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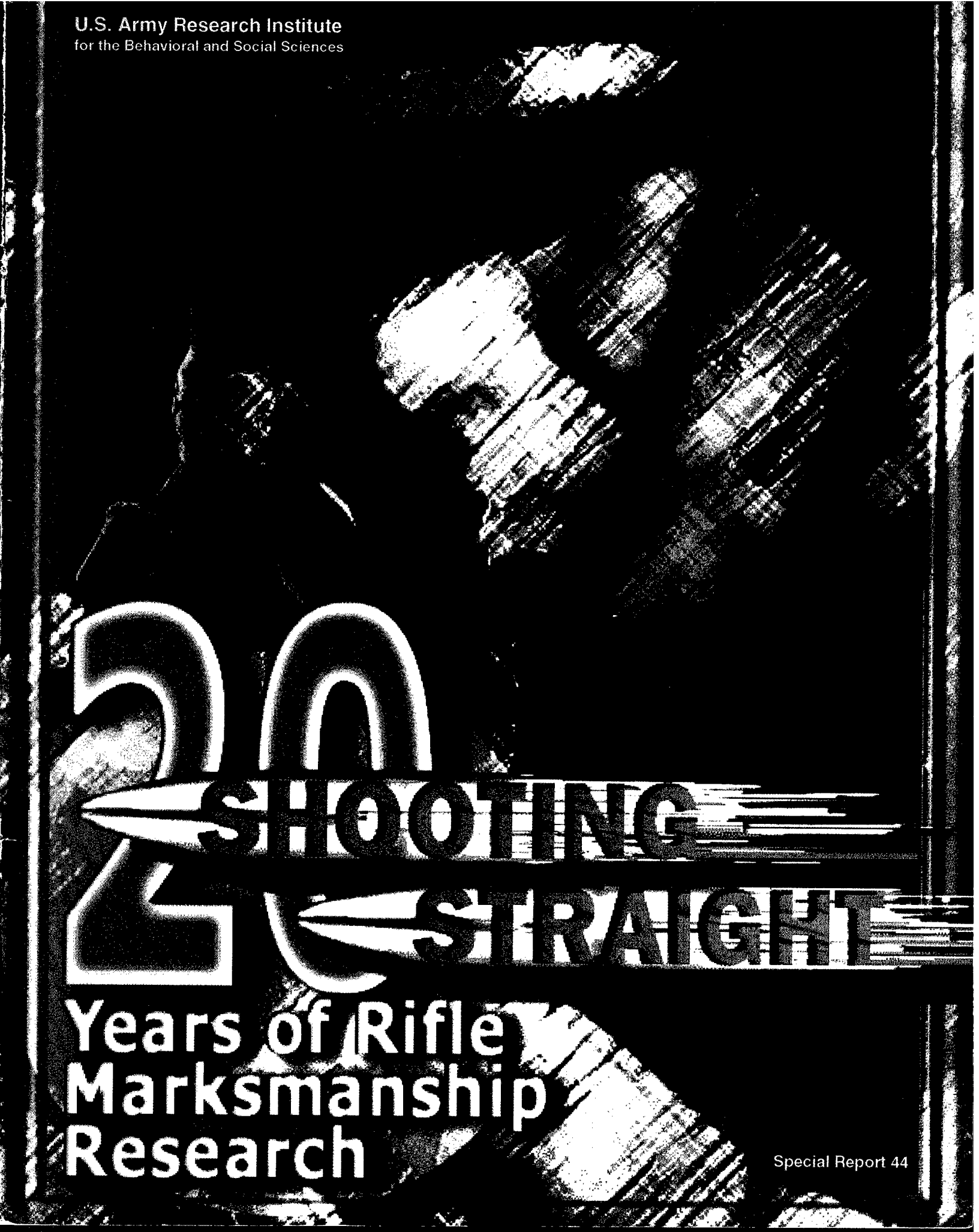


20 Years of Rifle Marksmanship Research

SHOOTING STRAIGHT

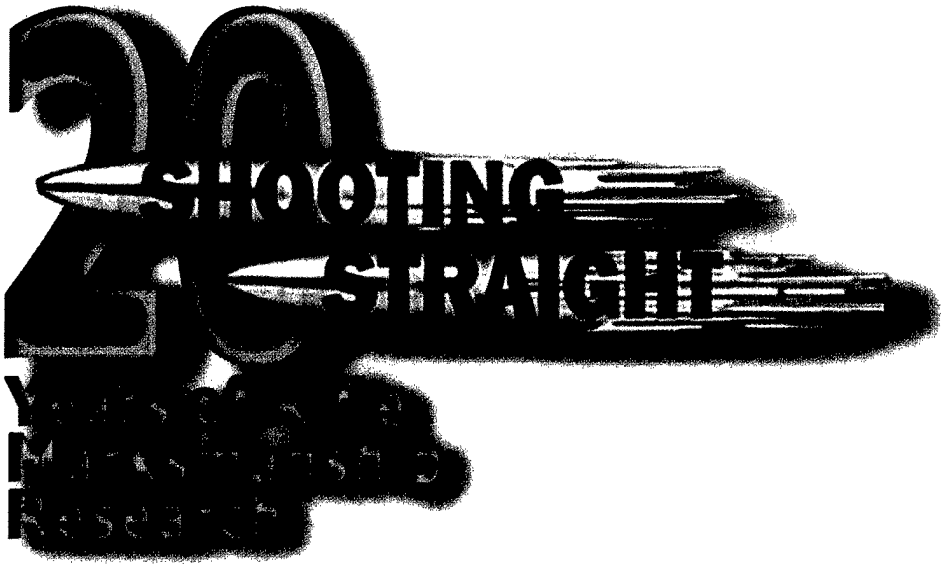
Special Report 44

Foreword

Any soldier who has received rifle marksmanship training in the past 20 years, and that's just about everyone, has benefited from the products of ARI research, probably without even being aware of it. This report highlights the many contributions we have made to marksmanship research since 1977. These contributions have included the development and evaluation of new training programs, along with a host of instructional materials for Army trainers. Our scientists have either developed or evaluated most of the marksmanship simulators and training devices in use today. In recent years, we have investigated the complex operational and training problems surrounding night fighting, as well as the relationship between simulator performance and live-fire qualification scores. Using a software tool developed by ARI, trainers can now calculate predicted scores for live-fire events based on scores from a number of different training devices.

Some of our marksmanship research products continue to be used today, two decades after they were originally developed. ARI products have continued to influence the design of follow-on training materials by other organizations, as new weapon systems and equipment have been fielded. Further, ARI has not lost sight of the marksmanship training challenges the Army will face as it enters the new millennium. The most significant marksmanship training problems we see ahead are discussed at the conclusion of this report.

EDGAR M. JOHNSON
Director



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DISTRIBUTION STATEMENT A
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ARI Special Report 44
October 2000

DTIC QUALITY INSPECTED 4

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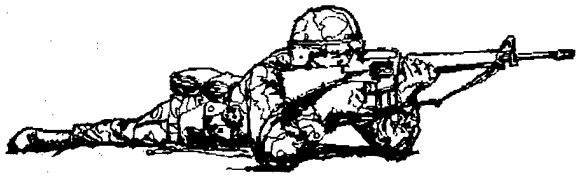
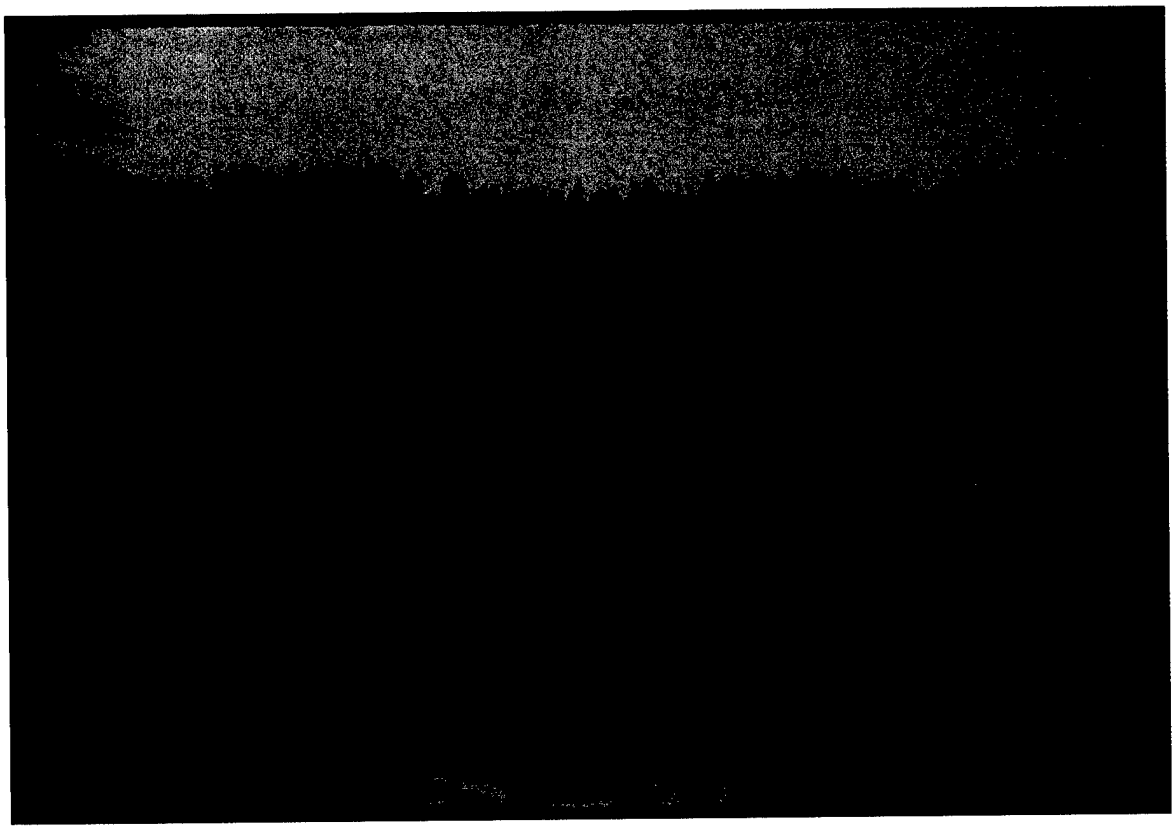
SHOOTING STRAIGHT:
20 Years Of Rifle Marksmanship Research



