A RAND NOTE

Applying the National Training Center Experience: Artillery Targeting Accuracy

Martin Goldsmith, James Hodges,
Marion L. Burn III

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This Note describes a study that examined the accuracy of simulated artillery fires during force-on-force engagements at the National Training Center (NTC). The authors found that only about one-third of artillery missions were either effective or suppressive. Available data show that artillery observers using only map, compass, and binoculars cannot consistently achieve accurate first-round fire-for-effect. NTC data show that initial fire plans are likewise insufficiently accurate. The authors make recommendations for doctrinal and procedural improvements and for added training equipment.

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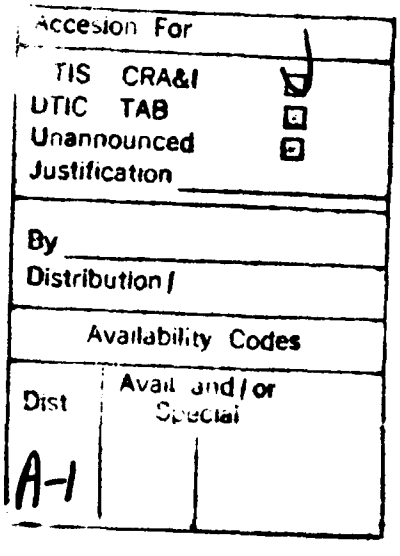

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PREFACE

This Note reports on one phase of an ongoing project at the Arroyo Center, "Applying the NTC Experience." The goal of the overall project is to apply the experience and information gained at the National Training Center (NTC) at Fort Irwin, California, to problems beyond the NTC's mission of training. Relevant matters might be doctrine, materiel development, or other factors for which the NTC "laboratory" can offer data and insights otherwise unobtainable.

Other Notes in this series have dealt with methodologies for conducting research using the NTC data system,[1] the problem of fratricide by indirect and direct fire as observed in training engagements,[2] and tactical reconnaissance as practiced by the Blue training forces and the opposing force (OPFOR).[3]

The problem examined here is the accuracy of artillery targeting during force-on-force engagements. The study suggests doctrinal, organizational, materiel, and training solutions to artillery targeting accuracy problems. It is directed toward both fire support and maneuver elements.

Major Burn is a member of the Operations Group at the NTC.

THE ARROYO CENTER

The Arroyo Center is the U.S. Army's federally funded research and development center for studies and analysis operated by The RAND Corporation. The Arroyo Center provides the Army with objective, independent analytic research on major policy and management concerns, emphasizing mid- to long-term problems. Its research is carried out in

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[1]N-2461-A, *Utilizing the Data from the Army's National Training Center: Analytical Plan*, R. A. Levine, J. S. Hodges, and M. Goldsmith, June 1986.

[2]N-2438-A, *Applying the National Training Center Experience--Incidence of Ground-to-Ground Fratricide*, M. Goldsmith, February 1986.

[3]N-2628-A, *Applying the National Training Center Experience: Tactical Reconnaissance*, M. Goldsmith with J. S. Hodges, October 1987.

five programs: Policy and Strategy; Force Development and Employment; Readiness and Sustainability; Manpower, Training, and Performance; and Applied Technology.

The Army sponsor for the NTC project is the Combined Arms Training Activity (CATA) at Fort Leavenworth, Kansas. CATA has identified fire support as a priority issue.

Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee, which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-86-C-0059.

The Arroyo Center is housed in RAND's Army Research Division. The RAND Corporation is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

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SUMMARY

BACKGROUND AND OBJECTIVES

During force-on-force battle simulations at the National Training Center (NTC), indirect fires (artillery, mortars) are played through use of the computerized position/location instrumentation system, based on the player's calls for fire. Sensory simulation is provided by pyrotechnics discharged by observer/controllers or fire markers. Because cannon error is absent, the accuracy of the artillery is wholly dependent on the accuracy of the initiating call for fire or on an existing fire plan.

In 1985, data taken incidental to another study showed that approximately one-third of artillery fires fell close enough to the opposing force (OPFOR) units to be rated as effective (in causing casualties) or suppressive. The volume of fires also seemed lower than desirable. Reaction to these data was that accuracy could and should be improved. The purpose of the present study is to determine what factors might be operating to limit accuracy and what means could be proposed to improve accuracy--and thus artillery effectiveness.

FINDINGS

The same data sources the 1985 study used were examined for the early months of 1987 and the late months of 1988. Although the 1987 data were essentially unchanged from those of 1985, in 1988 the volume of fires substantially increased. Consequently, battle damage assessment resulting from artillery had increased. However, the accuracy had not changed. Our first conclusion was that improvements in tactics, techniques, and procedures reflected in improved volume had not affected accuracy.

Reasoning that the accuracy of calls for fire would depend on (1) the actions and capabilities of forward observers (FOs) and company fire support officers (FSOs), and (2) the accuracy of fire support plans, we investigated these factors. We undertook a field study of the actions

of company FSOs and found that while such officers were often in a position to properly call for fire, they were almost never equipped with position/location equipment to assist in making accurate target determinations. We also found that the platoon FOs were generally underutilized.

Using the ability to replay NTC instrumentation tapes in the RAND Combat Analysis Laboratory, we examined the accuracy of the fire plans created by battalion task forces during offensive engagements. We found that the fires planned for individual targets were coincident with OPFOR locations in approximately one-fifth of all cases, whereas the fires planned for groups of targets fell, at least in part, on OPFOR locations about 40 percent of the time. Therefore, we concluded that initial fire plans are one factor limiting targeting accuracy and that means must be sought to improve the situation.

Knowing that in most cases forward observers, scouts, and planners are not equipped with any position/location aids other than map, compass, and binoculars, we sought data on how accurately a trained soldier could locate targets in the field. (Current laser rangefinders cannot be used at the NTC during force-on-force situations because they are not eye-safe.) Studies conducted by the field artillery community during the late 1970s and early 1980s showed that the unassisted observer can expect a mean target location error of about 500 meters. This is insufficient to obtain reliable first-round fire-for-effect. Therefore, the underlying capability for observer and target position/location must be one of the factors limiting artillery accuracy at the NTC.

This fact is inadequately covered in the doctrinal literature. Both maneuver commanders and fire support team members are led to believe that accurate first-round fire-for-effect is a reasonable expectation even without use of position/location equipment. In fact, such an expectation is highly situation dependent. Moreover, the manuals lack specificity regarding the shared responsibility for the correct placement of artillery observers on the battlefield. Several manuals concentrate on the planning and allocation of fires, but details of execution are given short shrift.

RECOMMENDATIONS

Based on these findings, we recommend that an eye-safe laser rangefinder-based target location system be provided for training. A position/location (navigation) system is also necessary for prebattle target location, as well as for targets of opportunity during battle. In addition, we recommend additions to doctrine that (1) emphasize the capabilities and limitations of observers, and (2) discuss in more detail the requirements for physical placement of artillery observers on the battlefield. Because of the mobility and equipment limitations of the FOs attached to the mechanized infantry platoon, we recommend that those personnel be converted to combat observation lasing teams (COLTs) and provided with the appropriate equipment.

ACKNOWLEDGMENTS

The authors wish to express their deep appreciation to the members of the Operations Group of the National Training Center. It was only through their cooperation that the data for this study could be collected. The field artillery community within the Operations Group was generous with advice and guidance.

Kevin Terpstra and James House of The RAND Corporation staff were responsible for much of the data gathering and reduction effort.

The authors wish to acknowledge their debt to all the soldiers who have contributed their insights and observations during the conduct of this work; their input brought life to our study.

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FIGURES

TABLES

GLOSSARY

BDA	Battle damage assessment
BMP	Soviet infantry fighting vehicle
COLT	Combat observation lasing team
DA	Deliberate attack
DIS	Defend in sector
FASCAM	Family of scatterable mines
FDC	Fire direction center
FFE	Fire for effect
FIST	Fire support team
FIST-V	FIST vehicle
FO	Forward observer
FSE	Fire support element
FSO	Fire support officer
G/VLLD	Ground/vehicle laser location designator
GPS	Global positioning satellite
GSR	Ground surveillance radar
HA	Hasty attack
IFCAS	Indirect fire casualty assessment system
IPB	Intelligence preparation of the battlefield
LRF	Laser rangefinder
ME	Meeting engagement
MILES	Multiple integrated laser engagement system
MRE-m	Mean radial error-meters
MTC	Movement to contact
NCO	Non-commissioned officer
NTC	National Training Center
O/C	Observer/controller
OP	Observation post
OPFOR	Opposing force
PLRS	Position location ranging system
TAF	Training analysis and feedback
TRP	Target reference point

I. INTRODUCTION

MOTIVATION FOR THE STUDY

In 1985-1986, RAND's Arroyo Center carried out a study of direct and indirect fire fratricide at the National Training Center (NTC). During the analysis of the indirect fire data contained in the daily logs of the fire support team of the NTC Operations Group, several interesting results were noticed (aside from the fratricide values themselves). On average, some 27 fire missions were fired by the Blue task force in each battle, and of those about one-third were rated as effective or suppressive against the opposing force (OPFOR); the others were classed as misses.[1]

These results were discussed in passing in the written report of the work and in briefings. Reactions varied: some Army personnel felt that these values were about what they would expect; others felt that the artillery effectiveness should be higher. No standards existed at the time, so differences in viewpoint were to be expected.[1] Many factors might affect the volume of fire. However, the question of accuracy is more circumscribed, and we can reasonably conclude from the results that there is opportunity for improvement. (If artillery effectiveness (accuracy) were close to 100 percent, opportunities for improvement would be limited.)

