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Training Lessons Learned on Sights and Devices in the Land Warrior (LW) Weapon Subsystem

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14. ABSTRACT *(Maximum 200 words)*:
The Land Warrior (LW) system is the Army's future system for the individual soldier. The LW consists of five subsystems, with the weapon subsystem the focus of the training research. The training of two platoons in preparation for a LW operational test was observed. Four sights and devices were trained (the close combat optic, two aiming lights, and the thermal weapon sight), plus a bore light. The training adequately prepared the soldiers to qualify on the M4 carbine with the close combat optic and the thermal weapon sight. Qualification standards were extremely difficult to achieve with the aiming lights on the M4, due to environmental conditions typical of Army ranges, not to lack of firer expertise. A standardized technique for boresighting all the devices was developed. Diagnostic skills needed by trainers and soldiers to effectively hit targets with each device were identified. The findings have immediate applicability to the Army, as the devices are currently being fielded. The report describes what contributes to quality training on the devices, and what should be integrated into marksmanship programs of instruction, technical manuals, and the training and doctrine literature.

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FOREWORD

The Land Warrior (LW) system is the Army's future system for the individual soldier. It integrates and expands current capabilities to move, shoot, and communicate. The LW system consists of five subsystems: weapon, computer/radio, software, integrated helmet assembly, and protective clothing and individual equipment. The training research in this report is part of a larger effort supporting training on all LW subsystems. The research focused on the weapon subsystem, and was conducted as part of the train-up for a LW operational test. The findings apply to future LW training, whether given in the institution or units by military or contractor personnel. They also have immediate applicability, as the Army is currently fielding many of the devices that were trained.

The report integrates findings from the training of two rifle platoons from the 82d Airborne Division at Ft. Bragg, North Carolina. The equipment included small arms sights and devices, specifically the close combat optic, the AN/PAQ-4C and AN/PEQ-2A aiming lights, the thermal weapon sight, and a bore light. There were several unique features to the training setting. First, this was the first time all devices had been trained simultaneously. Second, it provided an opportunity to examine the validity of proposed qualification standards for the devices on the M4 carbine, the M249 squad automatic weapon, and the M240B machine gun. Third, the training provided an extensive assessment of the use of a bore light to boresight different devices. The report provides substantial information on what contributes to quality training on the devices, instruction and diagnostic skills required of trainers, effective and efficient boresighting techniques, and what should be integrated into institutional and unit marksmanship programs of instruction, technical manuals, and the Army's training and doctrine literature. In addition, the research is an excellent example of how formal training observations are a valuable methodological tool in training research.

The results, in the form of separate reports on each platoon, were distributed to the Directorate of Operations and Training in the Infantry School, the TRADOC Systems Manager-Soldier, Cdr 2-29th Infantry Regiment, the Program Manager-Soldier, and the Project Manager-Land Warrior in October 1998 and June 1999. The findings were briefed to the Directorate of Operations and Training in the Infantry School, the TRADOC Systems Manager-Soldier, and the Cdr 2-29th Infantry Regiment. The Baseline platoon results were presented in May 1998, and the LW platoon results were presented in April 1999. The aiming light firing data have been used to assist the 29th Infantry Regiment and the Infantry School to develop Army-wide standards for night qualification with aiming lights and night vision goggles.

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TRAINING LESSONS LEARNED ON SIGHTS AND DEVICES IN THE LAND WARRIOR (LW) WEAPON SUBSYSTEM

EXECUTIVE SUMMARY

Research Requirement:

The Land Warrior system is the Army's future system for the individual soldier. It integrates all the technologies soldiers use to move, shoot, and communicate, and enhances these capabilities as well. The LW weapon subsystem integrates government furnished equipment (GFE), specifically, four target acquisition sights and devices: the close combat optic, the AN/PAQ-4C and AN/PEQ-2A aiming lights, and the thermal weapon sight: In preparation for an operational test of the LW, training was conducted for a Baseline platoon and a LW platoon on these devices and a bore light. With the exception of the AN/PAQ-4C, all devices were new to the soldiers. The research purposes were to: provide information to the system proponent and to the operational testers on the adequacy of pre-test training, and to identify training issues to be resolved prior to LW fielding. It was the first time soldiers had been trained on all devices simultaneously, as is required with the LW system. Thus it was possible to determine positive and negative transfer effects as well as the total training requirement for trainers. Proposed device qualification standards for the small arms weapons organic to the rifle platoon were assessed. Lastly, the training was the first extensive application of a bore light to boresight several devices on different weapons and to determine the effectiveness of this boresighting process.

Procedure:

There were two phases to the research: the Baseline platoon was trained in April 1998; the LW platoon, in December 1998. Some enhancements were made to the program of instruction given to the LW platoon based on findings from the Baseline platoon, but the overall structure was very similar. Both platoons were trained on the same equipment. Both training periods were about 8 days in length. All classroom instruction was formally observed and recorded. When squad practical exercises were conducted, observers were assigned to the different squads. All range firing was conducted on automated ranges, and the results for every soldier on every exercise by distance to the target were recorded. Times to complete major blocks of instruction, practical exercises, and firing exercises were documented. Photography, both day and night (image intensification and thermal), supplemented the written record and illustrated soldier techniques and range firing conditions.

Findings:

A major outcome of the assessments was a recommended, standardized technique for boresighting all the devices. Additional diagnostic skills needed by trainers and soldiers were identified for all devices. Findings showed that soldiers firing the M4 carbine could achieve the proposed qualification standards for the close combat optic and the thermal weapon sight, but not for the aiming lights. The difficulty with the aiming lights related to environmental conditions typical of Army ranges, not to firer expertise. Definitive statements regarding qualification

standards for aiming lights and the thermal weapon sight with the M249 squad automatic weapon and the M240B machine gun could not be made, due to ammunition restrictions and the limited number of gunners.

Utilization of Findings:

The findings from both training efforts were briefed to the Directorate of Operations and Training in the Infantry School, the TRADOC Systems Manager-Soldier, and Cdr 2-29th Infantry Regiment. The results were also disseminated to the Program Manager-Soldier and the Project Manager-Land Warrior. The findings have immediate applicability to the Army as the devices are currently being fielded. The findings from the aiming light firings have been used to assist the 29th Infantry Regiment and the Infantry School to develop Army-wide standards for night qualification with aiming lights and night vision goggles. The report also provides substantial information on what contributes to quality training on the devices and what should be integrated into institutional and unit marksmanship programs of instruction, technical manuals, and the Army's training and doctrine literature.

TRAINING LESSONS LEARNED ON SIGHTS AND DEVICES IN THE LAND WARRIOR (LW) WEAPON SUBSYSTEM

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Introduction

The purpose of this report is to summarize the primary lessons learned from two assessments of training on key components of the Land Warrior (LW) weapon subsystem. These components were four target acquisition devices (sights and aiming lights) that were used with three different weapons, which are also part of the LW system. All devices and weapons were government furnished equipment (GFE), although the soldiers had varying degrees of experience with each item of equipment. This summary is based on two other reports (Dyer, 1999; Dyer, Reeves, & Wampler, 1998) that provide more detail on the two training assessments. In each assessment, all members of a single Infantry platoon were trained.

The report documents training techniques found to be effective versus those that were not as effective. It also points to training issues that should be addressed prior to training for LW tests and in the current training of these devices. Recommendations on how to improve training are made. Similarities and differences in the training and performance of the two Infantry platoons are reported, as the program of instruction (POI) for the second platoon was modified, based on the findings from the first platoon. .

Although the assessments and training were done in support of an operational test of the LW system, the lessons learned are not restricted to the LW system. They also apply directly to units who have this equipment or will receive it in the near future. Furthermore, the performance data have direct applicability to institutional marksmanship training and performance standards.

Two Infantry platoons, from the same company from the 82d Airborne Division at Ft. Bragg, NC, were trained on the GFE for the LW weapon subsystem. The first, called the Baseline platoon, was trained in March-April, 1998, in preparation for the LW test scheduled for September 1998. This Baseline platoon was issued the AN/PEQ-2A aiming light, M68 close combat optic (CCO), the AN/PAS-13 thermal weapon sight (TWS), and a bore light device. The platoon already had the AN/PAQ-4C aiming light and the AN/PVS-7B night vision goggles (NVGs). At that time, the AN/PEQ-2A, CCO, TWS, and bore light were not fielded. But as fielding for these was imminent, the platoon was issued the items so the test would compare a LW platoon to a baseline platoon equipped with the equipment that the Army as a whole would have when the LW system is fielded.

Shortly after the Baseline platoon training, the LW test was postponed. Nonetheless, it was decided to train the LW platoon on the same GFE in December 1998, eight months later. Except for the bore light, the LW platoon had been issued the other GFE items in the fall of 1998, but had little experience with them.

The two assessments provided a unique opportunity to examine what happens when soldiers are trained on all the GFE at the same time, as must occur with the LW system. To our knowledge, this type of training had not happened previously for several reasons. First, not all the items were fielded. Second, at that time, there were no Army-approved, published qualification standards for any of the weapon-device combinations. Nor was there any formal training on the systems in Infantry One Station Unit Training (OSUT); only some familiarization training on aiming lights in the Infantry Officer Basic Course. Third, much of the available documentation on training for each device was in the context of separate tests (e.g., Army Operational Test & Evaluation Command, 1997; Boylan, Riemenschneider, & Fye, 1997; McDonald, 1997). Consequently, the assessments provided the first opportunity to examine skill transfer from one device to the other as well as potential confusions and interference among training procedures/techniques used with the different devices.

The two periods of training also allowed an examination of the effectiveness of training as a function of enhancements to training techniques and materials. The instruction for both platoons was conducted by cadre from the 29th Infantry Regiment at Ft. Benning, GA. Modifications to the POI for the LW platoon were made based on experiences with the Baseline platoon. In addition, some unexpected changes occurred in the process of training the LW platoon that provided quasi-experimental comparisons of the effects of equipment and training conditions on performance.

The Equipment

The weapons used by both platoons were the same: M4 carbine with Picatinny rail (modular weapon system), the M249 squad automatic weapon, and the M240B machine gun. Throughout this report these weapons will be referred to as the M4, M249, and M240B. No further description is provided of these weapons.

The CCO is a daylight, reflex collimator sight with unity power optics. It uses an illuminated red dot as an index point of aim. The firer can keep both eyes open during target engagement, potentially allowing awareness of close-in surroundings. The CCO is intended to eliminate the aiming error associated with aligning the front and rear sight posts on small arms weapons.

The two aiming lights, referred to here as the PAQ-4C and PEQ-2A, are used for night firing with night vision goggles (NVGs). In fact, NVGs, or a similar image intensification device, must be used with the aiming lights. Both aiming lights emit a steady infrared laser beam that is visible only with image intensification devices, such as NVGs. This beam is not visible to the naked eye nor with thermal sights. The PAQ-4C is a follow-on to the PAQ-4A and PAQ-4B aiming lights, which have been fielded in the Infantry for a considerable period of time. The PAQ-4C has a single beam with a predetermined width. The PEQ-2A uses the same technology as the PAQ-4C, but has two infrared beams. One beam, called the aimpoint, is like the PAQ-4C. The other is called an illuminator; its width can be varied. The range of these two lasers is greater than that of the PAQ-4C, and the power of each laser can be varied independently. All soldiers had NVGs; the baseline platoon had AN/PVS-7Bs and the LW platoon had AN/PVS-14s. The differences between these two NVG versions are described later in this section.

The AN/PAS-13 TWS operates in the medium infrared spectrum and can be used in day and night as it detects differences in the temperatures of objects in the environment. It was used primarily for night firing in the two courses of instruction. Thermal sights have been used by the Infantry for many years (e.g., on the TOW and Dragon antitank weapons), but the TWS is the first thermal sight developed for use with small arms.

The bore light device provides a means to boresight sights and aiming lights to the soldier's weapon. The bore light was used to boresight each device (CCO, TWS, aiming light) to each weapon (M4, M249, M240B). It emits a visible, red laser beam. To boresight, soldiers must first center the bore light in the weapon's barrel. Deviations from this central alignment have a negative impact on the accuracy of a device's boresight setting. The intent of using the bore light with sights and aiming lights is to ensure that soldiers get bullets "on paper" when live-fire zeroing. The bore light aligns the device with the bore of the weapon, or in other words, "boresights" it. Boresighting does not constitute a live-fire zero of the weapon. No bullets are fired during boresighting to check the adequacy of the device's alignment to the weapon.

There also is interest in whether the boresight setting can serve as a dry-fire zero, eliminating the need for live-fire zeroing. In the LW POI, the boresighting procedure was used as a dry-fire zero only for aiming lights on the M4. Live-fire zeroing at 25 meters with aiming lights and NVGs has been found to introduce considerable error into the zeroing process, due to the halo of the aiming light in the NVGs and the resultant inability to achieve a precise point of aim at 25 meters (Dyer, Smith, & McClure, 1995, 1996). There has been extensive work on determining the boresight procedures for aiming lights on the M16A2 rifle and M4 carbine. Boresighting has resulted in satisfactory hits at range with aiming lights on these weapons without 25-meter live-fire zeroing (McDonald, 1997).

The boresighting distance was 10 meters. Boresight offset targets (Appendix A) for this distance were developed for each weapon-device combination by the US Army Armament Research, Development, and Engineering Center (ARDEC). As shown in Appendix A, an offset target has two markings, one for the soldier's point of aim with a device and the other for the bore light itself. To boresight at the close distance of 10 meters, the soldier's point of aim with a device and the position of the bore light beam should not be coincident with each other. That would result in the wrong bullet trajectory when shooting at more distant targets. The two points must be distinct, or "offset" from each other, as the bore light is in the barrel and the soldier's point of aim varies with where the device is mounted on the weapon. For each weapon-device combination, the specific boresight offset at 10 meters corresponded to a battlesight zero of 300 meters, i.e., the point of aim corresponds to the point of impact.

For both platoons, the same marksmanship qualification standards were applied, with the exception of a slight modification for the TWS with the M240B machine gun. Target engagement and zeroing were conducted on the same ranges for both platoons.

The equipment assigned to the platoon members, by duty position, is presented in Table 1. There were two differences in the equipment assigned to the platoons.

One difference was the NVGs. All LW platoon members had the AN/PVS-14 monocular, helmet-mounted NVGs, whereas the Baseline platoon had the helmet-mounted biocular AN/PVS-7B NVGs. As the Baseline platoon had had the AN/PVS-7Bs for a considerable period, its NVGs were not always in the best state of repair. In contrast, the AN/PVS-14s had been issued recently to the LW platoon. Both NVGs are 3d generation image intensification technology. However, the Omnibus IV AN/PVS-14 NVGs have higher resolution, signal to noise ratio, and photocathode tube sensitivity.[1] Performance models show that the AN/PVS-14 NVGs, Omnibus IV, result in the ability to detect targets at farther distances, from full moon to overcast starlight conditions, than the AN/PVS-7B Omnibus III NVGs.[2] Because the LW platoon had better quality NVGs, we expected that there might be differences in marksmanship performance of the two platoons when they fired with the aiming lights.

[1] Briefing by Mr. D. Stevenson, ITT Night Vision, to Infantry School personnel, March 1999.
[2] Memorandum from Mr. Bill Markey, Night Vision and Electronic Sensors Directorate, April 1999.

Table 1
Assignment of Equipment to Duty Positions

Equipment	Baseline Plt	LW Plt
Weapons		
M4 Carbine - Modular Weapon	All positions but M249 and M240B gunners	All positions but M249 and M240B gunners
M249 Squad Automatic Weapon	SAW gunners	SAW gunners
M240B Machine Gun	M240B gunners	M240B gunners
Sights, Aiming Lights, and Devices		
M68 Sight: Close Combat Optic (CCO)	All positions but M249 and M240B gunners	All positions but M249 and M240B gunners
AN/PAS-13: Thermal Weapon Sight (TWS) - Medium	All squad members, M249 and M240B gunners	All positions
AN/PAS-13 - Thermal Weapon Sight (TWS) - Heavy	Plt Ldr, PSGT, and squad leaders	*(not used)*
AN/PAQ-4C Aiming Light	All squad members and assistant gunners (Ags	All squad members and assistant gunners (AGs)
AN/PEQ-2A Aiming Light	Plt Ldr, PSG, squad ldrs, M249 and M240B gunners	Plt Ldr, PSG, squad ldrs, M249 and M240B gunners
AN/PVS-7B NVGs - Helmet-Mounted, Biocular, 3rd gen I^2 (Omnibus III)	All positions	*(not used)*
AN/PVS-14 NVGs - Helmet Mounted, Monocular, 3rd gen I^2 (Omnibus IV)	*(not used)*	All positions
Bore Light Device	1 per squad	1 per squad

The other difference in equipment was that the LW platoon used only the medium TWS, whereas the leaders in the baseline platoon were issued the heavy TWS. The difference between the two sights is their magnification and the resulting field of view. For the medium TWS, the wide field of view (WFOV) is 15 degrees with 2.0 power, the narrow field of view (NFOV) is 9 degrees with 3.3 power. For the heavy TWS, the WFOV is 9 degrees with 3.3 power, the NFOV is 3 degrees with 10 power.

The association between each weapon and each device is illustrated in Figure 1. The solid arrows between a device and the oval surrounding a weapon(s) indicate all soldiers assigned that weapon(s) used that device. The dashed arrows indicate only some of the soldiers used the device. Thus all soldiers assigned an M4 carbine used the CCO, TWS, and bore light. Some used the PAQ-4C aiming light; the others (leaders) used the PEQ-2A aiming light. Those assigned the M249 SAW or M240B machine gun used the TWS, PEQ-2A, and bore light. They did not use the CCO or the PAQ-4C aiming light. The lighter double-headed arrows between the NVGs and the two aiming lights indicate that NVGs were always used with the aiming lights.

One additional difference in the equipment was body armor. Body armor was worn by the Baseline platoon during all range firings. It was not used by the LW platoon.

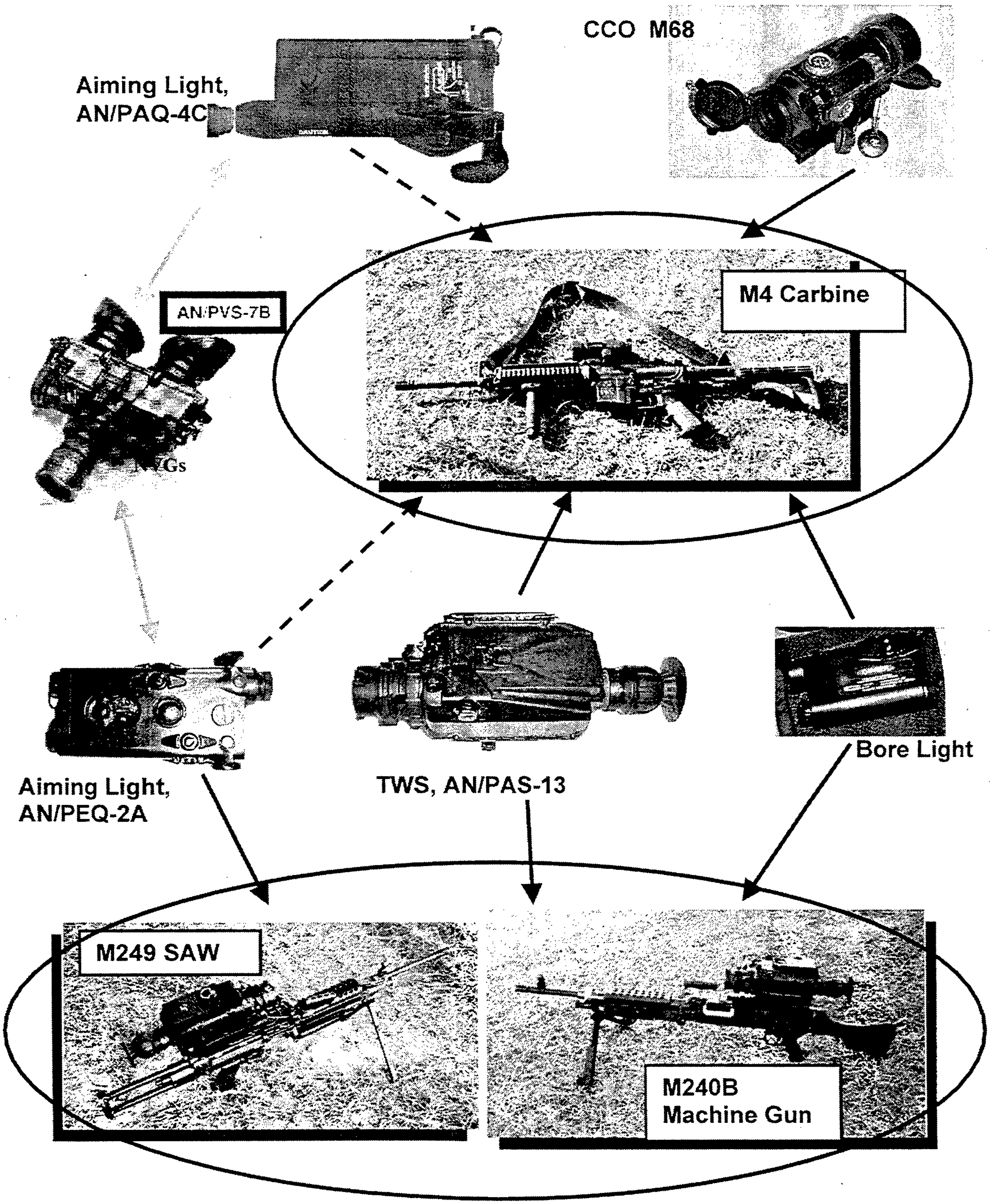


Figure 1. Equipment used by the platoons. (AN/PVS-14 NVGs and heavy TWS not shown.)

The Soldiers

Time in Army

Neither platoon was at full strength. The Baseline platoon had 32 soldiers; the LW platoon, 26 soldiers. A breakout of squad size and the platoon members' time in the Army is in Table 2. In terms of Army experience, the squad members within the platoons were similar. The leadership profile was somewhat different, although the two platoon sergeants were equally experienced. The Baseline platoon leader's time in the Army was half that of the LW platoon leader, but the Baseline squad leaders had, on average, twice as much time in the Army as the LW squad leaders (10.6 vs. 5.7 years).

Table 2
Squad Size and Soldier Time in the Army

	Baseline Platoon	**LW Platoon**
Squad Size	8, 8, & 6 with 7 in Wpns Sqd	6, 6, & 5 with 7 in Wpns Sqd
Time in Army		
Platoon Ldr	0.8 years	1.5 years
Platoon Sgt	14.0 years	14.5 years
Wpns Sqd Ldr	14.0 years	17.0 years
Rifle Sqd Ldrs	6.0, 10.7, and 15.2 years	3.9, 4.5, and 8.7 years
Sqd Members	Mean: 2.5 years; Range: 0.09 to 8.6 years	Mean: 2.7 years; Range: 0.5 to 9.7 years

Experience with Equipment

Almost all soldiers had used some form of NVGs and aiming light (Table 3). However, squad leaders indicated that this experience was primarily force-on-force or live-fire at close range, rather than the type of marksmanship training executed in the GFE POI described in this report. The percentages in Table 3 indicate that more soldiers in the LW platoon had experience with the other equipment being trained. However, with regard to the CCO, the TWS, and the bore light, this experience was limited. They had received the equipment two months earlier and had no systematic training on it.

Computer Experience

Because a major component of the LW system is the computer/radio subsystem, soldiers were given a survey on their computer experience (see Appendix B for survey and data). The survey addressed where they had used computers in their formal education, their current use of computers, and whether they owned a computer. They were also asked to rate themselves on their degree of computer expertise ("novice" to "Bill Gates would hire me") and on their typing skill. Lastly, they were given a 12-item icon test that provided an objective indicator of skill. Twelve icons common to commercial software packages (word processing, graphics, Windows operating system), as well as icons in prototype versions of the LW software, were presented. Soldiers had to name the function of each icon. The icons were spell check, cursor, zoom, open file, save, print, cut, copy, paste, undo, new file, and arrow.

Table 4 summarizes the survey results. As the computer experience of the two platoons was very similar, no distinctions are made between the two platoons. In general, their computer background was not strong, as indicated by their experience profiles, their self-ratings of skill, and the icon scores.

Table 3
Soldier Experience with the Devices and NVGs

Equipment	**Baseline Platoon**	**LW Platoon**
	% Soldiers using Equipment	
NVGs (any model)	**97%** 97%: AN/PVS-7B helmet-mtd 0%: AN/PVS-14 (not issued)	**100%** 82%: AN/PVS-7B helmet -mtd 79%: AN/PVS-14
Aiming Lights (any version)	**91%** 91%: AN/PAC-4 0%: AN/PEQ-2A issued as new equipment	**93%** 89%: AN/PAC-4 25%: AN/PEQ-2A
Thermal Sights (Dragon, TOW Javelin CLU, TWS)	**41%** (TWS issued as new equipment, no prior experience)	**75%** 54%: TWS
CCO	**0%** (issued as new equipment	**82%**
Bore Light	**0%** (issued as new equipment)	**32%**

More soldiers had used a computer than owned one (65% used versus 35% owned). Formal experience with computers increased from grade school through high school (from 15% to 70%). Less than half (41%) had used computers in more than one educational setting: 13% had never used a computer in school. With regard to computer features (LW platoon only), 40% indicated they used a mouse, computer games, and menu-based programs on a daily or weekly basis. In contrast, graphics software was used by only 15% on a daily or weekly basis.

The survey produced both subjective and objective indices of computer skill. On the self-rating question, almost half (45%) rated themselves as a computer novice, 18% as good with one software program, and 28% as good with several or more software programs. Very few (8%) indicated they had programming skills. The mean icon score was 4.14 out of a maximum of 12; 80% of the scores were at or below 50% correct (a score of 6). So the soldiers' low subjective ratings were corroborated by the low icon scores.

The relationship between the survey items and the icon score was examined. The correlations were as follows: .61 with an index that summed the items on use of computer features (LW platoon only), .56 with self-ratings, .42 with whether they currently use a computer, .36 with number of formal educational settings where they used a computer, and .27 with whether they owned a computer. All correlations were significant at the .05 level. These results show that self-ratings correlated fairly well with the icon scores, a finding consistent with Van Vliet, Kletke, and Charkraborty (1994). But the correlation with the computer-features-used index, reflecting the type of computer experience, was higher. Interestingly, computer ownership, per se, was the lowest correlate.

