. One of the less noticeable, though certainly significant, of these changes was the addition of six more self-propelled howitzers into each of the three Direct Support[1] artillery battalions of the Division Artillery. Not a costly or seemingly dramatic change, this upgrade was motivated by the need to provide battlefield commanders with increased firepower, which had been determined to be lacking. Within each battalion, these six howitzers were not introduced as a single, additional battery, but rather were distributed among the three existing batteries, up-gunning them from six to eight guns each--thus creating the "3x8" battalion. The rationale for this force structure (vice a fourth battery) was that the only costs incurred would be those of the additional howitzers' equipment and personnel. The "overhead" costs associated with forming another battery would be avoided. The proposal, along with the supporting analysis, appeared solid; no one anticipated the repercussions that were soon to appear.

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1 A tactical mission assignment in which the field artillery battalion is immediately subordinate to the maneuver commander, usually at the brigade level. In this role, the artillery battalion becomes an integral part of the maneuver force, and is highly responsive to the maneuver commander's needs. In contrast, other standard tactical missions are General Support (GS), Reinforcing (R), and General Support-Reinforcing (GSR).

In 1986, the first units which had transitioned to 3x8 (within CONUS[2]) began rotating with their associated maneuver brigades to the National Training Center (NTC) at Fort Irwin, California. Everyone in the Land Combat arena was anxious to witness the increased firepower and responsiveness that the new organization would provide. But dramatic increases were not seen. That could be considered normal; any newly implemented doctrine requires time to mature, and there was no immediate expression of concern. But as more units transitioned to 3x8 and conducted routine training at the NTC, dramatic increases still did not appear. In fact, after more than two years of observation, it was becoming apparent that something was very wrong. But explanations were elusive. Reluctantly, the NTC Artillery Observation Team[3] admitted that not only were increases *not* observed, but there was actually a *decrease* in the observed effectiveness of artillery during battles witnessed at NTC! This was not good news, and there was now reason for concern.

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2 Continental United States

3 The Observer.Controllers who observe artillery units at the NTC are part of the NTC Fire Support Operations Group; for the purpose of clarity in this report, the term "Artillery Observation Team" will be used to indicate these people

II. OBJECTIVE

The problem addressed by this research is the recent observed trend of decreased artillery effectiveness at the National Training Center. The issue itself is surrounded by controversy. The observations have come from personnel at the National Training Center, who are rightly considered experts in their areas. There have been on-going analyses, discussions, and proposed solutions in terms of many subjective factors involved, but resources at the NTC are not available to conduct extensive quantitative analyses. Therefore, this research was conducted with the cooperation and mutual interest of personnel at the NTC.

The purpose of this research is to provide some form of quantitative analysis to aid in confronting the issue of battlefield effectiveness of 3x8 battalions. A large portion of the effort was devoted to defining and refining the problem statement, and designing a methodology which would be plausible from both a statistical and an operational point of view. The following chapters are devoted to explaining how the issue was refined, and how a new methodology was engineered in order to attack an underlying premise of the NTC Artillery Observation Team personnel. It is necessary to first understand the source of the issue, and what possible causal relationships exist. It is also desirable to review existing analyses, to understand what has been done so far. With this background, the model is proposed along with its output, and the results are then analyzed in the context of operational significance to the current Army force.

III. BACKGROUND AND PROBLEM FOCUS

A. AN HISTORICAL OVERVIEW

The modernized battalion force structure, consisting of three batteries with eight howitzers each, was designed to provide increased firepower in an era of resource constraints. The Army's Threat Area Analyses of the mid and late 1970's looked toward the then current and future threats of the post-Vietnam world, and projected critical weaknesses of the future force of the 1990's. These analyses exposed a lack of immediately responsive, organic (within the division) firepower available to commanders at the division and brigade levels. That is, although there existed adequate firepower resources within the Corps and Theater levels (which would be used to augment and support the forward maneuver forces), there was a lack of artillery and other "force multipliers" that were under the immediate authority of division and especially brigade commanders. The "Division 86" concept was the official Army response [Ref. 1]. It was the plan and the vehicle which would upgrade the then current forces into better equipped and more powerful combat Divisions by 1986. "Division 86", however, was too optimistic, failing to realize resource limitations. It was soon replaced by the "Army of Excellence" modernization plan [Ref. 2], which took over as the guiding document to force modernization. The 3x8 concept had been originally incorporated in "Division 86", and was carried over into the "Army of Excellence". By the mid-1980's, divisions were gradually, but methodically, upgrading Tables of Organization and Equipment as they received personnel and equipment to implement the changes authorized.

The concept of 3x8 battalions had been developed and proposed by the U.S. Army Field Artillery School and Center in the late 1970's, in response to the stated need for increased divisional firepower. A series of studies was commissioned to specifically analyze alternatives for doing so. The "Legal Mix V" study [Ref. 3], which would become the supporting document for 3x8 authorization, was a side-by-side comparison of five of various combinations ("mixes") of artillery batteries comprising a battalion, with each mix having a different organizational configuration. The five proposed mixes are shown in Table 1 on page 5 . The Measures of Effectiveness (MOE's) in the evaluation were based upon (1) battlefield effects and (2) survivability of the battalion in a simulated high-intensity, western-European scenario. Each of these was divided by the incurred cost for the respective mix, resulting in actual MOE's of marginal-gain-per-unit-cost.

Though the ranked outcome of mixes was different for each MOE, mixes 2 and 3 were very close, and ranking at the top for both MOE's. Based upon this report, the Army approved the Field Artillery's recommendation to upgrade direct support battalions to eight-gun batteries, adding two guns and also a second fire direction center[4] to each existing battery, but staying at only 3 batteries per battalion,

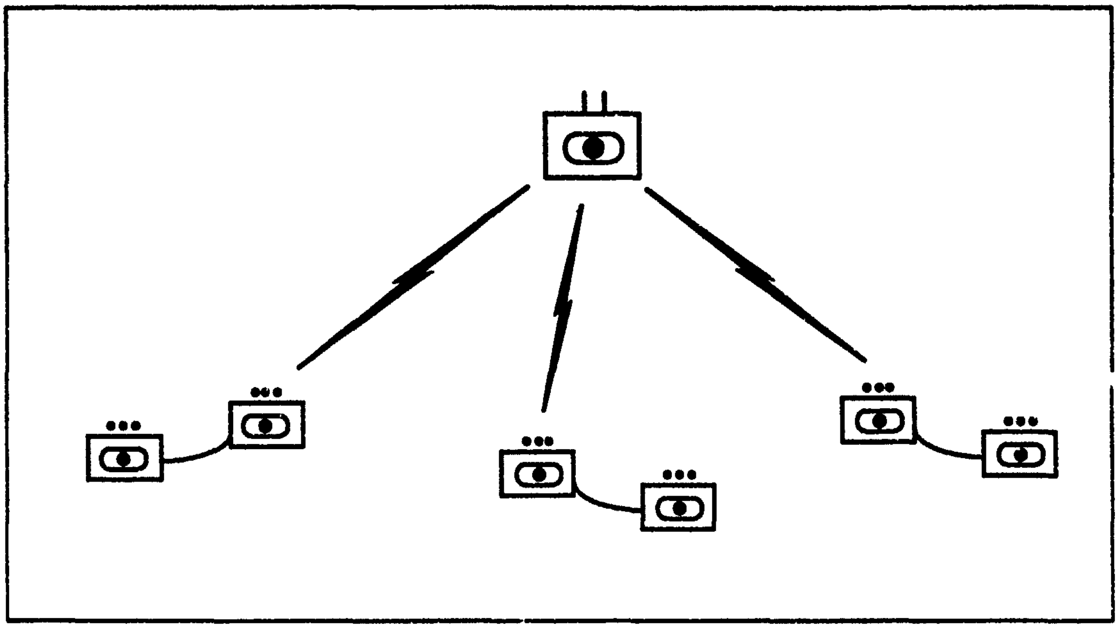
Table 1. LEGAL MIX V VARIATIONS

	No. Batteries per Battalion	No. guns per Battery	No. Fire Units	No. FDCs per Battery
Mix 1	3	6	1	1
Mix 2	4	8	2	1
Mix 3	4	8	2	2
Mix 4	4	8	1	1
Mix 5	5	6	1	1

The initially proposed doctrine for 3x8 employment was not a radical departure from the then-current operations procedures. The battery would still deploy, conduct fires, and reposition as a single unit. The primary difference was that the two platoons would be physically separated in location by approximately 800-1600 meters, which would provide a significant advantage in survivability (Figure 1 on page 6). The second FDC was envisioned to provide a back-up fire-direction capability to the battery, allowing real-time battle hand-off when required. (Battle hand-off occurs when the primary FDC becomes non- functional, either through combat attrition or other catastrophic event. Immediate, real-time hand-off was virtually impossible under the old system of manual or hand-held-calculator fire direction backup, a shortfall even before 3x8).