Because of that report and as a general consequence of other observations made at the NTC, interest in the fire support system at the NTC increased. A growing consensus of dissatisfaction developed, but clear solutions to perceived difficulties proved elusive. During rotation 86-5, Field Artillery School personnel led a Combined Arms Assessment Team (CAAT) in an intensive look at artillery play, and the team made several findings and suggestions for improvement.[3] In

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[1]Subsequently, Army Training and Evaluation Program (ARTEP) Mission Training Plans (AMTP) have been published that contain such standards. For example, AMTP 71-1 [2] states that 80 percent of rounds should fall on the enemy and 75 percent of the fire missions should fall on the enemy.

rotations 87-10 and 88-12, other CAATs revisited the problem. In each case, specific recommendations were made to increase the overall effectiveness of fire support. In spite of this increased attention to fire support, it was commonly believed until quite recently that little improvement resulted, although units improved on many other aspects of their training.

To corroborate (or contradict) the belief that artillery effectiveness had not improved, the Observation Division of the NTC Operations Group began accumulating summary data for the indirect fire play, both for force-on-force and live-fire exercises. During 1987, the data indicated that nothing had changed substantially since 1985, the time of the earlier RAND report. With this background, the Center for Army Lessons Learned (CALL) at Fort Leavenworth named fire support as a priority issue and has been following several avenues of approach to identify solutions. Our study is but one of these. Its purpose is to determine what factors might be operating to limit accuracy and to propose means to improve accuracy and, thus, artillery effectiveness.

APPROACH TO THE PROBLEM

A brief scrutiny of the process of delivery of indirect fires reveals the complexity of the problem. The reader is reminded that fires are requested by observers whose knowledge of the target and the general situation may be inaccurate or incomplete. The request must be processed and fire direction given to a cannon crew at a different location. The players are connected by battlefield communication systems that are often fragile and subject to enemy interference. All this activity takes place in a fast-moving situation, and is compounded by the fact that artillery is a limited commodity that a commander must allocate with care. To fully analyze such a system, concurrently for all factors, requires a major resource commitment. Such an approach may not be necessary to obtain meaningful results. Often it is preferable to divide a problem into component parts, examining the segments separately; we have elected that approach.

We divided the problem according to the following rationale. At the outset, we recognized that we were dealing with fire support at the battalion and brigade level. Thus, we expected the battlefield to be dynamic, with movement of both attackers and defenders. In a classic bombardment in which saturation of fixed positions is carried out, the fires can be called by commanders according to fixed plans. Such was not our situation. The *first element* we considered was the forward observers (FOs) and company-level fire support officers (FSOs) who operate as a fire support team (FIST). They are expected to call fires on targets of opportunity and synchronize fires on known targets according to the fire support plan. They connect into the *second element*, a fire support communication and decision system that can operate manually and by voice communication, but that is now most likely to be carried out by the TACFIRE computer system with digital communication. The battalion and brigade level maneuver commanders are in that decision system indirectly through their fire support staffs. Once the fires are called for, approved, and processed, the actual delivery is carried out by the firing batteries (the *third element*). Thus, the fire execution system has three major divisions: the callers, the processers, and the shooters. Because of the necessity for careful allocation of fire support, the prebattle planning process receives great attention and should be considered a *fourth element*. We have organized our approach to analysis of fire support according to these divisions.

Another factor that must be considered in our study is the artificiality of the NTC indirect fire system. While the live-fire exercises involve the actuality of real tubes shooting real bullets whose effects can be clearly observed, such is not true for the force-on-force exercises. The system works as follows. When fires are called for and processed in the standard fashion, the approved fire call is passed to a firing battery as the last step. (Sometimes this battery is a real one that must execute a dry-fire exercise. Often, however, the actual batteries are employed in the live-fire exercise area, and the "tubes" are notional, although a substitute battalion fire direction

center is in place.) Unfortunately, there is no indirect fire analogue to the direct fire multiple integrated laser engagement system (MILES) for executing the fires in a nonlethal fashion while properly influencing the course of the battle. Instead of a physical firing from the battery, the call for fire is simultaneously passed to the NTC Core Instrumentation Subsystem (CIS) facility. There, Operations Group personnel enter the details of the fire command into the computer system. The Indirect Fire Casualty Assessment System (IFCAS) generates an impact area "box" at the called-for target point. There are no firing battery mistakes; the rounds land where the call for fire specifies. At this point, two things must happen: some physical evidence of the firing must be created, and proper casualties must be assessed.

The fire support team at the CIS puts out a call to fire markers or to observer/controllers located in the field, who move to the correct location and discharge ground-burst and/or air-burst pyrotechnic artillery simulators. These simulators by no means represent the full impact of artillery rounds, but they do yield a visual and acoustic signature that indicates to fire callers and maneuver elements where and when indirect fires have fallen.

For casualty assessment, munitions effects tables are used to determine the effectiveness of the rounds fired against standard targets (e.g. infantry platoon, prone). The information on the fire call is passed to the analysts in the Training Analysis and Feedback (TAF) center, who monitor the progress of the battle with the aid of the CIS and who maintain constant contact with the observer/controllers (O/C) in the field. The TAF analysts and the O/Cs in the impact area determine whether there are actual target elements in the IFCAS box, and if so, what casualties should be assessed. Either the O/C directly, or the analyst remotely, activates the MILES sets on the player elements to produce the casualties.

Thus, we see that there is actually a *fifth element* to the fire support system at the NTC (i.e., the NTC indirect fire system itself). This study will not, however, analyze the performance of the NTC system,

except insofar as it affects our analysis of training unit fire support problems.

FOCUS OF THE STUDY

We will subsequently show that in terms of volume of fire, the performance of units at NTC has improved. However, accuracy of fire has not improved. Therefore, our work will concentrate on the first sequential elements in the fire support chain--the FOs and the FSOs. There is a two-fold rationale for this selection. First, other parties have given a great deal of attention to fire support planning (the fourth element) and to the operation of the fire support decision and communication system (the second element). It is not clear that further observation of the rotational units would yield new insights. Second, to obtain detailed quantitative information on such an important point as the time sequencing of calls for fire through the TACFIRE system seems technically beyond our reach at this time. Problems such as inaccuracy of fire cannot result from battery operations (the third element), at least for force-on-force exercises at the NTC. These negatives caused us to put the last four elements aside for the moment in our investigation.

The positive factors that caused us to concentrate on the first element stem from previous research and observations. In a study of tactical reconnaissance [4], we found that artillery forward observers were seldom included in reconnaissance activity, that the scouts identified enemy positions only about half the time, and that scouts had great difficulty accurately locating themselves and the enemy. Thus, we have good reason to suspect that preplanned targets may not coincide with actual enemy locations and that the enemy was not under actual observation by the artillery observers. Other less structured observations lead us to believe that maneuver units are often unable to locate themselves and the enemy accurately; therefore, we might expect that indirect fire targets of opportunity are similarly inaccurately specified. These considerations alone suggest that the company-level fire support system will be a fruitful research topic.

OUTLINE OF THE REPORT

In Sec. II, we review firing data as contained in the logs of the fire support division of the Operations Group. The review includes the volume and accuracy of fires, as well as some information on the origin of calls for fire. Section III deals with data taken for our study by O/Cs in the field about the actions of FOs and FSOs. Section IV includes data relating to the accuracy of fire support plans. These three sections show what is actually happening at the NTC. Section V briefly discusses some data on the capabilities of trained fire observers taken from previous U.S. Army studies, and Sec. VI reviews the doctrinal literature so we can compare what is being done (or what is needed) to what "the book" says. In Sec. VII, we summarize the fire support problem in the light of the data and information from the previous sections and present our conclusions and recommendations.