Table 4
Computer Experience

Survey Items	Baseline Platoon (*n* = 32)	LW Platoon (*n* = 28)
% Soldiers who own a Computer	34%	36%
% Soldiers who Currently use a Computer	62%	68%
% Soldiers who used a Computer in:		
Grade School	12%	18%
Junior High School	28%	43%
High School	59%	82%
College/University	31%	25%
Never used computer in school	16%	11%
% Soldiers who used Computers in more than one Educational Setting	31%	54%
Self-ratings of Typing Skill - % Soldiers		
Hunt and Peck Slowly	6%	14%
Hunt and Peck Quickly	44%	57%
Type Slowly	38%	21%
Type Quickly	13%	7%
Use of Computer Features: % Soldiers indicating daily or weekly use	*Baseline platoon not asked frequency of use, but simply whether used or did not use.*	
Mouse		43%
Games		43%
Icon-based programs		35%
Menu-based programs		39%
Graphics software		15%
E-mail		32%
Internet		36%
% Soldiers Rating Themselves as:		
Computer novice	38%	54%
Expert with 1 software package	19%	18%
Expert with several software packages	34%	21%
Expert with several software packages And can program	9%	7%
Statistics on 12-item Icon Score		
Mean	5.12	4.14
Median	5.00	4.00
SD	2.50	2.39
Range	1-11	0-10
% scoring at or below 50% correct (score of 6)	72%	89%

Finally, the relationship of time in Army to the self-ratings and the computer scores was examined using χ^2 statistical techniques. Time in Army was categorized as less than 3 years, 3 to 10 years, and more than 10 years. Icon scores were split at 50% correct (score of 6 or less vs greater than 6). Self-ratings were split as novice or experience with one software program versus experience with several programs and/or programming experience. Neither the self-rating nor icon score related significantly to time in the Army. Of interest, however, is that of those with 10 years or less in the Army, 77% (of 54 soldiers) scored 50% or lower on the icon test, while for those with more than 10 years in the Army, all (100%, 6 of 6 soldiers) scored 50% or lower.

Personnel Turbulence in Baseline Platoon

The battle roster of the Baseline platoon was obtained in December to determine the amount of personnel turbulence that had occurred during the intervening 8 months from April to December. Of the 32 platoon members, 18 (56%) were still in the platoon, 11 (34%) were in the same squad, and 6 (19%) were in the same duty position. Within the platoon headquarters only the radio telephone operator was still there (new platoon leader and platoon sergeant). Within the each squad the turbulence figures were as follows: 1st squad, 5 of 8 members (63%) remained; 2d squad, 2 of 6 members (33%) remained; 3rd squad, no members were the same as the original 8; weapons squad, 2 of the 7 members (28%) remained.

Method

Three individuals observed classroom instruction and documented the training events. The observation technique was a form of a narrative observation system called a specimen description (Evertson & Green, 1986). This is an on-line, systematic and intensive recording of events. The intent is to record "all" behavior during a designated time period in an uninterrupted stream and in detail. It is useful for recording "everything" in sequence and unselectively about what individuals do and say, and the situation. A log indicating the time of day for events is an essential feature of the procedure, allowing a record of the time required for different phases of training and instruction. The technique was expanded by having the observer comment on the effectiveness of the instruction and training techniques, and on possible improvements.

In addition, records of individual performance were obtained: written test scores and firing results during zeroing, practice firing, and qualification. Training resources and materials were documented as well. Day and night (image intensification and thermal) photographs were taken during selected practical exercises (PEs) and firing exercises. Soldiers were interviewed about the instruction and firing techniques. During the PEs, each observer had primary responsibility for watching one squad.

The Program of Instruction (POI)

Training consisted of classroom presentations and demonstrations, as well as hands-on PEs. Following this training, soldiers employed the sights and aiming lights with their assigned weapons in range firing exercises, culminating in weapon qualification on each device. The primary tasks in the POI for both platoons are in Table 5.

The sequence of training differed somewhat for the two platoons. Based on experience with the Baseline platoon, the LW platoon instruction began with the aiming lights and firing was conducted on the first night. This "front-loading" was done to expedite the training, as considerable time was required to qualify the Baseline platoon on the aiming lights. For both platoons, firing exercises with the M249 and M240B were conducted during the second week of training. In addition, the number of days available for training was 9 for the Baseline platoon and 7 for the LW platoon. The training sequences are in Table 6.

Table 5

Instruction and Tasks in the POI for Both Platoons

Content of Course	Equipment: Sights, Aiming Lights, and Bore Light				
	Bore Light	CCO	PAQ-4C	PEQ-2A	TWS
Equipment characteristics	X	X	X	X	X
Place into operation	X	X	X	X	X
Maintain	X	X	X	X	X
Operate	X	X	X	X	X
Theory behind thermal sights	NA	NA	NA	NA	X
Boresight with bore light	NA	X	X	X	X
Zero	Dry-fire	Live-fire w M4	None (M4 - boresight only)	Live-fire w M249 & M240B. Boresight w M4	Live-fire w all weapons
Engage targets	NA	X	X	X	X
Qualify	NA	X	X	X	X
Written test	X	X	X	X	X

There were four important differences in the M4 live-fire exercises for the two platoons (see Table 7). The first was planned; the others occurred inadvertently.

First, the heat sources for the TWS zero targets differed. For the Baseline, it was a heat pad stapled to the back of the target. This did not produce a satisfactory aiming point. To overcome this problem with the LW platoon, the zero range was modified so thermal blankets could be used, in accordance with the TWS Technical Manual (DA, 1997).

Second, both platoons were to zero in daylight with the TWS. However, the LW platoon zeroed at night because of time constraints.

Third, there were differences in the practice qualification scenarios for both the aiming lights and the TWS. With both platoons, the targets (# and range) in practice qualification were identical to those in qualification. However, the plan was to add two seconds to the target exposure time during practice qualification. This happened with the Baseline platoon, but accidentally failed to occur with the LW platoon. Therefore, one might expect practice qualification scores to differ for the two platoons on both the TWS and aiming lights.

The last difference was in the execution of the TWS exercises. For the LW platoon, the full complement of exercises was reduced because of time constraints. Known distance firing was not executed. Only some soldiers fired field fire and practice qualification. In fact, some soldiers only fired qualification (and qualified). More detail on these exercises is in the range firing section of this report. The result of this change was to provide the LW platoon with considerably less experience with the TWS prior to qualification.

Table 6
Training Sequence for Both Platoons

Day and Time of Day	Baseline Platoon	LW Platoon
1 Daylight	Instruction & PE on bore light and CCO	Instruction & PE on bore light, PAQ-4C, and PEQ-2A
1 Night		M4: Dry-fire through qualification with PAQ-4C/PEQ-2A
2 Daylight	Instruction & PE on PAQ-4C and PEQ-2A	Instruction & PE on CCO
2 Night	Dry-fire w PAQ-4C and PEQ-2A	M4: Requalification with PAQ-4C/ PEQ-2A
3 Daylight	Instruction & PE on TWS	Instruction & PE on the TWS
3 Night	Night PE with TWS	
4 Daylight	M4: Live-fire zero with CCO; dry-fire through qualification with CCO.	M4: Live-fire zero with CCO; dry-fire through qualification with CCO
4 Night	M4: Dry-fire with PAQ-4C and PEQ-2A	M4: Live-fire zero and qualification with TWS
5 Daylight		M4: Reconfirm zero with CCO & TWS; Requalify on CCO
5 Night	Night firing cancelled because of stormy weather	M4: Requalify on TWS
6 Daylight	M4: Live-fire zero with TWS	
6 Night	M4: Dry-fire through qualification with TWS; field fire through qualification with PAQ-4C & PEQ-2A	M249 & M240B: Live-fire zero through qualification with TWS WFOV
7 Daylight		M240B: Live-fire zero through qualification with TWS NFOV
7 Night	M4: Continued field fire through qualification with PAQ-4C/PEQ-2A. M249 & M240B: Live-fire zero though qualification with PEQ-2A	M249 & M240B: : Live-fire zero through qualification with PEQ-2A
8 Daylight	M249 & M240B: Started live-fire zero with the TWS	
8 Night	M4: Continued qualification with PAQ-4C/PEQ-2A. M249 & M240B: Finished live-fire zero with TWS; field fire through qualification with the TWS	
9 Daylight		
9 Night	M4: Continued qualification and requalification with PAQ-4C/PEQ-2A	

Note. The second week of training began with day 6.

For both platoons, more M249 and M240B live-fire exercises were planned than executed as a result of limitations in ammunition and training time (see Table 8). And not all soldiers had the opportunity to requalify. All qualification scenarios had 11 targets, with the standard being 6 target hits. The M249 gunners had 66 rounds for qualification; M240B gunners had 154 rounds; all gunners had a 4 to 1 ball to tracer mix.

Table 7
M4 Live-Fire Exercises in the POI

Exercise	Live-Fire Plan			Differences between Platoons in Execution of Plan
	CCO	PAQ-4C & PEQ-2A	TWS	
25m zero	Day	None	Day	**TWS:** Baseline zeroed in daylight; LW zeroed at night. Different heat sources used.
Dry-fire	Day	Night	Night	Group dry-fire sometimes executed with LW soldiers to save time.
Known Distance (KD)	None	Night	Night	**TWS:** KD executed only with Baseline
Field Fire (FF)	None	Night	Night	**TWS:** FF executed in Baseline; Only a few LW soldiers did FF
Dry-Fire - Qualification	None	Night	Night	No differences
Practice Qualification (PQ)	Day	Night	Night	**TWS & Aiming Lights:** Baseline had 2 seconds additional exposure time for targets **TWS**: Not all LW soldiers did PQ
Qualification	Day	Night	Night	No differences

Note. 25m zero with M4 back-up iron sight (BIS) was also planned and executed with the LW platoon.

There were some differences in the qualification procedures, primarily with the TWS (see Table 8). First, when field zeroing the PEQ-2A at 300 meters at night, the Baseline platoon had difficulties detecting the bullet location at this distance. This problem was eliminated with the TWS. Since the TWS can be used both day and night, field zeroing started during daylight hours for the Baseline platoon, but had to continue into dusk. Daytime zeroing of the TWS was also the plan for the LW platoon, but time constraints prevented this from happening in the WFOV for both the M249 and M240B. Second, field zeroing with the M240B was at 300 and 500 meters for the LW platoon; at 300 meters only for the Baseline platoon. Third, the TWS qualification standard for the Baseline platoon required gunners to qualify in both FOVs. For the LW platoon, each FOV was treated separately. And the data are presented separately in this report. Lastly, the TWS qualification scenario for the M240B gunners differed. The Baseline platoon had targets from 200 to 600 meters; the LW platoon, from 400 to 800 meters. Table 16, presented later, gives a more complete breakdown of all target distances.

A breakdown of the training time by device and by classroom and range firing is in Table 9. The total time for the Baseline platoon was 47.9 hours, 58% at night. The total time for the LW platoon was 53.3 hours, 60% at night. Both execution times were less than those specified in the POI; 59 hrs for the Baseline platoon and 61.25 hours for the LW platoon. Figure 2 compares the execution and planned times. There is greater consistency in these two times for the LW platoon than for the Baseline platoon. This can be attributed to applying what was learned about time requirements in the Baseline training to the LW training. LW platoon POI times were increased for the most difficult system on which to qualify, the PAQ-4C, and were decreased to reduce redundancy in the Baseline platoon POI times for the TWS.

Table 8
M249 and M240B Live-fire Exercises in the POI

Exercise	Live-Fire Plan		Differences between Plan and Execution of Plan
	PEQ-2A	**TWS**	
Field zero with M249	Night	Day	**TWS:** LW zeroed at night in WFOV only and did not zero in NFOV.
Field Zero with M240B	Night	Day	**TWS**: LW zeroed at night in WFOV and during day in NFOV. LW zeroed at 300 and 500 m; Baseline zeroed at 300m only. **PEQ-2A**. LW zeroed at 300 and 500 meters; Baseline zeroed at 300.
Dry-fire	Night	Night	No differences
Field Fire 1 (FF1)	Night	Night	**PEQ-2A and TWS**: FF1 not executed for either LW or Baseline.
Field Fire 2 (FF2)	Night	Night	**TWS**: FF3 replaced FF2 for LW. Baseline did not conduct FF2.
Dry-fire Qualification	Night	Night	No differences
Practice Qualification (PQ) and Qualification (Q) *Targets exposed 5 sec longer in PQ than Q.*	Night	Night	**TWS - M249**: LW did PQ and Q only in WFOV. Baseline did PQ only in NFOV; did Q in both FOV. **TWS - M240B**: LW did PQ and Q in WFOV at night and NFOV during the day. Target ranges were 400-800m for LW vs 200-600m for Baseline.

Table 9
Instruction and Training Times (minutes and hours)

Content of Course	Bore Light	CCO	PAQ-4C	PEQ-2A	TWS
Classroom Times in Minutes					
Baseline Plt	112	124	223	112	317
LW Plt	93	135	105	80	267
Range Times in Minutes					
Baseline Plt	NA	350	690	150	785
LW Plt	NA	590	610	345 w M249 & M240B	970 w all weapons
Total Times in Minutes and Hours					
Baseline Plt Minutes Hours	112 min 1.9 hrs	474 min 7.9 hrs	913 min 15.2 hrs	272 min 4.5 hrs	1120 min 18.4 hrs
POI Time for Baseline Plt	2.2 hrs	9 hrs	6 hrs	14.5 hrs	27.5 hrs
LW Plt Minutes Hours	93 min 1.6 hrs	725 min 12.1 hrs	715 min 11.9 hrs	425 min 7.1 hrs	1237 min 20.6 hrs
POI Time for LW Plt	2 hrs	10 hrs	14.75 hrs	11.25 hrs	23.25 hrs

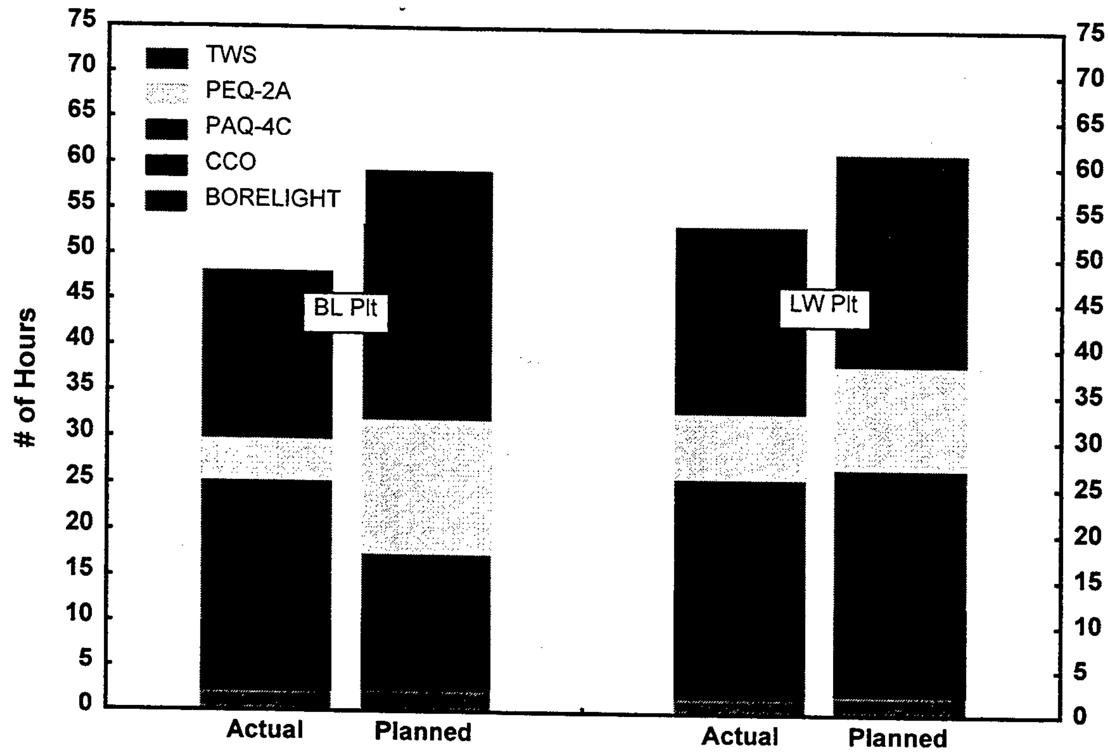


Figure 2. Actual and planned (POI) times by device for each platoon.

Total time for classroom instruction on all equipment characteristics and capabilities and the boresighting PEs was typically lower for the LW platoon (14.8 hours for Baseline, 11.3 hours for LW). However, a constant within this instruction was the boresighting PEs, which required an hour for each device with both platoons. The shorter platform instruction time for the LW platoon reflected modifications in this phase of the POI resulting from prior experience with the Baseline platoon.

Nonetheless, the total time to train the LW platoon was longer, despite fewer days in which to train, shorter classroom instruction, reduction in range firing for the PAQ-4C, reduction in the M4 TWS exercises, and the smaller LW platoon. This increased time was due primarily to the more extensive range training with the M249 and M240B, night time zeroing of the TWS on all weapons, and zeroing of the back-up iron sight on the M4 that was added to CCO zeroing.

The numbers in Table 9 should be viewed as underestimates of the training time required to fully execute the POI as planned. If both platoons had been at full strength, if ammunition limitations had not occurred for the M249 and M240B, and if there had been no time constraints, the training times would have increased.

Results on Classroom Instruction and Practical Exercises

Procedures Common to All Devices and Both Platoons

For each device, the sequence of instruction was to present information on the technical and operational characteristics first, followed by a PE where the platoon was then broken down by squads and boresighted the device. A review and a written test concluded each block of instruction. View graphs were used as the training media during the platform instruction. Although the content covered was highly similar for both platoons, the view graphs were substantially different. An entirely new set of viewgraphs was prepared for the LW platoon, based on the lessons learned with the Baseline platoon. With the LW platoon, more viewgraphs were presented to support the instruction. The presentation quality of these view graphs was superior: better graphs, actual photos of the equipment, and more legible text. In addition, with the LW platoon there was more consistency across devices in terms of the information presented (information on batteries, boresight and zeroing adjustments, device controls and components, weight, maintenance, mounting brackets, etc.).

With the Baseline platoon, the soldiers had the devices available to them to examine as the instruction proceeded. With the LW platoon, only the TWS was available during the platform instruction. With both platoons, boresighting demonstrations were presented by the instructors prior to the boresighting PE. An assistant instructor was assigned to each squad for the boresighting PEs. Each soldier boresighted each device that he was to use in range firing. The boresight distance was 10 meters.

Each written test consisted of 20 items. Both platoons were tested on the CCO, TWS, PAQ-4C and PEQ-2A. Only the LW platoon was given a test on the bore light. The LW platoon's tests were an edited version of the Baseline platoon tests. Grammatical corrections were made to the Baseline tests and some items were clarified.

The results on the written tests provide an indication that the instructional revisions helped the LW platoon. Table 10 presents the test results from both platoons. A multivariate analysis of variance showed an overall significant difference between the platoons when all four tests were considered simultaneously ($F(4,52) = 9.16$, $p < .0000$, Wilks' $\Lambda = .587$). The LW platoon scored higher on the CCO and TWS tests (Tukey *a*, $p < .001$ on each test).

Table 10
Scores on the Written Tests

Test	***M***	**Minimum Score**	**Maximum Score**	***SD***	**# & % Soldiers Passed First Time**
Baseline Platoon					
CCO	15.69	8	20	2.99	25 (78%)
PAQ-4C	16.09	10	19	2.11	28 (87%)
PEQ-2A	17.56	11	20	2.31	30 (94%)
TWS	14.12	4	20	3.85	21 (65%)
LW Platoon					
CCO	17.83	14	20	1.97	26 (100%)
PAQ-4C	16.81	12	20	2.31	25 (96%)
PEQ-2A	18.08	15	20	1.56	26 (100%)
TWS	18.82	12	20	1.89	25 (96%)
Bore Light	18.07	14	20	1.87	26 (100%)

Note. Scores are based on the first time soldiers took the tests.

Lessons Learned Common to All Devices

Platform instruction. It was critical to present the basic characteristics and components of each device. The backgrounds of the soldiers differed considerably, with those new to the unit from Infantry OSUT having no training and experience with most of the devices, to include NVGs. Even for those soldiers with some experience with the devices, their backgrounds varied, dependent on their time in the Army. Based on the observations of the platform instruction given to each platoon, it is recommended that the common core of information presented on each device should include the following as applied to each weapon:

- Purpose of the device; tactical advantage it provides
- The technology underlying the device
- Size and weight
- Battery requirements, how to insert/remove, battery life
- Mounting brackets, mounting location on weapon, spacers needed, if any. Need to check adequacy of mounting after firing. Where to re-mount to maintain boresight and zero.
- Thorough explanation of each control, its settings, how it operates, and what it does. Include PEs for the soldiers to practice use of the each control, to experience its function and to develop eye-hand coordination with the device itself.
- Reticle, reticle markings
- Boresight adjustments; boresight offset targets
- Zero adjustments, zero targets, bullet impact area
- Preventative maintenance checks and services (PMCS)
- Safety precautions
- Range exercises; qualification standards

Information on the adjustments needed to boresight and zero is critical. For each device, one increment or "click" in the windage or elevation adjuster will, relative to the firer's point of aim, move the barrel a given distance at 25 meters and a different distance at 10 meters. The movement of a windage or elevation adjuster results in a change in the impact point of bullets during live-fire zeroing at 25 meters and to a change in the location of the bore light beam on the offset target during boresighting at 10 meters. Both distances should be given during classroom instruction. This information is needed to make boresighting and zeroing more efficient, as soldiers must use both procedures. For example, a soldier should know that during boresighting, as he keeps the PAQ-4C aiming light beam on the same spot at 10 meters, 1 click of the windage adjuster on the PAQ-4C moves the barrel (and thus the bore light) 2.5 mm at 10 meters. If he is zeroing at 25 meters, 1 click of the windage adjuster moves the barrel (and thus the bullets) 10 mm (1 cm) at this distance. A "cheat sheet" or guide could be provided to help soldiers retain this information across all devices as well as the direction in which the bullets move.

The need to clarify these adjustments and develop mnemonic aids to assist soldiers to remember them is obvious as they differ from one device to the other. In addition, the M16A2 zero target that most soldiers and leaders have used in the past differs from the M4 carbine target. The dimensions of the "squares" on these two targets differ, with the M16A2 being 10 mm wide by 9 mm high, and the M4 being 14 mm wide by 13 mm high. The number of clicks required to move bullets one "square" on the M4 carbine 25-meter zero target should be provided for zeroing purposes when the M4 is used, because the adjustments differ from the M16A2 target.

The number of clicks must be an approximation, because none of the windage and elevation adjustments on the devices corresponds exactly to the size of the squares on the M4 zero target. As indicated in Table 11, 3 clicks on the CCO or the PEQ-2A will move the bullet's impact point 1.2 squares on the M16A2 target but only 0.85 squares on the M4 target. Thus an instructor, for sake of simplicity, might state that 3 clicks on both devices move bullets 1 square on either target. On the other hand, 3 clicks with the PAQ-4C correspond to 3 squares on the M16A2 target but only 2.14 squares on the M4 target. In this case the instructor would cite 3 clicks corresponds to 3 squares on the M16A2 target, but only 2 squares on the M4 target. Similar inconsistencies from one zero target to the other and from one device to another are evident from the numbers in Table 11. The soldier's and trainer's understanding of these relationships directly impact the time and number of rounds required to zero these devices.

Table 11
Windage Adjustments on Each Device and Their Relationship to the 10m Boresight Distance and the M4 and M16A2 25m Zero Targets

Device	Movement of Barrel (in mm) with 1 "click"		# of Squares Covered on M16A2 25m Zero Target			# of Squares Covered on M4 25m Zero Target		
	10 meters	25 meters	1 click	3 clicks	5 clicks	1 click	3 clicks	5 clicks
CCO	1.60mm	4.0mm	0.40 sq	1.20 sq	2.00 sq	0.28 sq	0.85 sq	1.43 sq
PEQ-2A	1.60mm	4.0mm	0.40 sq	1.20 sq	2.00 sq	0.28 sq	0.85 sq	1.43 sq
PAQ-4C	4.00mm	10.0mm	1.00 sq	3.00 sq	5.00 sq	0.71 sq	2.14 sq	3.57 sq
TWS								
WFOV	5.00mm	12.5mm	1.25 sq	3.75 sq	6.25 sq	0.89 sq	2.68 sq	4.46 sq
NFOV	3.00mm	7.5mm	0.75 sq	2.25 sq	3.75 sq	0.53 sq	1.60 sq	2.68 sq

Boresighting demonstrations. The boresighting demonstrations are essential parts of the instruction. When soldiers thoroughly understand the boresighting process, the PEs that follow will be executed efficiently. If the boresighting process is not understood by all, then the PEs will take considerable time. Furthermore, errors in the boresight settings may occur, resulting in the need to boresight again during range firing.

The boresight offset target for each device must be shown and explained. Each device's offset target is unique to that device. An instructor cannot assume that if a soldier understands one offset target that he will understand the markings on the others. For example, the PEQ-2A offset target has three points of aim or alignment; the PAQ-4C has two points. Use of the correct offset target must also be stressed. Whether spacers are used when mounting the device, the location of the device on the weapon (top, left), and the weapon being used must be taken into account, so the correct offset target is selected. See Appendix A for the boresight offset targets used in the training. All the boresight offset targets corresponded to a battlesight zero at 300 meters for the M4 carbine, M249, and M240B.

The instructors' demonstration should be oriented so all soldiers can see the boresight techniques and adjustments, and how they impact the final boresight setting. This can only be accomplished if there is more than one instructor; two or three assistant instructors are required, depending on the device. The primary instructor should describe the procedures as the assistant instructors illustrate them. Consideration should be given to having the soldiers use their NVGs and their TWS during the PE, so they can see the movement of the aiming lights and the hot spots used for alignment of the TWS reticle, respectively. The demonstration should be conducted so soldiers can see the offset target, and visually see the change from a non-boresighted device setting to a setting where the device is boresighted. View graphs illustrating different system alignments that trigger questions like "What do you do now? How should you move the adjusters?" will also help soldiers in this phase of the instruction.