ARI has produced a rich history of rifle marksmanship research and related research products spanning more than two decades. Based on growing concerns that rifle marksmanship training was not producing qualified marksmen for U.S. Army units, ARI began a systematic examination of basic, advanced, and unit marksmanship training programs in 1977.[1] After developing and implementing a series of improved marksmanship training programs in the early 1980s under the joint sponsorship of the U.S. Army Infantry School (USAIS) and the U.S. Army Forces Command (FORSCOM),[2] ARI researchers began to increasingly focus their attention on issues related to marksmanship simulation and training devices.[3] With an eye towards supporting the new training programs, new devices and simulators were either evaluated or developed in the 1980s and early 1990s. In 1992, ARI research began to address problems associated with night firing and night operations in general. Over a period of seven years, the NIGHTFIGHTER program identified the most problematic combat tasks performed at night and addressed those problems through the conduct of training experiments and the development of research products.[4]

The marksmanship research featured in this report is generally presented in chronological order, recognizing that a small amount of overlap actually existed among some of the individual research projects. Chapter 1 describes ARI efforts in the area of program development, including the creation of course materials like paper targets, graphic training aids, and written guides for both students and instructors. Chapter 2 presents research and product development work in the areas of marksmanship simulation and training devices. Chapter 3 highlights marksmanship research and development associated with the NIGHTFIGHTER program. Finally, Chapter 4 discusses marksmanship problems and associated research questions the Army will likely face in the first decade of the new millennium.

Until now, the entirety of ARI research related to rifle marksmanship had never been summarized in a single publication. Although this report serves that purpose, it does not describe every single marksmanship research project conducted by ARI. Rather, it presents only those projects that have made the greatest contributions to the Army, still exerting their influence in the training of today's soldiers. Readers interested in a more exhaustive history should consult the references listed at the end of the report, especially the first four, which are summary reports in their own right.



Chapter 1
Program Development

Rifle marksmanship training in the U.S. Army is conducted in three separate, though conceptually related phases: Basic Rifle Marksmanship (BRM), Advanced Rifle Marksmanship (ARM), and unit rifle marksmanship training.[1] BRM training focuses on teaching common rifle marksmanship skills needed by every soldier. All initial entry soldiers receive BRM training, which is conducted at every Army Training Center (ATC). A minimum performance standard against stationary personnel targets, measured on a prescribed qualification course of fire, must be met by each soldier. ARM training focuses on more advanced skills, such as the engagement of moving targets. This training is given only to Light Weapons Infantrymen as part of Infantry One-Station Unit Training (OSUT) at Fort Benning, GA. Unit marksmanship training has a twofold purpose. First, it attempts to maintain soldier proficiency in the marksmanship skills acquired during BRM and ARM. Each soldier must annually meet a minimum performance standard on a qualification course of fire. Second, units must selectively develop and maintain other marksmanship skills based on the nature of their assigned missions (e.g., quick fire techniques for use in urban operations).

Basic Problems Identified

Following a gradual decline in rifle marksmanship performance over several years, the average soldier in the late 1970s could hit only 55 percent of stationary personnel targets from distances between 50m and 300m.[5] ARI began to tackle this problem by defining the rifle defeatable combat threat,[6] by examining previous marksmanship research,[7] and by investigating existing and alternative training procedures.[8, 9] These initial efforts defined the rifle defeatable threat as being briefly exposed personnel targets, both stationary and moving, within a range of 300m. It was also clear that BRM training was not adequately preparing soldiers to meet this threat. Through ARI's participation in and observation of the BRM programs at four ATCs, problems were identified in four areas of training.[2, 10] These problems are summarized in Table 1.

Table 1

Summary of Problems Identified in BRM Training

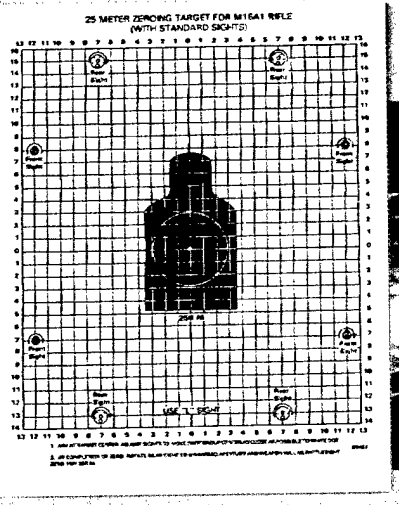
Moving Towards a Solution

Beginning in 1978, a series of field experiments was conducted to evaluate potential solutions to some of the problems listed in Table 1. Initially, three different experimental training programs were compared, using airborne soldiers from a FORSCOM unit preparing for their annual rifle qualification. Soldiers in the training program that featured greater performance feedback, increased instructor quality, and increased instructor quantity achieved significantly more hits on a culminating record fire scenario than other soldiers.[11] This training program was subsequently published by the U.S. Army Marksmanship Unit as a recommended interim marksmanship training program for FORSCOM units.[12]

Two of the major problems identified in BRM were that soldiers didn't understand the zeroing process and inadequate feedback was provided about shots fired at ranges

ARI Develops an Easier Way to Zero

The old 25m zeroing target, called the Canadian Bull, gave soldiers no intrinsic clues about what they should do to zero their rifle. Its aiming point was like no other target they would ever encounter and its large grid squares didn't really correspond to the increments of sight adjustment (i.e., clicks) built into the M16A1 rifle. So ARI set about designing an easier and more meaningful zeroing target for soldiers. The new 25m ARI zeroing target featured a scaled 250m silhouette surrounded by an easier-to-understand grid system. Each grid square corresponded to one click of sight adjustment, whether windage or elevation. Small diagrams of the rifle's front and rear sights in the margins of the target reminded soldiers which way to turn their sights to make subsequent shots hit closer to the silhouette's center. Grid lines were numbered, so soldiers could easily tell how many clicks of vertical and lateral adjustment were needed.



Invisible from the firing line, a 4cm circle was positioned at the center of the silhouette target. This circle provided a zeroing performance standard for consecutive three-round shot groups. Based on minutes of angle, it also equaled the width of the most distant silhouette target on the record fire range (i.e., 300m). Thus, the marksmanship ability needed to consistently place shots in the 4cm circle of the new 25m zeroing target was roughly equivalent to that needed to hit 300m targets on the record fire course with no crosswind. Although the ARI zeroing target has since been redesigned by USAIS personnel to better accommodate the ballistics of the M16A2 rifle and M4 carbine firing new ammunition, all of its instructional features have remained intact.

beyond 25m. Another field experiment addressed these problems by evaluating the effects of a revised zeroing target and downrange feedback training on the record fire scores of 2,124 basic trainees.[13] The intent of the revised zeroing target was to simplify the zeroing process, while making it more meaningful to the soldier. Downrange feedback training involved firing at paper silhouette targets on a modified field fire range at 75m and 175m distances. After firing a shot group at each of these targets, soldiers walked downrange and placed spotters in the bullet holes, enabling instructors on the firing line to see which individuals needed additional coaching. Compared with standard training, the revised zeroing target and downrange feedback training each led to significant increases in record fire scores. As a result, it was decided that these two features would form an integral part of a projected new BRM program for the Army.[13]

Improved BRM Training is Introduced

Incorporating potential improvements identified through earlier research, a revised BRM training program was developed and subsequently tested in 1979 with 1,151 male and female soldiers at Fort Jackson, SC.[14] This program differed in four major ways from the standard BRM training existing at that time. First, it used a revised 25m zeroing target that was easier to understand.[13] Second, scaled 25m silhouette target exercises were introduced to help increase the overall amount of performance feedback provided.[15] Specifically, a slow fire target having six scaled silhouettes was designed to give trainees additional practice in marksmanship fundamentals prior to field firing. A timed fire target having ten scaled silhouettes was also designed to provide practice in the rapid application of marksmanship fundamentals prior to practice record fire. Third, downrange feedback exercises were used.[13] Fourth, instructors emphasized a simplified set of four marksmanship fundamentals: steady position, aiming, breath control, and trigger squeeze.

Before this program was introduced, instructors emphasized over 20 teaching points to soldiers, including eight "steady hold" factors. This amount of information was too much for most soldiers to remember on the firing line and many of these teaching points had little influence on whether soldiers hit or missed a target. For example, controlled test firings with 60 M16A1 rifles drawn at random from the weapons pool at Fort Benning established that one of the most emphasized teaching points, sight alignment, had little influence on where rounds landed.[15] In fact, improper sight alignment procedures were found to cause no more than six inches of error at 300m. In contrast, each of the four marksmanship fundamentals taught in the revised BRM program was critical to soldier success. Failure to properly perform any one of the four would likely cause a target to be missed.