II. NTC ACCURACY DATA

OPERATION OF THE NTC ARTILLERY SYSTEM

As a preface to the following discussion, we will again outline briefly the mode of operation of the artillery system at the NTC for force-on-force exercises. Although the direct fires of the battle are simulated by the MILES, no such physical analogue exists for indirect fires. The simulation is handled using the NTC instrumentation computer. Calls for fire are made by the training unit as they would be in actual battle. When the call for fire reaches the battalion fire direction center (FDC), a member of the NTC Operations Group fire support team (Werewolves) passes the called-for mission to an operator in the central computer facility, using the O/C radio net. The data for the mission are entered into the NTC computer manually; an NTC fire marker is dispatched to the intended impact area. When the mission is fired (notionally) by the battery, the observer at the FDC notifies the NTC computer operator, who "fires" the mission, and instructs the fire marker to discharge pyrotechnic simulators in the impact area as appropriate.

A scaled IFCAS box appears on the map on the computer screen at the end of a vector from the firing battery. All IFCAS boxes are of uniform size, 260 by 600 meters on the ground. Between the analysts in the central computer facility and the O/Cs in the field, battle damage assessment (BDA) is evaluated using standard tables of casualties from the NTC Rules of Engagement, depending on the number and nature of the munition and the disposition of personnel and vehicles in the target area (if indeed such exist). In manual logs maintained by the Werewolf personnel, the missions are recorded and include a judgment as to whether a mission was effective, suppressive, or ineffective.

Effective missions are defined as those in which the defined area of fall of rounds (the IFCAS box) as exhibited by the NTC instrumentation computer system encompasses enemy elements. A suppressive mission is defined as one in which the boundary of the IFCAS

box lies within 500 meters of an enemy element. The falling rounds are considered to have no effect on elements outside that area. Thus, the definition of effectiveness refers only to accuracy, not to battle damage that might actually be achieved by the mission or to the mission's importance to the battle. A diagram of the IFCAS box is shown in Fig. 1. The area encompassed by the suppressive box is approximately 1.8 square kilometers, covering nearly two standard grid squares.

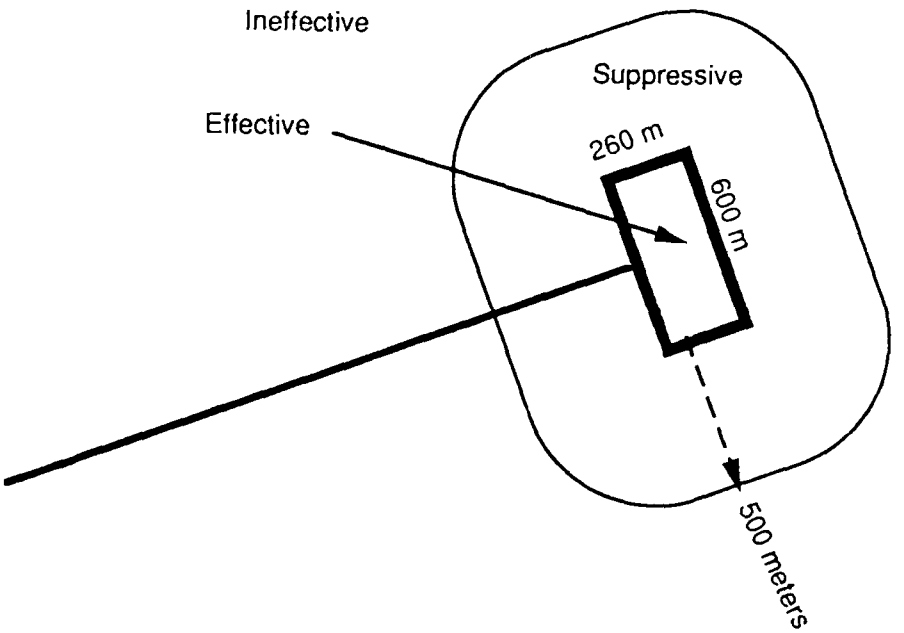

Fig. 1--The IFCAS box

BLUE ARTILLERY ACCURACY

In a 1985 Arroyo Center study of fratricide, some NTC data on artillery results were examined. At that time, researchers found that approximately 3 percent of artillery missions fell on or near friendly forces (fratricide). As a secondary finding, the study displayed the accuracy exhibited in artillery play at the NTC. Table 1 summarizes the data, which cover 116 battles of various types. The average number of

Table 1

ARTILLERY EMPLOYMENT, 1985

Battle Type	Average Missions Fired	Effective/ Suppressive Missions	
		Average	Percentage
Deliberate attack	27.7	8.5	30.7
Movement to contact	24.9	8.3	33.3
Night attack	17.9	8.8	49.2
Defend sector	25.2	6.8	27.1
Defense battle position	34.1	12.5	36.6
Average overall	26.7	8.8	33.0

SOURCE: M. Goldsmith, *Applying the National Training Center Experience--Incidence of Ground-to-Ground Fratricide*, The RAND Corporation, N-2438-A, February 1986.

fire missions is listed together with the number of effective plus suppressive missions. Smoke, illumination, and family of scatterable mine (FASCAM) missions are excluded.

At the time the study was presented, reactions to the artillery data varied. However, the most general response was that it should be possible (and would be desirable) for the training forces to fire more missions during a battle, and that the value of approximately one-third for effective/suppressive missions, while not necessarily unexpected, showed that there was an opportunity to greatly increase the artillery system's effectiveness, without increasing the number of guns or units or even the expenditure of munitions. As we have stated, that study and the reactions to it prompted our study of artillery effectiveness at the NTC.

The units training at the NTC have shown continuous improvement in many combat capabilities through the years. Like other operating systems, the artillery system has received training attention from the NTC staff, the U.S. Army Field Artillery School, and the training units

themselves. Therefore, the first step in this study was to examine the artillery record for years after 1985 to see what changes might have occurred. Table 2 shows some results taken from two time periods. The first includes battles conducted in early 1987, from rotations 87-4 through 87-8. Both mechanized infantry and armor battalion task forces are included and encompass approximately 50 offensive and defensive force-on-force battles. Data for artillery were taken from the logs kept by the fire support training section of the NTC Operations Group. As mentioned above, the logs are kept on a daily basis by the Operations Group staff manning the artillery control computer stations. The circumstances of each artillery and mortar mission are recorded and include the origin of the call for fire, the rounds, the target location, and the outcome of the mission in terms of the location of the IFCAS box in relation to the enemy force.

The data are divided into offensive and defensive engagements. The average number of fire missions in each battle did not increase substantially from the values found in 1985. Likewise, the fraction of effective and suppressive missions did not change significantly. The fraction of effective/suppressive rounds is quite similar to the fraction of effective/suppressive missions, indicating that there is little "loading up" on missions observed to be effective. We also used the tables of casualties in the written take-home packages to determine the battle damage assessment attributed to artillery for this data set. We chose to consider only kills of tanks and BMP armored personnel carriers in making this determination, simply as an indicator of the effectiveness of artillery against the OPFOR.

We then repeated this data collection for battles during rotations 88-10 through 88-14, in the second half of 1988. Here we see some substantial changes from the earlier data samples. Again, some 50 battles involving ten mechanized infantry and armor task forces are included. The number of fire missions per battle more than doubled--a significant change. The number of rounds fired per battle likewise markedly increased, although not at the same rate as the number of missions. This finding indicated that fewer rounds were being fired on

Table 2

ARTILLERY EMPLOYMENT

	1987 (Rotations 87-4 to -8)		1988 (Rotations (88-10 to -14)	
	Offense	Defense	Offense	Defense
Average fire missions/battle	21.0	28.11	46.9	74.2
Average rounds/battle	1559	19400	2047	4106
Percent effective/suppressive missions	37.2	35.11	39.4	32.2
Percent effective/suppressive rounds	43.7	36.11	44.5	33.8
Average OPFOR T-72/BMP killed	2.2	7.00	4.7	8.1

each mission than in 1987. In fact, the 1987 average of 72 rounds per mission fell to 47. A typical fire mission at the NTC is a "battalion 3," or 54 rounds, and is driven in part by the tables in the Rules of Engagement.

No substantial improvement took place in the percentage of effective/suppressive rounds or of effective/suppressive missions. Although improvements in artillery procedures led to the application of considerably more fire missions, the accuracy of the missions did not improve. The battle damage assessment numbers for the offense showed an expected level of increase reflecting the increased round counts (at a constant effectiveness fraction); on the the defense, there was no such commensurate improvement. We have not investigated the reason for this anomaly, nor will we speculate on possible explanations. Overall, the "accurate" missions divide roughly equally between effective and suppressive in all the data samples; we did not analyze them separately.

COMPARISON WITH OPFOR

In many cases at the NTC, it is useful to examine the methods used by the OPFOR and the results it achieves. The OPFOR is, after all, a unit whose training opportunities are unparalleled and therefore offer a benchmark for unit performance. However, the staff planning and execution system for fire support used by the OPFOR follows neither Soviet nor U.S. practice. Its methods, being transparent to the training units, are chosen for expediency. Nonetheless, we thought that looking at the results it obtains for its artillery missions might be instructive. The data, taken from a number of battles in 1988, are shown in Table 3.