Boresighting PEs. The boresighting PEs were indispensable. The platoons were divided into their four squads (including the weapons squad), and each soldier had to boresight each device to his weapon. An assistant instructor was assigned to each squad. Although one might hypothesize that if a soldier can boresight one device, he can boresight another, that proved not to be the case, because of the differing device technologies which inhibited positive transfer. Soldiers had to practice the procedures associated with each device.

Three major lessons were learned with the two platoons with regard to boresighting.

➊ Soldiers must establish a stable position using field-expedient techniques.
➋ The boresighting technique should be the same for all optics/devices to enhance understanding and reduce confusion among the devices.
➌ Every soldier should rotate through each of the boresighting duty positions.

Stability is required for accurate boresighting. Soldiers should use field-expedient techniques to enhance positive transfer to field settings. Dependency on classroom materials, simply meant that soldiers had to spend substantial additional time determining what field-expedient techniques (sand bags, rucks, etc.) would work. Consequently, use of special boxes or cradles or tables should be discouraged as they are typically not available in the field. The instructor can also demonstrate techniques that provide a stable position and compare them to techniques that fail to provide stability.

Table 12 illustrates the differences in windage and elevation adjustments and amount of movement of the barrel (rounds) associated with each device. Because the M16A2 and M4 carbine zero targets differ, both are illustrated as well. The lack of consistency among devices shown in Table 12 reinforces the need for the instructor to be consistent in all other aspects of the boresighting and zeroing processes.

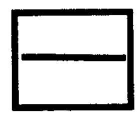
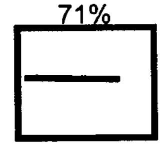
The recommended boresighting technique derived from work with both platoons is as follows:

➊ A stable firing position using field-expedient materials is established.
➋ The bore light is zeroed. This zero is checked whenever the bore light is placed in the barrel of a different weapon or even removed from a weapon and re-inserted in the same weapon.
➌ The device is aligned <u>first</u> with the offset target, as a firer would do when engaging an actual target.
  • When aligning the CCO and the aiming lights with their offset point, it is best to cover up the bore light to eliminate confusion as to which light is being aligned.
➍ The location of the bore light beam on the offset target is determined.
➎ Adjustments are made to the adjusters/knobs on the device to bring the bore light beam into alignment with its spot on the offset target.
  • With this technique, the direction in which the device's adjusters are turned are consistent with the technical manual citations for live-fire zero (DA, September 1993, January 1997), reducing potential confusion on the part of the soldier.

⑥ The final setting should be rechecked. The gunner should get "off the weapon" and then get back on again and check the alignment. For the TWS the windage and elevation settings can be recorded, as they are provided digitally in the TWS reticle.

⑦ The adjusters on the bore light must never be touched in this process as the bore light has been previously zeroed to the bore of the weapon.

Table 12
System Adjustments for Windage, Elevation and Distance During Zeroing and Boresighting

System	Direction of Movement with CW Turn of Adjuster		Movement of Barrel/Rounds at 25m w 1 "Click"	Amount of Zero Target Square Covered with 1 "Click"	
	Windage	Elevation		M16A2 Zero Target "Square" (10x9mm)	M4 Zero Target "Square" (14x13mm)
PAC-4C Left side of M4	←	↓	10mm	100% 	71% 
PEQ-2A Aimpoint Left side of M4	→	↓	4 mm	40%	28%
PEQ-2A Illuminator Left side of M4	→	↑	4 mm	40%	28%
CCO	←	↓	4 mm	40%	28%
TWS Medium WFOV	Right or left push of 4-sided switch.	Up or down push of 4-sided switch.	12.5 mm	125%	89%
TWS Medium NFOV	Right or left push of 4-sided switch.	Up or down push of 4-sided switch.	7.5 mm	75%	54%

Note. CW stands for clockwise. Distances given for zeroing at 25m. Boresight distances at 10m would be proportionately smaller. The amount of movement within a square is illustrated only for the PAC-4C. For the bore light, a CW turn moves the barrel to the right and up.

For the M4 carbine, the best stable position for the aiming lights differed from that with the CCO and the TWS. With the CCO and the TWS the gunner had to shoulder the weapon, and look through the sight itself to achieve the correct alignment. With the aiming lights, the gunner did not shoulder the M4, but instead turned the M4 on its side and stabilized it with rucks or sandbags. He then aligned the aiming light to the offset target using his NVGs. With this procedure the offset target must also be rotated 90 degrees in the correct direction for proper boresight. This technique greatly improved the stability of the weapon. It also eliminated problems the gunners had in getting a precise aiming point with the aiming light at 10 meters when they shouldered the weapon. The instructor should clarify why this procedure works and is preferred. With the M249 and M240B the bipod legs were used for weapon stabilization.

Enforcing Step 3 when boresighting each device is critical. This step creates consistency across systems, is consistent with target acquisition (aim and fire at the target with the device), and makes the adjuster movements consistent with zeroing procedures in the devices' technical manuals. The key here is to first align the device with its offset on the boresight target. Thus the CCO red dot would be aligned with its cross-hair on the offset target. The PAQ-4C or PEQ-2A beam would be aligned with its dot on the offset target. The TWS reticle aiming point would be aligned with hot spots on the offset target. With this technique, the bore light beam will then fall somewhere on the target. Changes to the adjusters on each system will move the bore light beam to its dot/mark on the offset target, just as changes to the adjusters will move the weapon's barrel and consequently the round's point of impact during live-fire zeroing. (During the training of the two platoons, it was learned that first aligning the bore light beam with the offset target, rather than the device with the offset target, did not work.)

Lastly, during the PE, soldiers should rotate among the boresight duty positions so they fully understand what is required during the boresight process. They should be the gunner when boresighting their own system. They also need to move the windage and elevation adjusters. They need to be the spotter at the offset target, calling off the needed adjustments. And they need to be the holder of the offset target. Cross training on these positions is essential to reducing errors.

Once soldiers had established a stable position and expertise had been developed at all the boresight duty positions, the time required for each soldier to boresight the CCO, an aiming light, or the bore light was only one or two minutes. Times were longer for the TWS, about 4 minutes for each FOV. When soldiers were learning these techniques, times could be as long as 10 minutes. Figure 3 illustrates some of the many boresight positions and configurations soldiers used during the training.

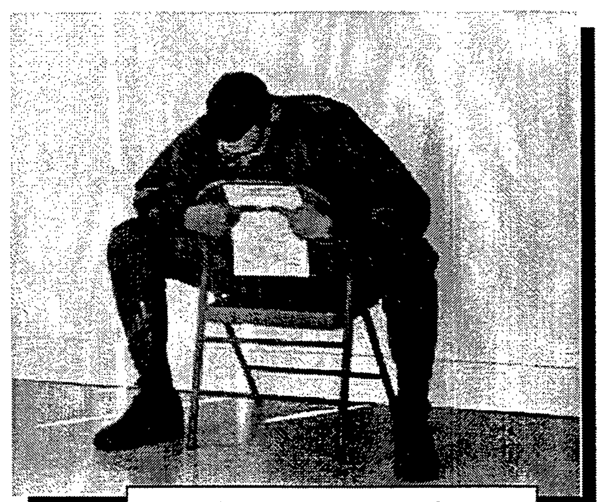
Additional Lessons Learned on Specific Devices

The bore light. In addition to stressing the importance of establishing a good "zero" on the bore light, soldiers need to completely understand the purpose of the bore light and how it works. They should be able to explain why the rotation process "works" (steps 3 through 8 presented below). They need to understand why offset targets are needed and why the offset point on the offset target corresponds to a 300 meter "zero." The later requires instruction with supporting graphics on the relationship between the bore light's trajectory, the round's trajectory, and the mounting location of the device. A training challenge is to develop these instructional materials.

Based on the experience with the two platoons, the recommended steps for "zeroing" the bore light, centering it both vertically and horizontally in the bore of the weapon, are as follows:

❶ Mark off 10 meters with a 10-meter wire or string.
❷ Make a "zero mark" for the bore light on a piece of paper and attach this paper to a wall or other vertical surface that is 10 meters from the gunner or have a buddy hold the paper very steady.

Illustration of three boresighting positions.
Picture 1 shows a cradle to the side of the firer that is not being used --- did not create a stable position and is not field expedient.
Pictures 2 and 3 illustrate use of rucks.



Two-finger technique for generating hot spot point-of-aim for TWS on the boresight target.

Figure 3. Boresighting positions and techniques.

Boresighting the PAQ-4C.
Spotter with NVGs at offset target.
Gunner and assistant trying to stabilize weapon with wooden cradle.

Use of sandbags to zero the bore light in the field.

Use of rucks to boresight the CCO in the field.

Figure 3 cont. Boresighting positions and techniques.

❸ Align the laser bore light beam with the zero mark. This is the start point. The weapon must be stabilized and can be in any orientation. The gunner does not need to shoulder the weapon.
❹ The start position of the bore light is with the battery up.
❺ Turn the bore light 180 degrees counterclockwise (CCW, from the viewpoint of a soldier behind the weapon). After this turn, the adjusters are on top and easy to reach.
❻ The buddy at the target must then mark the position of the bore light beam after the 180-degee turn. This is referred to as the turning point. He then determines a reference point that is half way between the start point (zero mark) and the turning point.
❼ The buddy tells the gunner which direction(s) to adjust the bore light and how many clicks are required to move the beam to the reference point.
❽ The gunner makes the adjustments.
❾ The gunner repeats the initial steps. He turns the bore light to the initial position (battery up), aligns it with the zero mark, and rotates it 180 degrees.
❿ The buddy at the zero target indicates whether further adjustments are needed. The bore light is zeroed when it turns or spins on itself (zero mark and turning point are the same).

A critical point in this procedure is that the orientation of the weapon is immaterial; the gunner need not shoulder the weapon. This allows the gunner to establish a very stable position using ruck sacks or sand bags. In addition, the target paper can be placed in a permanent location; there is no requirement for someone to hold it. Both factors will generate a more accurate zero or centering of the bore light, as human movement of the weapon, the target paper, or both have been eliminated.

During instruction on the bore light, the distinction between zeroing and boresighting should be made. These marksmanship terms and concepts should be used precisely. The purpose of the bore light is to get "bullets on paper" during live-fire zeroing. Boresighting is not the same as zeroing the weapon. In some instances, units may wish to use the boresight setting as a dry-fire zero, but they should be aware of potential inaccuracies with this procedure.

Lastly, if soldiers understand the concept of centering or zeroing the bore light, then they will understand that this bore light adjustment should not be changed when boresighting a device. But often, the phase "move the bore" of the weapon was interpreted to mean that they should adjust the bore light, when in fact the reference was to making adjustments to the device so that the bore of the weapon moved relative to the device. Again, precise use and definition of terms are critical parts of this instruction.

The CCO. Critical to instruction on the CCO is the issue of parallax. Within 50 meters, there is a parallax problem[3]. Consequently, firing at distances beyond 50 meters poses no

[3] The following information regarding parallax with the CCO was obtained from the Armament Research, Development, and Engineering Center (ARDEC). Physical parallax "deals with eye position with respect to the line of sight. The red dot is projected into the eye and appears to originate at a distant range (300 meters). Light from the dot can be thought of as exiting the sight in a parallel bundle of rays across the exit aperture of one-inch diameter. When viewing a distant target the light from the target also exits the sight in a parallel bundle and there is no physical parallax. As you look at targets closer and closer in there is an increasing amount of physical parallax as you move your eye across the exit aperture because the light from the

problem, but boresighting and zeroing, which are both conducted at distances less than 50 meters, do present problems. The firer must keep the same sight picture whenever he realigns the CCO to boresight, checks boresight, or zeroes at 25 meters. It was recommended that soldiers put the tip of their nose on the charging handle in order to maintain the same sight picture. This is a good technique for inexperienced firers. In addition, if one eye is used to boresight, then one eye should be used to zero. If two eyes are used to boresight, then two eyes should be used to zero.

Other boresighting tips were learned during the training. The firer should rest his eyes between adjustments. To prevent gunner confusion between the two red dots/lights during the initial alignment, the bore light beam should be turned off or a finger held over it. Finally, one gunner with glasses saw two CCO red dots, one in the CCO itself and the other, a reflection from the CCO, on his lenses. The solution to this problem was to move the CCO closer to his eyes, which then eliminated the red dot image on his lenses.

There are variations in the boresight and live-fire zero procedures that result from whether the weapon's iron sights have been zeroed previously. The primary technique covered in the POI and the exercises involved zeroing the CCO with a non-zeroed weapon (boresight the CCO, followed by live-fire zero at 25 meters). A second procedure involved zeroing the CCO when the weapon's iron sights have been zeroed previously through live-fire. Here, the CCO red dot is centered on top of the front sight post, followed by traditional 25-meter live-fire zeroing procedures. A third technique was to zero the CCO with the backup iron sight (BIS). With this technique, the BIS is boresighted using the bore light (see offset target in Appendix A), the CCO is mounted, and the CCO is adjusted so the red dot is centered in both the front sight post and the rear sight post. The boresight setting is confirmed with live rounds. Lastly, the BIS could also have been used to boresight the CCO if the iron sights had been zeroed through live-fire procedures. If a soldier is having trouble zeroing the CCO because he cannot achieve a consistent sight picture, it was recommended that he use the rear sight post or the BIS to eliminate this problem.

The CCO controls are simple; they control the brightness of the red dot and the ability of the soldier to hit targets under various light conditions. However, soldiers need to be reminded that they can adjust the brightness to compensate for light that can range from bright sunlight to dusk.

The PAQ-4C and PEQ-2A. A good boresight with the aiming lights requires a stable position. The technique of laying the weapon on its side and stabilizing with rucks or sandbags was the solution that emerged from the two training sessions. Not only did this provide a stable position, but it also eliminated the difficulties gunners had in determining a precise point of aim at 10 meters when wearing their NVGs. When this technique is used, the offset target must also be aligned accordingly. For example, if the weapon is laid on its right side, then the offset target must also be rotated 90 degrees to the right. This additional step must be emphasized as some squads did not do this correctly prior to qualification firing, and every squad member had to boresight again. Boresight accuracy is particularly important with the aiming lights because with the PAQ-4C on the M4, the boresight setting substituted for live-fire 25-meter zero. If the boresight procedures are sloppy, soldiers will miss during live fire at range.

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target is no longer parallel to the light from the dot. ... Parallax should not be a significant error source for targets beyond 50 meters. ...For use with a target board at ten meters an eye movement limiting device is helpful for the majority of users."

There are some additional factors to consider with the PEQ-2A, primarily the difference in the two aiming lights and how they should be employed tactically to achieve the highest percentage of target hits. Instruction must stress that the aimpoint is used for hitting targets, for accurate fire, not the illuminator. The illuminator is used to help detect targets. Thus the most critical boresight setting is that for the aimpoint. In addition, when boresighting the illuminator, the small beam width is used. Soldiers need to practice adjusting the filters and the illuminator beam width so they understand how these controls function and how different settings can help them on the battlefield.

The TWS. The TWS is the most complicated of the devices, as there are more controls and soldiers must become expert in using the many possible control settings and setting combinations. In addition, the difference between thermal and image intensification night capabilities must be explained, as frequently soldiers are either unaware of these differences or confuse the two technologies.

Although some trainers think instruction on the "electromagnetic spectrum" is not necessary, soldiers often use such terms as "IR," "FLIR," "IR light," and "IR energy" without fully comprehending their similarities and differences. For soldiers to understand the two night technologies being trained and the employment implications of theses devices, they need a conceptual understanding of how these technologies relate to the electro-magnetic spectrum. With the TWS, soldiers need to understand what appears as hot within a scene; how the temperatures of objects vary with such factors as the time of day, solar loading, environmental conditions (rain); what objects/materials block heat signatures; what materials (man-made and natural) hold heat the longest; what materials cool quickly; and so on. These general concepts and principles must then be applied to military objects of interest (vehicles, enemy soldiers, roads/trails), as well as to military situations where the TWS is likely to be used (engaging targets, observation points, reconnaissance). Finally, the soldier must be thoroughly instructed on how to operate the TWS to maximize its capabilities for his mission or task. For example, the black-hot polarity setting may be more beneficial in some day situations than white-hot. Or the brightness and contrast settings should be adjusted differently for target/vehicle detection versus discrimination of target/vehicle features. The long-term challenge is to determine which concepts should be presented, how to present them, and the supporting images and exercises that need to be developed as instructional materials and training activities.

The TWS has the following controls: Contrast, emergency, brightness (also the "on/off" switch), diopter control, range focus, field of view, reticle select, reticle adjust, polarity switch, and eyecup. In addition there are indicators that show system status, e.g., cool/not cool, low battery. A gradual, systematic approach to introducing these controls and indicators is needed, with practical exercises inserted throughout the instruction. This technique was used effectively with the LW platoon. Soldiers indicated they had time to "learn it" as opposed to just "hearing it."

The TWS contains the reticles for all the weapons with which it is used. Consequently, soldiers must be trained on the reticle specific to their weapon, as the reticle markings vary with the weapon system. Viewgraphs displaying the different reticles greatly help this process. Figure 17, presented later, shows the reticles for the M249 and the M240B.

The NVGs. As aiming lights are seen only through image intensification devices such as NVGs, NVGs are an integral part of this night firing system. The training sessions showed that many soldiers needed training on NVG adjustments; many had just come from Infantry OSUT and had had no NVG training. Instruction is needed on the fit of the goggles to the helmet or to the head, adjustments for interpupillary distance, focus adjustments, diopter adjustments, and lastly establishing the appropriate eye relief and elevation adjustments with the helmet-mounted version. Soldiers need to adjust their goggles to provide the best image possible and enhance their ability to detect and hit targets (Dyer & Brooks, 1996; Dyer, et al., 1996). Practical exercises that allow soldiers to make adjustments under supervision and to check on the quality of the adjustments (e.g., with NVG visual acuity charts) are needed. Viewgraphs that illustrate defects in image intensification tubes and indicate when the tubes should be repaired or replaced are also needed.

M4 Zeroing and Range Firing Results

Zeroing

Zeroing the M4 was conducted with the CCO and the TWS. The standard procedure for each system was to fire two, three-round shot groups before making any adjustments to the device. For the CCO, five of the six shots had to be within the 4-centimeter circle on the zero target. For the TWS, five of the six shots had to be within a rectangular target impact area. For the LW platoon, the back-up iron sight (BIS) was also zeroed. All M4 zeroing was done from the prone supported position. More information on the zero results is in Table 13. Note that the maximum number of rounds to group was high in some instances, and that these scores and other high scores (above 18 rounds) affected the means. Due to the non-normality of the data (positive skewness for each measure and peakedness of the WFOV data), analysis of variance techniques were not used to determine significant differences between the two platoons. Instead a nonparametric approach was applied. The median test was conducted, where the percentage of soldiers grouping within 12 rounds or less was compared to the percentage grouping with 15 rounds or more. There were no significant differences between the two platoons on any of the rounds to zero measures. It should be noted that the χ^2 value for the CCO rounds to zero was almost significant at the .05 level ($\chi^2(1) = 3.05$, $p < .08$), reflecting the fact that more of the LW soldiers grouped within 12 rounds than did the Baseline soldiers.

For each system, boresighting preceded zeroing. It is important to reiterate that the purpose of the boresight device is to get bullets on the 25-meter zero target. In fact, this was the case for every soldier who fired the CCO and TWS with the M4. However, another issue is whether the bore light constitutes a dry-fire substitute for 25-meter live-fire. If so, one would expect soldiers to zero within 6 rounds. However, this was not the case for either platoon for either the CCO or the TWS, as indicated in Table 13.

Parallax problems could have affected the accuracy of the boresighting and zeroing with the CCO. Some soldiers clearly had a problem in obtaining consistently tight shot groups; instructors worked extensively with them to eliminate this problem. The slightly lower number of rounds to zero for the LW platoon could have resulted from the fact that the parallax issue had not been fully disclosed to the Baseline platoon instructors and they did not stress how to overcome this problem. However, the LW platoon instructors were fully cognizant of the issue and stressed techniques to reduce parallax in the classroom and on the live-fire zeroing line.

Rounds to zero the TWS did not differ significantly for the two platoons. But the zeroing techniques were entirely different. The LW platoon zeroed at night; the Baseline platoon zeroed during daylight. The heat source for the LW platoon was a thermal blanket, with the zero target placed on top per TM 11-5855-302-12&P (DA, 1997). The heat source for the Baseline platoon was an air-activated heat pad stapled to the zero target.

Table 13
Rounds to Zero the CCO and the TWS on the M4

Sight	**# of Rounds** 6	<=9	<=12	<=15	<=18	**# Rds: *M(SD)***	**Max # Rds**
	Cumulative % of Soldiers						
Baseline Plt							
CCO	4%	8%	42%	62%	71%	16.67 (7.16)	40
TWS-WFOV	4%	18%	42%	77%	91%	14.18 (4.16)	24
TWS-NFOV	4%	27%	73%	82%	95%	12.82 (4.45)	27
LW Plt							
CCO	10%	26%	68%	78%	84%	13.42 (5.51)	24
TWS-WFOV	0%	6%	44%	61%	72%	17.55 (8.34)	42
TWS-NFOV	6%	22%	56%	56%	56%	19.33 (11.88)	48
BIS	12%	17%	41%	59%	82%	15.17 (5.76)	27

The heat pad technique did not work well. It heated more than just the aim point; the center mass of the heat pad was not always center mass of the aim point; and as more rounds were fired, heat began to emanate from the bullet holes in the zero target, thereby eliminating/obscuring the true point of aim. Given the inadequacies of the heat pad, the range was electrified for the LW platoon so thermal blankets could be used. This procedure was effective.

Although TWS zeroing was done at night for the LW platoon and night zeroing could be conducted if required, zeroing was more efficient during the day. Also in daylight hours it was easier to determine shot location and provide corrective adjustments to the soldiers.

Figures 4 and 5 illustrate the 25-meter zero target configuration for the TWS. A discussion of these figures follows to clarify the zeroing process: how the zero target is modified, the use of the thermal blanket, and the distinction between the point of aim area and the bullet impact area.

Figure 4 compares the visible and thermal photos of the thermal target. A 4 cm by 4 cm hole is cut out of the target and a piece of corrugated cardboard with the center two-thirds cut-out (like a picture frame) is attached to the back of the target. This unit is then taped to the thermal blanket. The purpose of the corrugated cardboard is to provide an "air space" between the thermal blanket and the zero target, which in turn provides the temperature difference needed for the gunner to obtain a precise point of aim. The instructors found that two pieces of cardboard were needed to dissipate the heat adequately between the thermal blanket and the target, and provide a distinctly hot center of mass aim point.

A critical factor in zeroing the TWS is to prepare the 25-meter target so the gunner's target aim point is correct. The target has the M16A2 zero target on one side and the M4 on the other.

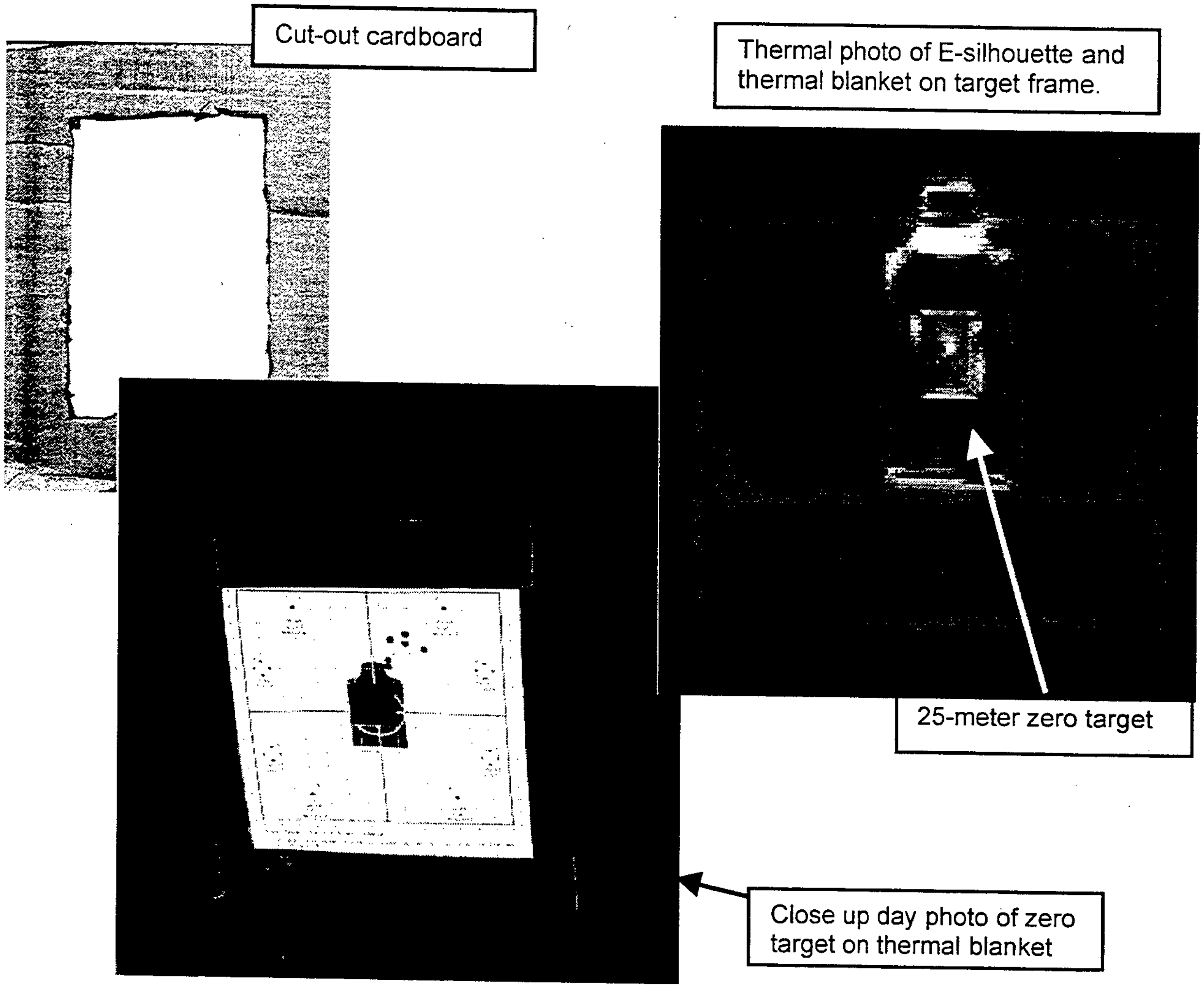

Figure 4. Day visible and night thermal photographs of the M4 25-meter zero target for the TWS. (*The right side of the square cut-out should cover all of the black in the silhouette.)*

The point of aim for the TWS on the M4 is most easily and accurately determined by using the M16A2 side of the target. A square hole is cut, 4 squares wide by 4 squares high. The center of this hole is the point where the zero vertical and horizontal lines intersect. Thus the 4x4 square hole covers the center 16 squares of the target. This area is shown on the left M16A2 target in Figure 5. When the target is turned to the M4 side, the center of the hole is not where the zero vertical and horizontal lines intersect. Instead 2/3rds of the square is above the horizontal zero line. The bottom of the target aim point square begins at the first square below the horizontal zero line (-1 zero line) and extends in height through the second square above the horizontal zero line (+2 zero line, see Figure 5). The width of the square covers the width of the black silhouette, as is the case with the M16A2 side. The reason for this difference is that the M4 and M16A2 zero targets are not identical, e.g., as stated previously the M16A2 lines are approximately 1 cm apart, while the M4 lines are slightly less than 1.5 cm apart. The instructions on preparation of the zero target for the TWS must, therefore, correspond to the version of the zero target available, otherwise the area that is cut-out for the target aim point will be incorrect.