Soldiers receiving the revised BRM training program at Fort Jackson achieved significantly higher record fire scores than those that did not.[14] During a period of additional refinement and testing, the revised BRM program was then provided to more than 8,000 initial entry soldiers at Fort Benning, with equal success. As a result, the Assistant Commandant of the USAIS, as proponent for rifle marksmanship training,

officially approved the revised BRM program in 1980. It was subsequently implemented at all ATCs by 1982. The new training provided a substantial gain in performance, using only 60 hours of formal instruction and 386 rounds of ammunition per soldier. Following implementation, the average soldier could hit almost 75% of stationary personnel targets between 50m and 300m, compared to only 55% a few years earlier.[5]

Advanced Training for Infantrymen

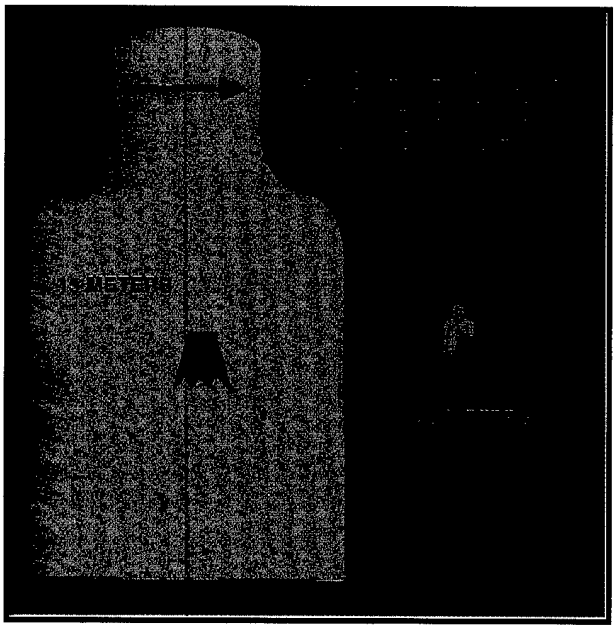
Based on observation, participation, and informal instructor interviews, the ARM training program existing in 1981 was found to have three major problems.[16, 1] First, the scope of the program was limited, including only automatic fire and night fire training. Second, this training was largely inappropriate, from both instructional design and combat realism viewpoints (e.g., soldiers could increase their scores on any automatic fire scenario by firing in the semi-automatic mode). Third, performance feedback was severely limited. Although soldiers did fire rounds downrange at night, they could not see their targets, no scores were kept, and trainees never knew whether or not they hit any targets. When night vision scopes were available, they were not zeroed to their rifles.

In order to identify the most important marksmanship skills required of infantrymen that had not been taught in BRM, an extensive analysis of Army Training and Evaluation Programs (ARTEPs) for both the Infantry (ARTEP 7-15) and Mechanized Infantry (ARTEP 71-2) was conducted.[16] From this analysis of the expected role of small arms in infantry missions, the tasks of quick fire, suppressive fire, and moving target engagement were identified for inclusion in a revised ARM training program at Fort Benning. The amount of automatic fire was greatly reduced, target exposure times were shortened, and some of the automatic firing was performed while wearing the protective mask. Night fire was improved through the use of artificial illumination and the use of zeroed night vision scopes.

A revised ARM program consisting of five periods of instruction was implemented at Fort Benning in 1982. It required 24 hours of formal instruction and 302 rounds of ammunition per soldier. Compared with the previous ARM program, the revised program provided more performance feedback to soldiers, through its more extensive use of paper targets on 25m ranges. The previous ARM program had been conducted almost exclusively on field fire ranges, which only provide "hit or miss" information about targets engaged.

Moving Target Engagement

Of the five subjects taught in the revised ARM training program, more research has been devoted to issues surrounding moving target engagement than any other. This relatively greater emphasis was partly due to the fact that an ongoing range modernization program would soon enable soldiers to engage moving personnel targets with live fire. Rifle marksmanship simulators of the era were also beginning to feature moving targets for the first time.



Previous doctrine (Field Manual 23-9 of 1974) outlined four different points of aim for laterally moving personnel targets. Determining which of these four lead rules to use required soldiers to estimate the range and speed of the target. This approach appeared too complex for most soldiers to acquire with limited training.[1] In the few seconds a moving target might be exposed, one would have to detect the target, estimate its range, estimate its speed, select the proper lead rule from memory, and then apply it properly while tracking the target.

In an attempt to simplify these procedures for moving target engagement, nine different lead rules were subjected to a trigonometric analysis to determine the theoretical locations of bullet impact with each lead rule.[1, 16] Various combinations of target speed, angle of movement, range, front sight post width, and projectile velocity were examined. A lead rule requiring the shooter to place the trailing edge of the front sight post at the target's center was found to work fairly well for all targets out to 200m. The advantage of this lead rule is that it automatically increases one's lead as the range to the target increases. Later experimentation with soldiers confirmed the theoretical advantages of the single lead rule concept under live fire conditions.[17, 18]

Additional research focused on comparing two methods for engaging laterally moving targets: tracking and trapping.[17, 19] Tracking involves moving the barrel of the rifle to match the speed and direction of the target, as closely as possible. A lead is maintained throughout the firing process. In contrast, trapping involves steadily holding the barrel ahead of the target's anticipated path, and then firing the moment the proper amount of lead is seen through the sights. In an experiment based on rifle marksmanship simulator performance, trapping was found to be a better approach for those with a relatively low level of marksmanship ability, while tracking was found to work better for those having a relatively high level of ability.[19] This experiment also

suggested trapping may work better for relatively close targets moving at faster speeds, while tracking may work better for more distant targets moving at slower speeds. The participants in the experiment preferred to use the method that gave them better results. Later experimentation under live fire conditions was inconclusive, though soldiers preferred to be taught both methods of moving target engagement.[17]

Unit Training

Unit rifle marksmanship training must consider both individual and collective firing proficiency.[1] The individual portion of the unit marksmanship program was designed to insure skill retention and progressive improvement, while the collective portion of the program focused on the application of those skills in a group tactical environment.[20] Unit marksmanship programs must also be flexible, to support the particular training environments of various units.[21, 22] Because time, facilities, and ammunition available for training vary among Active and Reserve Component units of the Army, unit training programs must be responsive to such variation.

Building upon improvements made in the BRM and ARM programs, selected components of a unit training program were successfully pilot tested in 1981 and 1982 at Fort Bragg, Fort Riley, and Fort Benning.[1, 20] Following a two-day instructor training program, a 24-hour unit marksmanship program was conducted. On a 25m timed fire exercise using scaled silhouette targets, substantial increases in performance were measured after only the first eight hours of training.[1]

The collective skills portion of unit marksmanship training was less standardized than the individual firing portion, due to differing mission requirements across units. To support customization of unit training, ARI developed a *Unit Rifle Marksmanship Training Guide* that contained over 40 separate sections on a variety of marksmanship training activities.[21, 22] It was designed so that individual sections could be selected and implemented by a unit as its training schedule permitted. It was published by the USAIS as Field Circular 23-11 in 1984.[21]

Equipment Research

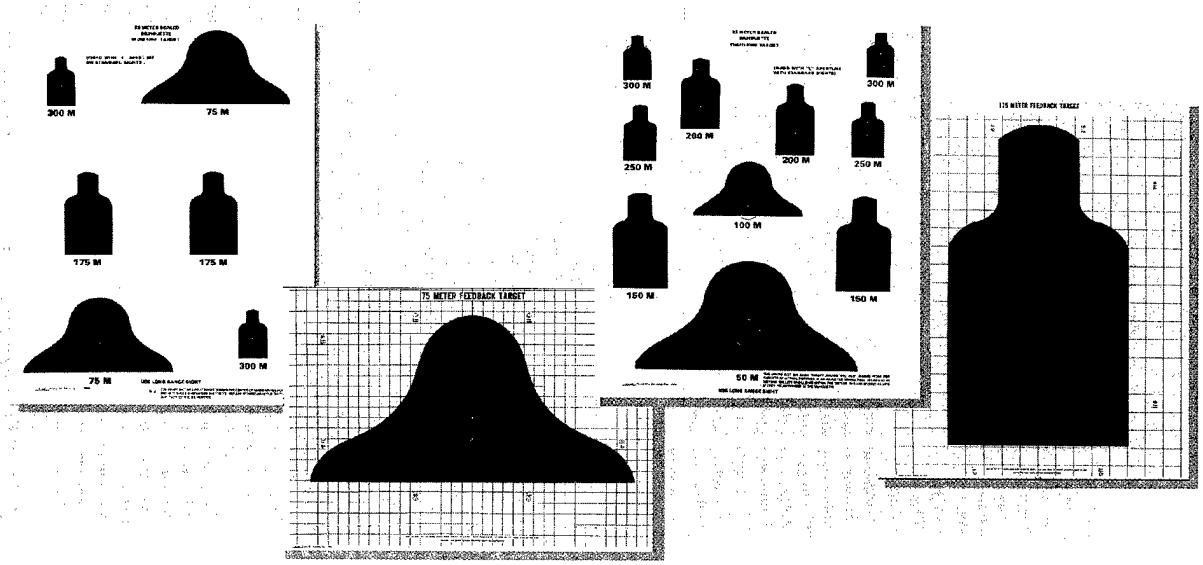
In designing a rifle marksmanship training program, it is essential that both the positive and negative operational characteristics of the service rifle, as a man-machine weapon system, be fully understood.[1] For this reason, ARI conducted a systematic and comprehensive equipment research effort concurrent with the early stages of its program development activities. This equipment research focused on the adequacy of

M16A1 rifle performance and its implications for marksmanship training.[15] Findings from this research guided the design of the BRM, ARM, and unit training programs in several important ways. In particular, they helped to determine which human performance variables were crucial to hitting targets and which were not. They also guided the establishment of instructional standards and helped to validate a new and easier method for zeroing at 25m. Later, another research effort examined features of the M16A2 rifle and described their implications for marksmanship training.[23] It also provided numerous recommendations for improving the design of the service rifle.