There are a number of interesting points exhibited in the table. First, the OPFOR shoots fewer fire missions, on average, than do the Blue units. The OPFOR is credited with a doctrinally correct number of artillery units, and, as is well known, the Soviets are generous in

Table 3

OPFOR ARTILLERY RESULTS

Item	Offense	Defense
Average fire missions/battle		
Total	20.0	29.8
Target	6.5	11.2
Grid	13.5	18.6
Average rounds/battle		
Total	2311	2866
Target	1078	927
Grid	1233	1939
Percent effective/suppressive missions		
Total	53	51
Target	51	44
Grid	55	55
Percent effective/suppressive rounds		
Total	47	57
Target	34	52
Grid	59	59

SOURCE: Data from 42 battles in CY 88.

their allocation of tubes. Note, however, that the OPFOR shoots substantially more (~100) rounds per mission as compared to the training units. Another reason for the lower number of fire missions than might be expected is that the OPFOR shoots many chemical missions and makes generous use of smoke, thus occupying the available tube time. It is perhaps surprising that the OPFOR, which is known for accurate reconnaissance on the offense and for carefully setting up target reference points on the defense, still shoots many more grid missions than target missions. Although the OPFOR shoots slightly more total rounds on an attack compared to the Blue units, it must be remembered that they generally attack as a regiment, while Blue attacks as a battalion (or as two battalions, with artillery counted separately). Thus, the OPFOR overall seems to shoot comparatively less on the attack. On the other hand, the OPFOR usually defends as a reinforced company or a battalion minus, thus their smaller number of rounds expended on the defense are perhaps commensurate with those fired by Blue.

The OPFOR achieves a higher ratio of effective/suppressive missions and rounds than do the training units, with a ratio of approximately one-half (as compared to one-third). This higher ratio may reflect its reconnaissance capability, its attention to target reference points, and its greater familiarity with the terrain. Note, however, that the OPFOR does not have assigned to it the fire support personnel that normally are attached to Blue units (and that an enemy unit would actually have) or the artillery units present in an actual motorized rifle regiment. The OPFOR commanders feel they would make more effective use of artillery if they were doctrinally manned to do so.

SOURCES OF FIRE CALLS

These data reinforce our original intention to concentrate on the issue of accuracy and the execution of fire missions from the standpoint of the origins of the calls for fire. The data tables show that more missions are being called, indicating that planning, communication, and computing problems are being overcome. Further work is doubtless needed. However, the lack of change in the values for accuracy indicates that this is a more fruitful area for research.

Accuracy of fires at the NTC depends primarily on the accuracy of the fire plan prepared before the battle and on the ability of observers to locate enemy forces correctly during the battle. In the NTC system, it does not depend on the ability of the tubes to deliver rounds accurately (except in live-fire exercises). To determine which elements we must examine, we began our research on accuracy by considering the sources of the calls for fire. The logs of the NTC fire support section indicate the source of all fire calls, as they are introduced into the artillery communication system. Major Lee Burn, using the resources of the NTC staff, provided the data in Table 4.[5]

We see that the preponderance of calls originate with brigade and task force FSOs and from company-level FSOs and FOs.[1] We do not know how many of the calls from the higher level FSOs actually result from their own observations and how many are relayed from other callers on the net or are based on spot reports coming in from other places on the battlefield. We suspect that it is the exception when the brigade or battalion FSO is able to observe the actual spot where fires are to fall. Therefore, calls from those sources must usually depend on

Table 4

SOURCES OF CALLS FOR FIRE
(Percent)

Brigade and task force FSOs	55
Company FSOs/FOs	35
Other[a]	10

[a]Scouts, counterfire radar, commanders, etc.

[1]The paucity of calls originating with scouts and counter-fire radars is another source of concern, and surely must have a connection with the overall accuracy problem. Both elements have the potential for calling effective artillery fire. Apparently the targets located by the military intelligence electronic assets are only infrequently fired on because the electronic equipment has no self-location capability and the target locations are often found to be in error.

accurate locations for preplanned fires or on grid locations called in by others. We suspect, but cannot show, that most of the task force and brigade FSO fire calls are based on preplanned targets. The other large source of calls comes from company-level personnel. We believe that they will likely be able to see the enemy at the time they call for fire. Thus, their ability to locate themselves and the enemy is vital for accurate fire. In subsequent sections, we will examine the accuracy of fire plans and the actions and capabilities of company-level fire support personnel that would influence accuracy.

As we have pointed out, there are many steps in the complex process of delivering effective fire support. Some problems are high level, involving the appropriateness of the fire plan to support the maneuver commander's concept of the operation; others involve the operations of the TACFIRE system and its ability to support a battle in which numerous demands are being made simultaneously on the fire support system. A critical problem is the timeliness of fires when attacking a moving target. Another element is the operations within the firing batteries themselves. All these factors will influence the volume of fire and the effectiveness of the fires in the context of the battle. Consequently, judgments as to the adequacy of any part of the system may be difficult to make. However, there is great room for improvement in the accuracy of the fires actually delivered. That is why we have chosen to concentrate on this aspect of the fire support problem in our investigation.

We will examine the two elements of the fire support system having the greatest influence on the accuracy of delivered fires. The first is the accuracy of the target locations provided in the fire plan. If they are incorrectly located in relation to known positions or grids, then missions fired against them will be ineffective unless the fires are subsequently adjusted. Section IV covers this topic in detail, but we can say here that unit fire plans usually lack sufficient accuracy to yield a high fraction of effective missions without further observation or adjustment. The second element is the ability of the FO teams to accurately locate targets of opportunity. Section V reviews some of the

available data concerning the capabilities of variously equipped fire support teams to determine target location. Here again, we can say that an observer equipped only with map and compass cannot (in actual practice) locate targets with sufficient accuracy to yield effective first-round volleys. It is worthwhile to remind ourselves that at the NTC, current laser-assisted position/location systems cannot be used because they are not eye-safe.

In addition to the accuracy of target location, other factors affect the ability of the fire support teams to accomplish their mission. Among these factors is the ability to position themselves so they can observe the targets and the effects of fire on them. It is a fact of life that the task force FSO may only rarely be positioned where he can directly observe most targets in a battalion-size sector. Moreover, according to doctrine, he is to be in the vicinity of the Task Force commander, where he can coordinate and advise. Thus, he is not the person to whom we should look for accurate fire calls. Most of these must come from the company fire support teams (FISTs) or combat observation lasing teams (COLTs), or from maneuver unit leaders who are in closer proximity to the target areas. Therefore, we also wished to investigate how individual company FSOs and platoon FOs go about their business, because our data indicate that a large fraction of calls for fire come from them. This will be covered in Sec. III.

III. NTC FIELD INVESTIGATION

FIELD DATA CARDS

To investigate the actions of the FIST before and during battle, we developed two data cards to be filled out during each battle by NTC O/Cs in the field. The questions were selected after consultation with experienced fire support O/Cs; cards were provided to members of both the armor task force and mechanized infantry (mech) task force trainer teams, as well as to the live-fire O/Cs. Figure 2 shows the cards. One was intended to cover FOs, while the other was directed toward company FSOs. The questions are quite basic and explore the hypotheses that FOs and FSOs are often not given specific fire support responsibilities, are frequently unable to observe important target areas, and are not always able to locate themselves or potential targets accurately.

Several questions concern matters taking place before the battle, during planning and preparation. Clearly these things are essential, and doctrine elaborates on many of them. Several other questions deal with the actions assigned to company FSOs and FOs before the battle, to be carried out during the battle. Assignment of responsibility is important: if a task is not assigned, all parties tend to believe it is someone else's responsibility, in which case the task is never carried out. A hypothesis we considered when preparing this data instrument was that many planned targets are never fired on because no individual is clearly charged with the responsibility.