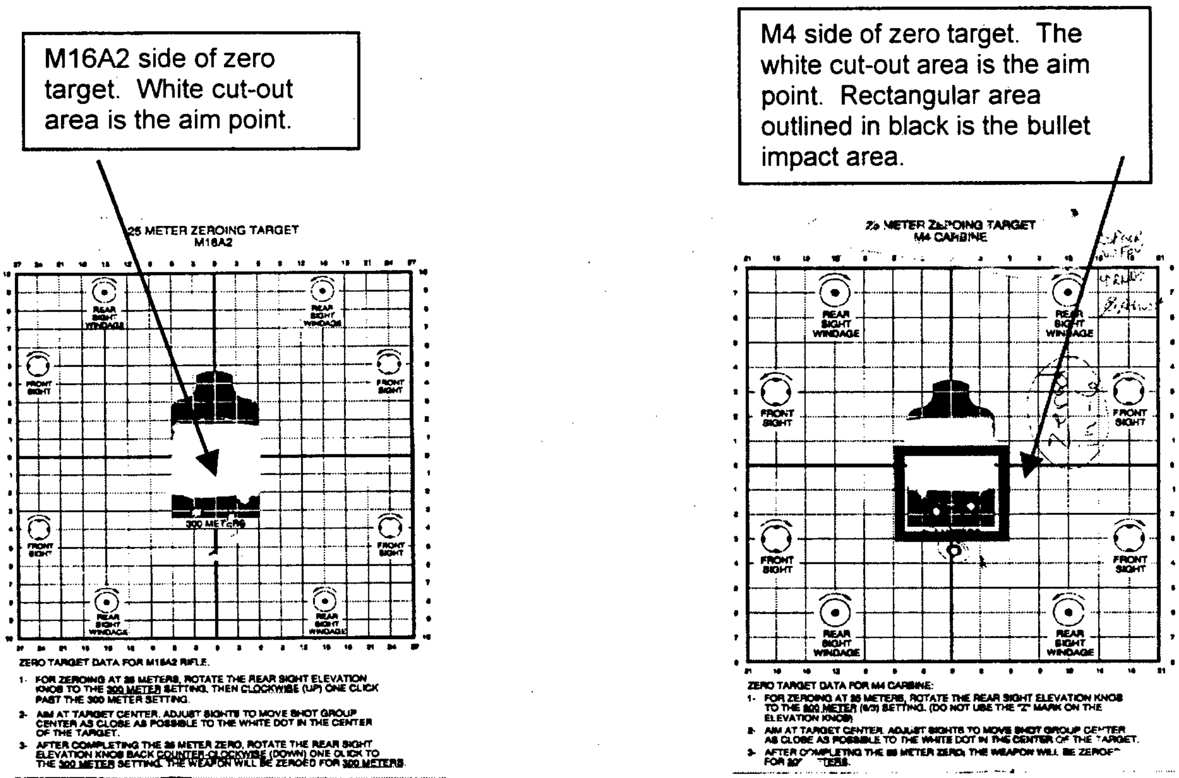

Figure 5. M16A2 and M4 sides of the 25-meter zero target configuration for the TWS on the M4 carbine.

To zero, soldiers must know where their bullets must hit the zero target and the amount of dispersion allowed. In other words, they must know the size and location of the bullet impact area. For the TWS on the M4 carbine, this location is not the 4 cm circle centered in the black silhouette on the target, as is the case with iron sights. Instead, it is all of the black part of the silhouette below the horizontal zero line on the zero target. The bullet impact area is outlined by the black rectangle in Figure 5. Note that this area covers a portion of the silhouette that has been cut out for the heat signature. Therefore, proper zeros will include shot groups with bullets impacting only the thermal blanket. The bullet impact area is consistent with the top mount location of the TWS on the M4 (see Figure 6).

Another factor to consider in zeroing the TWS at 25 meters is the fact that when the gunner is shooting well, many of his bullets may not be easily traceable when they hit the portion of the bullet impact area exposing the thermal blanket. It is hard to triangulate bullet hits on a black thermal blanket, particularly at night. And when the 25-meter target is removed, an incomplete record of zeroing exists on the paper (some bullet holes may remain on the thermal blanket). Thus it is important to physically record all firer adjustments, number of rounds fired, etc. on the zero target itself.

Figure 6. Heavy TWS on M4 carbine.

To ensure soldiers fired at the appropriate zero target (no cross fires), a non-heated target was used to separate a series of three heated targets; that is, three heated, one non-heated, three heated, one non-heated sequence of targets. This was particularly valuable for night zeroing.

All the requirements and steps involved in zeroing the TWS should be reviewed before soldiers begin zeroing. All soldiers should be instructed thoroughly on the location of the bullet impact area. A review of elevation and windage adjustments will make the zeroing process more cost-efficient by reducing the soldier's likelihood of accidentally making the wrong adjustments. Instructions on how to prepare the zero target for the square cut-out will prevent incorrect preparation of the bullet impact area. Reminders on appropriate brightness and contrast settings and use of white-hot or black-hot polarity will help the soldier achieve a precise aim point. Even though these settings are personal preferences, guidance as to what typically works and reminders to soldiers that they can vary these settings to enhance their zeroing ability are needed. These zeroing tips are particularly critical when the TWS is new to the soldiers.

As stated in the POI section of this report, live-fire zeroing was not conducted with the aiming lights on the M4, thus avoiding the halo problem with zeroing at 25 meters (Dyer, Smith & McClure, 1995, 1996). McDonald (1997) stated that zeroing introduced errors into the process, but did not present data on the nature or extent of these errors.

Target Engagement Exercises and Qualification

Qualification rates and scores. The M4 qualification range was automated. It was equipped with mannequin targets as opposed to the standard E- and F-silhouette targets. For the M4, the qualification standard for all devices was the same as the current daytime Army standard (DA 1989, FM 23-9). This qualification scenario has 40 targets at the following ranges: 5 at 50 meters, 9 at 100 meters, 10 at 150 meters, 8 at 200 meters, 5 at 250 meters, and 3 at 300 meters. The standard for the TWS and PAQ-4C was the daytime standard of 23 of 40 target hits. The standard for the CCO, however, was set higher, at 28 target hits. Prior to qualification, soldiers were to conduct a dry-fire exercise, known distance firing (not required with CCO), field fire (not required with CCO), dry-fire qualification, practice qualification, and qualification. These exercises were conducted as described, with the exceptions noted previously in Table 7. Soldiers were given a second attempt at qualification, if they did not qualify initially. If they did not qualify on this attempt, they were allowed to fire until they qualified, or until time or ammunition constraints prevented addition firing. With both platoons there were some soldiers who did not qualify on some devices.

For TWS firing, thermal blankets were attached to the targets. For the aiming lights, no artificial illumination sources (chem lights, blinking lights, flood lights, IR illuminators) were used.

A summary of practice qualification, first time qualification, and final (last) qualification scores is in Table 14. The final qualification score is the qualification score for all soldiers who qualified; for those who did not qualify, it is their last score.

Table 14
M4 Qualification Scores

Qualification	*M*	Minimum Score	Maximum Score	*SD*
		CCO		
Baseline Plt				
Practice Qualification	29.04	21	35	4.17
First Attempt at Qualification	32.00	23	39	4.88
Final Qualification	33.71	28	39	3.44
LW Plt				
Practice Qualification	26.87	13	38	6.85
First Attempt at Qualification	29.79	20	38	4.90
Final Qualification	31.26	26	38	3.48
		PAQ-4C and PEQ-2A		
Baseline Plt				
Practice Qualification	18.04	3	32	7.42
First Attempt at Qualification	17.50	4	31	8.09
Final Qualification	23.62	15	31	4.92
LW Plt				
Practice Qualification	14.17	6	25	6.03
First Attempt at Qualification	17.67	7	28	6.53
Final Qualification	25.22	15	35	4.49
		TWS		
Baseline Plt				
Practice Qualification	29.50	18	39	5.94
First Attempt at Qualification	29.79	14	38	5.94
Final Qualification	30.79	23	38	4.01
LW Plt				
Practice Qualification	---	---	---	---
First Attempt at Qualification	29.68	22	38	4.86
Final Qualification	29.89	22	38	4.59

Note. Baseline - 24 soldiers; LW - 19 soldiers. The maximum score was 40.

A multivariate analysis of variance was conducted comparing the two platoons on their initial qualification scores for the three devices. There were no significant differences between the platoons (Wilks' Λ =.95, *Rao's R* (3, 38) = .65, $p < .59$). Of particular note are the TWS results. First, regardless of platoon, TWS night qualification scores were equivalent to CCO daytime scores. Second, 89% of the LW platoon qualified on the initial qualification attempt with the TWS with fewer practice firing exercises than specified in the POI. Yet this qualification rate was the same as the 88% rate for the Baseline platoon, which executed all the exercises.

The box plots in Figure 7 illustrate what happened with experience on each of the three devices. The top scores did not change, but the lowest scores improved from practice qualification to qualification. This was a consistent increase for the CCO and TWS, but the lowest scores on the aiming lights did not increase substantially until the final qualification scores were tallied. The median value also tended to increase slightly with experience, but there was a substantial increase in this value for the final qualification scores on the aiming lights. Also illustrated is the absolute level of difference in marksmanship performance with the CCO and TWS as compared to the aiming lights.

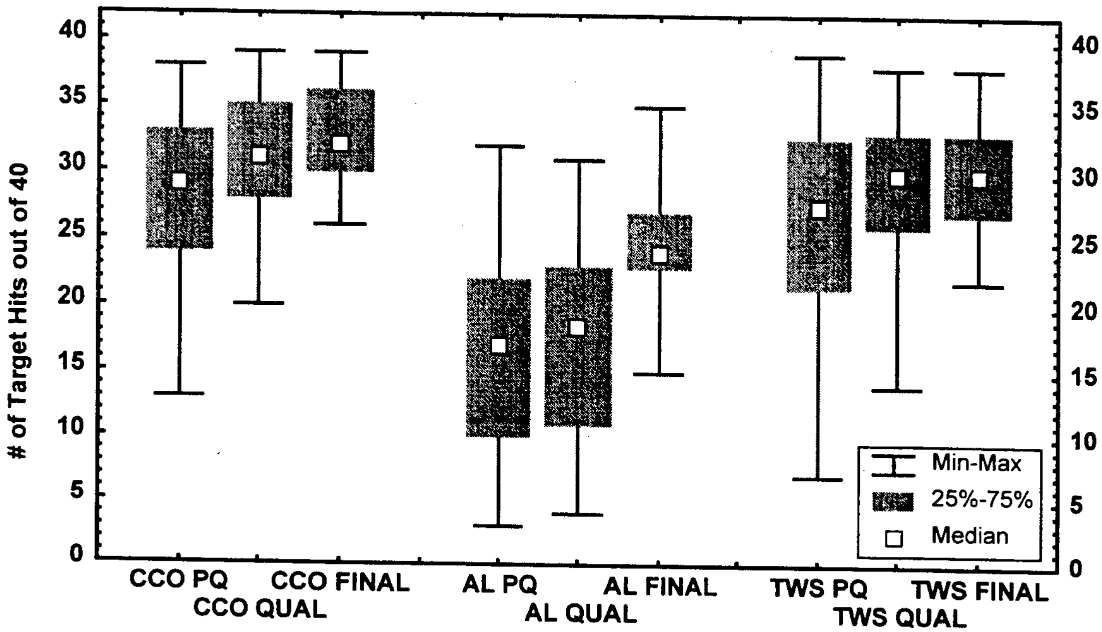

Figure 7. Box plots of practice qualification, qualification, and final qualification scores for both platoons on the CCO, aiming lights (AL), and TWS.

Figures 8 and 9 show the qualification results by the percentage of soldiers who qualified on different attempts. The first set of columns represents the percentage who qualified on the first attempt; the second set represents the percentage who qualified after two attempts, and the last set is final qualification. Clearly, soldiers performed better with the CCO and TWS than with the aiming lights.

As cited previously in Table 7, the baseline platoon was given an additional two seconds during practice qualification for the aiming lights. Inadvertently, this did not occur for the LW platoon. Figure 10 shows the "learning curves" for the two platoons in terms of percentage of targets hit for the known distance, field fire, practice qualification, qualification, and final qualification scores. The major difference between the platoons is the percentage of targets hit during practice qualification. This difference, 14 versus 18 hits, was not significant ($t(40) = 1.81$, $p < .08$), but is suggestive of the impact the longer exposure time had upon the ability to acquire targets and subsequent practice qualification performance. Of interest, as well, is the fact that the longer exposure time did not carry-over to the qualification scores, which were the same for both platoons.

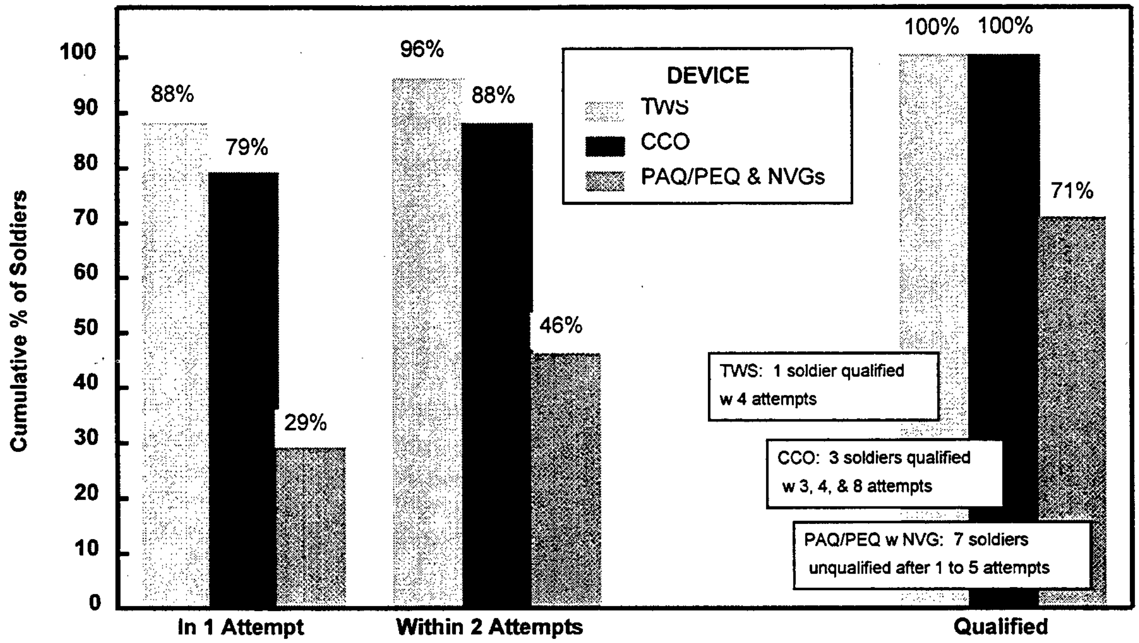

Figure 8. Qualification rates for the Baseline platoon on the M4.

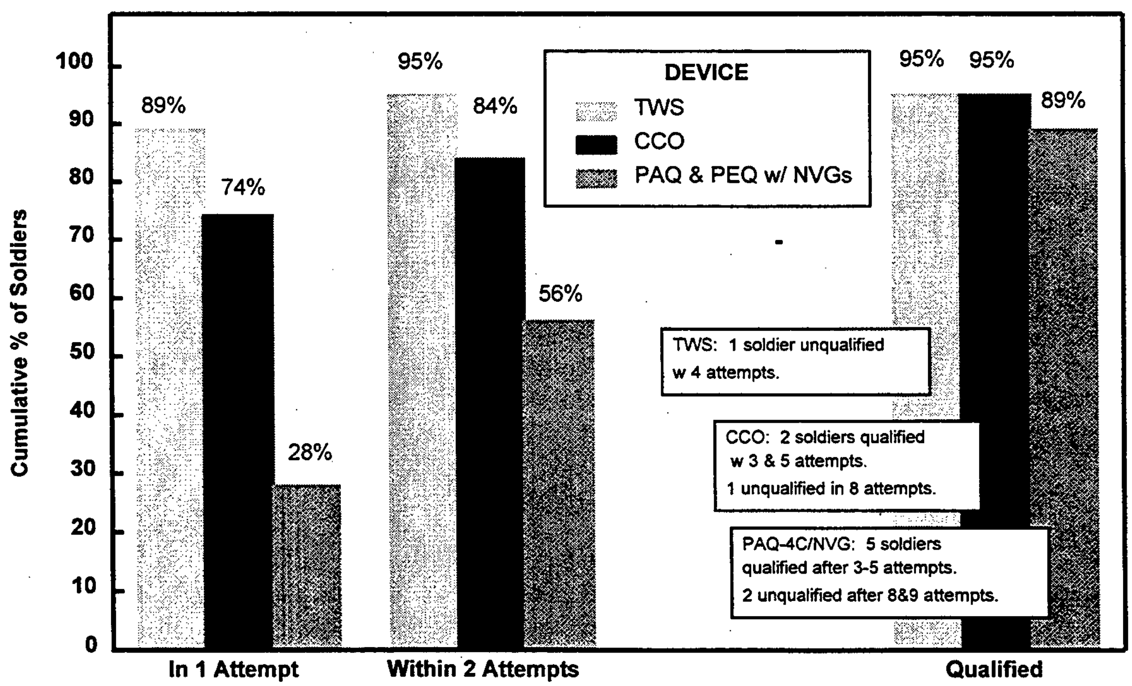

Figure 9. Qualification rates for the LW platoon on the M4.

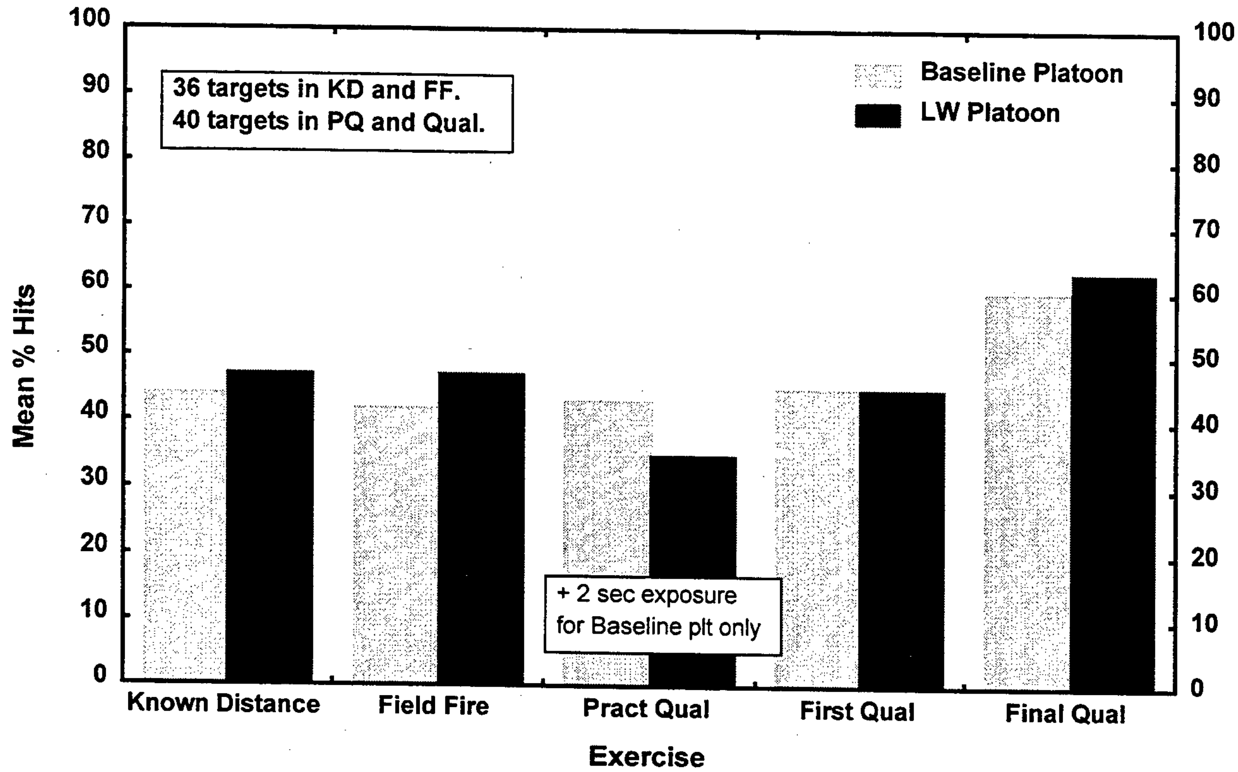

Figure 10. Mean percentage target hits with the aiming lights for each platoon on each firing exercise.

Performance by range to target. The percentage of targets hit at each range is illustrated in Figures 11 and 12 (see Appendix C for exact numbers). Again, the difference between the aiming lights and the other two devices is clear, with this difference increasing as the distance to the target increased. For both platoons, aiming light performance decreased sharply at 100 meters and was very low at 200 meters and beyond (less than 10%).

What accounts for the difference in performance between the two night devices, the TWS and the aiming lights? The most probable reason is target acquisition. Soldiers used both FOVs in the TWS, 2x and 3x magnification. In addition, the thermal blankets presented a distinctive signature at range, as depicted in Figure 13.

On the other hand, with NVGs target acquisition presented great problems for both platoons, even though the LW platoon had the most recent technology with their AN/PVS-14 NVGs. Targets at the far distances were often difficult to find. On some lanes and under certain ambient light conditions, these targets were impossible to detect. The M4 range, as shown in Figure 14, was surrounded by trees, with some 300-meter targets in the tree line, making it extremely difficult to see these targets at 200 meters and beyond. There was very limited target contrast. At these far ranges, a dark target "popped up" against a dark background. If the background had been a sandy berm, then there would have been sufficient contrast to see a dark target.

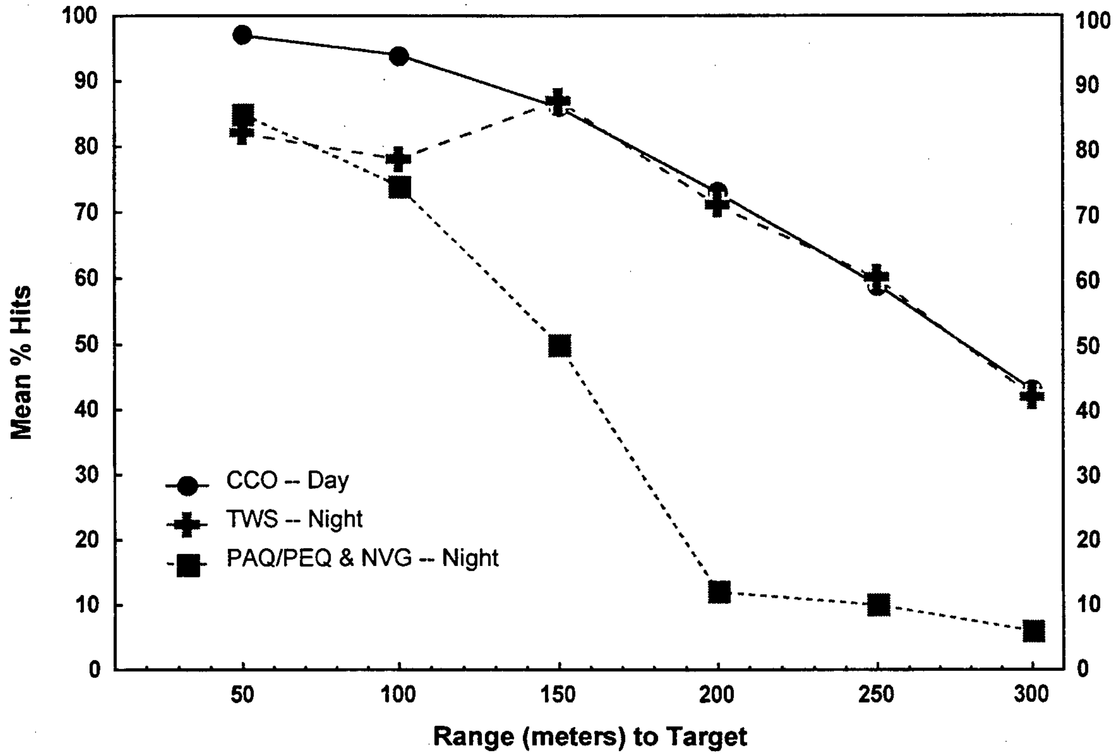

Figure 11. Baseline platoon M4 qualification by range to the target.