As the first units transitioned to 3x8, this doctrine was followed. But what happened next is not certain. Perhaps there was not a good understanding of the 3x8 employment concept. Some would argue that the initial 3x8 guidance was unrealistic and contained doctrinal contradictions. Perhaps leaders experimented with the design, to make up for weaknesses they perceived in the structure, and to strengthen it for their own particular

[4] The Fire Direction Center (FDC) is the section of equipment and personnel responsible for controlling fires; at the battery level, this includes computing all of the technical data required by the guns, at the battalion level, this usually entails planning schedules of fires, receiving fire missions from observers, and routing missions to subordinate units for execution.



F'ջure 1. 3x8 Field Artillery Battalion: As initially proposed; note each battery's internal communications.

environment. In any case, as the modernization to 3x8 continued throughout the Army, the tactical operating procedure of the converted units began to change.

The change taking place was subtle, however. It did not draw much attention in and of itself. "Autonomous operations", which up until now had been associated with batteries, was now being associated with *platoons*. The term had been coined earlier (about a decade before) during the conversion to automated fire direction computers, and had been defined as a *battery* operating under its own command and control authority (not within the battalion computer network). The new meaning was analogous: *autonomous platoons* operated independently, not under centralized battery control (Figure 2 on page 7). Although the possibility of separate platoon operations had been recognized and addressed in the 3x8 concept, it was not initially intended as a routine alternative. But rapidly the concept of "autonomous *platoon* operations" was taking on a life of its own. In early 1989, the concept was given official recognition by the Commandant of the Field Artillery School [Ref. 4]. "Autonomous platoons" were now legitimate.

It was during this same period that leadership and observers at the National Training Center were reporting that they observed decreased battlefield effects from artillery units, and they tended to blame "3x8." Their reasons were myriad and diverse, ranging from extremely technical to acutely subjective issues (discussed below). To their credit,

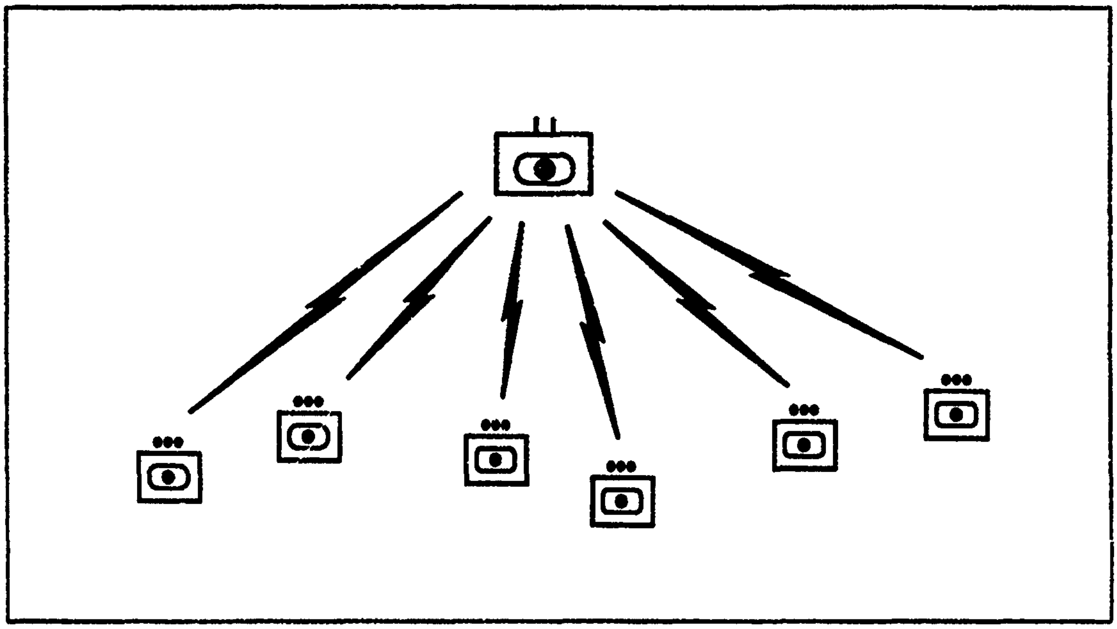


Figure 2. **3x8 Field Artillery Battalion:** As the distances separating platoons grew (to 3-5 km), "Autonomous Platoon Operations" took their own course; laying communication wire between platoons was becoming infeasible.

they had already analyzed the more blatant causes, and were proposing solutions to the artillery community, both through the artillery school and to the units in training. But the artillery community itself was divided into those who recognized a problem, and those who discredited it. There would be no easy solutions.

B. CURRENT SITUATION

Possible causes of the supposed decrease in artillery effectiveness are numerous and interrelated. Some of the factors under suspicion are:

1. **Lack of massing.** Massing fires is one of the five basic tenets of Field Artillery. Obviously, if the units were operating as autonomous platoons, there was an inverse effect upon massed fires. A primary argument of NTC personnel is that this is precisely why the observed decrease in effects is so pronounced.
2. **Command and control of fires.** With the greater distances between platoons (sometimes up to five kilometers!), more often than not the platoons of a same battery do not have wire communications between them (Figure 2). This means that units cannot exploit the quick massing capability afforded by the FDC computer when there is direct FDC-to-gun communication. To fire as a battery, the platoons must perform a laborious manual coordination procedure, just as when multiple batteries are coordinated to fire as a massed battalion. This coordination comes at the high cost of time (i.e., loss of responsiveness).

3. **Battery leadership responsibilities.** The Battery Commander and the First Sergeant, the two senior personnel of the battery, no longer have clearly defined roles, and often find themselves separated from the battery for long periods of time, and at critical moments. In battle, these two are the critical links in knowing the tactical scenario, and their absence arguably degrades the unit's tactical capability. Other battery leadership positions are affected as well.

4. **Human factors issues of automated fire control.** Under 3x6, the battalion Fire Direction Center was responsible for maintaining and processing message traffic for three units (the three batteries). Additionally, in warfare conditions, it is very likely that a reinforcing battalion will also be under total control of the Direct Support battalion's FDC. On top of this, standard doctrine of "mutual support" requires that databases be maintained and updated for one or possibly two sister battalions in neighboring sectors. Meeting all these requirements for **batteries** in a fast-paced battle is quite a task. Double the number of units in each battalion (when platoons are autonomous), and the workload explodes. There are multiple functions associated with a "unit" identified in the computer, so the workload vs. the number of "units" is certainly not a linear relationship. When batteries operate as autonomous platoons, it is necessary for each platoon to be entered into the computer's database as a separate unit. It can be argued that just the workload of six units (platoons), alone, overloads the capability of the computer-to-human interface (i.e., overloads the input/output capability of the operators). If so, the battalion's tactical operations are degraded without even including the demands of mutual support.