Training Support Products

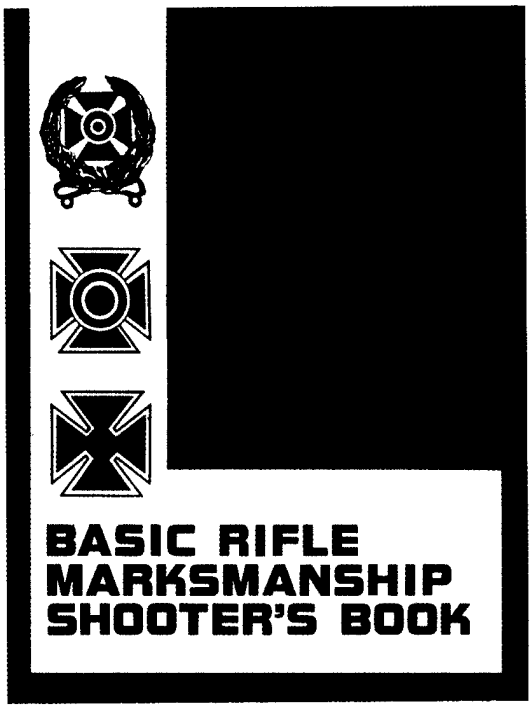
The process of implementing new methods of conducting basic, advanced, and unit rifle marksmanship training was an enormous undertaking, involving much more than simply providing new programs of instruction to Army trainers.[1] This section highlights a diverse array of ARI products developed to support the new training programs and to help insure the success of the implementation process after we had left. A more exhaustive listing of these products has been published previously,[1] as have ratings of all previously existing marksmanship training support items.[20] ARI work related to marksmanship training devices and simulators is presented in Chapter 2.

Targets. ARI designed more than a dozen paper targets to support the new M16A1 rifle marksmanship training programs.[1] Though not shown to scale, some of them are pictured in this report. These targets were officially adopted by the proponent, assigned National Stock Numbers, and became available to ATCs and all units through normal supply channels in the mid-1980s. More recently, these targets have been modified for use with the M16A2 rifle and M4 carbine, though most of their instructional features have changed very little over time.



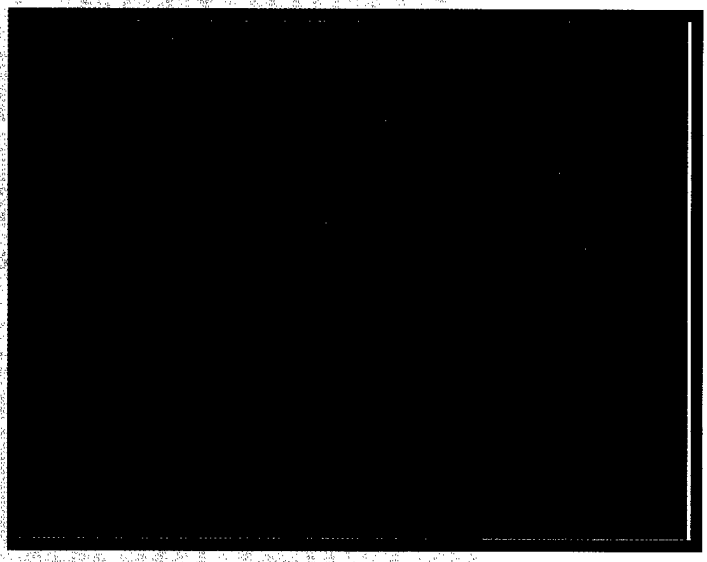
Graphic Training Aids. Graphic training aids include items such as charts, diagrams, posters, slides, and transparencies that can be used in a classroom or on a firing range. Before the new BRM program was implemented, ARI provided written and verbal input to marksmanship instructors and to the Training and Audiovisual Support Center (TASC) at Fort Benning. This input led to the production of a set of graphic training aids to support each of the new program's 14 periods of instruction.[1] Some of the marksmanship topics taught with graphic training aids were the Four Fundamentals of Rifle Marksmanship, the Zero Target, Correct Sight Picture, the Effects of Gravity on Bullets, and Adjusted Point of Aim. Using materials developed at Fort Benning as a standardized guide, other ATCs were able to produce them locally. A similar process was used in developing a set of graphic training aids for the ARM program.[16]

Instructor Training Materials. Two reference guides were developed to provide training guidance to rifle marksmanship instructors. In addition to providing extensive consultation to USAIS during its substantial revision of Field Manual 23-9, the *Basic Rifle Marksmanship Trainer's Guide* was prepared, evaluated, refined, and then fielded throughout the Army.[24] A more comprehensive reference published as Field Circular 23-11, the *Unit Rifle Marksmanship Training Guide* was devoted to both basic and advanced marksmanship skills, as well as to unit collective training.[21, 22] In conjunction with U.S. Army Infantry Center Educational Television personnel, a set of two videotapes were produced to help trainers understand the instructional principles underlying the new program and to help them develop better diagnostic and coaching skills.[25, 26]



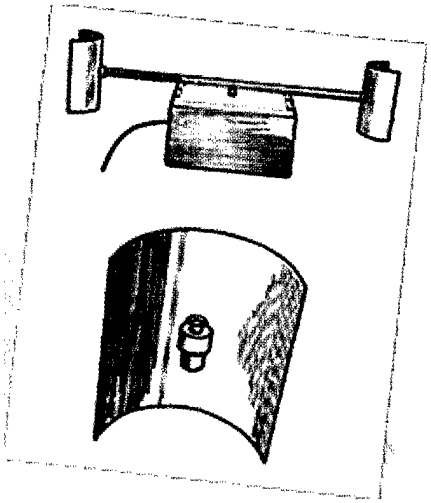
BRM Shooter's Book. This pocket-sized book was developed for use by initial entry soldiers.[27] Its purpose was twofold. First, it provided each soldier with a handy reference to read and study, giving ready answers to most questions that could potentially arise during each period of BRM instruction. Second, it allowed soldiers to record their individual marksmanship performance and progress during training. Reduced copies of all BRM paper targets were included so soldiers could record the locations of their hits and misses. Scorecards were provided for all periods in which pop-up targets were used. It was thought that more effective remedial and reinforcement training could be given to soldiers when they had kept accurate records in their shooter's book.[27]

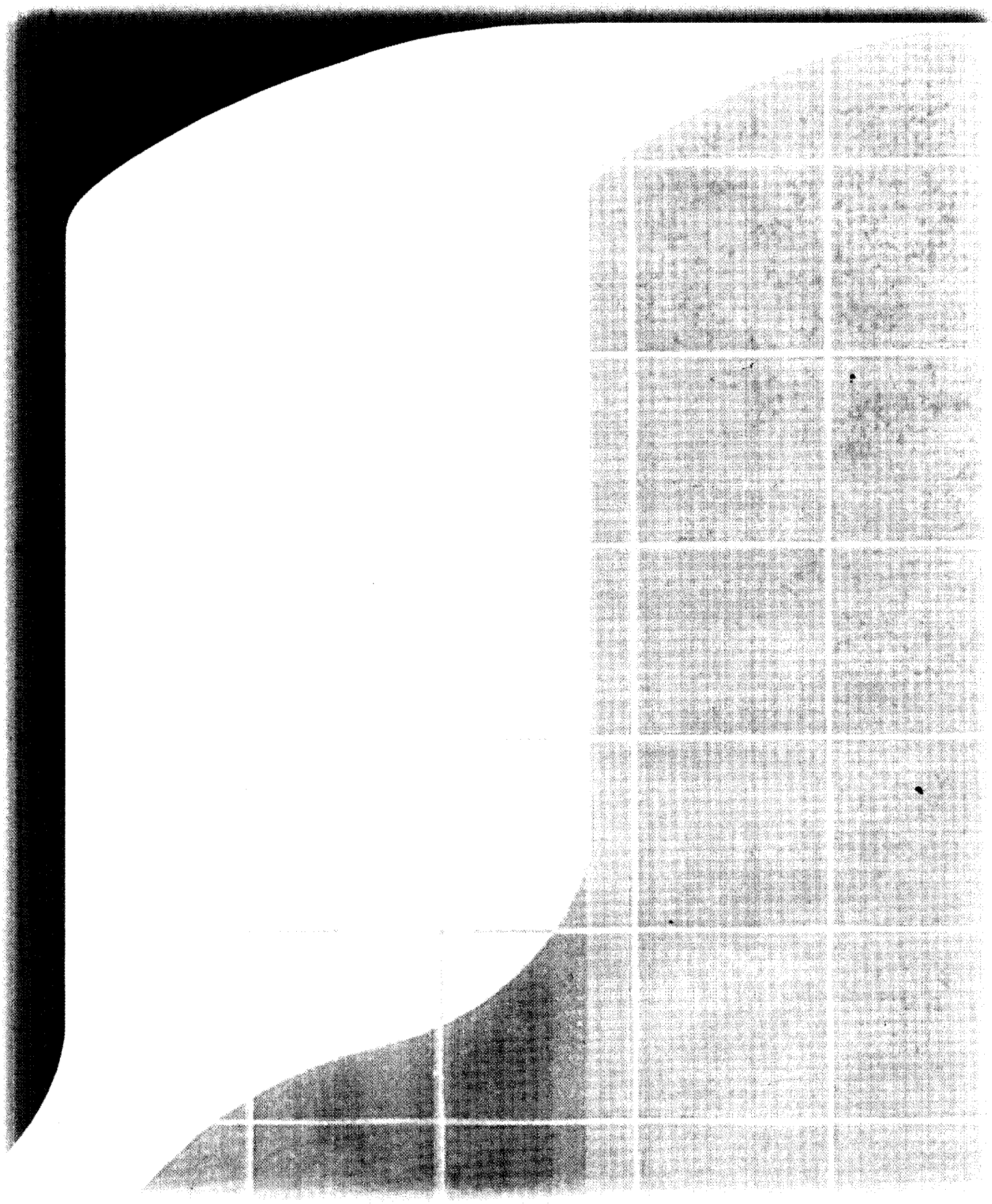
Moving Target Engagement Training Aids. The Aid to Improved Marksmanship (AIM) book was developed by ARI to teach and reinforce aiming skills, particularly adjusted aiming points for moving targets and for the effects of wind and gravity. The AIM book consists of multiple sets of parallel photographic targets, each set printed on separate pages in the book. The right hand target in each set is covered by a flap.