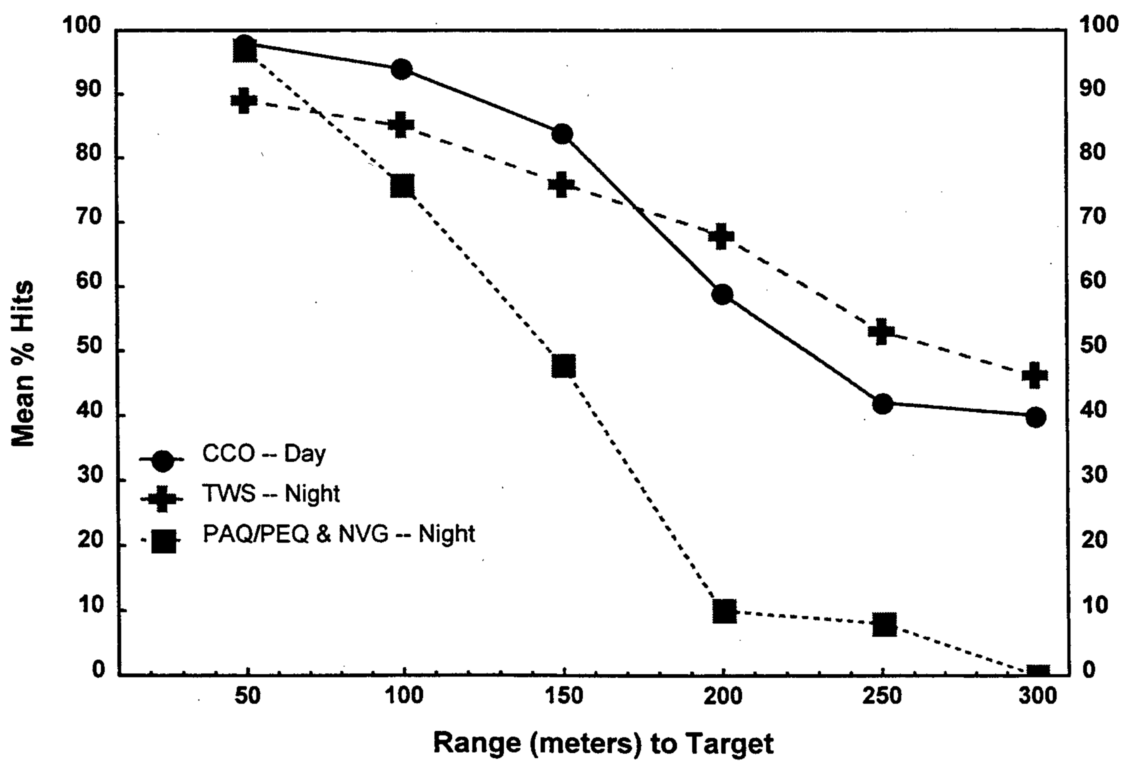

Figure 12. LW platoon M4 qualification by range to the target.

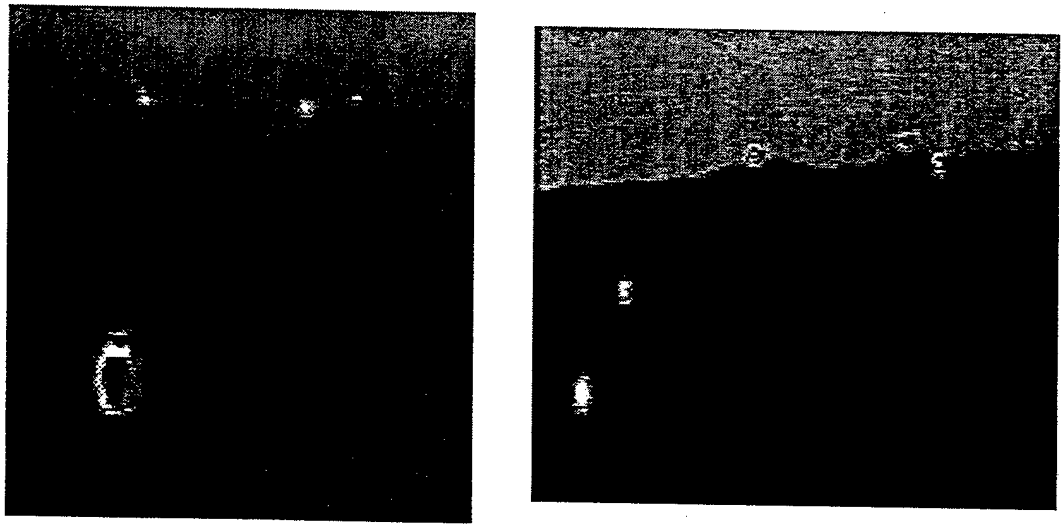

Figure 13. Thermal signatures of targets on the M4 range.

Figure 14. M4 qualification range.

In addition to the limited target contrast, other factors could have reduced marksmanship performance with the aiming lights and NVGs. These factors were:

- At far distances, it was difficult to obtain a precise point of aim as the halo from the aiming lights covered the target.
- No guidance was provided on adjusting goggles to get a good focus and good visual acuity prior to the firing exercises. In addition, there was no guidance on establishing the appropriate eye relief and interpupillary distance, both factors critical to ensuring the soldier uses the entire 40 degree field of view in the NVGs.
- Some NVGs used by the Baseline platoon soldiers had defects and were in need of maintenance.

- For all soldiers, the weight of the NVGs caused some problems in establishing and maintaining a good firing position. This was particularly the case with the prone position, where soldiers had to hold their head up in order to see down range and compensate for the forward center of gravity of the NVGs.
- LW platoon soldiers may not have used the brightness and contrast controls on the PVS-14 NVGs to enhance their ability to engage targets. Certainly, changes in these adjustments would have been difficult during a firing exercise. The optimum setting, however, could have been established during the initial dry-fire exercise.
- For both platoons, the ambient light varied over the nights of firing. And for some soldiers it varied considerably from practice qualification to qualification. Low light levels had less impact on the LW platoon from 50 to 100 meters than on the Baseline platoon (Figures 15 and 16). This difference is attributed to the higher resolution, signal-to-noise ratio, and photo-cathode tube sensitivity of the PVS-14 NVGs used by the LW platoon versus the PVS-7B NVGs used by the Baseline platoon.
- Lastly, the PAQ-4C and PEQ-2A boresight settings for the M4 were not confirmed by 25-meter, live-fire zero. Although the boresighting setting seems to have produced satisfactory results in other tests (McDonald, 1997), the poorest M4 performance was with the aiming lights, as compared to the CCO and the TWS. Given the difficulty trainers, soldiers, and observers had in detecting targets at distance, documented with image intensification photography, it is highly doubtful that the poor performance at range resulted from the boresight setting. But it might have been a contributing factor to the lower performance at 100 and 150 meters, where targets were visible.

Clearly, marksmanship performance with aiming lights and NVGs is affected by many factors, some of which are not under the soldier's control. The relative contribution of these factors to the soldier performance presented here cannot be determined. It is clear that target acquisition was the major factor in hit performance at the farthest targets. How the other factors cited above contributed to the performance at closer distances is less clear. Yet if soldiers are to maximize their marksmanship with aiming lights and NVGs, they must consider the aiming lights and the NVGs as a system, and fine-tune all components. In addition, there probably is a need to verify whether 25-meter zeroing improves the boresight setting for aiming lights, or whether it disturbs the boresight setting, resulting in a poorer adjustment. However, in order to create a definitive point of aim and conduct a valid comparison, the standard 25-meter zero techniques must be modified to eliminate/reduce the halo/bloom of the aiming light in the NVGs.

Comparison with other research and tests. Of interest is how the platoons' marksmanship performance compared to results obtained in prior tests of the devices. Comparison data were available on all three devices.

For the CCO, hit probability data from 150 to 300 meters with the M4 carbine were available in the CCO System Evaluation Report (SER) (Army Operational Test and Evaluation Command, June 1997). For one of the firing events, soldiers fired the standard day qualification scenario from 150 to 300 meters. No data from closer ranges were cited nor were data cited for each target range. The overall hit probability was .70. This finding is consistent with the overall hit probability of .68 for the two platoons at the same distances during qualification (.72 for the baseline platoon, .63 for the LW platoon)[4]. The SER report indicated that the CCO probability of hit under low light conditions (low light not operationally defined) was .51

[4] This probability of hit was based on the 26 targets presented in the record fire scenario from 150 to 300 meters. Each target was weighted equally in these calculations.

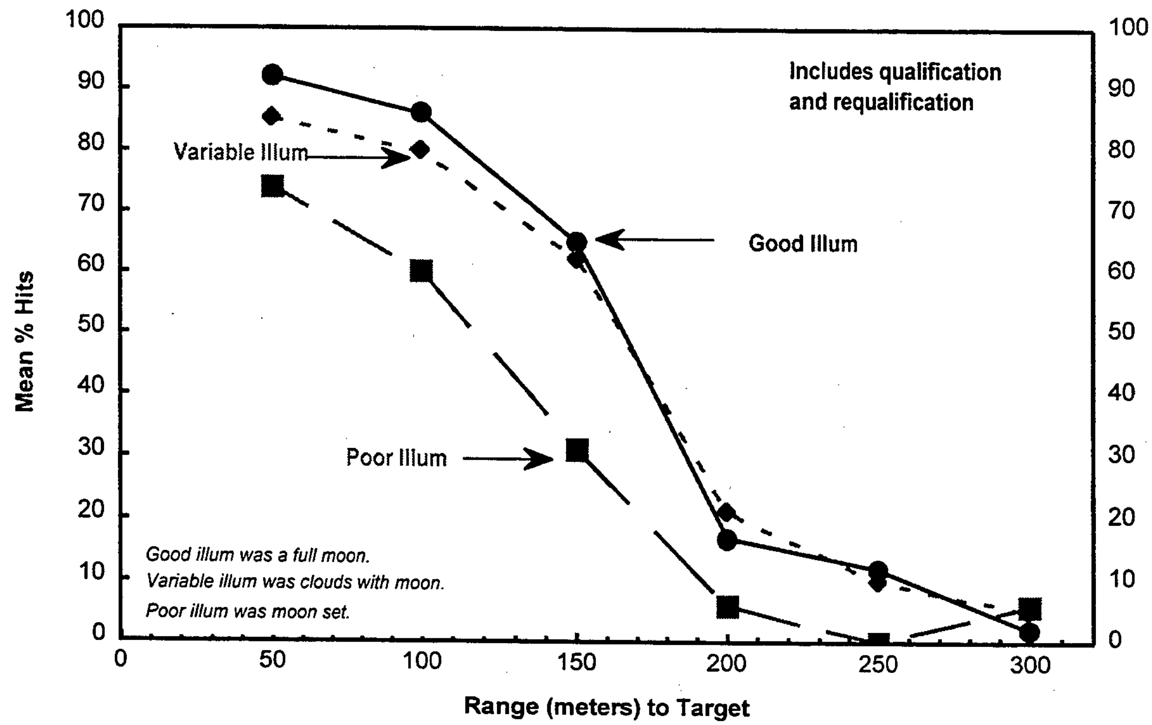

Figure 15. Effect of ambient illumination on M4 hits with aiming lights/NVGs for the Baseline platoon.

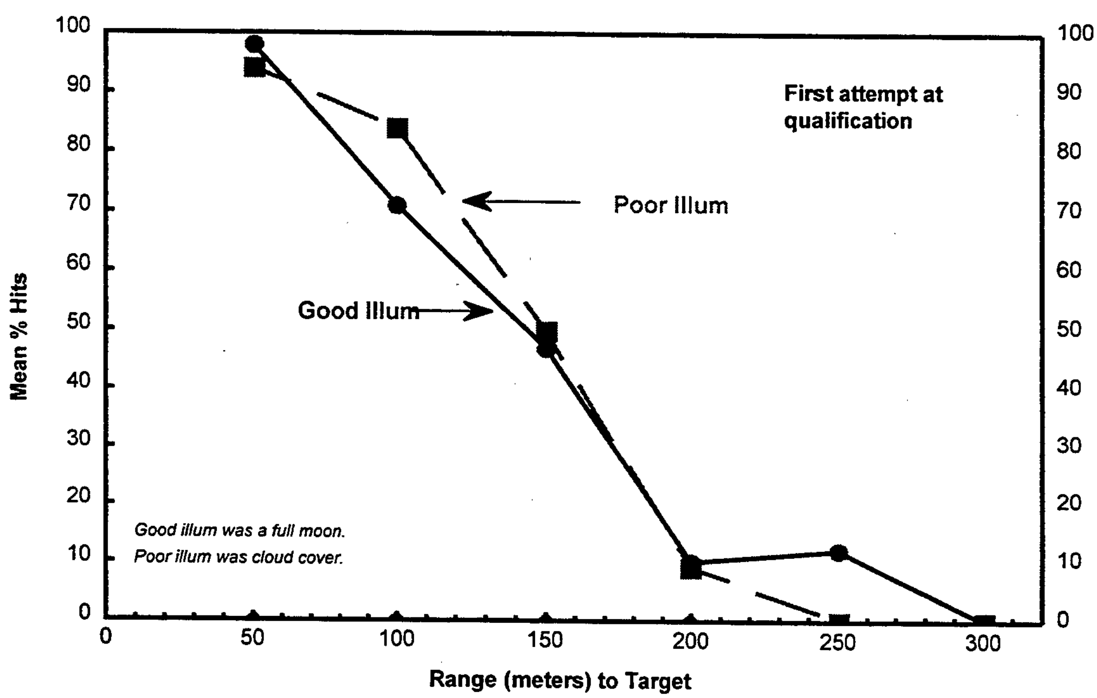

Figure 16. Effect of ambient illumination on M4 hits with aiming lights/NVGs for the LW platoon.

For the aiming lights, data were available from an earlier effort aimed at developing a training program and standards for the PAC-4C aiming light. That effort was conducted by the Dismounted Battlespace Battle Lab (McDonald, 1997). The data were obtained at three Army posts; 71 soldiers participated; the standard day time record fire qualification scenario was used; and efforts were taken to minimize target acquisition problems. In addition, soldiers used the M16A2 rifle, not the M4 carbine. As with the two platoons, soldiers in the Battle Lab study boresighted the aiming light, and no 25-meter live-fire zero was conducted. The train-up for the Battle Lab soldiers differed slightly from that for the two platoons. The train-up included known distance firing, one period of field fire with a random exposure to single targets, a second field fire with both single and multiple targets presented in random order, an extended record fire where targets were exposed for an additional two seconds, the standard practice record fire, and lastly record fire. Two posts had mannequin targets, not the standard silhouettes. It was reported that the mannequins' light green color made them hard to detect at night with NVGs. To make them more visible, at one post the mannequins were wrapped in black plastic bags. At the other post, an aiming light with an expandable beam, the ground commander's pointer, was used to enhance target detection. As illustrated in Figure 17, except for 200 and 250 meters, the platoon and Battle Lab data are quite similar. At 200 and 250 meters, the platoons' performance was 30 percentage points below the Battle Lab data. This discrepancy could be due to several factors: the range configuration at Ft. Bragg for the platoons made many 200- and 250-meter targets difficult to see, the attempts to enhance target detection in the Battle Lab study, and/or the differences in training. As noted in the Battle Lab report, ranges were selected

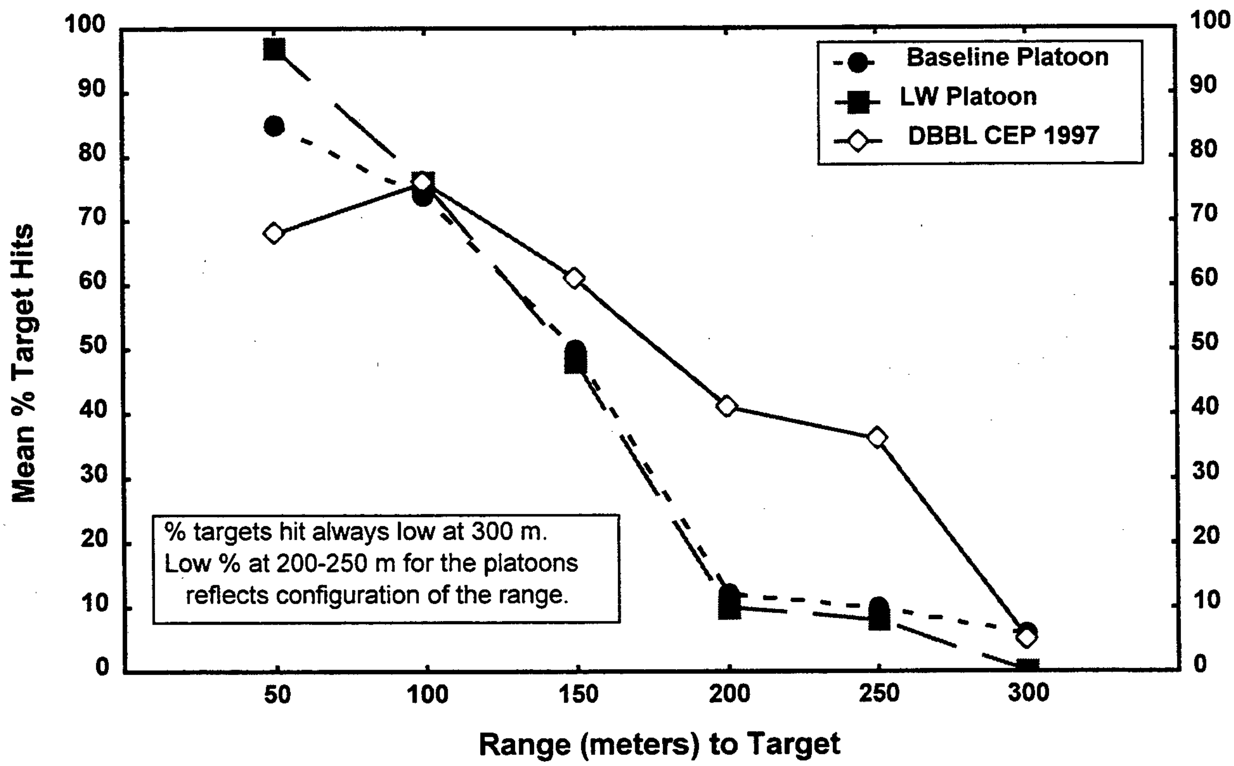

Figure 17. Percentage of target hits by range with aiming lights for the two platoons compared to a prior test by the Dismounted Battlespace Battle Lab.

that did not have city lights coming from down range. When soldiers must look into these lights, NVG performance is degraded. The low probability of hit at 50 meters cited in the Battle Lab report occurred at only one post; no explanation was given for this finding. Finally, it is important to note that in all efforts, the percentage of target hits at the maximum range of 300 meters was very low, less than 6%.

For the TWS, findings from the Initial Operational Test and Evaluation (IOTE) were available (Boylan, Riemenschneider, & Fye, 1997). Training lasted for 7 days. It consisted of classroom instruction on the operation and characteristics of the TWS following by weapon qualification. Six M4 gunners fired record fire at day and night on an instrumented range. It is assumed that the record fire scenario used is that established for the M16A2 (DA, 1989), and the same as that used for the two platoons in our study. The percentage of targets hit in the IOTE was 68%. For the two platoons, it was 74% (30 out of 40, see Table 14). So in this case, the platoon performance was somewhat higher than the comparison data available, but in general the levels of performance were similar.

Relationship Among Scores

If soldiers fired well with one device on the M4, did they also fire well with another? The relationships among practice qualification and qualification scores on each device were determined by combining the data from both platoons. The sample size for the correlations involving TWS practice qualification was reduced because not all LW platoon soldiers fired the practice qualification scenario. In general, the findings indicate that performance was primarily a function of the particular device, not general marksmanship skill.

For each device, if soldiers performed well on practice qualification, they also tended to fire well on qualification with the same device (see Table 15). For the CCO and the aiming lights, the practice qualification and qualification scores correlated significantly with each other, being .67 and .66 respectively. The relationship between these two scores for the TWS shown in Table 15 is tempered by the fact that only a limited number of LW soldiers fired practice qualification. Yet, for the Baseline platoon only, the correlation was .49. For the aiming lights, additional data showed that the known distance and field fire scores tended to correlate with each other and with the practice qualification and qualification scores. Of importance is that the qualification scores across the three devices did not correlate significantly. These correlations ranged from -.05 to .21, and are bolded in Table 15. Thus, for example, high performance on CCO qualification was not associated with high performance with either the aiming lights or the TWS, nor were high qualification scores on the aiming lights associated with high TWS scores.

To investigate the relationship among the three qualification scores further, each variable was categorized into low, medium and high scores. These categories were defined as scores at the 25th percentile and below, from the 25th to 75th percentile, and the 75th percentile and above. Although no strong relationships occurred when all three variables were considered, there was a slight tendency for soldiers who scored low on one device to score low or medium on the others. Of interest, is that the soldiers who scored in the bottom 25th percentile on all three devices were identified by the instructors as lacking basic marksmanship skills. Those with medium scores on one device tended to have medium scores on the others. However, there was little to no consistency across the devices among the soldiers with high scores. In fact, only 1 soldier, out of the 43, scored high on all three devices. Marksmanship performance was not consistent even among the most experienced within the platoons, the squad and platoon leaders. Three of these leaders scored in the upper 25% on one or two of the devices but in the lower 25% on the others.

Table 15
Correlations among M4 Practice Qualification and Qualification Scores

	CCO		**PAQ/PEQ Aiming Lights**		**TWS.**	
	PQ	Q	PQ	Q	PQ	Q
CCO						
PQ	...	.67*** n = 43	.41** n = 42	.24 n = 42	-.01 n = 32	.07 n = 43
Q		...	.27 n = 42	**.06** n = 42	.20 n = 32	**.21** n = 43
PAQ/PEQ						
PQ			...	.66*** n = 42	.04 n = 31	.01 n = 42
Q				...	-.30 n = 31	**-.05** n = 42
TWS						
Q					...	.28[a] n = 32

Note. PQ = Practice qualification. Q = Qualification (first attempt).
[a] Correlation not indicative of performance by all soldiers. Correlation between TWS PQ and Q for the baseline platoon, where complete data were available for all soldiers was .49
* $p < .05$. ** $p < .01$ *** $p < .001$

The lack of a relationship across devices cannot be fully explained. The following discussion offers some possible reasons for these results, but is definitely not exhaustive. Certainly, the dynamics that affected qualification scores varied with the devices. For example, the ambient illumination varied on the nights when soldiers qualified with aiming lights and NVGs. With the CCO, the amount of sunlight also varied, with some soldiers firing into a bright sun and others firing at dusk. Targets were easier to detect on some lanes at some distances than on other lanes. These factors were not consistent across soldiers. So a soldier might have had good qualification conditions with one or two devices but not with the others. Another factor may simply be the experience soldiers required in using these devices with a degree of proficiency. Some soldiers may adapt more slowly to one device than another, and consequently need more firing practice with one device than with others. For example, anecdotal comments by some soldiers indicated that not all were comfortable with the "two-eyes open" method of shooting with the CCO, nor with the TWS controls. With more experience, a different correlational pattern could emerge.

Ammunition

Current Army standards for ammunition for the M16A2 rifle (DA, February 1993) address day firing with iron sights and some limited night firing. For units, 98 rounds are allocated for day firing (zeroing, practice qualification, and qualification). For night, the allocation is 60 rounds (20 ball and 10 tracer each for practice qualification and qualification). Needless to say, the ammunition required to zero, train, and qualify the two platoons on the three devices exceeded these allocations. The most significant difference was in the allocation of rounds for night firing, where two devices were used, the aiming lights and the TWS. The POI called for 150 rounds for all target acquisition exercises, including a single qualification exercise. To zero and qualify everyone, more than 150 rounds were required. In general, five to six times as much ammunition was required for night firing than is currently allocated. It is anticipated that the Army standards will be changed in the near future to account for the increased number of weapon devices being fielded in the Army.

M249 and M240B Zeroing and Range Firing Results

The M249 and M240B results are more limited than the M4 results because of ammunition constraints and the fewer number of gunners within a platoon (6 M249 gunners, 2 M240B gunners, and 2 M240B assistant gunners). Direct comparisons between the two platoons on all exercises and devices were not always possible.

Boresighting and Zeroing

The PEQ-2A and the TWS were both boresighted for a distance of 300 meters for the M249 and the M240B (see Appendix A for the boresight targets). Both platoons field zeroed at 300 meters; the M240B gunners in the LW platoon also field zeroed at 500 meters.

The PEQ-2A. The 300-meter field-zeroing procedures did not work well with the Baseline platoon. Bullet location was hard to determine at this range in the dark and greatly complicated the zeroing process. Therefore, additional procedures were established for the LW platoon to alleviate these zeroing difficulties.

With the LW platoon, the instructor stressed that the quality of the zeroing and shooting would depend upon the boresight setting on each aiming light. In addition, prior to zeroing, the instructor reviewed the key features of the PEQ-2A — the aimpoint and the illuminator, and which way to turn the adjusters. He stressed that the illuminator could be moved to help get a good point of aim, but the aimpoint could not be adjusted. He reminded them to aim from the ground or berm up, not scan the sky. If the boresight was not good, they would waste bullets.

Also prior to zeroing, gunners in the LW platoon were given the time to locate the targets in their lane (all were up), to determine whether they wanted to use the aimpoint only or the aimpoint with the illuminator, and to determine the size of the illuminator beam most advantageous to them. This was an excellent use of range time. It gave the gunners an opportunity to become more familiar with the PEQ-2A, and how to employ it effectively at range. It also served to identify soldiers who were having difficulties. Some soldiers had forgotten some of the fundamentals of operating the PEQ-2A as well as how to make the appropriate zero adjustments. One gunner did have major difficulties. He was new to the unit, was given remedial instruction on adjusting his NVGs as he did not have a good NVG image and had great difficulty detecting the 300-meter zero target. He also required assistance with the aimpoint and illuminator adjustments, and firing fundamentals.