5. **JMEMs arguments.** Concern has been expressed that the Joint Munitions Effects Manual (JMEMs) tables are not accurate for current munitions, particularly Improved Conventional Munitions (ICM). Some argue that four guns shooting ICM is just as effective as the previous six guns shooting High Explosive; i.e, platoon operations are justified, and *desirable*.

All of these factors have been argued from both sides. The point is that there are many factors which could account for what was going wrong. Unfortunately, most of these are not suitable for quantitative analysis, until the problem issue is much better refined. It is possible that each of these factors contributes to the degraded performance. More likely, there are interactions between all the factors.

It is interesting to note that many of the units which were being scolded by NTC observers for running platoon operations actually *thought* they were employing battery fires. This misconception is due to the way fire missions are processed: the battalion FDC computer operator allocates a particular fire mission to a battery. But in sending the mission down to autonomous platoons (via FM radio), each platoon must be contacted separately. This is done by the computer automatically, completely transparent to the operator. Since each platoon is receiving its own fire order, each executes the mission immediately, but not necessarily *simultaneously* with its sister platoon. The misperception is that the battalion fire direction operator thinks he has executed a battery mission, whereas he has actually generated two identical platoon missions. A subtle difference, yet very significant. Thus, not only was there conflicting opinion about tactical employment procedures, but the misperceptions of what was actually being executed compounded the problem further.

C. A BRIEF DESCRIPTION OF NTC

There are two distinct types of training environments at the National Training Center: Force-on-force and Livefire. In the force-on-force environment, the training unit is opposed by a real enemy, the Opposing Forces (OPFOR), who look, train, and are equipped like a Soviet Motorized Rifle Regiment. Obviously, real ammunition is not used in this phase. Rather, all direct fire systems (rifles and tanks, for example) are equipped with laser-beam firing simulation systems. Likewise, all personnel and vehicles are equipped with laser detection sets, which signal a "kill" when the person or vehicle is engaged by an appropriate opposing system.

In the Livefire environment, on the other hand, live ammunition *is* used, but the OPFOR is simulated through the use of a vast array of pop-up targets. These targets are full-size silhouette panels representing Soviet armored vehicles. The synchronized presentation of the pop-up silhouettes provides an amazingly realistic effect of a mobile enemy. Because of this extensive, semi-permanent target array, Livefire battles are restricted to the one particular "corridor" which contains all of the targets. Force-on-force battles are conducted on other regions of the NTC reservation.

D. CURRENT COMBAT MODEL SHORTFALLS

One of the shortfalls of combat training, even at the National Training Center, is that a combat environment cannot be perfectly replicated. This shortfall is more pronounced in the arena of indirect (i.e., artillery) fire than with direct fire systems. With regard to both the Force-on-force and Livefire environments at the NTC, the direct fire systems (tank, rifles, and machine guns) are fairly well represented in lethality effects by the laser-beam instrumentation systems. But there is very little realization of actual artillery effects in a training environment. Even at the NTC Livefire range, where all combat systems fire live ammunition, the effects of artillery are not fully realized, either by the troops on the ground or by the automated instrumentation system.

This is not to say that it is not good training. The opportunity to coordinate and fire actual artillery rounds at a moving target is a valuable experience. But the *effects* are not captured, even at the NTC. That is, there is no credible measure of how the artillery as a whole impacted upon the outcome of the battle.

In the Force-on-force environment, (as well as in computer combat simulation models), there is an equally unrealistic factor: artillery is too perfectly played. There are no timing errors, no confused communications, no maintenance or logistic error, and certainly no misfires. Much of the reality, and challenge, of the real world is assumed away. This real world chaos, the "fog of war", is extremely important in shaping battle. It can cause a near perfect plan to become worthless in a matter of seconds (literally), because timing is critically important in a highly fluid combat situation. The inability to model confusion in simulation is a significant shortfall of most battle analyses.

E. THE IMPLIED HYPOTHESIS TEST

At this point, a review of the facts is in order. First, as far as NTC is concerned, there *is* a problem with the employment of 3x8. Many Army agencies, as well as high ranking individuals, are interested in getting some analyses and results. Secondly, the transitions to 3x8 are now complete in all active divisions, and no one is keen about yet another force structure change so soon. Thirdly, Legal Mix V already conclusively supports 3x8 employment, but it does so within a specific set of parameters. The mix actually supported by the report [Ref. 3, p. 5] was the one in which the two platoons were operating independently, but with *simultaneous* fires, i.e., operating under *unified battery* fire control. Therefore, the current usage of *autonomous platoons* is not really within the context of the Legal Mix V supporting argument.

Given that the transition to 3x8 has already been made, the interest is not in whether the transition was right or wrong, nor is it in looking for yet another, improved, force structure. Rather, the focus of attention is on how to get the best results with the already existent 3x8 organization. It is within this context that the theme of massed fires has been constantly reiterated by the NTC observers. It is continually suggested that if units would fire missions as a battery instead of as platoons, much greater effects could be realized. This statement is, in fact, the "party line" for the NTC Artillery Observation Team, and the motivation for this research.

NTC artillery observers collected and analyzed data, and generated conscientious proposals for corrective action in many areas of concern. But they do not have the resources available to check their primary premise, which is that "3x8" can work better if the units are firing as batteries. They are certain that all other factors are secondary to the fact that eight guns, fired simultaneously, give better battlefield effects than two groups of four fired independently.

IV. METHODOLOGY

A. THE NECESSITY FOR A NEW APPROACH

It is desired to make a direct comparison between what is real (3x8 "autonomous" platoons), vs. what is exhorted as being better (3x8 battery operations). It is known that the battles conducted at NTC provide one of the most accurate insights to actual command, control and communication (C3) dynamics in a combat environment. Also, it is a fact that validated combat simulation models provide plausible, reproducible lethality assessments.

A new approach was devised, which exploits the strengths of these two proven methods, to form a credible model for use in making a comparison. The methodology does not deny C3 interactions through assumption, but rather, captures the C3 realities of the NTC, holding them constant as with the other interrelated factors.

B. A NEW APPROACH

The methodology proposed here is to model the NTC Livefire OPFOR target array in a combat simulation model, and recreate the training units' actual artillery battles as recorded on the NTC fire mission worksheets. Because the combat simulation model provides valid information on the effects of fires (combat kills, for example), this provides a "base case" evaluation of the effects of the units' *actual platoon fires*, whether intentionally or circumstantially autonomous. A second (comparative) case is constructed by using the same fire mission worksheets, but restricting all fires to battery level missions. The result is two sets of fire effects data: one in which the fire missions were executed within the combat simulation exactly as they had been conducted at the NTC Livefire, and the other based upon the same firing data but being restricted to battery fires.

To implement this approach, a high-resolution combat simulation model was required. Janus was chosen for this role, for the following reasons:

1. **Validity.** Janus has been approved for use by the US Army, and is the model of choice for high-resolution combat simulation.

2. **Capability.** Janus allows the modeling of both realistic maneuver forces and realistic artillery fires. Its resolution allows a combat force to be represented down to the individual vehicles, with a planned movement route for each. This degree of resolution is necessary for the proposed approach.

The position which is stated time and again by the NTC Artillery Observation Team personnel is summarized as follows:

> . . . [The 3x8 units] would have greater effect if, [instead of trying to engage multiple targets with platoon fires], they would just pick one target and shoot the entire battery . . . . [Ref. 5]

The analysis suggested by this statement is a direct comparison of what is actually being done (implicitly caused by the new force structure), versus what the outcome could be if the batteries were *required* to shoot as a cohesive unit. Quantitative analysis, therefore, should be addressed to the comparison of 3x8 artillery effects under two differing methods of fires.

3. **Availability.** The current Janus version is in use and is maintained by the US Army Training and Doctrine Command (TRADOC) Analysis Command cell at Monterey (TRAC-MTRY), which is co-located with the Naval Postgraduate School, so it was readily available for use with this research. Additionally, TRAC-MTRY has personnel who can provide expertise and experience for the model and its implementation.