Soldiers position a clear plastic sheet, on which a replica of the rifle's front and rear sights is superimposed, over the left hand target. After deciding the best point of aim to use for that target, the soldier lifts the flap over the right hand target. This exposes a dot on the right side of the plastic sheet, showing where a bullet would have theoretically impacted with the aiming point chosen.

The Dry Fire Moving Target Engagement Trainer (DRY MOVER) was developed to teach soldiers how to smoothly track and lead moving targets prior to live firing. This portable and relatively inexpensive device consists of two scaled three-dimensional targets, each situated in front of a curved shield and mounted at the end of an aluminum rod. The rod is seated on a rotating shaft driven by a variable speed, reversible AC motor. As many as 15 soldiers can be arranged in a semi-circle (5m radius) around the device during training. Target exposure times can be controlled by changing the position of the targets relative to the curved shields. Depending on the rod's direction of rotation, targets are seen as moving from right to left (clockwise) or left to right (counterclockwise). Two DRY MOVERs were fabricated by the TASC at Fort Benning to support the new ARM training program (TASC No. TAD-239).



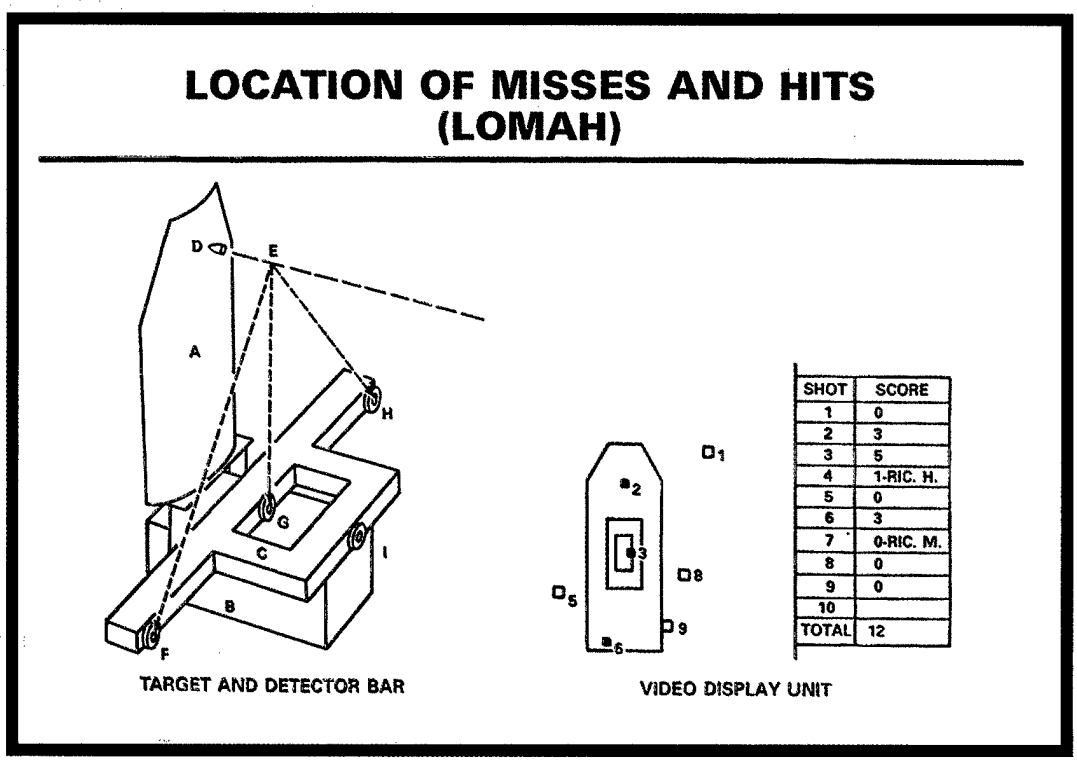


Chapter 2
Training Devices and Simulation

ARI has long recognized the difficulty of providing precise and timely performance feedback to soldiers in rifle marksmanship training. To partially address this problem, ARI began to investigate the potential benefits of a variety of marksmanship training devices and simulators in the early 1980s. Since that time ARI research efforts have focused largely on five training systems: the Superdart projectile location system (Australasian Training Aids), Weaponeer (Spartanics), Multipurpose Arcade Combat Simulator (ARI), Engagement Skills Trainer (Firearms Training Systems), and Laser Marksmanship Training System (BeamHit). To various extents, these five systems continue to play a role in Army marksmanship training programs today.

Superdart Projectile Location System

When positioned at the base of a target on a live firing range, the Superdart system electronically detects and locates supersonic projectiles passing overhead. The

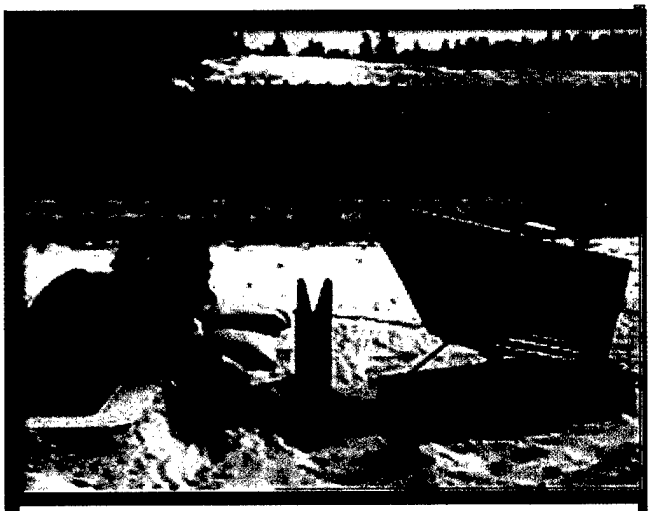


Positioned at the base of a silhouette target (A) on a pop-up mechanism (B), the Superdart system's detector bar (C) senses a supersonic projectile (D) passing overhead. The projectile's shockwave (E) is triangulated from three sensors (F, G, & H), while a fourth sensor (I) helps to calculate projectile velocity. Locations of hits and misses are presented on a video display unit at the firing point. Ricochet hits and misses are detected if their velocities remain supersonic.

precise location of each projectile, whether a hit or a miss (up to 5m from the target), is then visually displayed to the shooter at the firing point. Using Australian soldiers, ARI conducted an experimental evaluation of the training effectiveness of the Superdart system, before such technology was commercially available in the U.S.[27] Soldiers receiving enhanced feedback via the Superdart system achieved significantly higher levels of marksmanship performance than soldiers receiving only the usual hit-miss feedback associated with pop-up target engagement.

Subsequently, the U. S. Army equipped a field fire range at Fort Jackson with this technology, where it has been used in the downrange feedback portion of BRM training. At Fort Jackson, initial entry soldiers receive immediate feedback on their marksmanship performance, without having to actually walk downrange. Over the years, ARI has advocated this kind of technology to provide both students and instructors with the precise and timely performance feedback necessary for the effective acquisition of marksmanship skills. ARI has also recognized its value as a measurement instrument for evaluating the performance of weapons, ammunition, equipment, tactical employment techniques, and training strategies.

The Superdart system detector bar at the base of a pop-up target.

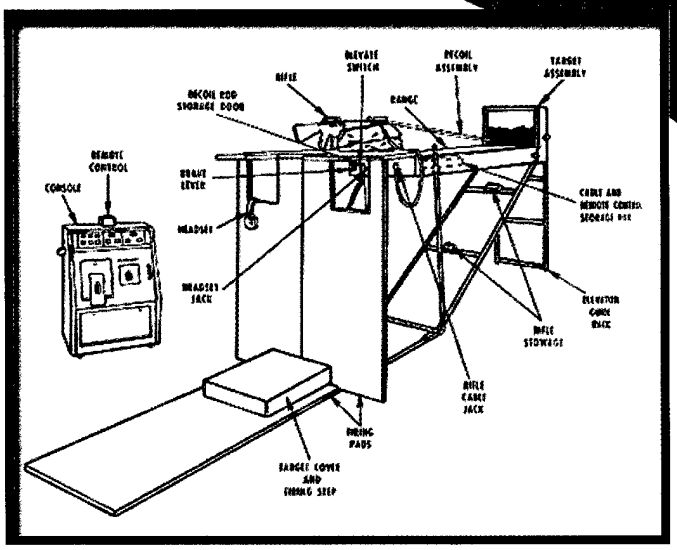


A soldier engages targets equipped with the Superdart projectile location system.