For the LW platoon, M249 zeroing, a single round (ball/tracer) was used, not a three-round burst as was the case with the Baseline platoon. Five of the six M249 gunners zeroed without any need to change their boresight adjustment. This zeroing technique was an efficient use of the M249 ammunition, which was limited. Both M240B gunners field zeroed successfully at 300 and 500 meters. Neither gunner made changes to the boresight setting on the PEQ-2A. These gunners used a large number of rounds to zero (see Table 17). The reasons for the high number of rounds are not known, but may reflect poor marksmanship and inadequate control of the gun initially. Once the gunners settled in, they had better gun control. The assistant gunners used the same zero as the gunners and conducted familiarization fire of about 50 rounds.

The TWS. For the LW platoon, a zeroing problem resulted from the TWS boresighting procedure. The reticles for the M249 and M240B do not have a clearly marked 300-meter line in either field of view. A clearly marked aiming point is needed for precise boresighting as all TWS boresight offsets were for 300 meters. During classroom instruction, the LW platoon gunners were shown what reticle markings they should use as the 300-meter line. For the M249, the 300-meter aim point was described as being at the top of the 400-meter cross hair. For the M240B, the 300-meter aim point was described as being at the top of the 500-meter cross hair. These aim points are indicated by arrows and labels in Figure 18.

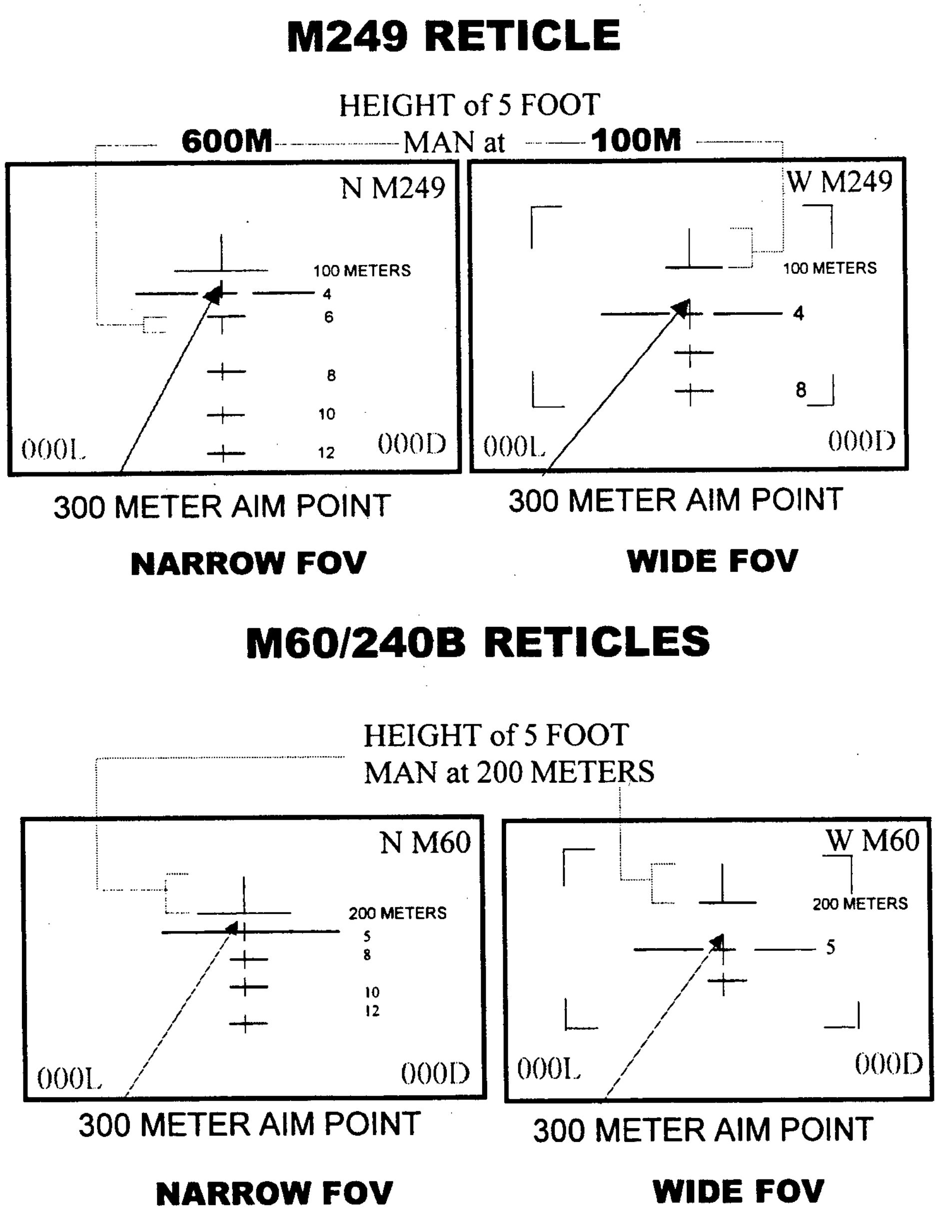

Figure 18. TWS reticles for the M249 and M240B. [Not to scale. The labels "100 meters" and "200 meters" were included on the viewgraphs for instructional purposes. They are not in the TWS reticle.]

During live-fire zeroing at 300 meters, it was discovered that some gunners had not used the appropriate reticle aiming point during boresighting. Two of the six M249 gunners and one M240B gunner used the wrong markings. One M249 gunner did not use the top of the 400-meter crosshair, but halfway in between the top and the 400-meter line (Figure 18). The other M249 gunner used the bottom of the vertical 400-meter crosshair. The M240B gunner used the top of the 200-meter crosshair (Figure 18). These findings clearly point to the need for consistency between the boresight offset distance and the live-fire zeroing distance, as well as a need for a clearly marked aim point on the TWS reticle.

For the M249 and M240B, a 25-meter live-fire zero procedure for the TWS has now been established that will result in a 400- and 500-meter battlesight zero for the M249 and M240B respectively. However, to our knowledge boresight offsets for 400 and 500 meters for these two weapons do not exist at this time and must be developed.

The field zeroing started the daylight (afternoon) for the Baseline platoon and continued into the night, and was planned for daylight for the LW platoon. But due to time constraints, the LW platoon zeroed the TWS at night, except for the NFOV for the M240B, where zeroing and firing was done during daylight. Mean number of rounds to zero for the LW platoon gunners is given in Table 17 (shown later). These numbers should not be viewed as typical numbers, since they are based on a limited number of gunners. As the assistant machine gunners (AGs) used the gunners' weapons, the AGs also used the gunners' zero setting. In addition, both the instructors and gunners learned more efficient zeroing procedures during the zeroing process itself, which impacted the number of rounds required.

The difficulty in zeroing at night with the TWS was strongly reflected by the M249 gunners in the LW platoon. Gunners initially used three-round bursts. But zeroing did not occur quickly, and ammunition was expended rapidly at first. Two M249 gunners zeroed in both fields of view, consuming a total of 52 and 69 rounds in the process. At this point the instructor switched to single shot tracer rounds to save ammunition and to aid the spotters in determining round location. After all tracers had been used, single shot ball ammunition was used. All six M249 gunners eventually zeroed the TWS in the WFOV. The requirement to zero and engage targets in the TWS NFOV was deleted from the course of instruction for these M249 gunners due to insufficient M249 ammunition.

Spotters reported they could not see rounds hitting the berm directly in front of the target or ground behind the target. Ironically, one of the advantages of thermal sights is their capability to penetrate dust, but the dust from bullet impact on the ground is what spotters and gunners often use to help them adjust rounds during field zeroing. Obviously, spotters would not have this problem during daytime zeroing, but gunners would. At night, tracers are needed, but do not necessarily provide all the cues necessary for expedient zeroing. When the TWS is zeroed during daytime, the traditional means of determining bullet impact at range can be used.

Lastly, prior to zeroing, instructors/trainers should review the TWS setting and controls needed for effective zeroing and target engagement. A check should also be made on how the gunners executed the boresighting process. Then gunners should be given time at their firing point to adjust the TWS controls so they have a good thermal image of the range and the targets. Some or all targets could be up for this exercise. Practice in scanning should also be included, so gunners know the scan rate that works well with their particular sight. As stated previously, this type of exercise was conducted with the LW platoon M240B and M249 gunners when they used the PEQ-2A and proved to be a very beneficial use of range time. It led to more efficient zeroing and also served to identify gunners who needed assistance.

Target Engagement Exercises and Qualification

Qualification range and exercises. The machine gun qualification range is shown in Figure 19. It was an automated range. It did not present the same background problems as did the M4 range. However, there was some low-lying land with ground water on some lanes where the 200 and 300-meter targets were located. Later in the night for the LW platoon, ground fog occurred over these low areas, obscuring targets for both the TWS and the NVGs/PEQ-2A.

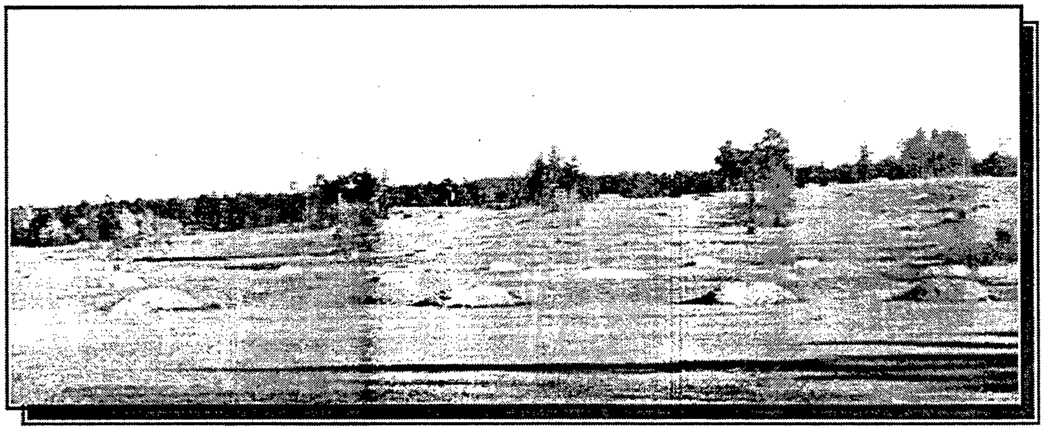

Figure 19. Machine gun qualification range.

The qualification standard for both the M249 and M240B was 6 hits of 11 target exposures. For the TWS, this meant 6 hits in each field of view, wide and narrow. The numbers of targets at each range for field fire, practice qualification, and qualification are shown in Table 16. Standard single E-silhouettes were at 100 to 300 meters; double E-silhouettes at 400 meters and beyond.

Table 16
Target Ranges and Number of Targets for the M249 and M240B Exercises for Both Platoons

Meters to Targets	**M249**	**M240B**			
	FF, PQ & Qual with TWS and PEQ-2A	FF with PEQ-2A And TWS	PQ & Qual with PEQ-2A	PQ & Qual with TWS	
	Number of targets				
	BL & LW Plt	BL & LW Plt	BL & LW Plt	BL Plt	LW Plt
100	3	---	---	---	---
200	3	3	2	2	---
300	2	2	2	2	---
400	3	3	3	3	3
500	---	2	2	2	2
600	---	1	2	2	3
700	---	---	---	---	1
800	---	---	---	---	2
Total # targets	11	11	11		11

Note. Only one thermal blanket was used on the double silhouettes as the range wiring allowed for a single blanket only. Practice qualification target exposure times were 5 seconds longer than qualification.

As indicated previously in Table 8, neither platoon was able to execute the POI as planned due to ammunition constraints. In general, the field fire exercises were reduced for both platoons. Some practice qualification and qualification exercises were eliminated for M249 gunners in both platoons. Even if sufficient ammunition had been available, it is likely that the POI could not have been executed fully because of time constraints.

Qualification rates and scores. The percentage of soldiers qualifying on each weapon system with each device depended highly on the ammunition available, whether soldiers were given the opportunity to requalify, whether there was sufficient time to requalify, and whether the environmental conditions (fog, ambient light) allowed firing to continue. The field zero and qualification results in Table 17. Because of the factors that prevented complete execution of the POI, it would be erroneous to use the qualification percentages as an indicator of success or nonsuccess with a particular weapon-device combination. These percentages are presented in conjunction with the rounds required to zero and the number of gunners. Also the limited number of gunners should be kept in mind when examining the results.

Table 17
Field Zero and Qualification Results on the M249 and M240B for Both Platoons

Weapon and Sight/Device	Mean # Rounds to Zero[a]	% Qualify on First Attempt	% Qualify after Requalification
Baseline Platoon			
M249			
TWS - WFOV -Night	NA	17% (1 of 6 gunners)	No requal due to limited ammunition
TWS - NFOV-Night	NA	33% (2 of 6 gunners)	No requal due to limited ammunition
PEQ-2A - Night	NA	17% (1 of 6 gunners)	No requal due to limited ammunition
M240B			
TWS - WFOV- Night	NA	75% (3 of 4 gunners)	75% (remaining gunner did not qualify after 3 attempts)
TWS - NFOV - Day	NA	50% (2 of 4 gunners)	75% (but only 1 gunner allowed to requal)
PEQ-2A - Night	NA	0% (0 of 4 gunners)	25% (but only 1 gunner allowed to requal)
LW Platoon			
M249			
TWS - WFOV -Night	20 (n =6)	0% (0 of 5 gunners)	No requal due to limited ammunition
TWS - NFOV-Night	44 (n =2)	Not executed	Not executed
PEQ-2A - Night	18 (n =6)	33% (2 of 6 gunners)	100% (6 of 6 gunners)
M240B			
TWS - WFOV- Night	141 (n =2)	50% (2 of 4 gunners)	No requal due to fog
TWS - NFOV - Day	16 (n = 2)	50% (2 of 4 gunners)	75% (3 of 4 gunners)
PEQ-2A - Night	140 (n=2)	25% (1 of 4 gunners)	No requal due to limited ammunition and poor visibility

Note. NA stands for "not available." LW platoon: One M249 gunner did not fire TWS qualification because of a weapon malfunction. Both platoons: for the M240B, qualification results are based on the two gunners and two assistant gunners.
[a] n in parentheses indicates numbers of gunners for which rounds to zero were available.

The qualification scores are in Table 18. The means are based on a total of 11 target exposures. Across all ranges, the mean percentage of hits for the PEQ-2A with the M249 was 35% and with the M240B was 40%. The corresponding mean percentages for the TWS WFOV were 33% for the M249 and 43% for the M240B. For the TWS NFOV, the percentages were 47% for the M249 and 52% for the M240B. So in general, gunners did best with the TWS NFOV. This higher level of performance probably resulted in part from the higher magnification available in this FOV.

Table 18
M249 and M240B Qualification Scores

Platoon and Weapon	Mean	Minimum Score	Maximum Score
	PEQ-2A		
M249			
Baseline Plt	4.00	0	8
LW Plt	3.83	1	6
M240B			
Baseline Plt	5.25	2	9
LW Plt	3.53	2	6
	TWS WFOV		
M249			
Baseline Plt	3.00	0	4
LW Plt	4.20	1	5
M240B[a]			
Baseline Plt	6.00	0	10
LW Plt	3.50	0	6
	TWS NFOV		
M249			
Baseline Plt	5.17	4	10
LW Plt	----	----	----
M240B[a]			
Baseline Plt	6.75	4	10
LW Plt	4.75	2	7

Note. There were 6 M249 and 4 M240B gunners in each platoon. The top scores on the machine gun with the PEQ-2A and TWS (scores of 9 and 10) were achieved by one excellent gunner in the Baseline platoon. In practice qualification he hit all 11 targets.
[a] For the Baseline platoon, TWS targets were from 200 to 600 meters; for the LW platoon they were from 400 to 800 meters.

As indicated by the minimum and maximum scores in Table 18, there was considerable variability in the marksmanship abilities of the gunners. Due to the limited number of gunners, no statistical comparisons were made between the two platoons.

Performance by range to target. Figures 20 through 23 show the percentage of target hits for the device-weapon combinations for each platoon. With the M249 and the Baseline platoon, performance generally decreased with increased distance to the target. But for the LW platoon the percentage of hits was the same from 200 to 400 meters (Figures 20 and 21). For the M240B gunners (Figures 22 and 23), the performance curves are more erratic, in part because they represent only 4 gunners. There is no ready explanation for the variability in

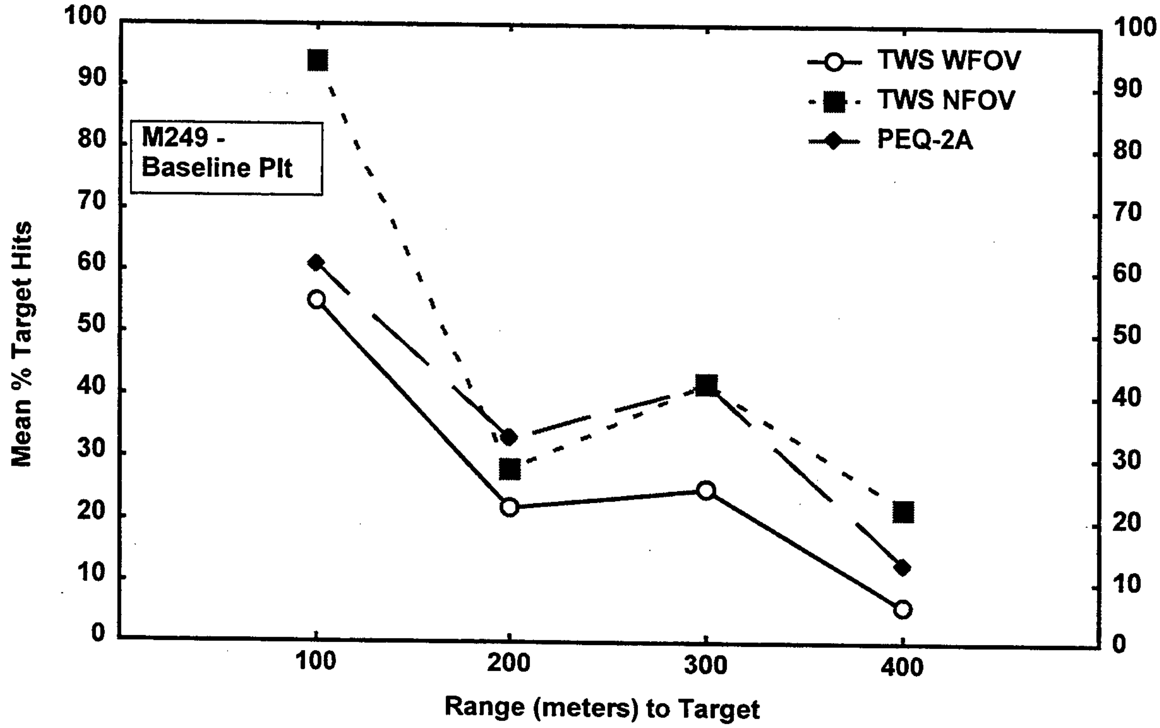

Figure 20. Baseline platoon M249 qualification by range to the target.

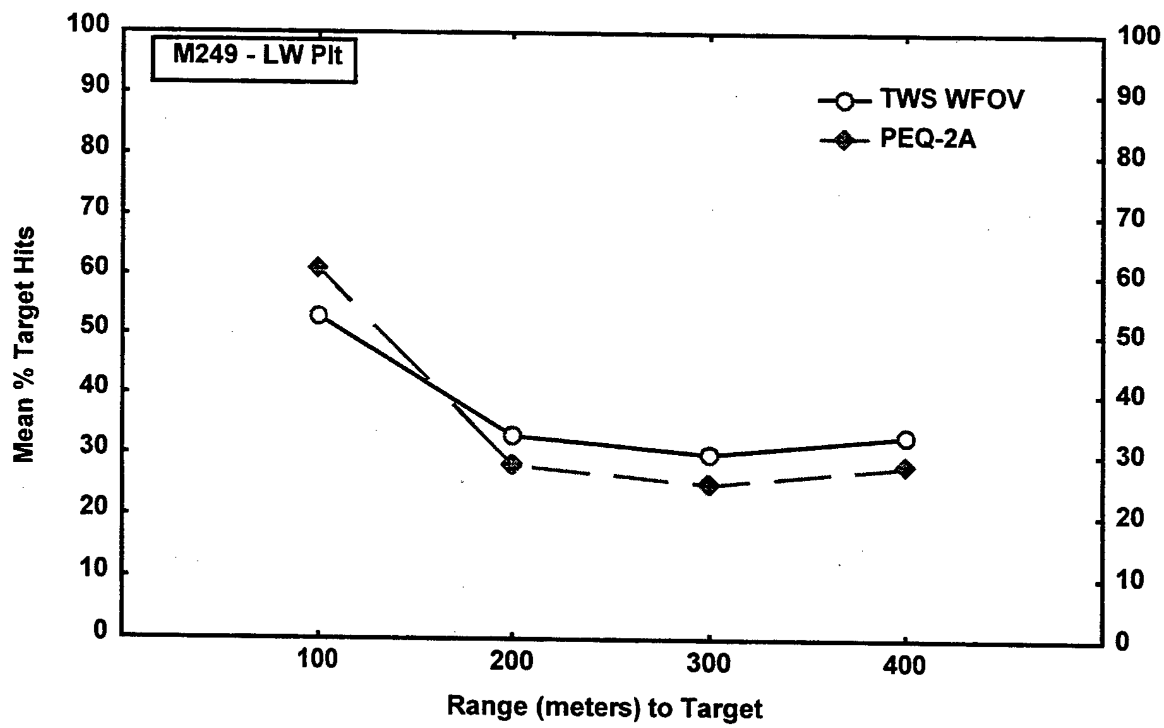

Figure 21. LW platoon M249 qualification by range to the target.

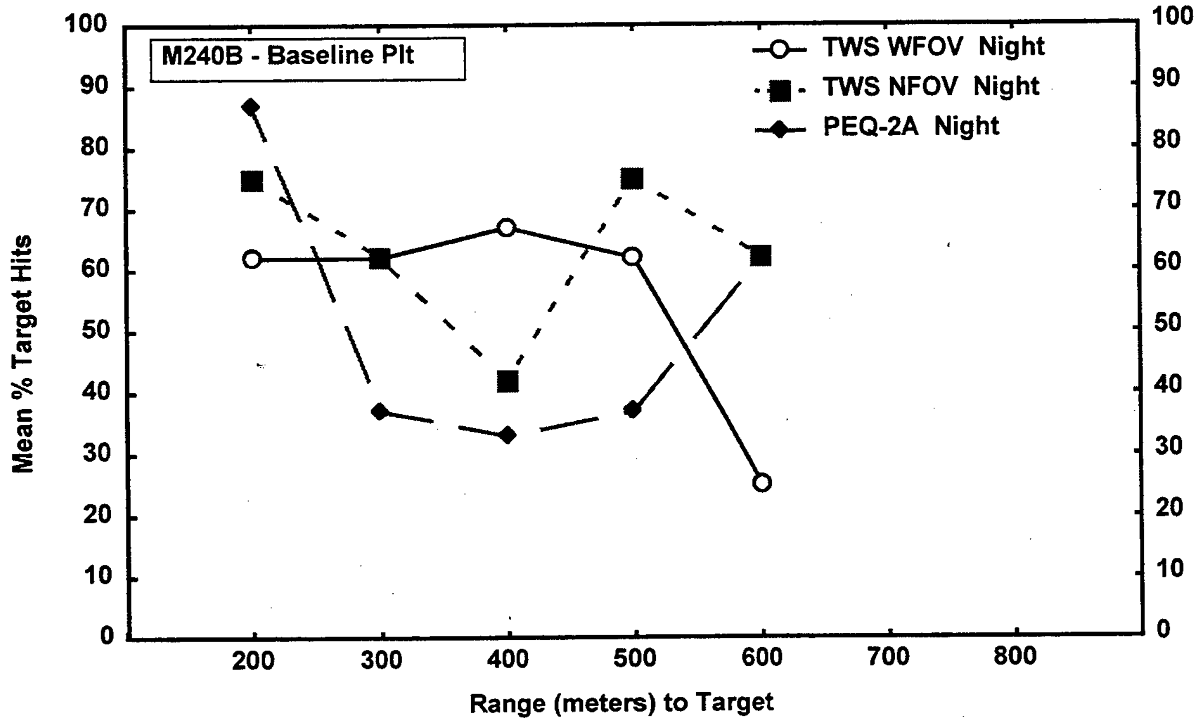

Figure 22. Baseline platoon M240B qualification by range to the target.

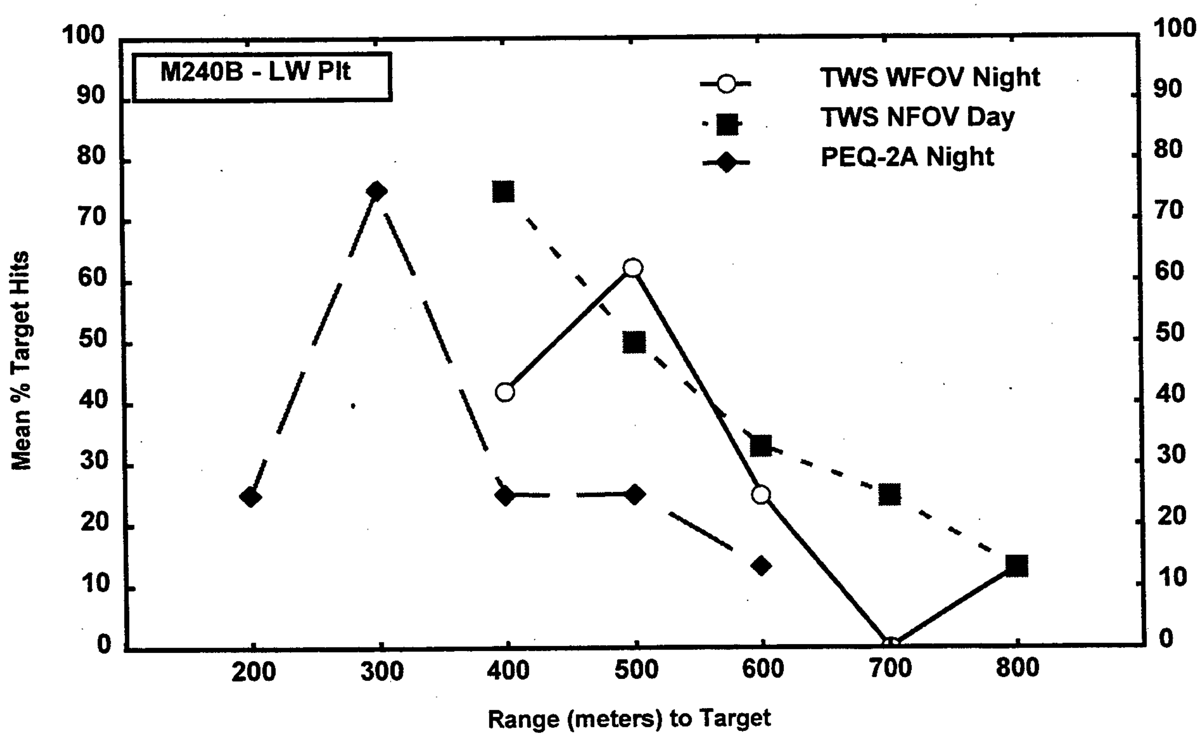

Figure 23. LW platoon M240B qualification by range to the target.

performance for the Baseline platoon. For the LW platoon, the TWS curves were higher than the PEQ-2A curves, results consistent with the respective capabilities of these two devices. The low point at 200 meters for the PEQ-2A was due to ground fog obscuring the targets at that distance.