4. **Artillery algorithms.** The Janus algorithms, in particular ICM, are considered adequate for lethality assessment in this type of scenario [Ref. 6].

C. CONSTRUCTING THE OPFOR IN JANUS

The Livefire OPFOR target array replicates a Soviet Motorized Rifle Regiment, consisting of two Motorized Rifle Battalions. The targets represent 114 armored vehicles, predominantly BMP armored personnel carriers. Other vehicles include T-72 tanks, BRDM armored personnel carriers, self-propelled artillery, and armored air defense systems. The OPFOR target array presented against a rotational training unit in a defensive scenario was standardized and automated[5]. In the hour before attack time, small groups of distant targets are raised to indicate the impending attack. At H-hour, the computerized control system begins automatically raising and lowering belts of target panels in order to replicate steady movement of an enemy (at 18 kilometers per hour in daytime, 12 at night). This automated, standardized OPFOR scenario was exploited in the analysis methodology employed here.

Within the target array, each OPFOR vehicle is represented by a series of pop-up target panels from one end of the battlefield to the other. That is, within each target belt, there is a specific target corresponding to a particular vehicle (weapon system), which corresponds to the same vehicle in preceding and subsequent belts. Thus, the replicated OPFOR unit maintains a spatial relationship consistent with an advancing motorized rifle regiment, throughout the course of the attack.

Each of the OPFOR vehicles represented by the target array was entered into the Janus model by representative vehicle type, and assigned a movement route corresponding to its particular series of target panels. Data for the exact locations and types of each target panel within the target array was provided by the NTC Livefire Team. Each individual pop-up target location was represented in Janus as a route "node" for the corresponding vehicle. Thus the movement plan for the vehicles in Janus directly corresponded to the "movement" of the simulated OPFOR units. Some nodes, particularly the first few for each vehicle, were later designated as "timed nodes" within Janus

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5 Due to a recent hardware upgrade, the scenarios since July 1990 now incorporate some randomness in target presentation, and can no longer be considered standardized.

to coordinate the timing, keeping all of the vehicles on line with one other. Execution of the final movement plan was closely scrutinized to ensure the Janus representation exactly matched the actual NTC battle movement.

D. PROGRAMMING THE ARTILLERY MISSIONS

Data for the training units' (BLUEFOR) artillery fires were obtained from the fire mission worksheets which are maintained by the NTC Artillery Observation Team during each battle. These worksheets are manual records of the actual fire missions transmitted by the fire direction computer and executed by the firing units. A random sample of worksheets was collected for Livefire deliberate defense scenarios conducted at the NTC during the period May 1989 to April 1990. Only Livefire battles were considered, in order to capture command, control, and communication (C3) interactions in the analysis. The scenario type was restricted to deliberate defenses (as opposed to offense and hasty defense) because, due to their standardization, they could be plausibly recreated. From these worksheets, ten scenarios were ultimately chosen for use, based upon criteria of legibility and completeness of data. All missions were programmed with Dual Purpose Improved Conventional Munitions (DPICM)[6], since this is the primary projectile for use against an armored threat, and is the only munition capable of killing armor systems.

Having collected the data, two cases were generated for each scenario, for input into Janus:

1. Case 1: Platoon missions (Base Case)

The fire mission worksheets contained the time, grid location, firing unit, and total number of rounds fired for each target and/or fire mission. These missions were entered exactly into Janus, paying particular attention to the total number of rounds, which was converted into number of volleys for Janus input. The timing of the battle was accomplished by establishing the H-hour of the actual battle from the fire mission worksheet, and coordinating this with the Janus OPFOR movement timing. H-hour was usually apparent from the targeting sequence. Whenever there was doubt, the judgment was always in favor of the BLUEFOR; that is, for establishing the scenarios, the model was biased towards "BEST CASE" effects. This *does not* bias the comparison, however,

[6] A sub-group of Improved Conventional Munitions; DPICM rounds deploy bomblets capable of defeating light and medium armored vehicles (given a bomblet direct hit). At present, this is the only "dumb" artillery munition capable of defeating armor.

for the identical timing sequence was used for the alternate case (Case 2) of each scenario.

2. Case 2: Battery missions

In constructing the alternate case for each of the ten scenarios, in which the fire missions would be conducted as battery missions, it was imperative to: (1) maintain the integrity of the fire mission timing, (2) maintain the same number of total rounds fired, per mission and per battle, and (3) not introduce bias in target selection. To accomplish this, a procedure was established which was a fair treatment of converting platoon fires to battery fires. In the few cases where the units *had* fired as batteries, no changes were made. Otherwise, each platoon fire mission was evaluated, in sequence, to determine if, at the time of execution, the sister platoon was in a conflicting fire mission ("conflicting" meaning that the sister platoon had a mission whose execution window overlapped the mission being considered), preventing it from being available to join the mission. The two possible situations were treated as follows:

No conflict: Schedule a battery fire mission with exactly the same number of total rounds as used for the platoon fire mission.

Conflict: Perform a random selection ("coin flip"), schedule the winner as a battery mission, keeping the total number of rounds fired the same as if *both* missions had been executed.

During the discussion of statistical analysis, these two cases of artillery implementation are refered to as "treatments," since each is actually a treatment factor for each scenario.

E. MEASURE OF EFFECTIVENESS

The Measure of Effectiveness (MOE) used for this evaluation is kills. This is very simplistic, yet applicable within the context of the evaluation. Suppression is not measured, because there is no adequate "yardstick." Suppression is very difficult to play in a combat simulation, including at the NTC, and impossible to measure with current methods. It is therefore treated as a *lesser included effect* of kills, i.e., a measured difference in effectiveness by "kills" would have applicability to suppression effects, in terms of relative significance. Furthermore, in NTC vernacular, weapon system "effectiveness" has the underlying implication of "kills", even in artillery contexts.

Secondly, this is a *comparative* analysis. Any reasonable Measure of Effectiveness should suffice, as long as it is applied equally to all cases. Due to the difficulty of quantifying suppression, the "Kills" MOE serves as a plausible, though perhaps not rigorous, surrogate for many battle effects.

V. RESULTS AND STATISTICAL DATA ANALYSIS

A. MODEL AND HYPOTHESIS

The model to be used is:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

where

Y_{ijk} = kills in the *k*th run, *i*th scenario, *j*th treatment,

μ = grand mean,

α_i = effect of scenario *i*,

β_j = effect of treatment *j*,

$\alpha\beta_{ij}$ = effect of interaction, and

ε_{ijk} = random error.

Here, $i = 1, 2, \ldots, 10$; $j = 1, 2$; $k = 1, 2, \ldots, 80$.

The hypothesis to be tested is whether there exists a significant difference between treatments. It is anticipated that there could be vast discrepancies between scenarios, since each scenario incorporates numerous exogenous factors which influence the overall results of the battle. The intention is to treat the scenarios as a "nuisance" factor, since there probably will be a significant difference *between* scenarios. The hypotheses under test are formally defined as:

$$H_0: \ \beta_1 = \beta_2,$$

$$H_A: \ \beta_1 \neq \beta_2.$$

B. SIMULATION RUNS

There were a total of 20 different situations for evaluation: ten scenarios with two treatments each. Due to time constraints, each was initially run 40 times in Janus systemic processing mode. As more time became available, an additional 40 runs were made for each situation, independent of the first set.

The results of the battle simulation runs are summarized in Table 2 on page 17. The sample mean and sample standard deviation for each of the situations is shown, computed from the 80 values of "kills" for each cell. It can be seen that in some scenarios Case 2 appears to be superior to Case 1, but in others the reverse is true. So there is no clear "winner". Further inspection reveals that, in both Case 1 and Case 2, there is a large discrepancy between the means obtained for different scenarios. Within a particular scenario, however, the two treatments are fairly close in outcomes. So contrasts between scenarios are expected to be highly significant. This is not surprising, considering what these numbers represent. Each of the scenarios *is* distinctly different, in regard to each units' tactical plan, execution capability, level of training, the weather and environmental conditions, and numerous other factors. Proper analysis of treatment effects will require appropriately addressing this difference between scenarios.