Weaponeer

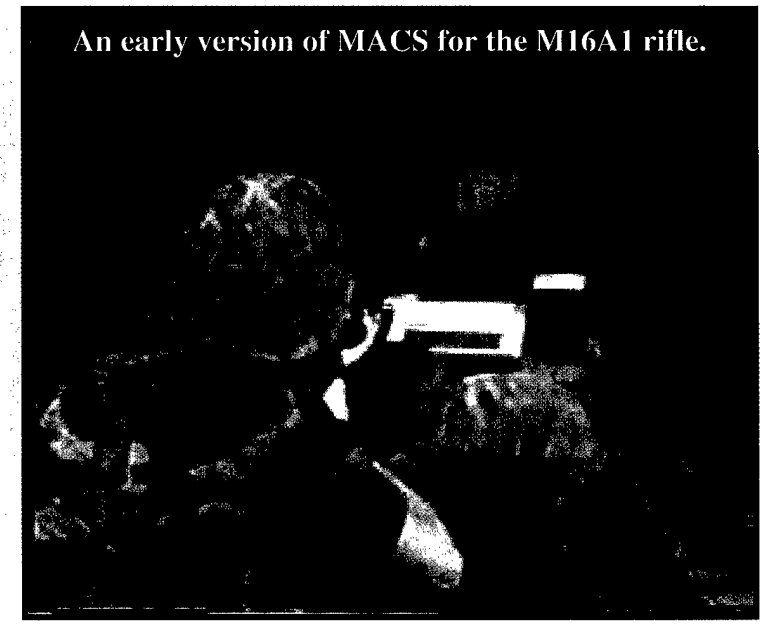
The Weaponeer is the granddaddy of all rifle marksmanship simulators and it was the first to be involved in ARI research. It is considered to be a full-task trainer, as it can simulate the noise and recoil of firing. Although the original Weaponeer presented only stationary targets, later models included moving targets as well. On its operator console, a replay of up to three seconds of barrel movement before firing can be displayed. This feature allows an instructor to diagnose errors in a soldier's application of marksmanship fundamentals.

Early ARI research focused on helping instructors diagnose shooting errors using the replay feature of the Weaponeer. A guide for Weaponeer instructors was developed from information and data obtained through interviews, field observation, and experimental research.[28] ARI research concluded the Weaponeer could be used to quickly and effectively diagnose shooting problems, though high demand for the limited numbers of Weaponeers purchased made them impractical for widespread use in the conduct of remedial training. At that time, only nine simulated shots could be fired on a Weaponeer for each initial entry soldier, given the number of soldiers to be trained and the number of simulators available. Thus, ARI recommended its use as a diagnostic tool, but not as a substitute for any live firing. Later research with the Weaponeer examined moving target engagement methods and the relationship between performance on the Weaponeer and performance during actual rifle marksmanship qualification.[19, 29]



Multipurpose Arcade Combat Simulator

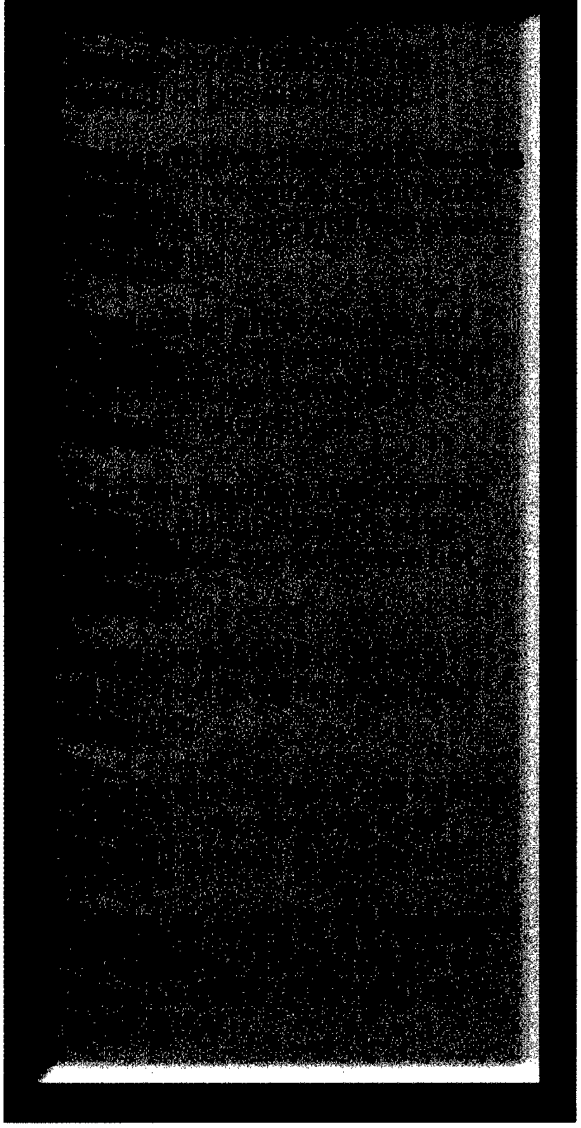
ARI began developing the Multipurpose Arcade Combat Simulator (MACS) in 1982, in the era of the first microcomputers. The key discovery in this development process was that a light pen fitted with a converging lens system could be focused to read the raster scan on a video monitor at distances from 4 to 20 ft. This led to the realization that relatively inexpensive trainers could be designed for a variety of weapon systems, by attaching a light pen to a weapon and then engaging microcomputer-controlled targets on a video monitor. In 1986 this training concept was awarded a U.S. patent.[30]


An early version of MACS for the M16A1 rifle.

The very first MACS prototype for M16A1 rifle marksmanship training was configured with a commercially available microcomputer, a pair of external disk drives,

video monitor, light pen, and software developed by ARI.[31] Corrective lenses were attached to the light pen, which was mounted on a dummy rifle along with an electronic switch attached to the trigger. Major features of early software included automatic zeroing, a variety of scaled targets and backgrounds, an exercise to teach the effects of wind and gravity, auditory and visual feedback on the location of hits and misses, and programs to diagnose errors in marksmanship fundamentals.

Seven Types of MACS Performance Feedback



Over 20 developmental hardware tests, training and cost effectiveness evaluations, and informal field investigations were conducted during the 1980s.[3] For example, MACS was not only evaluated for use in BRM, ARM, and unit rifle marksmanship training programs, but its application within U.S. Army ROTC, U.S. Army National Guard, U.S. Navy, and U.S. Air Force training programs was examined as well.[3, 32, 33] More experimentation has been conducted with MACS than with most other training devices and simulators for rifle marksmanship training. Several consistent trends from this body of research have been found.[3] In particular, MACS training effectiveness appears to be highest for those individuals having a low initial level of ability. In addition, its overall usefulness appears greatest in less extensive training programs having limited training resources. Finally, MACS usage is associated with consistent reductions in the percentage of shooters failing to achieve minimum performance standards and with significant reductions in remedial ammunition expenditures during training.

Compared to other training devices and simulators, MACS remains relatively low in cost, partly from its use of off-the-shelf hardware. The most recently purchased systems have cost under $2,000 per copy.[34] A second reason for its low cost is that it doesn't simulate the noise and recoil associated with firing live ammunition. Thus, MACS is considered to be a part-task trainer, well-suited for preparatory

marksmanship and dry fire training applications, where levels of performance feedback are typically low.[3] Consistent with research findings in the areas of classical conditioning and simulator fidelity, subsequent experimentation found that MACS performance did not change when a recoil component was added to the system.[35] This result suggests the accurate reproduction of recoil may be unnecessary in rifle marksmanship simulation, as long as live firing is a substantial part of the overall training strategy.[35]

Particularly noteworthy are the numerous instructional features embedded within MACS software.[33, 36, 37] For instance, MACS software provides an initial skills test to electronically zero the system and determine the most appropriate starting point for the soldier. There are nine distinct training levels, which vary in difficulty and the amount of performance feedback provided. Specific performance standards were established for each level, such that soldiers do not automatically progress to more difficult tasks without first demonstrating their mastery of more basic ones. Performance feedback is richest at the lowest levels of difficulty, then gradually withdrawn as soldiers progress to more difficult levels. Seven major types of performance feedback are provided.

A variety of other MACS software features are available to instructors, including optional wind effects, moving targets, a "call your shot" feature, and programs to check a soldier's understanding of sight alignment, aiming, and grouping techniques. Five generations of MACS software were developed in the 1980s. The last generation of MACS software has been translated into several programming languages to support training on more contemporary hardware platforms. Currently, the Fielded Devices Division of the U.S. Army Training Support Center (Fort Eustis, VA) is developing a new version of the MACS system. It is called MACS 2000.

Engagement Skills Trainer

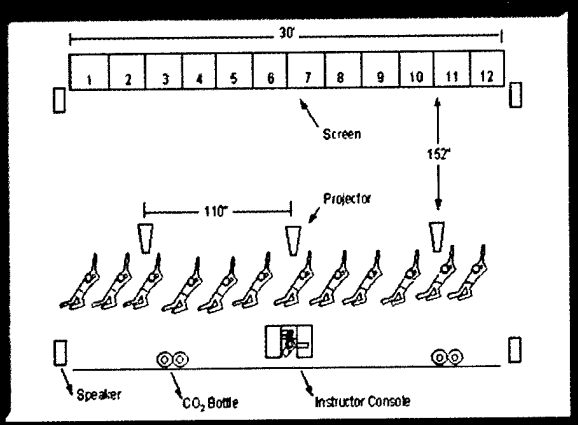
Engagement Skills Trainer (EST)

Unlike Weaponeer or MACS, the Engagement Skills Trainer (EST) can accommodate the simultaneous firing of up to 12 soldiers. Thus, it can provide both individual rifle marksmanship training and some squad-level collective training. The EST uses a combination of analog and digital video, synchronized image projection, laser hit detection, and microcomputer technology to display a variety of target arrays and courses of fire on an 8 ft high x 30 ft wide screen.[38] Like the Weaponeer, the EST is considered to be a full-task trainer, simulating both recoil and

sound. A new version of the EST is currently being developed for the Army. It is called EST 2000 (ECC International, Corp.).

An investigation of an early version of the EST concluded it could effectively support defensive tactical training if squads remain stationary.[38] To further explore its potential role in U.S. Army National Guard training, ARI then examined the relationship between EST scores and annual rifle qualification scores.[39] Using one group of soldiers whose EST scores and qualification scores were measured within a 24-hour period, a fairly close relationship was found between the two measures. The strength of this relationship enabled a tool to be developed that can predict qualification performance based on EST scores. This prediction tool is shown in Table 2.