Moreover, simply assigning a target is insufficient. The criteria for shooting must be made clear, and provisions must be made for ensuring that the responsible party will indeed be able to carry out the task. Simply telling an FO, for example, to call for fire on a particular target during a defense is insufficient. Should he call for the fire when only one enemy vehicle is near the target, or should he shoot only if a platoon is present? Will he be able to observe the target if he remains with the platoon leader, even in conditions of obscuration, or will he have to go elsewhere to be in a better vantage

Arroyo Center 9-14-87

TEAM FSO

Date _____ Team/Call _____ Unit _____

Battle Type -- MTC, DA, HA, NA, DIS, DBP

PLAN/PREP

Did he have TF fire plan/graphics? _____

Did he make input to fire plan? _____

Did he disseminate the plan? _____

Was he given specific responsibilities? _____

How many targets? _____

Did he assign specific responsibilities? _____

Did he issue specific guidance for locating FO's including transport protection and alternates? _____

Did he prepare/check commo channels? _____

nets _____ # radios _____

What pos/loc equipment was available? _____

EXECUTION

Where did he operate/what vehicle? _____

How many of his FO's did he have contact with? _____

Contact with team commander? _____ FSE? _____

In position to carry out assigned missions? _____

Could he see enemy? _____ Locate enemy? _____

If not, why not? _____

How many missions did he pass on from FOs? _____

How many missions did he call? Targets _____ Grids _____

Did he survive? _____

COMMENTS

Arroyo Center 9-14-87

FORWARD OBSERVER

Date _____ Team/Call _____ Unit ____/____/___

Battle Type -- MTC, DA, HA, NA, DIS, DBP

PLAN/PREP

Did he have input to the fire plan? _____

Was he given fire plan and/or graphics? _____

Was he given specific responsibilities? _____

How many targets? _____

Was he told where to place himself? _____

What commo equipment was assigned? _____

What commo nets were assigned? _____

What pos/loc equipment? _____

Were clear TRP defined? _____

EXECUTION

Did he perform pre-combat checks -- commo? _____

What vehicle was he in? Where? _____

If he had locating orders, did he fulfill? _____

How many assigned targets did he fire? _____

How many grid missions? _____

Did he adjust fires? _____

Could he see and locate the enemy? _____

How long did FO survive? _____

COMMENTS

Fig. 2--Field data cards

point? If he is to be elsewhere, how and when is he to get there? Will he require assistance from others? Will the communications work, and how will it be tested? These matters are what we refer to as specific guidance.

We intended that the FSO card be filled out by O/Cs on the maneuver teams (armor, mech, and live fire) whose mission is to train fire support personnel. Generally, but not always, an O/C is assigned to company team FSOs; the FSO cards were to be filled out by those O/Cs. On the other hand, no O/Cs are assigned to the platoon FOs. For those cards, we asked that the O/Cs assigned to the mechanized infantry platoons take on the additional assignment of observing and recording the actions of the platoon FOs. This tactic did not yield adequate results. Although we obtained a very high level of coverage of the FSOs, the return of data cards covering the FOs was too limited to be useful. Thus, we have learned a lesson about gathering field data: it is probably not reasonable to ask an O/C to collect data on a system that is not within his prime area of responsibility, except in special circumstances. Therefore, our field data reflect only the actions of the FSOs. Nonetheless, by inference, we were able to determine a number of things about what the FOs did and did not do.

RESULTS FROM FIELD DATA CARDS

Our data sample included 69 battles involving 11 task forces. We sorted the data according to whether the battle was live fire or force-on-force and whether it was an attack or a defense. We did not find substantial differences between average responses obtained from live fire and force-on-force. For certain issues, however, we did find noticeable differences between attacks and defensive battles. Table 5 shows most of the results from the FSO data cards. If no substantial differences between attack and defense exist, we simply show an overall average value. Where differences do exist, the attacks and defenses are shown separately. Note that the offenses include both hasty and deliberate attacks, with a preponderance of hasty attacks. In such cases, the opportunity for careful preparation for the battle is often lacking.

Table 5

RESULTS FROM FIELD DATA CARDS
(Fire support officers)

	Overall	Offense (Percent)	Defense
Had task force fire plan/graphics	94		
Made input to fire plan		34	78
Disseminated plan to FIST	81		
Was given specific responsibilities		45	78
Was assigned specific targets		58	92
Assigned specific responsibilities to FOs		16	44
Issued specific guidance to FOs		23	48
Had position/location equipment beyond map/compass		7	25
Located in team commander's vehicle	3		
Prepared/checked communications	92		
In contact with FOs during battle	86		
In contact with team commander	94		
In contact with task force FSE	90		
In position to carry out mission	77		
No missions passed on from FOs		74	53
No missions called on grids	55		
No missions called on targets		49	26
FSO survived battle	71		

Although many of these results are not surprising in any way, others may offer some useful insights into the fire support problem on the battlefield. We note that in nearly all cases the FSO had the task force fire plan. This does not speak to the issue of the value of the fire plan. The next response might offer cause for alarm at first glance: the 34 percent value for FSOs making input to fire plans in the attack appears low. However, it must be realized that there are more hasty attacks and movements to contact, as compared to deliberate attacks, at the NTC. In such attacks, it is not reasonable always to expect input from company FSOs. Moreover, artillery units are coached to conduct top-down fire planning. The answers to the next question--

concerning dissemination of fire plans to the FISTs--reflect, at worst, a training problem with a small fraction of FSOs.

The next two questions--concerning assignment of responsibilities to the FSO by the task force--led to expected results. Targets and responsibilities were assigned most of the time on the defense and about half the time on the offense. Fire planning on the defense is generally given considerable attention, in part because preparation time is available to do so. Of necessity, planning must take place against a situational template, and planning need not wait on the availability of accurate reconnaissance; we are dealing with our own positions and engagement areas. On the offense, however, such is often not the case. The fire plan must be created during the time the reconnaissance effort is under way; by the time the intelligence information is in and digested, little time may be left to prepare and disseminate a revised fire plan. Moreover, our general observations of battle planning at the NTC suggest that often more attention is paid to the details of movement to the assault point during an attack than to the details of conducting the assault (when the fires supporting a company are apt to come into play).

The responses to the questions concerning the assignment of responsibilities to the FOs by the FSOs suggest that a systemic problem may exist. Both in the matter of giving specific target responsibility to an FO and in instructing him as to how the assignment is to be carried out, the results show that the FOs are underused. In the attack, they are given missions less than one-quarter of the time, and even in the defense they appear to be fully integrated in fewer than half the battles. There are two possible ways of viewing this result: first, that the FSOs are failing to make use of their assets because of training deficiency; second, that the FSOs do not believe the FO is useful, in which case we have an organizational disconnect. We will return to this issue in later sections.

Responses to the next two questions are very interesting. The data show that seldom on the defense, and almost never on the attack, do FSOs have position/location equipment beyond map and compass. A later

section will discuss the consequences of this fact for fire mission accuracy, using data taken in past experiments by the artillery community. In essence, the data show that an observer armed with nothing more than map, compass, and binoculars cannot locate targets accurately enough to permit reliable first-round fire-for-effect. Another interesting response is that only in a few cases was the FSO reported to be located in the team commander's vehicle. Although a doctrinal debate continues concerning this point, the officers in the field have settled the issue for themselves. (Some of the responses we received were ambiguous. The answer "M 113" might mean the commander's track or a FIST track.)

We next had a series of questions concerning communications. The data indicate that the FSOs take some care in setting up and checking their communications and generally maintain contact with their maneuver commander and the fire support element.

Overall, the data show that three-fourths of the time, the FSOs are in a position to carry out their mission and survive the battle. However, the frequency of calling fire missions is not very high. Only in half the defensive battles do the FSOs pass on missions called by their FOs (which is consistent with the finding that only in half the cases are targets assigned to FOs), and in only half the battles overall do they call grid (unplanned) missions. Three-fourths of the time they do call planned missions on the defense. On the attack, calls for fire passed on from the FOs drop to only one-quarter of battles (again consistent with the frequency of target assignment), while the FSOs themselves call target missions in only half the battles. This is consistent with the earlier findings that FSO contribution to the fire plan before attacks is limited.

SUMMARY OF DATA

In summation, these data suggest that company FSOs are active in fire planning when that role is appropriate. They are not uniformly aggressive in assigning missions to the other members of their FIST, the FOs. These findings are underscored by some data taken by coauthor

Major Lee Burn [5], a member of the Operations Group Observation Division at the NTC. He has placed several card questionnaires, directed at many aspects of fire support, in the field with O/Cs. Although his questions primarily address battalion and brigade operations, the responses to one series of inquiries are particularly telling. The issue was the actions of the task force FSO in targeting obstacles on the defense.

Did the FSO:	Affirmative
Plan fires on/near obstacles?	85%
Verify obstacle locations?	35%
Position observer to see obstacle?	25%
Have contingency plan?	15%

Artillery and maneuver doctrine emphasizes such points as the targeting of fires on obstacles. In response to their training, the FSOs in more than four out of five cases planned targets to support the obstacle systems for which they were responsible. However, in only one of three cases did they follow through and verify that the obstacles were indeed located as shown on their graphics. Such verification is not easily accomplished and must be done with great care when using maps as coarse-grained as the standard 1:50000 issue.[1] The failure of planning in the total sense is reflected in the even lower fraction of occasions in which FSOs position themselves or require a company FIST to occupy a position so they can call timely and accurate fires on the planned target supporting the obstacle. The last figure for the planning of contingencies reflects a more widespread problem of failing to war-game at a low level and to provide for the inability of an observer to fulfill his mission because of obscuration or of becoming a casualty. If the more experienced battalion task force FSOs are deficient on these points, it would not be surprising that the often

[1]According to engineer doctrine (FC 5-71-2), location of obstacles is an engineer responsibility. The engineers have no position/location equipment to accomplish that task.

very junior company/team FSOs also tend to omit these important actions.