Table 2. JANUS RESULTS

Scenario Number	Case 1		Case 2	
	Sample Mean (Kills)	Sample Standard Deviation	Sample Mean (Kills)	Sample Standard Deviation
1	**1.313**	1.259	**1.412**	1.177
2	**1.075**	1.474	**1.262**	1.338
3	**1.075**	0.868	**0.525**	0.675
4	**0.800**	0.770	**0.850**	0.901
5	**0.263**	0.568	**0.537**	0.762
6	**0.088**	0.284	**0.087**	0.284
7	**1.475**	1.067	**0.187**	0.424
8	**3.813**	1.936	**3.125**	1.169
9	**2.288**	1.443	**1.212**	0.964
10	**0.725**	0.842	**0.675**	0.792

C. PRELIMINARY ANALYSIS

Figure Figure 3 on page 18 graphically depicts the differences in means between the various scenarios. As expected, each outcome appears to be dependent upon the scenario. As mentioned, the means for the two treatments within each scenario generally have similar magnitudes. (The same data, re-ordered by the difference of means between

Treatment 2 and Treatment 1, is shown in Figure 12 on page 28, in connection with discussion of scenario×treatment interactions.)

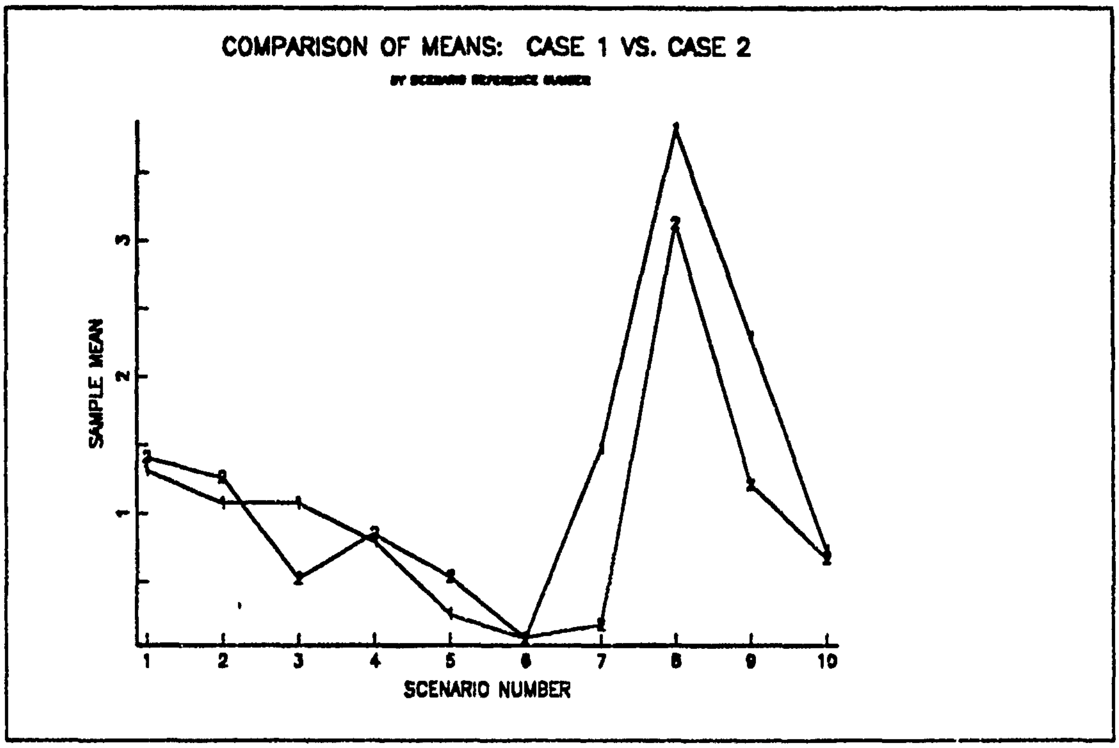

Figure 3. Comparison of Scenarios vs. Treatments: (Scenario numbering random; point symbol indicates the treatment number)

The SAS statistical analysis software package was used for analysis. A preliminary Analysis of Variance (ANOVA) test, according to the stated model, yielded the results summarized in Figure 4 on page 19. Predictably, this test indicates a high significance of the interaction between scenarios and treatments. Overall generalizations about the outcomes with each treatment cannot be made at this point.

GENERAL LINEAR MODELS PROCEDURE					
DEPENDENT VARIABLE: KILLS					
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	19	1429.30687500	75.22667763	66.68	0.0
ERROR	1580	1782.61250000	1.12823576	ROOT MSE	
CORRECTED TOTAL	1599	3211.91937500		1.06218443	

SOURCE	DF	TYPE IV SS	F VALUE	PR > F
SCENARIO	9	1280.73812500	126.13	0.0
TREATMNT	1	36.90562500	32.71	0.0001
SCENARIO*TREATMNT	9	111.66312500	11.00	0.0001

Figure 4. Initial ANOVA

A plot of the residuals[7] (Figure 5 on page 20) suggests that the ANOVA assumption of homogeneity of variance may not be satisfied with these data. In the figure, the plot on the left shows the discreteness of the data; over 98% of the data points are hidden. To get a better view, the data were jittered[8], resulting in the plot on the right. This plot, along with a plot of sample means versus sample standard deviations (Figure 6 on page 21), suggests that standard deviations may be proportional to means. This suggests that a logarithmic transform may be appropriate to stabilize the variance.

---

[7] the difference between the observed value, and the value predicted by the model (YHAT)

[8] The jitter was obtained by applying a random value from the interval (-0.5, 0.5) to both the YHAT and RESIDUAL components of each plotted point.