Recently, software development efforts have greatly extended the scope of the prediction tool beyond the EST. It can now calculate predictions for any live-fire event based on scores from a number of different training devices. After downloading this software from www.ari.army.mil, trainers can now make local predictions for first-run live-fire events based on performance data they obtain from their own ranges and devices. ARI's prediction tool appears particularly useful for identifying those who are ready to qualify and those who aren't.



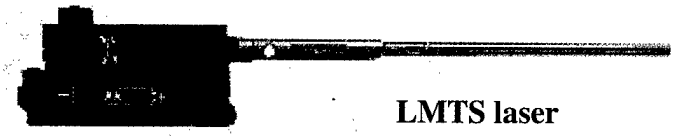
Engagement Skills Trainer (EST) Configuration

TABLE 2

EST-Based Tool for Predicting Soldier Probability of Record Fire Qualification at the Marksman (>23), Sharpshooter (>30), and Expert (>36) Levels.

EST Score	Predicted Mean Live-Fire Score	Probability (%) of Live-Fire Score ≥ 23	≥ 30	≥ 36
1	19	10	–	–
3	20	20	–	–
5	21	30	–	–
7	22	40	–	–
9	23	50	–	–
10	24	60	–	–
12	25	70	–	–
13	26	–	10	–
14	26	80	–	–
16	27	–	20	–
17	27	90	–	–
18	28	–	30	–
20	29	–	40	–
21	30	–	50	–
23	31	–	60	–
24	32	–	70	10
26	33	–	80	–
27	33	–	–	20
29	34	–	90	30
30	35	–	–	40
32	36	–	–	50
33	37	–	–	60
35	38	–	–	70
37	40	–	–	80

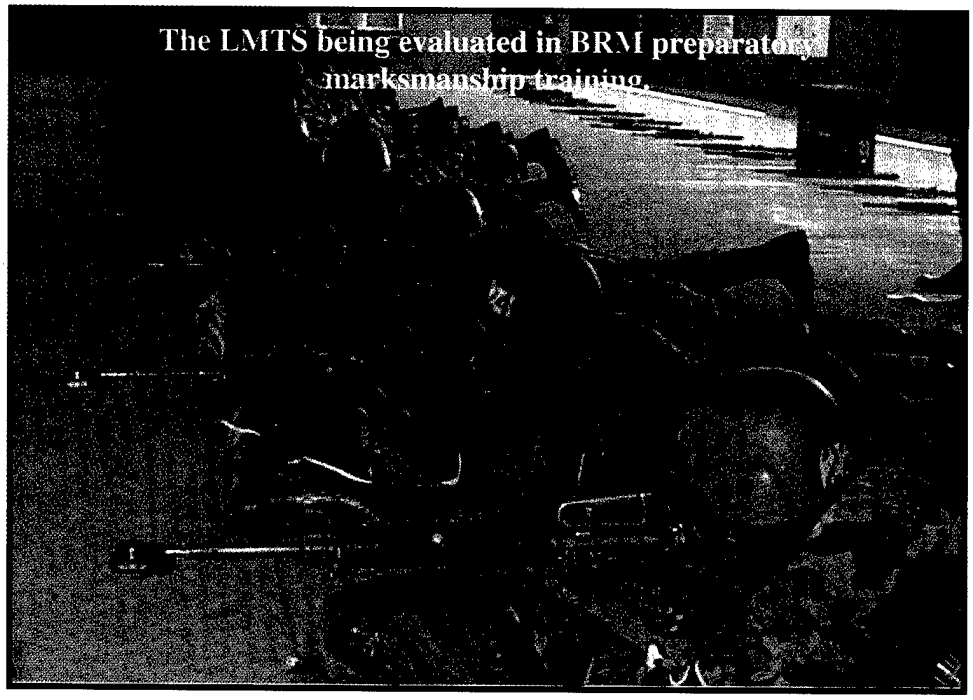
Laser Marksmanship Training System



LMTS laser transmitter with attached mandrel.

LMTS electronic target.

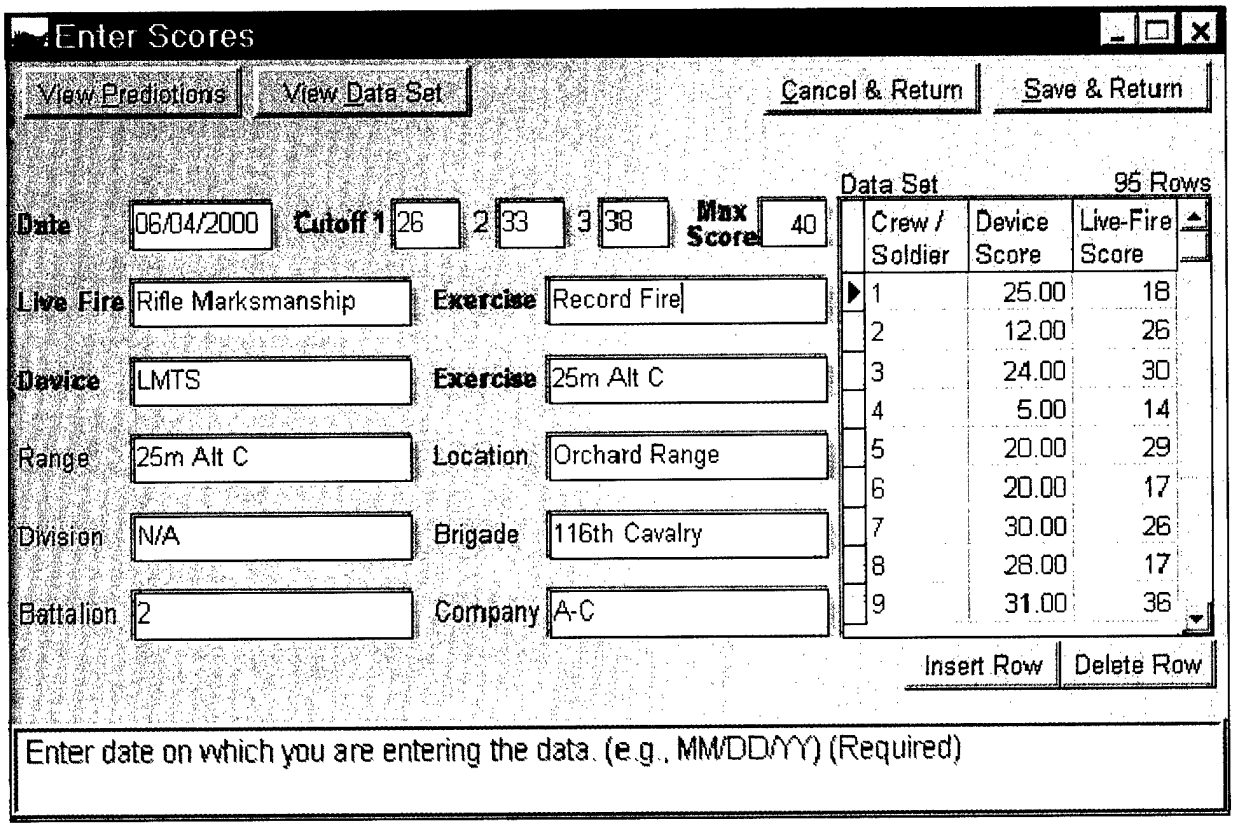
Recently, ARI has examined the potential role of the Laser Marksmanship Training System (LMTS) in providing rifle marksmanship sustainment training to U.S. Army Reserve units at their home stations.[40] The major components of the LMTS are a laser transmitter, the mandrel to which the transmitter is attached, laser-sensitive targets, and a laptop computer. Unlike the Weaponeer, MACS, or ETS, soldiers use their assigned unit rifles with the LMTS. Each laser transmitter has two distinct modes of operation. In one mode, vibrations from a rifle's firing mechanism activate the transmitter when dry firing. A laser-sensitive target then provides shot location feedback. In another mode, the transmitter emits a continuous beam. Precise aiming point location feedback is then provided on a reflective version of the 25m zeroing target.



The LMTS being evaluated in BRM preparatory marksmanship training.

At the request of the Army's proponent for rifle marksmanship training (USAIS), ARI evaluated the effectiveness of LMTS for conducting preparatory marksmanship training in the BRM program at Fort Benning.[40] The LMTS was found to be highly effective for this purpose. In addition, ARI has investigated the use of the LMTS in weapons zeroing and has recently examined the relationship between LMTS performance and live-fire qualification scores.[41, 42]

ARI's software tool for predicting live-fire scores from training device scores has been updated to include LMTS performance as a predictor. Due to indoor range closures and the long distances that must be traveled to use outdoor range facilities, the U. S. Army Reserve is hopeful LMTS training will prove to be an effective substitute for some live-fire training.



ARI's software tool for predicting record fire scores from LMTS scores.

Chapter 3
Night Fighting

The 1990s saw an increased emphasis on night operations within the Army. An integral part of this effort was research to improve the dismounted soldier's ability to see and hit targets at night. Today night equipment, including night vision goggles (NVGs), aiming lights, and thermal sights, is becoming relatively common within the Infantry and other branches of the Army. Initially, ARI conducted research on aiming lights and NVGs.[4, 43] Later, marksmanship training and performance with both aiming lights and thermal sights were assessed.[47] This chapter summarizes those research efforts.