Overall, from the data generated by this inquiry, we find that company/team FSOs carry out many of the broad tasks necessary to provide fire support. For example, in most cases plans are created and distributed; communications are set up and are used. There seems to be a tendency for paying less attention to the more detailed aspects, such as issuing instructions to the FIST. In a later section, we will examine doctrine to determine whether this pattern reflects a weakness in training to doctrinal standards or an oversight in the doctrine itself. It is these details that are important to achieving fire mission effectiveness.

The data we have taken in this field inquiry do not speak directly to the issue of fire mission accuracy. To shed some light on that point, we must turn to other sources of data. Let us consider two types of mission: the first is the preplanned target (in the next section, we present data taken from fire plans prepared by the rotational units); the second is the grid-located mission on a target of opportunity. Generating NTC data that allow comparison between the specification of the mission actually called and the actual location of the target observed by the caller would be instructive. Unfortunately, this is almost impossible without seriously intrusive data gathering. However, this step is probably not necessary, since the U.S. Army has generated considerable data in times past concerning the capability of observers to locate themselves and targets. Section V presents these data.

IV. FIRE PLAN TARGET LOCATION ACCURACY

For a defensive battle, carefully locating some of the target positions during the process of preparing the fighting positions, obstacles, and engagement areas is often possible. After all, the ground belongs to the defender. The process of locating targets is more difficult in the offense, when the objective areas are in the hands of the enemy. A previous study of reconnaissance at the NTC [4], found that in about half the battles, the training task forces failed to locate enemy positions and obstacles. Therefore, enemy positions appearing on Intelligence Preparation of the Battlefield (IPB) products, from which the fire support plans are prepared, may not in fact represent direct observation at all. At the NTC, limited intelligence is available from higher headquarters to the battalion. The battalion's primary intelligence asset is the scout platoon. In the cases where the scout mission was successful in locating enemy elements and obstacles, problems still existed. In Ref. 4, we found that artillery observers seldom accompanied the scouts, and it was observed that the scouts had considerable difficulty with land navigation and the accurate location of points on the ground. For these reasons, we would expect that without adjustment, the locations of preplanned targets in a task force fire support plan might not be sufficiently accurate to permit effective fire missions. In this section, we describe an investigation of this point.

METHOD OF ANALYSIS

We examined a series of offensive battles using the NTC computer tape replay capability at RAND. We used the records of 14 battalion task forces ranging in time from June 1987 to June 1988. We were able to analyze data from 19 hasty attacks and 16 deliberate attacks, all from the records of force-on-force activity. For most (but not all) battles, the computer record shows the fire support plan as having been manually entered into the computer by the TAF analysts according to the

plan developed by the task force. We simply displayed that plan and compared the locations of targets to the actual location of the OPFOR elements at the time the battle began. If the individual target point was within 500 meters of any OPFOR symbol, we rated the target as potentially effective (to include suppressive). This criterion is somewhat more demanding than the effective/suppressive criterion used in Sec. II; this section's criterion is probably more realistic.

In our analysis, we first counted all individual targets and then potentially effective targets. Our technique for dealing with target groups was equally simple: if any target in the group would be rated as effective, we rated the group as effective. However, we did maintain a separate count of all targets located in groups; we also noted their effectiveness. Occasionally the counting task was made more difficult by the possibility of targets recorded for use in a previous battle having been left in the record. This was seldom a problem with groups, but could be a problem with individual targets. We used our best judgment in eliminating targets that appeared to be associated only with previous battles.

RESULTS

The results of the investigation are shown in Table 6. Note that we excluded from our data set movements to contact (MTC) that involved an initially moving OPFOR leading to meeting engagements (MEs). We included only movements to contact that resulted in hasty attacks (HAs) on prepositioned OPFOR objectives. At first glance, one might consider the fraction of effective individual targets to be very low. We observed, however, that many of these targets were clearly chosen to fall on counterattack routes, potential observation posts, security positions, and other features where one would not necessarily expect the enemy to be at the initiation of battle. The target groups, however, tended to correspond to objective areas, and here the effectiveness fractions are a better representation for our accuracy evaluation.

Table 6

FIRE PLAN ACCURACY RESULTS

Average Values	MTC/HA (excl. ME)[a]	Deliberate Attack
Separate targets	17.6	22.6
Effective targets	15%	17%
Groups	2.7	4.5
Effective groups	37%	43%
Targets in groups	7.7	11.6
Effective targets in groups	20%	23%

[a]See Glossary, p. xvii.

Thus, we see that even in deliberate attacks, the fraction of effective groups is less than one-half. In addition, generally only about half the targets in an effective group could be rated as individually effective. Consequently, without further observation or adjustment, simply shooting preplanned groups as part of an artillery preparation or later in the battle clearly leads to artillery effectiveness fractions consonant with those displayed in Sec. II.

Therefore, the results of this analysis are consistent both with the bottom-line effectiveness figures shown in this (and other) investigations and with the results of a previous investigation of reconnaissance. To improve the effectiveness of artillery preparations and preplanned fire on enemy positions, the reconnaissance function must be addressed; the solution does not lie wholly within the artillery system itself. The Army has initiated several steps to improve the reconnaissance capability of the heavy forces; these should pay off in artillery effectiveness, and in other ways. But both the reconnaissance elements and the fire observers seem to have difficulties accurately determining the location of what they see. This will be the topic of the next section.

V. ARTILLERY OBSERVER POSITION/LOCATION ACCURACY

Clearly, a basic issue in determining why artillery fires are less effective (or accurate) than desired is the accuracy of location of an observed target. Determining the absolute location of points on the ground has always been difficult, particularly when maps may be inaccurate or incomplete. Traditionally, artillerymen have used the practice of adjustment to bring the fall of rounds onto the target location. That is, even if the initial call for fire was off by a significant distance, the observer would estimate the change necessary to move the rounds to where they were wanted. This iterative procedure might be accomplished on preplanned targets or points before the battle (registration), or on targets of opportunity during a battle (adjustment). The system worked very well when targets were static and battles moved at a slower pace.

However, on today's battlefield the practice of adjustment has drawbacks and hazards. First, many targets are moving--often quickly--and adjustment is not feasible. Also, counterfire radars are able to detect even the single adjustment rounds, enabling the enemy to employ counterbattery fire, perhaps even before the friendly battery has been able to fire for effect. That Army artillery doctrine that warns against adjustment and encourages first-round fire-for-effect is quite reasonable. Yet for this warning to be effective, observer errors, tube location errors, and ordnance and meteorology errors must be at a low level. At the NTC, the game is such that ordnance error is not a factor; rounds are assumed to fall where the observer has called for them to fall.

In our examinations of fire logs at the NTC, we have never noticed a call for adjustment rounds. This observation is supported by the fire support training team of the Operations Group, which states that adjustment is a rare occurrence. Therefore, the limiting factor on fire mission accuracy is the ability of the observers to accurately determine the map grid coordinates of a target. Determining the actual locations

of the observed targets and comparing them to the coordinates being reported would be useful for our analysis. However, this procedure would be difficult and intrusive at the NTC. Therefore, we sought an alternate means to establish the basic accuracy that might be achieved by artillery observers. There is no reason to think, for example, that observers at the NTC are any less or more capable than others, although circumstances at the NTC may make accurate observation more difficult than at other locations (owing to lack of man-made structures or distinct geographical points). The standard military map of the area, with a scale of 1:50000 and a contour interval of 20 meters, is often not satisfactory for precision location. Therefore, we looked for data dealing with the general capability of observers to locate themselves and targets accurately.

RESULTS FROM PREVIOUS RESEARCH

Fortunately, the U.S. Army has done considerable research on this problem in the past. During the late 1970s and early 1980s, the artillery community was modernizing its equipment in many ways. Among the devices under consideration were various aids for FOs, including laser rangefinders (LRFs) and other thermal and optical devices. We have found summaries of various series of tests in two Army publications. The report written by Close Support Study Group III [7], a field artillery study, contained summary statements of several field trials. We reproduce in Table 7 their Table F-1, "Forward Observer Location Accuracy."

The conclusion drawn in the study's appendix is: "The data shows that the conventional FO can locate targets to within 500 meters." Although not explicitly stated, we assume that these values are for observers equipped with nothing more than map, compass, and binoculars.

The appendix describes the results of two additional tests relevant to a discussion of observer accuracy. One was the FIST Force Development Test and Evaluation conducted at Fort Polk, Louisiana, in 1980. This test of the FIST concept employed company FSOs and platoon FOs using map, compass, binoculars, and laser rangefinder AN/GVS-5. The

Table 7

FORWARD OBSERVER LOCATION ACCURACY

Source	Self-location Accuracy (Meters)	Target-location Accuracy (Meters)
WSTEA	213	674
ARTS-TEA-78	340	881
HELBAT 1	146	490
HELBAT 2	93	313
HEL MST	204	458
G/VLLD OT II	155	358
AMSAA/CDEC	290	na

SOURCE: Tech Memo 9-80, HUMAN Engineering Laboratories, 1980.