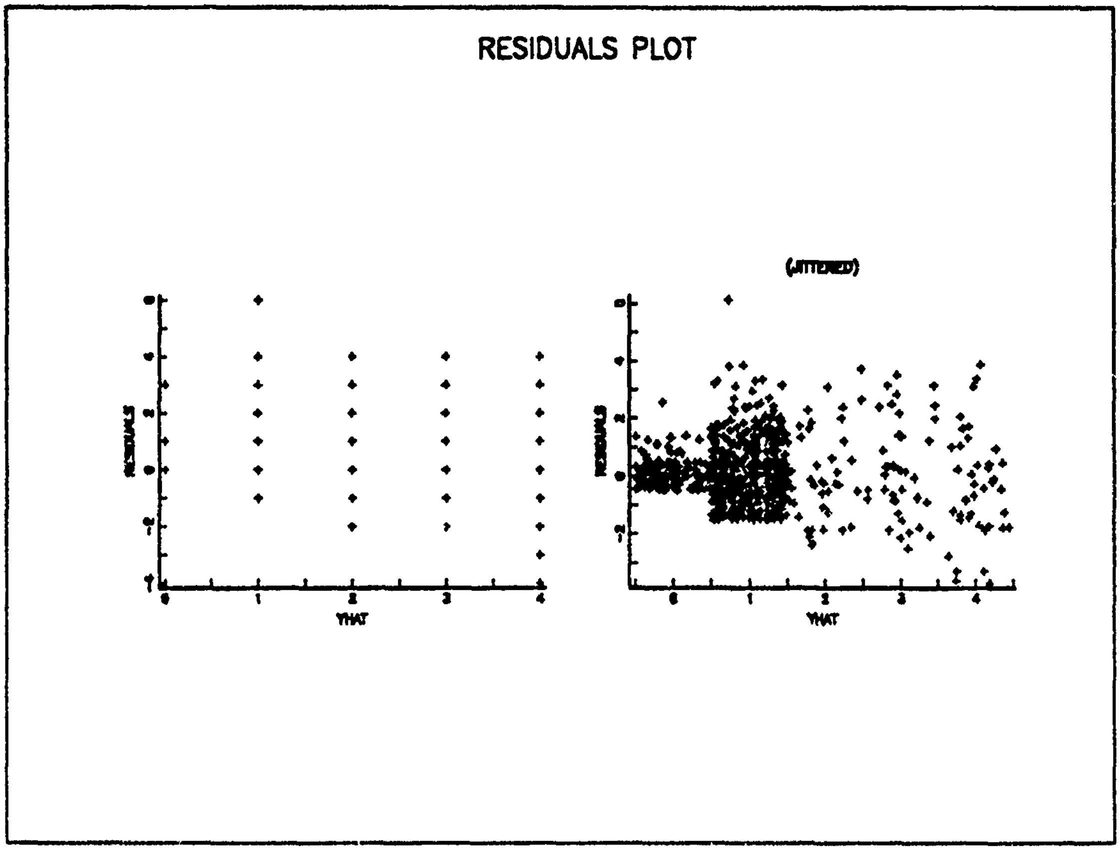

Figure 5. Residual plots, ANOVA with dependent variable KILLS

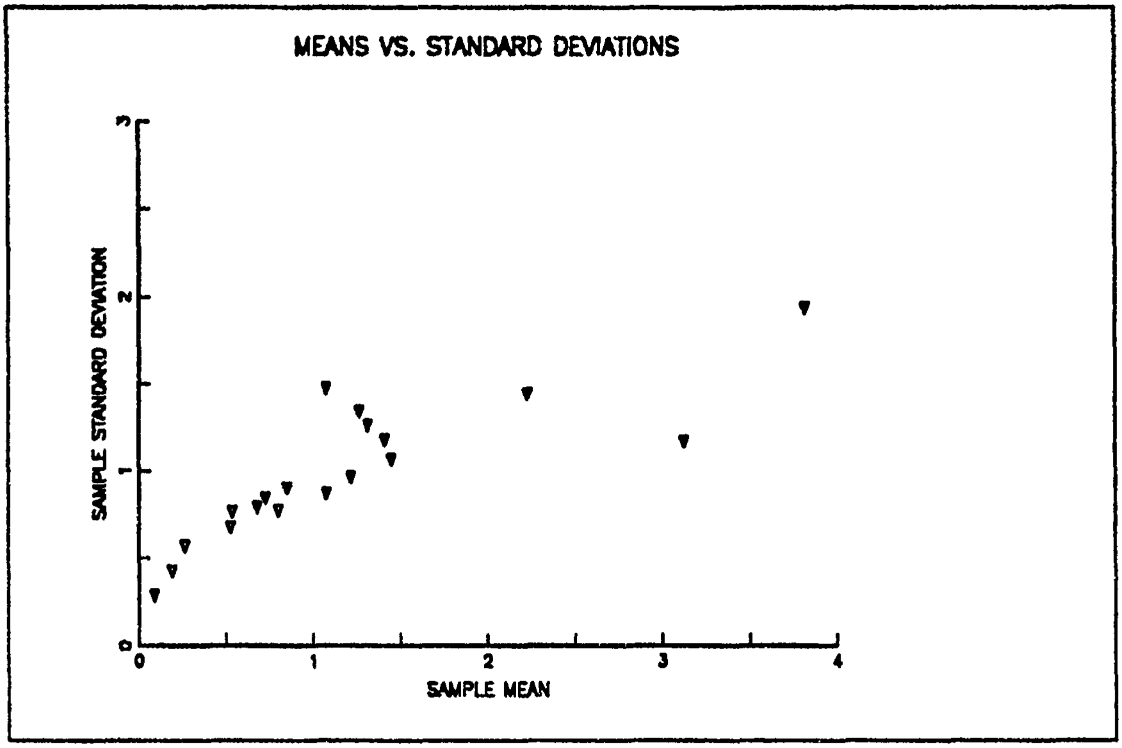

Figure 6. Means vs. Standard Deviations for Janus KILLS data

A logarithmic transform was performed on the "kills" data. Because several of the values are zero, the following was the actual transform used:

$$\text{LOGKILL} = \ln(\text{KILLS} + 0.5)$$

After conducting ANOVA on these values, the residuals were plotted (Figure 7 on page 22). This plot suggests the homogeneity of variance assumption is tenable for the LOGKILL data. The plot also shows clearly that the LOGKILL responses are discrete. Thus, technically, the normality of residuals assumption of ANOVA is not satisfied [Ref. 7]. However, the calculated significance values in ANOVA have been shown to be quite robust with respect to this type of non-normality [Ref. 8].

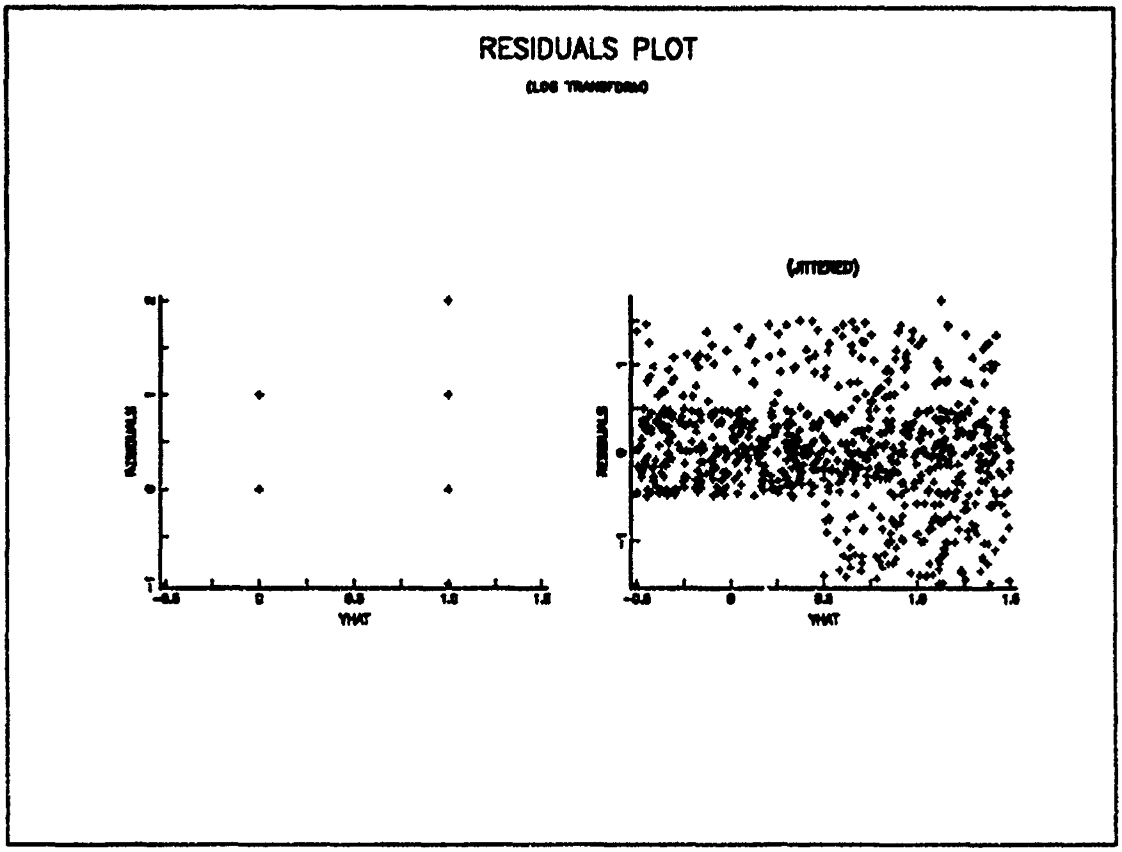

Figure 7. Residual plots, ANOVA with dependent variable LOGKILLS

Again, the ANOVA results with the transformed data (Figure 8 on page 23) indicate a strong significance of scenario×treatment interaction. These interaction effects have to be accounted for before a meaningful comparison of treatment effects can be made.