Comparison with other tests. No prior reports of the PEQ-2A with either the M249 or M240B were found. However, Boylan, Riemenschneider, and Fye (1997) reported overall percentage hits with the TWS. The only information on scenarios presented in this report was that soldiers fired record fire. The distances fired were not presented. At night, the M249 gunners averaged 54% hits; the M240B gunners, 25% hits. During the day, the M249 gunners averaged 59% hits; the M240B gunners, 53% hits. In comparison with our platoon results, the M249 gunners scored lower, while the M240B gunners scored higher. However, given the incomplete information in the TWS report (Boycan et al., 1997), it is impossible to know whether the firing conditions were comparable. Therefore firm conclusions about differences in performance in the two studies cannot be drawn.

Summary, Discussion, and Conclusions

The training sessions described in this report provided a unique opportunity to examine how soldiers acquired skills with three types of devices designed to improve the soldier's lethality during day and night operations, the typical and unexpected errors committed during this learning process, and the impact of changes in the training on soldier skill. The training sessions also provided an excellent setting to identify needed training support materials and exercises, and the knowledge and expertise needed by trainers to execute training and to diagnose shooting weaknesses with each device. Of additional interest was the systematic use of a bore light to boresight all the devices to different small arms weapons.

The equipment problems and training issues that emerged were typical of what would occur over an extensive one- to two-week period of training within a unit. The soldiers who participated in the training had a wide range of Army and weapon experiences, as they constituted intact platoons from an active Army unit. Consequently, the results have general applicability, and depict the weapon system lethality achievable with individual Infantry soldiers and with an Infantry platoon as a whole after immediate fielding and new equipment training on these particular devices.

Equipment Issues

Each device had its unique set of problems and issues that had to be resolved and addressed during training. Because of the different device technologies, techniques effective with one device did not necessarily apply to the others.

Aiming lights and NVGs. When firing with aiming lights and NVGs, soldiers often indicated they used special techniques to obtain a full field of view. These techniques were designed to counter the forward center of gravity of the NVGs. Some soldiers physically held the NVGs up and fired; some cocked their heads back; some got up on their elbows, most used parachute retention straps to stabilize the NVGs and helmet on their heads.

Not all soldiers used the aim point and illuminator features of the PEQ-2A in the same way. Some soldiers preferred the aim point only; some used the illuminator as well to help them to hit targets. With experience, soldiers will probably find the wide beam of the illuminator helpful in detecting targets.

With the Baseline platoon, M249 and M240B gunners encountered some phenomena with the PEQ-2A not experienced by the LW platoon. The M240B gunners experienced white-out with the NVGs when firing the 7.62 mm round. This did not seem to be a problem with M249 gunners, who use a smaller caliber, 5.62 mm, round. The machine gunners also indicated that they sometimes lost the PEQ-2A laser in the power residue from the 7.62 mm round. Gunners indicated there was some reduced visibility because of the dust kicked up by the rounds down range. When there was tracer burn, they were apt to lose their target.

Thermal weapon sight. With the TWS, several gunners in the Baseline platoon said they experienced a wavy picture that blanked out after firing several rounds. In most cases, the picture eventually returned. One machine gunner encountered a blur in the TWS during qualification that he could not correct in a timely manner. He finally selected the automatic contrast button and the image then stabilized, but the qualification exercise was over at this point. Some gunners mentioned interference in the TWS image from heat from the M4, M249, and M240B barrels. But the LW platoon did not mention image problems from heat from the barrel. Thermal camera imagery indicated that the barrels could get very hot. For instance, one thermal temperature recording indicated the barrel of the M240B was 270° Fahrenheit.

The scanning problems cited by soldiers in the Baseline platoon with the TWS (scanning too fast blurred the image or created a lag in image update) were minimized with the LW platoon as the instructors stressed the importance of scanning more slowly and systematically to reduce this problem. More experience with thermal sights should reduce problems encountered with the TWS and provide soldiers with "immediate reaction" skills to adapt to unexpected changes in thermal imagery. For example, one soldier with prior experience with the Javelin thermal sight was able to immediately adjust the "red out" in his image resulting from the M4's hot barrel; he lowered the brightness setting and increased the contrast setting.

Typically, soldiers preferred the black-hot polarity to white-hot (seen as shades of red to white) polarity for target engagement because the TWS reticle is shown in red. Switching to black-hot made it easier to determine the appropriate aiming point on the reticle and discriminate it from targets down range, i.e., a black-hot target with a red reticle superimposed on it. Soldiers found value in firing in both the wide and narrow FOV. Some discovered that the TWS fogged up, similar to the fogging problems often encountered with NVGs.

Close combat optic. Again, lessons learned with the Baseline platoon reduced problems the LW platoon encountered with the CCO. The critical factor with the CCO was learning how to minimize parallax at close-in distances, and soldiers were taught techniques to accomplish this. Some of the more experienced soldiers indicated they had difficulty employing the CCO with both eyes open.

All devices. Lastly, the importance of checking the stability of the mount and of insuring the device is mounted in the same location after removal from the weapon were important lessons learned in both training sessions. In many instances, instructors discovered loose mounts with soldiers who were not hitting well.

The POI and Training Support Materials

The expertise and knowledge required by trainers on all the devices should not be underestimated. Each device reflects a different technology. As such trainers must understand the basics of each technology thoroughly and be able to explain it to soldiers. They must know the device's capabilities that enhance lethality, the device limitations that impact system employment, and the device features that create learning problems for soldiers. The trainer must recognize when soldiers have these learning problems and develop training techniques to reduce them. Thus a good conceptual understanding of each device as well as practical expertise with it are required of trainers.

Training support materials must address, explain, and illustrate the unique features of each technology. Unfortunately, few training materials such as video, photos, graphic illustrations, or even non-technical explanations of the technologies are available for the devices used in the training. Thus minimal training support materials were available for the Baseline platoon training. The instructors for the LW platoon made substantial improvements in these materials. Nevertheless, there is a substantial need to improve these materials further and to develop stand-alone blocks of instruction that can be used by trainers in a variety of contexts.

One long-term challenge is the development of a block of instruction that describes and explains image intensification technology, thermal technology, the differences between the two, and the tactical implications of each. Optimal employment and training of these devices requires some technical knowledge. Soldiers from both platoons tended to confuse the two technologies, e.g., believing aiming lights can be seen by thermal sights, not knowing that NVGs are sensitive to near infrared (IR) while thermal sights operate in the middle and far IR regions. This block of instruction needs to be developed at the technical, conceptual, and tactical levels appropriate for both leaders and soldiers. Actual photography (image intensification and thermal) should be exploited to show soldiers how different targets and scenes appear under different environmental conditions, techniques for employing aiming lights, the impact of TWS adjustments on the image, etc. Current doctrine and training materials do not contain this information.

A second need is instructional materials that clarify the relationship between bullet trajectory, the boresight offsets, and the zero impact point. For all devices, training materials should address why the boresight offsets work: why the offsets should enable a soldier to hit at 25 meters or at range; why the offset targets vary with the weapon-device combination, and the difference between a 300-, 400-, and 500-meter offset. The materials should also address the potential degree and direction of error associated with such offsets. In addition, the relationship of each of these to the aiming light trajectory needs to be clarified. Of particular importance is the relationship between the bullet's trajectory and the straight-line aiming light trajectory.

Within the context of this instruction, precise definition and application of terms is essential. For example, the terms "boresighting" and "zeroing" must be distinguished from each other and used consistently. Reference to IR energy or IR light must also be precise and it is important to distinguish between near IR (image intensification devices) and mid and far IR (thermal devices).

Practical exercises (PEs) should be incorporated when introducing device controls and their function. This hands-on experience within the classroom instruction helped soldiers understand each device as well as develop some initial psycho-motor skills in finding and operating the controls unique to each. Every device should be viewed as part of a system. PEs are needed on all components that comprise the system. We found that PEs on mounting each device to the soldier's weapon and how to appropriate adjust NVGs were critical to soldier expertise on the range.

The boresighting demonstrations should be designed so soldiers can see the entire boresighting process — how to adjust the device, what must done at the target, and how and why adjustment decisions are made. Several instructors are typically required to achieve this goal.

Boresighting PEs are essential and must be conducted for each device, as we found that the skills used with one device did not necessarily transfer to the other devices. To fully understand all aspects of the boresighting process and to enable soldiers to boresight on their own, they need to rotate through all boresighting positions during the PEs. When the squad leader always makes the adjustments on the device and Private Jones at the boresight target always calls out the adjustments, the other squad members are not trained on all required skills.

Training should be continued on the range (prior to zeroing and target engagement exercises), reinforcing what was learned, checking soldier's retention on use of controls, determining if boresighting was conducted properly, and reviewing system employment issues. Of particular importance is giving soldiers time to adjust the PEQ-2A and the TWS for the range conditions they encounter on a particular night. These steps will save valuable time and bullets.

Boresighting

As stated previously, this was the first time a bore light had been used to boresight several difference devices on the small arms weapons integral to the Infantry platoon. Much was learned about how to boresight these devices. These lessons are invaluable for efficient and accurate boresighting. Therefore, they are repeated in this summary section.

The major lessons learned regarding boresighting were:

- Soldiers must establish a stable firing position and use field-expedient techniques.

- The basic boresighting technique should be the same for all optics/devices.

- Every soldier should rotate through each of the boresighting duty positions.

The lack of consistency among the devices' windage and elevation adjustments, shown previously in Table 12, reinforces the need for the trainers and soldiers to be consistent in all other aspects of the boresighting process. Consistency in this technique enhances soldier understanding, and reduces the potential for confusion among the devices. The recommended technique is also compatible with zeroing adjustments cited in the device technical manuals. The technique requires the firer to first align the device with the boresight offset (as when aiming at a real target). Then the firer, using the same point of aim, should adjust the device to move the barrel, i.e., the bore light beam, to the appropriate marking on the offset target.

The recommended boresighting steps for the sights and aiming lights are:

❶. A stable firing position using field-expedient materials is established.
  - With the CCO and the TWS, the soldier must shoulder the weapon to align the weapon. Thus the soldier must be steady.
  - With the aiming lights, the most stable position is achieved by laying the weapon on its side and stabilizing it with sand bags or rucks. Soldiers do not need to shoulder the weapon to align the aiming light properly.

❷. The bore light is zeroed (centered in the barrel of the weapon).

•This zero is checked whenever the bore light is placed in the barrel of a different weapon or even removed from a weapon and re-inserted in the same weapon.

❸. The device is aligned first with the offset target, as a soldier would do when engaging an actual target.

• When aligning the CCO and the aiming lights with their offset point, it is best to cover up the bore light to eliminate confusion as to which light is being aligned.

❹ The location of the bore light beam on the offset target is determined.

❺ Adjustments are made to the adjusters/knobs on the device to bring the bore light beam into alignment with its spot on the offset target.

• With this technique, the direction in which the device's adjusters are turned are consistent with the technical manual citations for live-fire zero, reducing potential confusion on the part of the soldier. In both instances, the barrel moves relative to the device. In bore sighting the bore light beam moves; in live-fire zeroing the impact point of the rounds moves.

❻ The final setting is rechecked.

•The soldier should get "off the weapon" and then get back on again, maintain the same sight picture as previously, and check the alignment of the bore light beam. For the TWS, the windage and elevation settings can be recorded, as they are provided digitally in the TWS reticle.

❼ The adjusters on the bore light must never be touched in this process as the bore light has been previously zeroed to (centered in) the bore of the weapon.

The other critical technique learned in the training assessments was how to accurately and efficiently zero the bore light itself. The key to accuracy and efficiency was learning that the weapon's orientation was immaterial to the process, making it easy to achieve a stable position with sandbags or rucks. The recommended zeroing steps for the bore light are:

❶ Mark off 10 meters with a 10-meter wire or string.

❷ Make a "zero mark" for the bore light on a piece of paper and attach this paper to a wall or other vertical surface that is 10 meters from the gunner or have a buddy hold the paper very steady.

❸ Align the laser bore light beam with the zero mark. This is the start point. The weapon must be stabilized and can be in any orientation. The gunner does not need to shoulder the weapon.

❹ The start position of the bore light is with the battery up.

❺ Turn the bore light 180 degrees counterclockwise (CCW, from the viewpoint of a soldier behind the weapon). After this turn, the adjusters are on top and easy to reach.

❻ The buddy at the target must then mark the position of the bore light beam after the 180-degee turn. This is referred to as the turning point. He then determines a reference point that is half way between the start point (zero mark) and the turning point.

❼ The buddy tells the gunner which direction(s) to adjust the bore light and how many clicks are required to move the beam to the reference point.

❽ The gunner makes the adjustments.

❾ The gunner repeats the initial steps. He turns the bore light to the initial position (battery up), aligns it with the zero mark, and rotates it 180 degrees.

❿ The buddy at the zero target indicates whether further adjustments are needed. The bore light is zeroed when it turns or spins on itself (zero mark and turning point are the same).

Target Engagement and Zeroing

Major findings with the M4. With the CCO, soldiers with prior experience with iron sights on the M4 and M16A2 transitioned easily to the CCO. They exceeded the current marksmanship qualification standard with a minimal train-up of practice qualification only. The current standard is 23 out of 40 target hits; the standard applied to the platoons was 28 out of 40 target hits.

Experienced soldiers using the TWS on the M4 at night achieved the current, daytime marksmanship standard, 23 out of 40 target hits, with few refires required. Although some soldiers achieved this standard with minimal train-up, the findings as a whole indicate that known distance, field fire, and practical qualification exercises contribute to increased expertise with the TWS controls, thermal imagery, and the ability to hit targets.

The ability of soldiers to hit targets with the aiming lights on the M4 was impacted by the degree of ambient light and the configuration of the range. Whenever these factors reduced target contrast, the targets were very difficult or impossible to detect with NVGs. Aiming lights themselves are easy to use. But aiming lights and NVGs must be considered as a system in establishing qualification standards. The current daytime qualification scenario is inappropriate for many unit qualification ranges, which are designed to have some degree of combat realism (not a sterile range). In addition, the degree of ambient light (full moon, clouds, no stars) and the direction of that light (in front or behind the soldier) are uncontrollable factors which affect the ability to acquire and hit targets.

Major findings with the M249 and M240B. Definitive statements regarding qualification standards for the M249 and M240B cannot be made due to the limited number of soldiers and the ammunition constraints which prevented full execution of the POI as planned. It appears that the standards used during the training are achievable, but perhaps only by soldiers who are proficient with the M249 and M240B. On the other hand, the standards might have been achieved by more gunners if all train-up exercises had been conducted.

Zeroing. Given the number of rounds required to zero, it appears that 25-meter live-fire zeroing with the M4 is needed after boresighting with the CCO and the TWS. Some form of zero confirmation is also needed with the M249 and M240B. Regardless of weapon, TWS zeroing should be done during the day to expedite the zero process and to ensure accurate determination of round location. In addition, boresight offsets for the TWS that are consistent with the M249 and M240B reticle markings are needed.

As noted extensively in this report, there was no 25-meter zeroing with the aiming lights for the M4. This was because of the halo problem associated with the zeroing process at this close range. Field zeroing the PEQ-2A at 300 meters with the M249 and M240B was not problem-free, as the bullet impact point was extremely difficult to identify at night. In principle, the concept of boresighting without zeroing could apply to the aiming lights on the M249 and M240B. Perhaps zeroing with any aiming light is not needed. But this proposal must be tested thoroughly prior to implementation. A comparison of the accuracy (precise bullet location and deviation from the target's center mass) of the boresight settings for hitting targets at range versus boresighting, then zeroing, and then firing at range is needed.

The special devices did not compensate for poor marksmanship skills on the M4 carbine, the M249 SAW, or the M240B machine gun. Poor firers should be identified prior to attempting to qualify with these devices and given remedial training. Zeroing provides a critical opportunity to identify soldiers with poor marksmanship skills. When boresighting is used as a substitute for live-fire zero, diagnosis of marksmanship strengths and weaknesses prior to target engagement does not occur.

Platoon lethality at night. Of interest is what the results showed in terms of overall platoon lethality. To examine this issue the data from both platoons were combined. The percentage of target hits was examined for each of the night systems for each weapon system and by target range. For the aiming lights, the distance covered was 100 to 600 meters. For the TWS, the distance covered by 100 to 800 meters. Figure 24 depicts aiming light performance curves. Figure 25 depicts the TWS performance curves. The M4 data points are the most reliable, as they are based on the largest number of gunners. Overall, the results show substantial night capability for the platoon weapons with these devices.

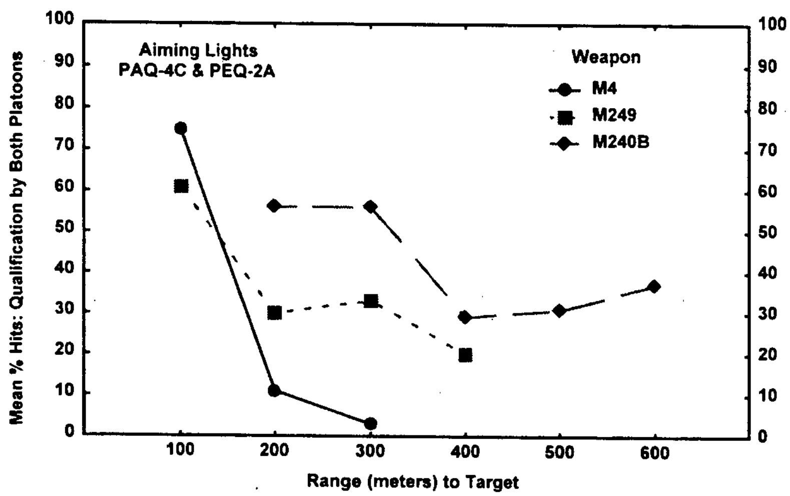

Figure 24. Summary of aiming light results on all weapons by range to the target.

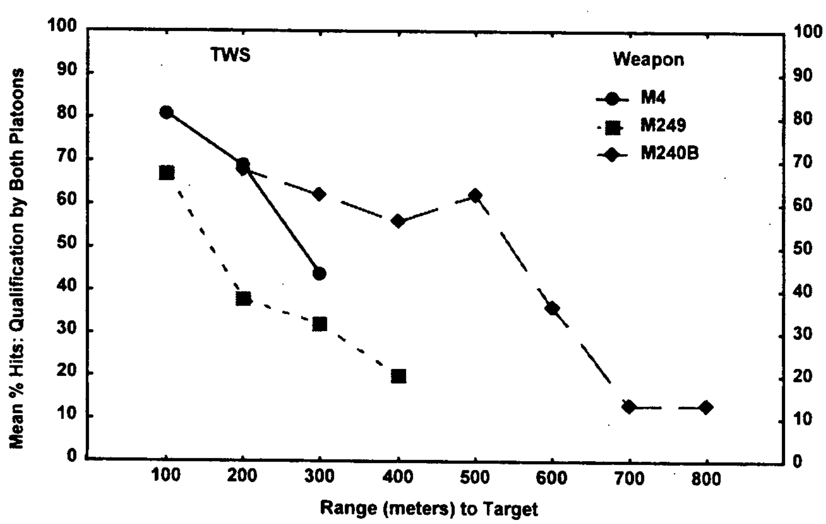

Figure 25. Summary of TWS results on all weapons by range to target.

The aiming light performance curves in Figure 24 are generally consistent with expectations. The higher curves for the M249 and M240B probably reflect use of the PEQ-2A with the illuminator and a qualification range that provided better target contrast than did the M4 range. The lower data point for the M249 at 100 meters compared to the M4, however, is inconsistent with expectations, and no explanation can be given for this particular result.

The TWS performance curves for the M4 and M240B in Figure 25 are also consistent with expectations. The low performance from 100 to 400 meters with the M249 cannot be pinpointed. One possible reason is that the M4 gunners had more train-up and zeroing experience with the TWS prior to qualification than did the M249 gunners. Another factor could be the relative difficulty in firing the M249 itself and the relative inexperience of the M249 gunners.

Diagnosis of Shooting Problems

The introduction of these new devices to the Infantry means that leaders and trainers must acquire more diagnostic skills. No longer does a failure to hit at range mean the soldier is not applying the four fundamentals of marksmanship. Nor does it necessarily mean that the device is hard to use. We learned that no matter what the device, the possible reasons for a soldier missing targets at range can be many. Troubleshooting is more complex than with iron sights. In addition, the cause(s) of the problem can vary with the technology. Trainers, leaders, and soldiers must understand each technology, how to use the technology well, and all the procedures/steps that culminate in range firing. A mistake or problem at any stage, as well as a limitation of the technology itself, can explain why soldiers do not hit targets. Below are diagnostic questions pertaining to all devices as well as questions unique to each system that should be considered in determining why soldiers are not hitting targets. These questions were derived from the problems and errors encountered during the platoon training.

- All devices
  - Is the soldier applying the four fundamentals of marksmanship?
  - Is the device/optic mounted tightly to the weapon?
  - Is the device/optic mounted at the correct location on the rail?
  - Was the boresight distance correct?
  - Was the correct offset target used?
  - Did the soldier achieve a good, tight boresight zero?
  - Are the batteries good?
  - If the sight/optic was remounted, was it remounted on the same rail notch?

- CCO
  - Did the soldier confuse the CCO red dot and the bore light red dot when boresighting?
  - Did soldier use same sight picture when boresighting and zeroing?
  - Is the brightness of the CCO dot appropriate for the amount of daylight?
  - Is the sun's angle creating glare on the optic?
  - Was the half moon spacer used during boresighting and firing?

- Aiming Lights (PAQ-4C and PEQ-2A)
  - Were the weapon and offset target aligned properly during boresighting?
  - Are the NVGs adjusted properly - tight on head, diopter adjustment, interpupillary distance, distance focus?
  - Is the aimpoint on the PEQ-2A centered in the illuminator?

- Does the width of the PEQ-2A illuminator beam help or hinder target acquisition?
- Is the illuminator expanded, or does the gunner see 2 dots?
- Does the power setting on the PEQ-2A (Hi/Low) help or hinder target acquisition?
- Are the targets hard to see because of environmental conditions - fog, poor ambient illumination, etc.?
- Are targets hard to see because of the range configuration - shadows on targets from trees, cultural lighting, etc.?

- TWS
    - Was the correct reticle for the weapon used during boresighting, zeroing, and/or firing?
    - Was the correct reticle aim point used during boresighting, zeroing and/or firing?
    - Was the correct aim point area cut out for 25-meter live-fire zeroing?
    - Was the correct impact area used during 25-meter live-fire zeroing?
    - Was the heat source small enough to achieve a good aiming point during zeroing?
    - Did the position of the TWS on the weapon allow for a good position?
    - Does the soldier have good settings on the TWS?
        - -- Diopter focus
        - -- Range focus
        - -- Brightness
        - -- Contrast
        - -- Polarity
        - -- Field of view
    - Is the gunner using the correct reticle aimpoint during target engagement?
    - Is firing being conducted during a period of thermal cross-over?
    - Are soldiers distinguishing between artificially hot targets and other hot objects (rocks) on the range?
    - Are thermal blankets secured firmly on all targets?
    - Are targets hard to see because of fog or other environmental conditions?
    - Are two thermal blankets on double E-silhouettes?
    - Did soldiers scan to facilitate detecting close targets?
    - Did soldiers scan at an appropriate rate to avoid image blur or temporary "freezing" of the image?

Conclusions

The devices used in the training will greatly enhance the platoon's lethality during day and night. Needless to say, this capability will occur only if soldiers have expertise with their weapon and the devices. In turn, they need quality training. This report provides substantial information on what contributes to quality training and what should be integrated into institutional and unit marksmanship programs of instruction, technical manuals, and the Army's training and doctrine literature.