NOTE: The acronyms refer to the different trial series; the accuracies are presumed to be mean values.

mean FO target location error (TLE) was 504 meters, which the report rated as poor. Without the laser rangefinder, TLE was between 400 and 600 meters, with a self-location error of more than 200 meters. The appendix goes on to summarize results from FIST FDTE II, conducted in 1984. Again, even with the laser rangefinders, TLEs of 400 to 600 meters were experienced against stationary targets.

Reference 8, *Fire Support Control at the Fighting Level*, summarizes the results of an extensive series of tests called HELBAT (Human Engineering Laboratories Battalion Artillery Test). These tests were directed at many aspects of fire support besides observer accuracy. Among the observer aids tested (in addition to the conventional map and compass) were hand-held LRFs and LRFs on tracking mounts with automatic data links to the battery. Figure 3 reproduces a figure from Ref. 8 that shows a performance summary for FO capability.

In these tests, the hand-held LRF substantially improved the ability of the FO to locate targets accurately, but performance against moving targets remained marginal. The times required for adjustment

PERFORMANCE SUMMARY
FO FIRE MISSIONS

Method	System Delivery Error (CEP)	TLE*(MRE-m)		Adj Rds (Stationary Tgt)		Average Response Time (min)		
		Stationary Tgt	Moving Tgt	# Rds	Last Rd (MRE-m)	1st Rd	FFE	1st Rd Mvg Tgt
Conventional	+1% of Rg or +150m at 15km	390	700	4 to 8	100	3	14	13
Handheld Laser Rangefinder (LRF)		180	400	4	85	2.5	5.0	7.5
LRF on Tracking Mount w/Auto Data Link		<25	80	2	40	1.0	2.4	1.8

*FO-Tgt Range : 1.5km for conv and handheld LRF; 2.5km for LRF on tracking mount.

SOURCE: Ref. 8.

Fig. 3--Forward observer performance summary--fire missions

missions did not allow for any queuing problems that might occur in a complex situation; thus, we must regard them as optimistic.

We have concluded from our review of these experimental data that the FO equipped with only map, compass, and binoculars cannot reliably locate stationary targets to better than 400-500 meters. Performance will be improved with a hand-held LRF, but the data conflict as to the degree of improvement. The data further indicate that with mechanisms similar to that of the ground/vehicle laser location designator (G/VLLD), the observers will be able to locate stationary targets well enough to obtain effective first-round fire-for-effect.

RELATION TO NTC PERFORMANCE

How do these conclusions relate to our observations at the NTC? During force-on-force exercises at the NTC, even observers equipped with G/VLLD laser equipment cannot use it since it is not eye-safe. The same would be true for hand-held LRF. But in this case, after asking officers from a number of divisional artillery units in training, we found that none of these units were equipped with the hand-held devices. Thus, when working against the OPFOR, Blue artillery units are no better equipped for accurate target location than they were in World War II; without adjustment of fire, the probability of effective or even suppressive fires is going to be low. If the results reported in previous studies reflect mean TLE capability, and if the data are normally distributed about the mean (which we do not know), then the probability of effective or suppressive fire (first-round) is less than one-half. In fact, if tested on the ground at Fort Irwin, we might find even less favorable results because of the scale of the available maps, their contour interval (20 meters), and the nature of the terrain. Our conclusion is that the accuracy of fires being reported at the NTC reflects primarily the basic capability of the low-technology FO or, similarly, the reconnaissance scout.

Overall, we conclude that the values we have found for percentage of effective/suppressive fires are consonant with basic capability. Improvement will not come from more intense training, but from improved equipment.

VI. DOCTRINAL REVIEW

REVIEW OF MANUALS AND CIRCULARS

The previous sections have uncovered a number of points that apparently contribute to the problem of inaccurate artillery fires at the NTC. Although the origin of some problems is clear, the origin of others is yet to be determined. Some problems might arise from deficiencies in individual or unit training; others reflect limitations of hardware capability; and still others may have their origin in incomplete or misleading doctrine. In this section, we will report on our review of doctrinal literature, in which we cover only those points that might reflect on attainable firing accuracy. Table 8 lists the documents included in our review.

Table 8

DOCUMENTS INCLUDED IN DOCTRINAL REVIEW

FM 6-20	Fire Support in Combined Operations (Dec 1984)
FM 6-20-1J	Field Artillery Battalion (June 1984)
FC 6-20-20	Fire Support Handbook (Oct 1985)
FM 6-20-40	Tactics, Techniques and Procedures for Fire Support for Brigade Operations (Heavy) (Final Draft)
FM 6-30	Observed Fire Procedures (June 1985)
TC 6-71	Fire Support Handbook for the Maneuver Commander (July 1987)
FM 6-121	Field Artillery Target Acquisition (Dec 1984)
FM 7-7J	Mechanized Infantry Platoon and Squad (Bradley) (Final Draft)
FM 71-1	Tank and Mechanized Infantry Company Team (Nov 1988)
FM 71-2	Tank and Mechanized Infantry Battalion Task Force (Sept 1988)

ARTILLERY MANUALS

FM 6-20 deals with fire support from the highest levels to the lowest. It is not a "how to" manual for fire support at the company level. Whereas it does review expected accuracy for various target acquisition assets, it does not deal with the capabilities and limitations of the traditional forward observer. In its discussions of

fire planning at company level, the emphasis is (as at the higher levels) on targets and coordination of assets. The manual generates no strong feeling in the reader that the fire plan must include the actions of fire support personnel during battle. But these points perhaps should not be expected in a capstone-type manual.

FM 6-20-1J deals largely with the activity of the artillery battalion itself. The specific capabilities and actions of the fire support personnel associated with the maneuver units are not covered.

FC 6-20-20 is a detailed manual for use in the field. In defining a standard target, it states that a six-digit grid (100 meter) accuracy is required, at a minimum. It does not state that the target should be a recognizable point on the ground nor does it treat the issue of attainable accuracy. It contains no discussion of the positioning of FOs or the requirement to plan for the observation of designated targets.

FM 6-20-40 deals only briefly with company-level fire support. It makes one point concerning FOs: that the FO should be collocated with the platoon leader. Our observations at the NTC suggest that the platoon leader is often not in a good position to call for fires. He is often in a covered or concealed position or possibly buttoned-up in his track. The observer is quite useless in such a situation. In Section 3 of the manual, there is a worthwhile discussion of the allocation, utilization, placement, and instructions for COLTs. Appendix K deals further with the employment of COLTs. Although much of the discussion covers matters of organization and assignment, the manual specifically mentions the placement of the COLTs by the maneuver commanders. This is the only place we found that discusses observer placement. A parallel discussion of the employment of FOs would have been useful.[1]

The preface to **FM 6-30** states that the manual is concerned only with technical observed fire procedures and that operational aspects of employing observers are discussed elsewhere, notably in FM 6-20. But we

[1]We also note that the employment of COLTs seems to lack coverage in most of the manuals. With the increasing use of COLTs, this seems an important doctrinal oversight.

have already seen that FM 6-20 does not elaborate on the details of how observers are to be used. In fact, FM 6-30 instructs the FO to prepare maps and sketches, select sites for observation posts and movement routes, and determine the six-digit grid coordinates of his location each time he moves. Section 3 of the manual discusses methods for self-location and target location. The implicit assumption seems to be that the observer will be able to attain accuracy of less than 100 meters by using map methods. But we have seen that Army data clearly show that this is not a realistic expectation. The first section of the manual includes a concise discussion of the value of first-round fire-for-effect and an exhortation to always strive for it, or at most for a one-round adjustment. But the manual does not address the question of observer capability. These discussions in FM 6-30 are very brief; the manual goes on to extended discussions of adjustment methods, munition selection, and other topics important to observed fire procedures.

TC 6-71 is aimed toward brigade and battalion commanders and outlines how indirect fires are to be used to support the battle. Attention is focused on planning and on the problem of maintaining synchronization between maneuver and fire support. There is no mention of the maneuver commander's responsibility to ensure that fire support personnel are in a position to call fires according to the plan (with the exception of issuing a short advisory that the commander ought to consider placing an FO or COLT with the scout element).

FM 6-121 is directed at the Target Acquisition Battery that is organic to divisional artillery. Their assets are largely electronic (radars, sound ranging devices, survey). The manual is not particularly appropriate to the interface between maneuver and fire support, which is the focus of our study.

MANEUVER MANUALS

The last three manuals we have reviewed are the maneuver manuals for mechanized infantry platoons, mech and tank companies, and mech and tank battalions.