GENERAL LINEAR MODELS PROCEDURE					
DEPENDENT VARIABLE: LOGKILL					
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	19	229.41961937	12.07471681	61.81	0.0
ERROR	1580	308.67656699	0.19536492		ROOT MSE
CORRECTED TOTAL	1599	538.09618636			0.44200104

SOURCE	DF	TYPE IV SS	F VALUE	PR > F
SCENARIO	9	198.76613342	113.05	0.0
TREATMNT	1	5.25035068	26.87	0.0001
SCENARIO*TREATMNT	9	25.40313528	14.45	0.0001

Figure 8. ANOVA with LOGKILLS

D. FURTHER ANALYSIS

In order to accommodate the scenario×treatment interactions, and yet be able to test the hypothesis of no difference due to treatments, a Scheffe contrast procedure was conducted on the differences between treatments for each scenario $(y_{i2k} - y_{i1k})$. The Scheffe procedure can be used to define groups of the "nuisance" factor (i.e., scenarios) which have similar levels of effect. Applied to differences between treatments, the Scheffe procedure suggests separating the scenarios into two distinct groups (Figure 9 on page 24). From these results, it was decided to define Group A as the six scenarios 5, 2, 1, 4, 6, and 10, and Group B as the remaining four scenarios, 3, 8, 9, and 7. Further ANOVA tests were next performed on these two sets of data, with the expectation that interaction effects would be less pronounced within each group.

```
SCHEFFE'S TEST FOR VARIABLE: KILLD
NOTE: THIS TEST CONTROLS THE TYPE I EXPERIMENTWISE ERROR RATE
      BUT GENERALLY HAS A HIGHER TYPE II ERROR RATE THAN REGWF
      FOR ALL PAIRWISE COMPARISONS

            ALPHA=0.05  DF=790  MSE=2.20843
            CRITICAL VALUE OF F=1.89171
            MINIMUM SIGNIFICANT DIFFERENCE=.98693

  MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

      SCHEFFE  GROUPING               MEAN      N  SCENARIO

                     A              0.2750     80  5
                     A
                     A              0.1875     80  2
                     A
                     A              0.1000     80  1
                     A
                     A              0.0500     80  4
                     A
                     A              0.0000     80  6
                     A
                     A             -0.0500     80  10
                     A
                B    A             -0.5500     80  3
                B    A
                B    A             -0.6875     80  8
                B
                B                  -1.0750     80  9
                B
                B                  -1.2875     80  7
```

Figure 9. Scheffe Test results, output from SAS procedure GLM

The ANOVA of LOGKILL for data in Group A (Figure 10 on page 25) indicates that the interaction is not significant for these data. Thus, the results can now be generalized over scenarios in Group A. The high F-value for treatments indicates that there *is* a significant difference in LOGKILL outcomes, due to the treatments. This F-value is sufficient to reject the null hypothesis of no difference in treatment effects, for Group A scenarios. Since the mean differences $\bar{y}_{i2} - \bar{y}_{i1}$ for the scenarios i = 5, 2, 1, 4, 6 are non-negative, it is concluded that LOGKILLS is significantly larger for missions conducted as batteries than for missions conducted as platoons. This suggests the same conclusion for treatment effects with KILLS.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGKILL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	11	48.98187676	4.45289789	22.25	0.0001
ERROR	948	189.73426461	0.20014163		ROOT MSE
CORRECTED TOTAL	959	238.71614137			0.44737191

SOURCE	DF	TYPE IV SS	F VALUE	PR > F
SCENARIO	5	46.83076707	46.80	0.0001
TREATMNT	1	0.84430472	4.22	0.0403
SCENARIO*TREATMNT	5	1.30680498	1.31	0.2591

Figure 10. ANOVA on sub-group A (scenarios 1, 2, 4, 5, 6, & 10)

The ANOVA results for Group B, however, are not as definitive. (Figure 11). The significance of the treatments here is also very strong, but it is clouded by the interaction between scenario and treatment. Interpretations about the difference between treatments in this group must be made with care.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGKILL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	7	123.53830122	17.64832875	93.77	0.0
ERROR	632	118.94230238	0.18819985		ROOT MSE
CORRECTED TOTAL	639	242.48060359			0.43382006

SOURCE	DF	TYPE IV SS	F VALUE	PR > F
SCENARIO	3	95.03592496	168.32	0.0
TREATMNT	1	22.54668462	119.80	0.0001
SCENARIO*TREATMNT	3	5.95569164	10.55	0.0001

Figure 11. ANOVA on sub-group B (scenarios 3, 7, 8, & 9)

The nature of the interaction for Group B scenarios can be seen in Figure 12 on page 28. There is not a "cross-over" in treatment means for scenarios in this group.

Rather, there is a "wedge-shape" increasing difference between these means, as scenarios range over 3, 8, 9, and 7. In all these scenarios, the Treatment 1 mean is greater than the Treatment 2 mean (i.e., $\bar{y}_{i2} - \bar{y}_{i1} < 0$, for $i = 3, 8, 9, 7$). It is thus reasonable to conclude there is evidence of higher KILLS with platoons that with batteries, for Group B scenarios.

VI. OPERATIONAL ANALYSIS

A. DISCUSSION OF THE RESULTS

The Scheffe procedure provided a categorization of scenarios, based upon the differences in LOGKILL between treatments. A positive mean difference suggests that Case 2 (batteries) was better than Case 1 (platoons); a negative value suggests the opposite. As seen in the previous chapter, the Scheffe contrast method applied to the difference data suggested two groups. Group A contains all of the scenarios in which the mean difference was positive (Case 2 superior) plus one [very small] negative value. These data were sufficient to reject the null hypothesis of no difference due to treatment effects. That is, in these scenarios (Group A), there appears to be a significant advantage with eight-gun batteries.

Group B was comprised of scenarios 3, 7, 8 and 9, all of which have negative differences of means (Case 1 is superior). Although the ANOVA for this group, alone, indicates there is still significant scenario×treatment interaction, it is possible to make an overall conclusion about treatment effects for these four scenarios. The plotted sample means in Figure 12 on page 28 support the reasoning that these four scenarios all have corresponding population mean differences less than zero. This implies that, for Group B scenarios, there is an advantage in firing as four-gun platoons.