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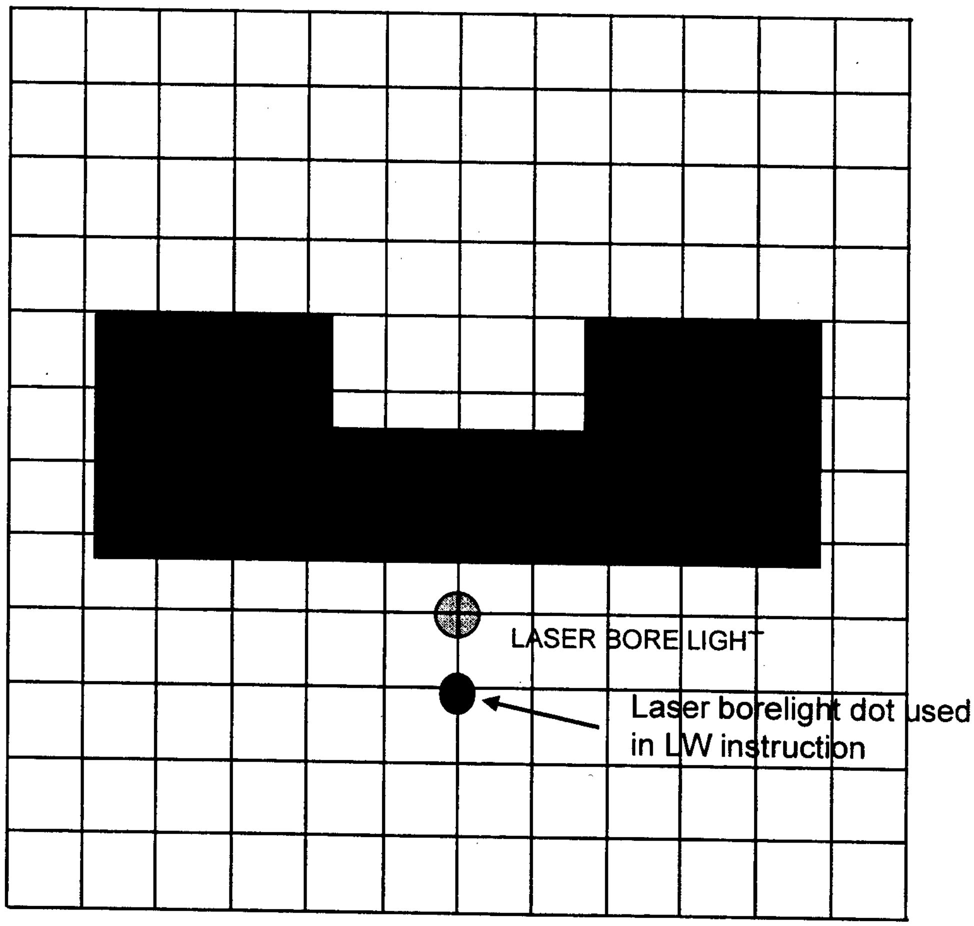
APPENDIX A

BORESIGHT OFFSET TARGETS

M4 MODULAR WEAPON SYSTEM
SOCOM 300 METER BACK-UP IRON SIGHT
10 METER BORESIGHT TARGET



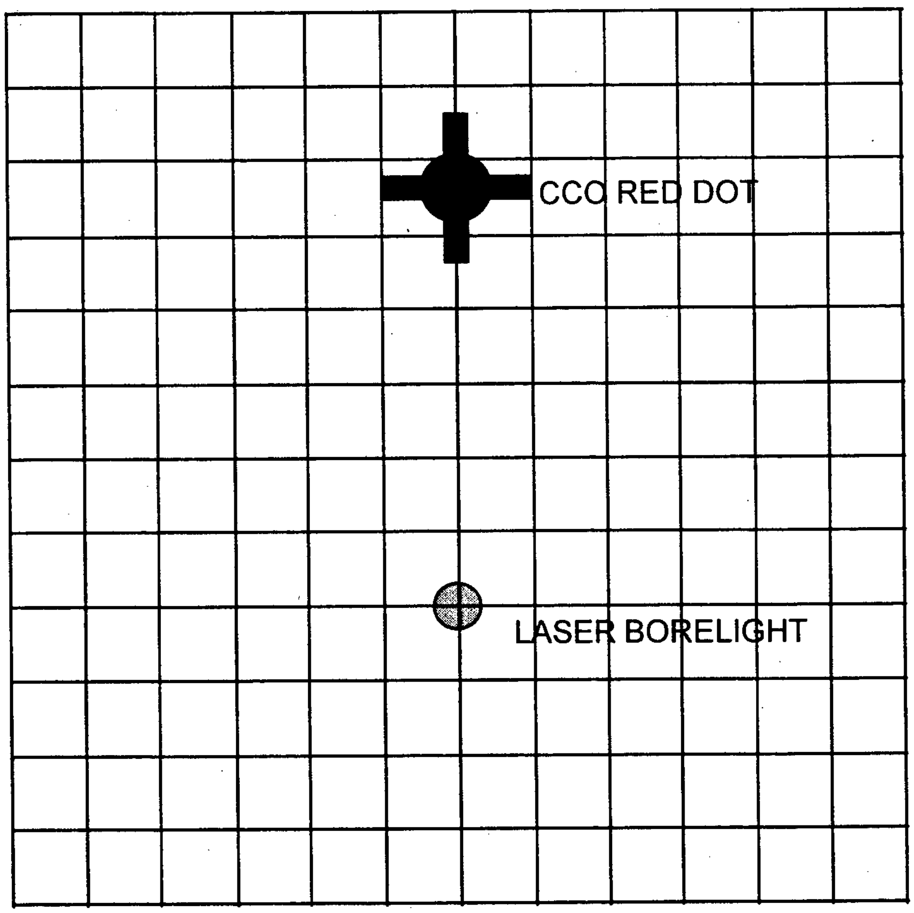
ZERO TARGET DATA FOR M4 MWS:

1- STABILIZE WEAPON
2- AIM AT TARGET AND BLACK-OUT RECTANGLE WITH FRONT POST
3- ADJUST WINDAGE ON IRON SIGHT AND ELEVATION ON FRONT POST OF WEAPON UNTIL THE LASER BORE LIGHT IS CENTERED ON THE DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR 300 METERS
4-6-98

M4 MODULAR WEAPON SYSTEM
M68 CCO (W/HALF MOON SPACER)
10 METER BORESIGHT TARGET



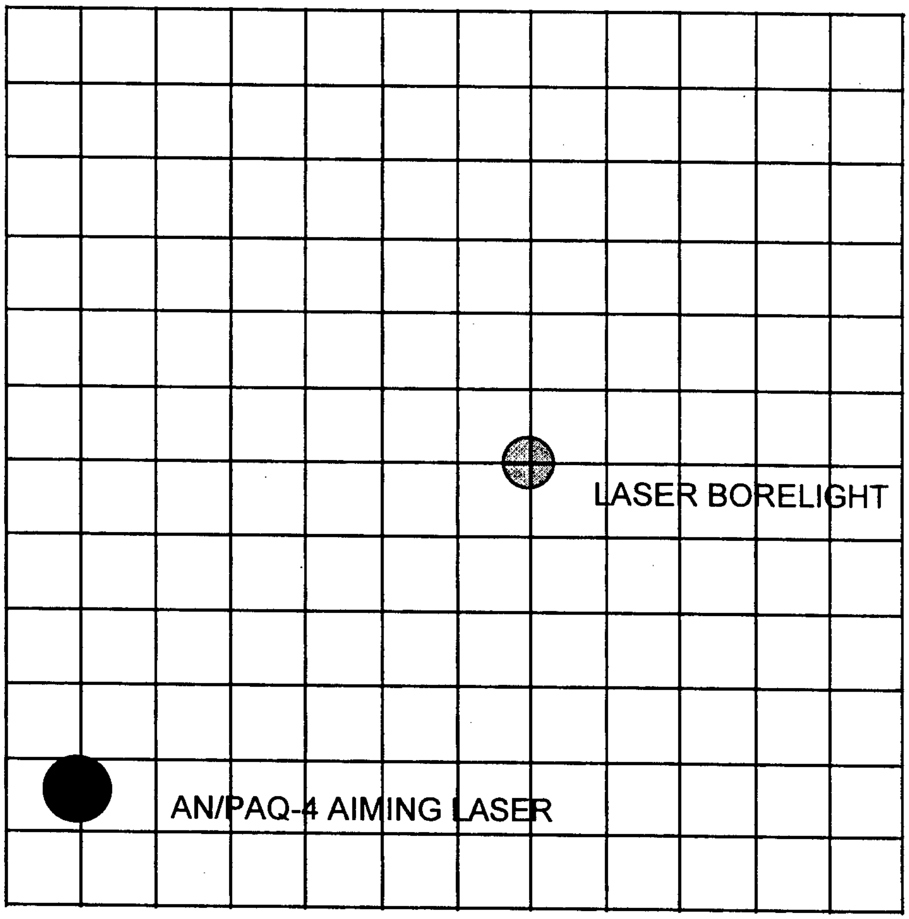
ZERO TARGET DATA FOR M4 MWS:

1- STABILIZE WEAPON
2- WITH REAR LENS COVER IN CLOSED POSITION, AIM AT CCO CROSS LOOKING THROUGH SMALL OPENING IN LENS COVER
3- ADJUST CCO UNTIL THE LASER BORE LIGHT IS CENTERED ON THE DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR 300 METERS
4-6-98

M4 MODULAR WEAPON SYSTEM
AN/PAQ-4B/C ON LEFT RAIL
WITH 0.975 inch/2.5cm SPACER
10 METER BORESIGHT TARGET



ZERO TARGET DATA FOR M4 MWS:

1- STABILIZE WEAPON

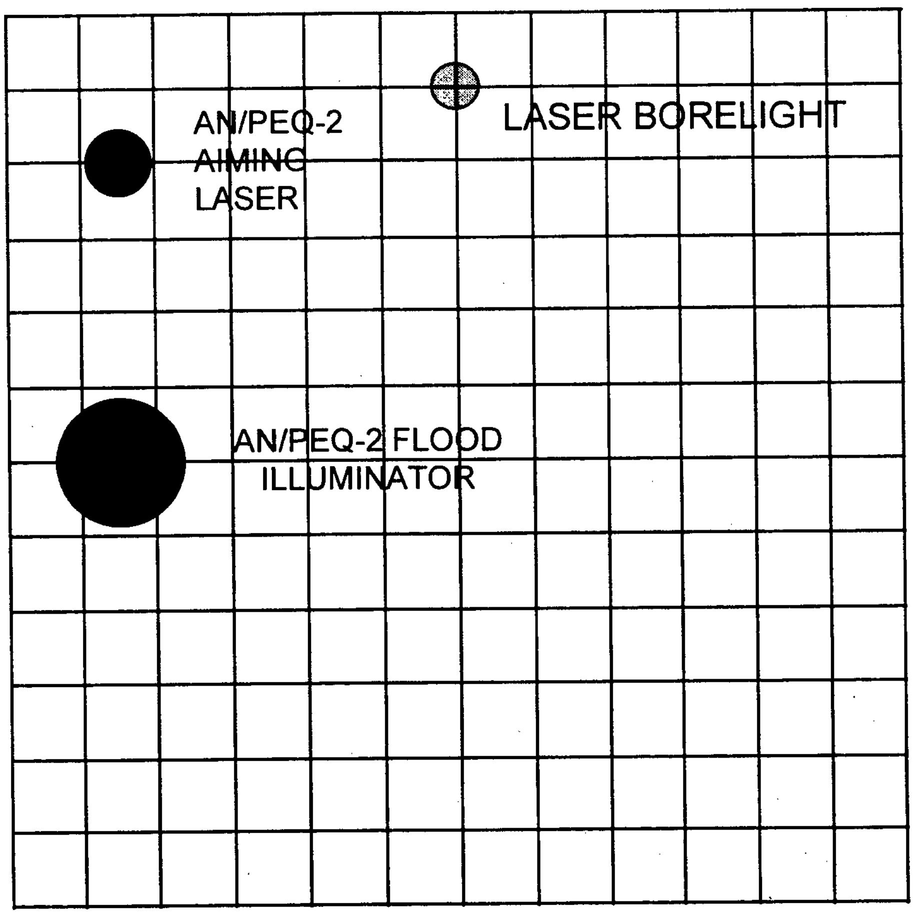
2- ALIGN LASER BORE LIGHT ON ITS DOT

3- ADJUST AN/PAQ-4 UNTIL THE AIMING LASER IS CENTERED ON ITS DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR 300 METERS
4-6-98

M4 MODULAR WEAPON SYSTEM
AN/PEQ-2 ON LEFT RAIL
10 METER BORESIGHT TARGET



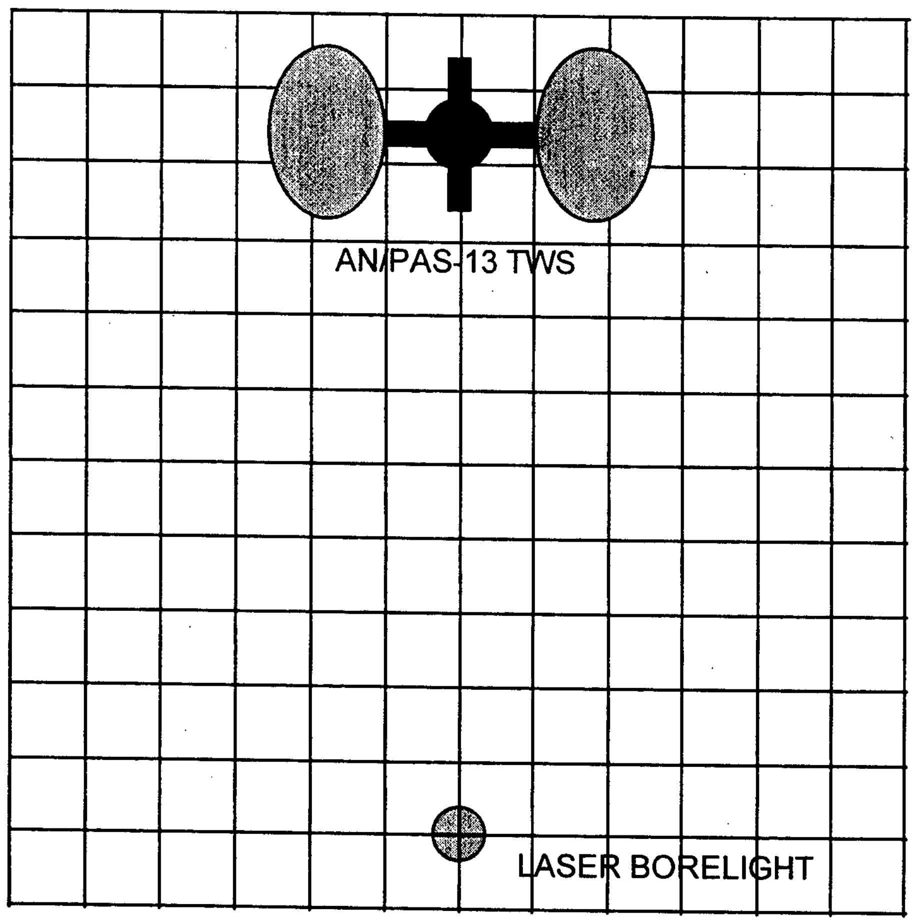
ZERO TARGET DATA FOR M4 MWS:

1- STABILIZE WEAPON
2- ALIGN LASER BORE LIGHT ON ITS DOT
3- ADJUST AN/PEQ-2 UNTIL THE AIMING LASER
IS CENTERED ON ITS DOT
4- ADJUST AN/PEQ-2 ILLUMNATOR TO ITS NARROWEST POINT,
AND CENTER ON ITS DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR
300 METERS
4-6-98

M4 MODULAR WEAPON SYSTEM
THERMAL WEAPON SIGHT
AN/PAS-13(V)2/3 with 0.875 in SPACER
10 METER BORESIGHT TARGET



M240B and M249 offsets:

Borelight dot was 7 cm down for the M240B.

The dot was 8 cm down for the M249.

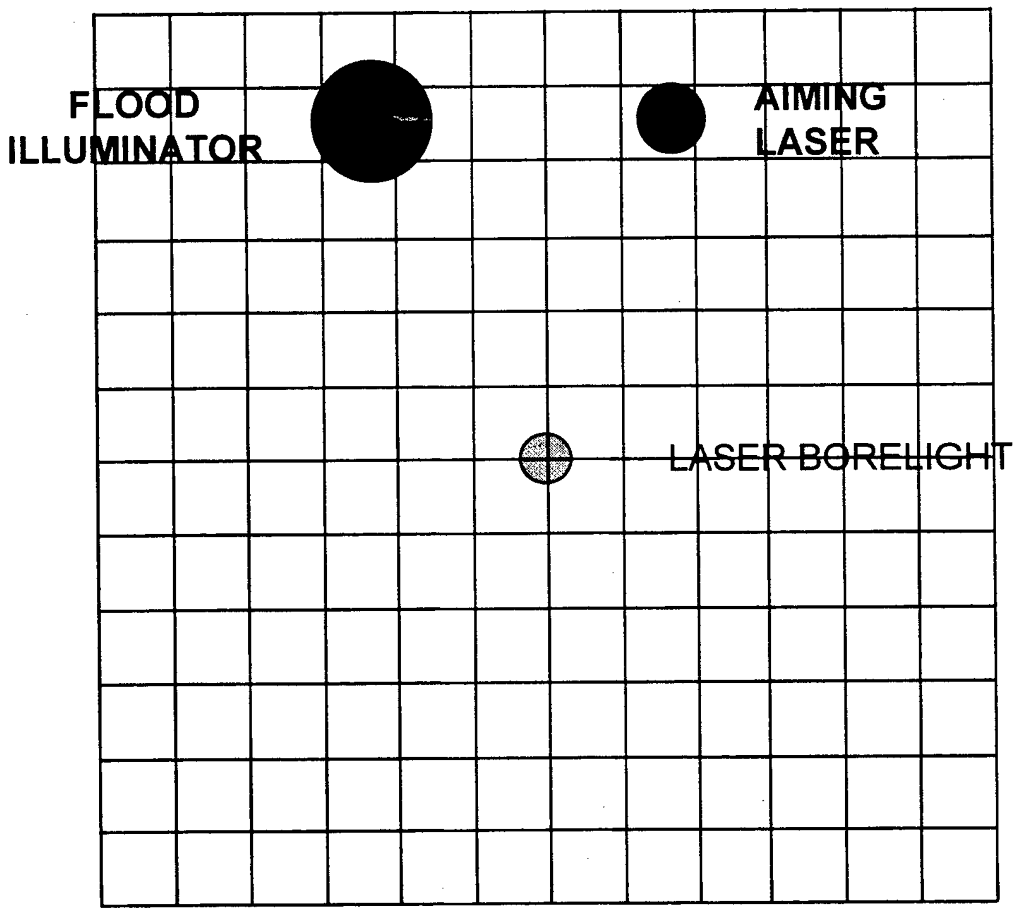
ZERO TARGET DATA FOR M4 MWS:

1- STABILIZE WEAPON
2- PLACE THERMAL SIGNATURE MATERIAL ON TWS CROSS-DOT
3- AIM TWS AT ITS CROSS
4- ADJUST TWS UNTIL THE AIMING LASER IS CENTERED ON ITS DOT
5- You **MUST** zero reticle in both Wide and Narrow Fields
6- IF NO THERMAL MATERIAL IS AVAILABLE,THE TWS CAN BE AIMED BETWEEN TWO FINGERS (HOT SPOTS) PLACED ON THE GRAY CIRCLES

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR 300 METERS
4-6-98

M240B - 7.62 mm Machine Gun
AN/PEQ-2 on Top of
FEED COVER RAIL
10 METER BORESIGHT TARGET



ZERO TARGET DATA FOR M240B MG:

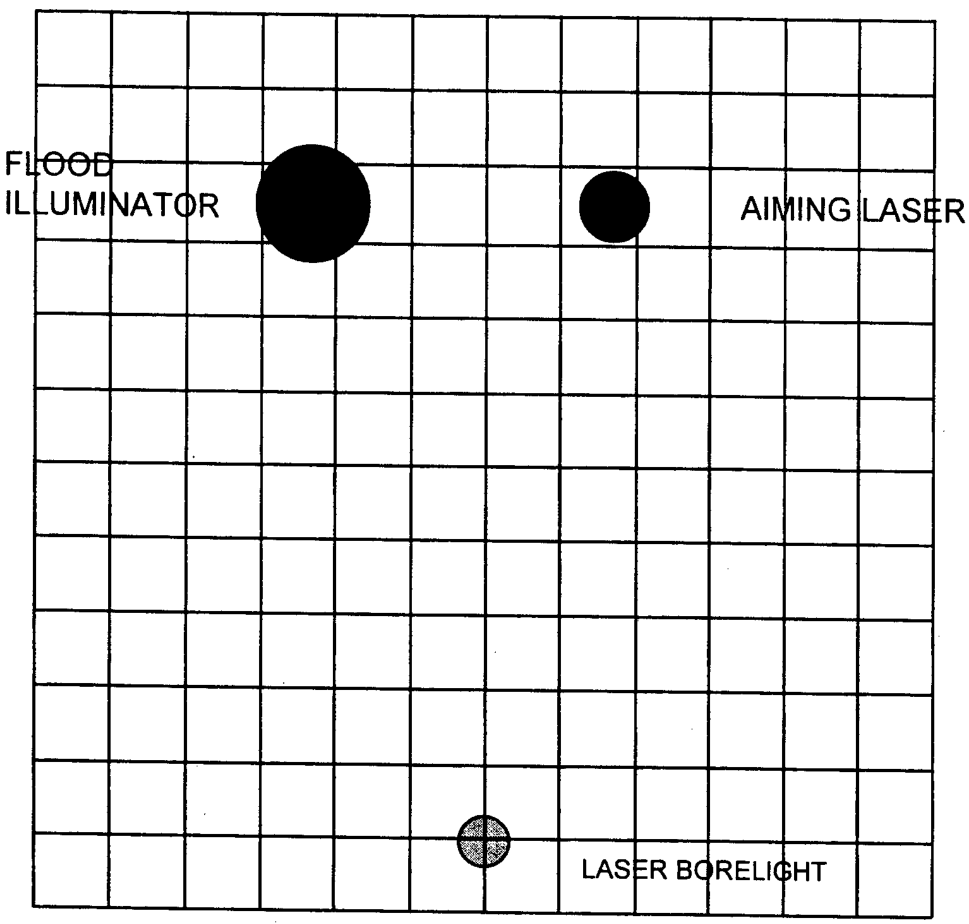
1- STABILIZE WEAPON
2- ALIGN LASER BORE LIGHT ON ITS DOT
3- ADJUST AN/PEQ-2 UNTIL THE AIMING LASER
IS CENTERED ON ITS DOT
4- ADJUST AN/PEQ-2 ILLUMNATOR TO ITS NARROWEST POINT,
AND CENTER ON ITS DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR
300 METERS

5-11-98

M249 SAW
AN/PEQ-2 MOUNTED ON
M249 TWS BRACKET
10 METER BORESIGHT TARGET



ZERO TARGET DATA FOR M249SAW:

1- STABILIZE WEAPON

2- ALIGN LASER BORE LIGHT ON ITS DOT
3- ADJUST AN/PEQ-2 UNTIL THE AIMING LASER
IS CENTERED ON ITS DOT
4- ADJUST AN/PEQ-2 ILLUMNATOR TO ITS NARROWEST POINT,
AND CENTER ON ITS DOT

US ARMY ARDEC
AMSTA-AR-FSF-R
AMSTA-AR-CCL-A
PICATINNY ARSENAL, NJ 07806

LAND WARRIOR IOT&E
10 METER DRY ZERO CHART FOR
300 METERS
5-11-98

APPENDIX B

COMPUTER SURVEY

COMPUTER SURVEY (with results)

Name:____________________ Age: _____ Rank:____________________

Years/Months in Army______________ Position ____________________

1. When did you use computers in your education? *(Circle all that apply)*

Grade School	Jr High	High School	Technical School	College	Did Not Use
15%	35%	70%	0%	28%	14%

[# of educational settings where used a computer]
0 = 14%; 1 = 45%; 2 = 25%; 3 = 13%; 4 = 3%

2. Where do you currently use a computer? *(Circle all that apply)*

Home/barracks/BOQ	Unit/Work Site	Library/Learning Ctr/Training Facility	Do Not Use
55%	18%	8%	19%

3. *For each of the following questions, circle the response that best describes you.*

   a. Do you own a personal computer? Yes -35% No - 65%

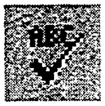
   b. How often do you:

	Daily	Weekly	Monthly	Less Often	Never
•Use a mouse?	29%	14%	11%	25%	21%
•Play computer games?	11%	32%	0%	32%	25%
•Use icon-based programs/software?	21%	14%	11%	29%	25%
•Use programs/software with pull-down menus?	25%	14%	7%	29%	25%
•Use graphics/drawing features in software packages?	4%	11%	7%	36%	43%
•Use E-mail (at home or at work)?	18%	14%	4%	25%	39%
•Use the Internet?	18%	18%	4%	25%	36%

4. Which of the following best describes your typing ability? (*check √ one*)
   10%_ Hunt and peck slowly
   50%_ Hunt and peck quickly
   30%_ Type slowly while not looking at the keyboard
   10%_ Type quickly while not looking at the keyboard

5. Which of the following best describes your expertise with computers? (*check √ one*)
   45%_ Novice
   18%_ Good with one type of software package (such as word processing or work calendars or slides)
   28%_ Good with several software packages
   8%_ Can program in one language and use several software packages
   0%_ Can program in several languages and use several software packages
   0%_ Expert – Bill Gates would hire me

6. What is the function of the following icons?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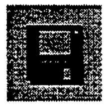
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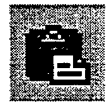
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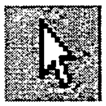
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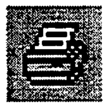
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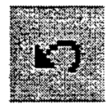
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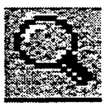
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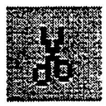
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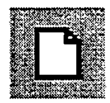
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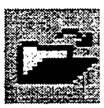
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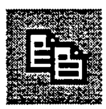
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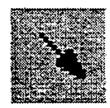
0%

Appendix C

Target Hits by Weapon and Distance to Target

Mean Percentage of Target Hits During Qualification with the M4

Device	Platoon	Distance (meters) to Target					
		50	100	150	200	250	300
CCO	Baseline	97	94	86	73	59	43
	LW	98	94	84	59	42	40
TWS	Baseline	82	78	87	71	60	42
	LW	89	85	76	68	53	46
Aiming Lights	Baseline	85	74	50	12	10	8
	LW	97	76	48	10	8	0

Mean Percentage of Target Hits During Qualification with the M249

Device	Platoon	Distance (meters) to Target			
		100	200	300	400
TWS NFOV	Baseline	94	28	42	22
	LW	---	---	---	---
TWS WFOV	Baseline	55	22	25	6
	LW	33	33	30	33
Aiming Light	Baseline	61	33	42	13
	LW	61	25	25	28

Mean Percentage of Target Hits During Qualification with the M240B

Device	Platoon	Distance (meters) to Target						
		200	300	400	500	600	700	800
TWS NFOV	Baseline	75	62	42	75	62	---	---
	LW	---	---	75	50	33	25	13
TWS WFOV	Baseline	62	62	67	62	25	---	---
	LW	---	---	42	62	25	0	13
Aiming Light	Baseline	87	37	33	37	62	---	---
	LW	25	75	25	25	13	---	---