FM 7-7J contains a fire support section that outlines the functions of fire support and how the platoon might use fires. Specific procedures are outlined for calling fires, in case no FO is available. The need and methods for adjustment of fires are briefly covered. Other than to state that the FO party normally accompanies the platoon leader, the manual gives no guidance as to the employment of FOs. This brief coverage of indirect fire support contrasts greatly with the detailed instructions included in an appendix on fire distribution and control. The appendix deals with direct fire and includes the selection of platoon fighting positions, designation of targets, graphical control measures, prioritization of targets, command procedures, and so forth. The disparity in coverage between the detailed guidance given for direct fires and the paucity of discussion of means necessary to deliver timely, accurate indirect fire seems very revealing--we may have uncovered a major cause of failure in the fire support system.

The recently released **FM 71-1** discusses the use of indirect fires to support company team missions. In its discussion of fire support, it specifically mentions the fact that company FSOs may have to occupy vantage points different from the location of the body of the team. It does not elaborate, but later lists examples of options for FSO placement. Although this treatment recognizes the problem of delivering indirect fire, it lacks detail. In particular, it does not mention the accuracy that might be expected from observers variously equipped, nor the means necessary to increase accuracy. As an aside, the ARTEP Mission Training Plan for the company team [9] contains a standard for supporting artillery fire accuracy. It states that 80 percent of rounds and 75 percent of missions should fall on the enemy. These numbers seem wholly unrealistic for today's units.

FM 71-2, the task force manual, explains how indirect fires are to be used to support various classes of battle. Discussing execution, it states that in general, company teams are responsible for executing the fires assigned to them. In some of the discussion of responsibilities, it mentions that specific FSOs or FOs may be assigned a particular target to be shot under specific conditions. The manual points out that

task force FSOs are seldom expected to personally direct or adjust fires; thus, we may reasonably expect that the manual for this organizational level would not dwell on the details of execution of fire, but rather would cover the planning process in detail.

DOCTRINAL OMISSIONS

In both the artillery and maneuver manuals, the reader comes away feeling that the prime fire support problem for commanders is the allocation of a scarce resource, which is manifested by the creation of the fire plan. The tacit assumption seems to be that the fire plan will be executed and that the rounds will do what they were intended to do: hit something. But we also find that information and direction on the limitations of the current observer system are sparse. We can summarize our findings from this study by the statement, **"It may be indirect, but it has to be directed!"**

It is clear from this brief review of both fire support and maneuver doctrine that a gap exists in the literature. The maneuver leaders are made aware of how fire support should be used in operations. Fire support personnel are told of the techniques necessary to operate the field artillery system. Neither group is made fully aware of the limitations of accuracy imposed by available equipment and of what can be done to overcome these limitations. The possibility that special attention may have to be paid to the maneuver of the fire observers--particularly those entrusted with a specific mission--is barely mentioned in either body of literature.

To expand on this point, if the placement of indirect fires is of key importance to the commander's concept of the battle, then in the extreme it may be necessary to design the scheme of maneuver to support the fire plan. This is an unaccustomed reversal of the normal practice. But consider the case in which artillery fires are an essential element and where for their accurate and timely delivery, an observer should be stationed on terrain overlooking a unit position. The maneuver commander must make some provision to get the observer to that point. If the location is vulnerable to air attack or is on a potential

infantry approach route, assigning appropriate assets to protect the position may be necessary. This is what we mean by the maneuver plan supporting the fire plan.

Clearly, this doctrinal review provides some explanation of the problems displayed in our field questionnaire and in the artillery results at the NTC. Having such points treated in both the artillery and maneuver literature will assist in developing mutual understanding between the branches, and will help trainers at the home station and at the NTC to accomplish their goals.

VII. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The study has uncovered a number of factors that tend to limit the accuracy of indirect fires, as measured at the NTC. The data from the fire mission logs kept by the Operations Group indicate that in the past year or so, substantial increases have been made in the number of fire missions carried out by the rotating units, but that there has not been a commensurate increase in the accuracy of fire missions. This finding suggests that improvements in tactics, in techniques and procedures, and in training by the units have been successful in some aspects of the fire support system, but not in the matter of accuracy.

Equipment

Data generated in previous Army experiments reveal that achieving accuracy must go beyond techniques and procedures. Without the mechanism of adjustment of fire, the unaided (without sophisticated instruments) artillery observer cannot locate enemy targets with sufficient accuracy to obtain reliable first-round fire-for-effect. At the NTC, even those teams equipped with the FIST-V cannot do substantially better, because they are not able to use the essential laser rangefinder. Therefore, hardware improvements and additions are necessary.

The same problem is encountered by the scouts, who are the prime reconnaissance element of the task forces. Even if they successfully penetrate into the enemy sector and find appropriate targets, they cannot reliably locate those positions on standard maps. Thus, our data show that even the fire support plans prepared in advance of offensive battles (which must depend for their accuracy on reconnaissance) lack accuracy. As a result, the accuracy of fires eventually delivered by the units seem roughly commensurate with the the accuracy of the plans.

Techniques and Procedures

In defensive battles, reconnaissance does not usually control fire plan accuracy. However, the placement and survey of target reference points (TRPs) and the ability to accurately time fires against a moving enemy are critical. Our field data indicate that FISTs are insufficiently diligent about the location and observation of TRPs. Our doctrinal review reveals that this point is insufficiently emphasized. Previous Army data support what we intuitively suspect: Placing fires on a moving target is a difficult task. This may be particularly difficult in a situation when many competing demands are being placed on the fire support system. Thus, even in the defense, the delivery of accurate fires proves elusive.

Although not directly related to accuracy of delivery, the data further indicate that FOs are underutilized. One reaction to this finding might be that it is a training problem. Another explanation may be that the FIST leaders have simply recognized the limited capability of an observer who is confined to a platoon leader's vehicle and who is unable to orient himself to the battlefield or to maintain observation of potential targets.

Another finding is that FSOs (and presumably maneuver commanders) are not sufficiently concerned with the placement and actions of those who are to call indirect fires. FOs were given specific guidance in less than half the defenses. The fraction is even smaller for offensive engagements. This topic receives little mention in the doctrinal literature.

Doctrine

In the NTC's training system, the trainer teams generally try to point out to the rotational units where the problems they are experiencing are caused by departures from doctrinal practice. This doctrinal emphasis is useful to the units in devising remedial training. Therefore, we reviewed the doctrinal literature to find where guidance may be offered in overcoming the problems discussed above. We found that appropriate doctrine is missing in many cases, and in some

instances existing doctrine is misleading. Several points are of prime importance.

First, doctrine does not clearly indicate the limitations on accuracy under differing observation conditions and with various levels of supporting equipment. Although first-round fire-for-effect is encouraged, the problems in accuracy to be anticipated are not delineated. An experienced fire support officer or NCO should be aware of these limitations (however, we suspect they are not); the junior maneuver leader or commander probably is not familiar with them. Therefore, he is caught unaware when requested fire missions do not have the anticipated result. Even if all artillery observers are equipped in the future with devices that provide the necessary accuracy, the maneuver leader must understand what his own (non-artillery) people will be able to accomplish when they must call for fire.

Neither maneuver nor artillery doctrine adequately address the issue of responsibility for placement of fire observers. It is easy to understand why each set of proponents may have assumed that the other party would cover this vital topic; whatever the cause, the result is that the problem has slipped d wn the proverbial crack. The placement of observers requires as much care as the placement of a direct fire element contributing to the battle. This point is missing from doctrine and requires detailed treatment.

RECOMMENDATIONS

From these conclusions, we have formulated recommendations concerning equipment, doctrine, and organization, as listed below.

Equipment

- Artillery observers should be equipped with navigational equipment as soon as it becomes available. Either PLRS or GPS types of systems might be considered.

- All artillery observers require a G/VLLD-like target location capability. If units are to train as they are to fight, any laser equipment must be eye-safe, or some means of auxiliary protection must be available.
- Until the new equipment is available, develop "work-around" methods to ensure accurate fire delivery in special situations.[1]

Doctrine

- Artillery and maneuver doctrine should cover the expected capability of observers to call fires when variously equipped.
- To provide appropriate fields of observation, artillery doctrine should treat the requirements for placement of observers.
- Maneuver doctrine should cover the responsibility of maneuver units for the movement, placement, and protection of artillery observers. The necessity for detailed tasking of observers should be emphasized (the equivalent of platoon and company direct fire plans).
- Both bodies of doctrine should emphasize the necessity of accurate location and physical delineation of target reference points.

Organization

- Shift to COLTs forward observer personnel currently intended to be attached to mechanized infantry platoons. This would require an increase in vehicles assigned to COLTS.

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[1]For example, using tank sights for resection; ground surveillance radars for TRP location, and so forth.

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