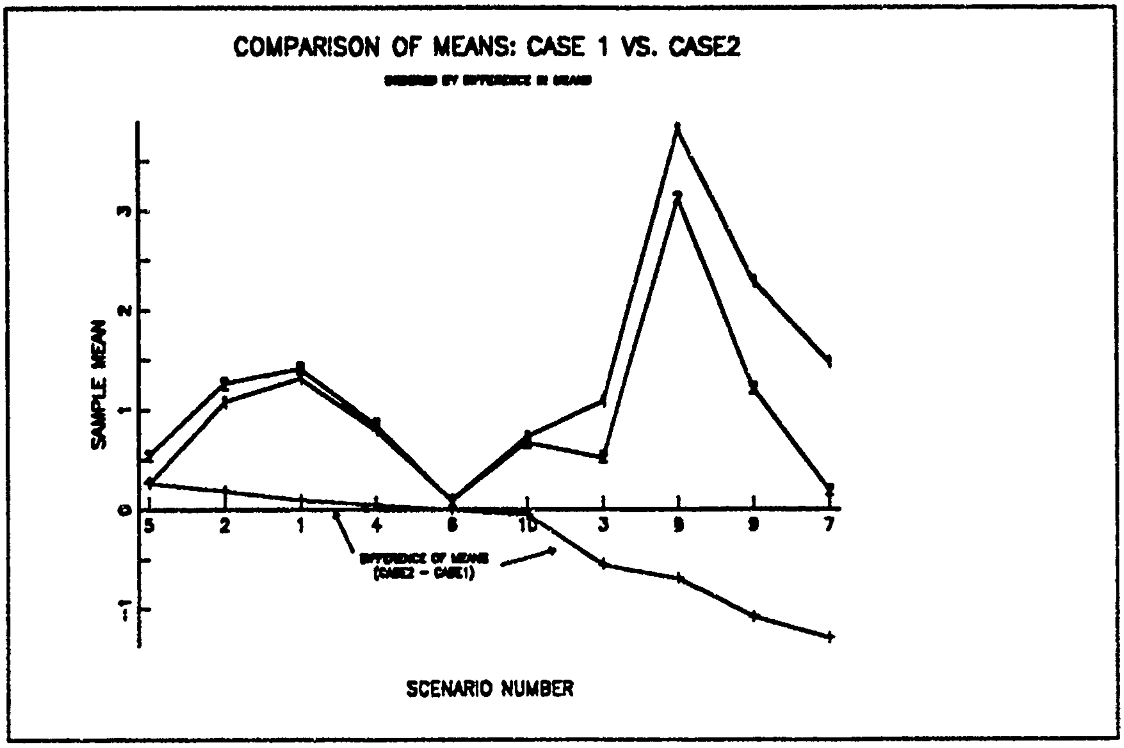

Figure 12. Comparison of Means: Scenarios ordered by decreasing difference in means.

B. COMMONALITY WITHIN SCENARIO GROUPS

In attempting to account for the different effects of treatments between the scenarios of Group B and those of Group A, several possible factors were evaluated, as shown in Table 3 on page 29. There are no simple, outstanding commonalities (recognizing that this is a subjective grading scheme). But one factor which *does* appear to be consistent and distinct among Group B scenarios is the volume of fire during the simulated battle. It seems that those scenarios which had a higher volume of fires[9] produced larger mean kills in Case 1 than in Case 2. But why?

9 volume of fires was the same for both cases within a given scenario

Table 3. **COMPARISON OF SCENARIOS:** (Group A normal, Group B *italics*)

Scenario	Time of Day	No. of missions fired	No. of rounds (approx)	Volume of fires	Accuracy and/or Timing
5	night	avg	192	mixed	poor
2	day	few	108	high	good
1	night	many	100	low	very good
4	day	few	120	mixed	good
6	day	few	150	low	poor-fair
10	day	many	180	mixed	fair
3	*night*	*avg*	*240*	*high*	*poor*
8	*night*	*many*	*250*	*high*	*fair-good*
9	*night*	*few*	*220*	*high*	*fair*
7	*day*	*avg*	*173*	*high*	*poor*

A possible explanation is this: With platoon missions, the smaller firing elements create a greater "variance" of fires. Note that the Group B scenarios also all had poor to fair accuracy of fires. So, with twice as many platoons engaging more "targets"[10] than batteries could, a greater "coverage" of fires is created, both over area and over time. Because the targets are rapidly moving, the larger area of coverage actually increases the probability of an artillery hit, even though the concentration of rounds per unit area has decreased. But this effect is only realized in the larger volumes of fire, perhaps because at lower volumes the total number of rounds is too low to have an advantage either way.

Analysis of Group A scenarios reveals the following trend: massed fires (i.e., battery missions) were generally more effective when more accurate target intelligence (location and timing) was available (as indicated by the accuracy/timing of a unit's fires). A corresponding *lack* of target intelligence gave an advantage to platoon fires. This makes intuitive sense, since massed fires can only kill a target if there is a target *hit*. Conversely, if the target location is vague, the area coverage provided by platoon fires yields a higher expected outcome, since the randomness increases the probability of a hit. This is exactly why massed fires are most effective against stationary, point targets; they are not necessarily so effective against moving, armored targets.

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10 meaning fire missions, regardless of whether an actual enemy target was at the location

VII. CONCLUSIONS

A. OPERATIONAL IMPLICATIONS

The results of analysis indicate that, statistically, there is a significant difference in whether artillery is employed as batteries or as platoons. But the advantage, in terms of kills, can go either way, depending upon the scenario. However, in determining the *operational significance* of these results, the numbers must be put into an operational context. In most scenarios, the actual difference in outcomes between cases was in terms of *fractions of a kill.* In *all* scenarios and treatments, the number of kills compared to the number of enemy forces (over 100) is very low. The statistical significance of the output data is therefore overshadowed by the fact that these differences have very little impact upon the actual outcome of the battle. It is therefore suggested that the difference in battlefield effects of artillery, merely as a function of battery vs. platoon operations, is negligible.

Also, as mentioned earlier, the effects of *suppression* have not been specifically addressed by this research. It has been assumed that implications derived from the analysis of "kills" can be applied to suppressive effects as well. Recognition should be given, however, to the fact that suppression is, in itself, a significant role of artillery, particularly for a direct support battalion in a deliberate defense scenario, against an armored threat. Suppression effects have unique qualities of their own, and can be used not only to influence "kills," but also to influence the tactical play of the battle. It can be used to influence enemy maneuver as well as to suppress enemy artillery. The results discussed in this analysis are valid for some aspects of suppression, but the value of suppression is likely to be much greater than indicated by the MOE of "kills". But just as with "kills", the results of this study indicate that the effects of suppression are not as dependent upon battery vs. platoon operations, as much as they are on other, scenario-driven factors.

The bottom line for the statistical analysis is that differences in effects *are* incurred due to the chosen method of employment, but whether the effects increase or decrease depends upon the *scenario*. In the model used for this research, the "scenario" includes not only environmental factors surrounding the battle, but also all of the intangible, unit-oriented factors such as level of training, unit proficiency, commander's intent, level of execution, command and control, communications, and innumerable others. The implication of the results is that the supposed decreases in artillery effectiveness which have been observed by the NTC personnel must be caused by factors other than just the firing unit size. Perhaps the causes for decreased observed effects are related to the 3x8 force structure, but it does not appear to be because of the *inherent* properties of four guns versus eight. Further analysis should focus on other factors surrounding this issue, such as training, leadership, and command and control.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

Further research could be applied towards other aspects of the 3x8 controversy. One of the many issues which surfaced during this research was that of equipment breakdown, and the subsequent ramifications upon artillery units' effectiveness. Considering the reality of situations in which one or two howitzers may be unavailable for fires at a particular time, the impact upon effectiveness could be significant.

It is doubtful that further analysis with this same methodology will yield new insights. The scenarios collected for this research represent an adequate sampling of the battles which have been conducted over the stated period. Further data collection has little potential for new results. Further, because of an upgrade in the livefire automation system the battle scenarios are no longer standardized as they were previously. Therefore, further research and analysis with this particular methodology is not recommended.

Currently, at the Field Artillery School and Center at Fort Sill, Oklahoma, research is being done to update the weapons effects tables for current munitions. Such data has not been verified in over 30 years. The results of these analyses could provide a new database of JMEMs data, which would justify a further analysis of optimal battery size for direct support battalions.

C. CONCLUSION

The level of battlefield effectiveness achieved by artillery *is* influenced by the factor of how the battery is employed, but whether the advantage lies in battery fires or in platoon fires is stringently dependent upon the scenario. People who are very close to the 3x8 controversy may not be comfortable with these results. But the results should not be ignored. "Scenario," in the usage of this methodology, includes many factors which may be a *direct result* of the way 3x8 has been implemented, so the 3x8 issue still needs tough scrutiny. The research presented here does not refute the *observations* of personnel at the National Training Center, but does provide a basis for declaring the argument that "eight is inherently better than four" as insubstantial. The findings are that other, scenario related factors dominate the issue of 3x8 battlefield effectiveness, and *that* is where attention should be focused.

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