Shooting with Aiming Lights and Night Vision Goggles

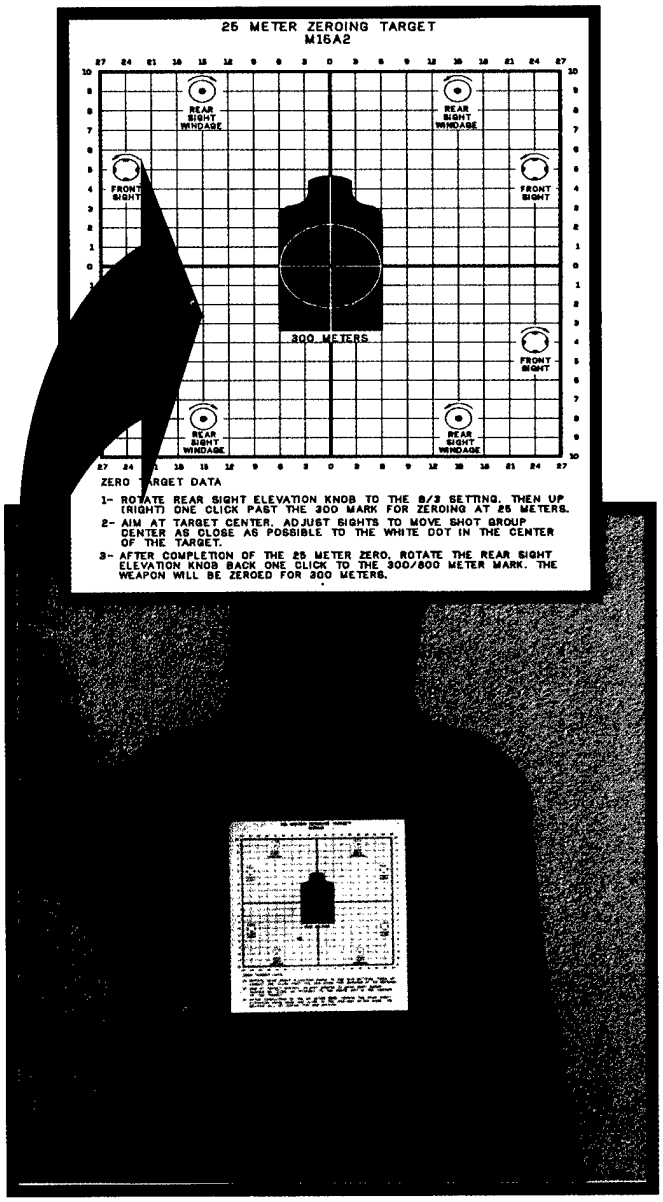
A common perception about aiming lights is that all you need to do is point and shoot. Although aiming lights do provide a point and shoot capability, unless soldiers are properly trained, most likely they will point and miss.

The Equipment. The beams of the aiming lights we examined are not visible to the human eye; they can only be seen through NVGs or other image intensification (I^2) devices. Hitting targets requires that both the aiming light and the NVGs be properly adjusted. Consequently, ARI took a systems approach in evaluating training requirements, looking at both types of equipment. Specifically, ARI examined alternative means for 25m live-fire zeroing and alternative means for effective dry-fire zeroing with aiming lights. This research also determined the impact of NVG acuity on marksmanship with aiming lights and compared the effectiveness of different field-expedient techniques for adjusting the visual acuity of NVGs.

Both NVG and aiming light technology have changed considerably since their initial introduction. During the period of our night fighting research in the 1990s, NVGs progressed from the AN/PVS-5 binocular model with second-generation I^2 technology, to the AN/PVS-7A/B head-mounted biocular models with third-generation technology, to the current helmet-mounted AN/PVS-7D biocular and AN/PVS-14 monocular models with improved third-generation technology.[44] The end result of this NVG evolution has been a lighter goggle, one that is more comfortable to wear, and one that provides a better image under poor light conditions. All soldiers used either the 7Bs or the 14s in this research.

Aiming lights have also improved, from the AN/PAC-4A to the AN/PAC-4B, and most recently, to the AN/PAC-4C and AN/PEQ-2A. Newer models have incorporated steady beams instead of pulsating beams. Their effective ranges have also increased from 150m to 300m and beyond, depending on ambient light conditions at night. The AN/PEQ-2A has the added feature of an illuminator. ARI conducted research with each of these aiming lights during the 1990s.

Initial ARI Research. As aiming lights were being introduced to units, increasing attention was given to the difficulty in zeroing them to weapons, a problem identified in initial Army tests. The basic problem with traditional 25m live-fire zeroing procedures is that the beam of an aiming light "blooms" when viewed through NVGs. Because this "bloom" covers up the silhouette in the center of the 25m target, a precise point of aim is almost impossible to achieve when zeroing. To help solve this serious problem, ARI investigated variations to existing 25m zeroing procedures, as well as dry-fire zeroing alternatives.[43]



ARI 25m Zeroing Target for Aiming Lights.

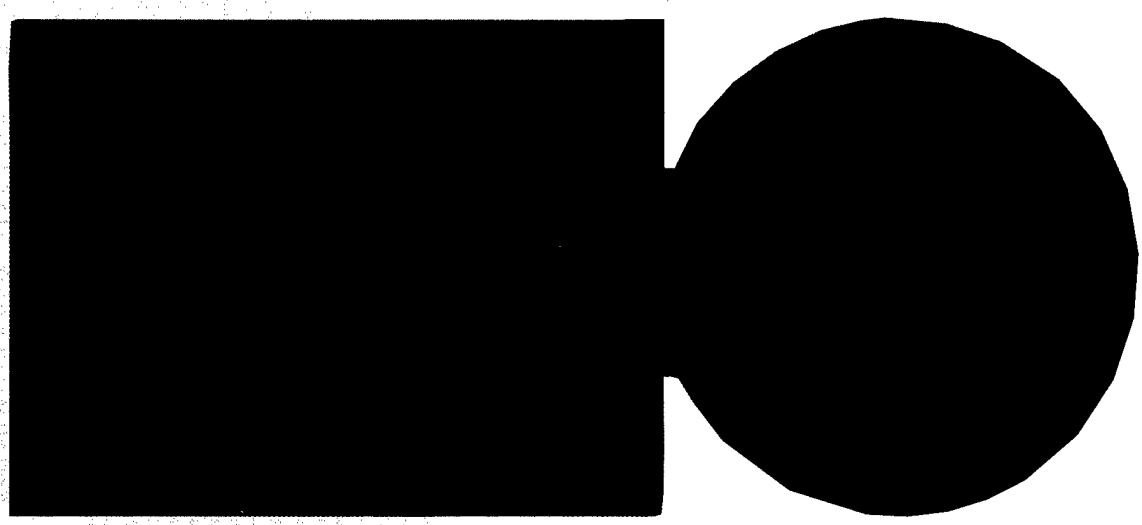
The solution to the 25m zero problem was to provide a target that allowed the soldier to obtain a definitive point of aim. The technique that worked the best was to attach the zero target to the tan side of an E-silhouette and use two strips of black tape to divide the silhouette in half vertically and horizontally. Typically, the best lighting condition was achieved by illuminating the target with a standard Army flashlight, which diffused the bloom or halo of the aiming light. When zeroing, the aiming light was aligned with the target so it fell at the perceived intersection of the vertical and horizontal lines formed by the black tape. The effectiveness of this technique was confirmed by firing at targets from 50 to 300m on a range equipped with projectile location technology (see Chapter 2).

In later work by the Army, it was found that a 3cm hole in the center of the zero target was also effective. When soldiers aligned their aiming lights with the 3cm hole, the bloom disappeared, indicating they were aiming at the silhouette's center of mass.

ARI also explored various dry-fire procedures as potential substitutes for live 25m zeroing. The goal was to develop a procedure that would help

soldiers achieve a satisfactory hit probability in emergency deployment situations without having to zero with live ammunition. ARI also wanted a procedure that, when used prior to live zeroing, would help more soldiers hit the 25m zeroing target with their initial rounds. The data showed that when soldiers used a "mechanical zero" setting, many failed to get their initial shot group on the 25m zero target. Thus, it was impossible for them to know what directional adjustments to make.

ARI's recommended dry-fire technique was essentially the reverse of live 25m zeroing procedures. A soldier aimed constantly at the center of a target using iron sights as during daylight. A buddy wearing NVGs then adjusted the aiming light so the beam hit a predetermined point on the target. To support this procedure, ARI developed special targets allowing the soldier to get a precise point of aim and the buddy to determine exactly where the aiming light's beam should fall.



A soldier at Fort Bragg engages a silhouette target using an aiming light and NVGs.

Since 1995 the Army has used a dry-fire procedure as the preferred method of zeroing aiming lights. This procedure involves the use of a borelight that works with all small arms. A series of offset targets has been developed by the Army to accommodate the various weapon-device combinations currently in the field. ARI worked extensively with this borelight in during subsequent training assessment research.

The other aspect of the initial work with aiming lights involved the other key component of the system, namely the NVGs. If you can't see a target or the target is not clearly defined, an aiming light does not help. Target detection is a function of NVG technology and how well soldiers adjust or fine-tune their NVGs. The quality of the image seen is affected by the adjustments made to the goggles. When you hear the

phrase "I can't see anything with these goggles," you know that soldier does not know how to adjust them properly.

The aviation communities within the Army, Navy and Air Force use indoor "test lanes" or special pieces of equipment to obtain good visual acuity with NVGs. Such equipment and facilities are unavailable to soldiers in the field. ARI compared objects typically found in a field environment to determine which provided the best visual acuity readings for soldiers.[45, 46] Objects such as a vehicle, a light trail against a dark background, or a star worked best. These high-contrast objects better enabled soldiers to know when a NVG image was the sharpest that could be attained.

To determine the effects of NVG visual acuity on marksmanship with aiming lights, soldiers fired their NVGs with both good and poor visual acuity settings.[43] With good visual acuity settings, the hit probability was significantly higher than with poor visual acuity settings. A continuing training problem with NVGs is to provide an objective means for the soldier to determine when he has the best possible visual acuity (diopter) setting on his NVGs.

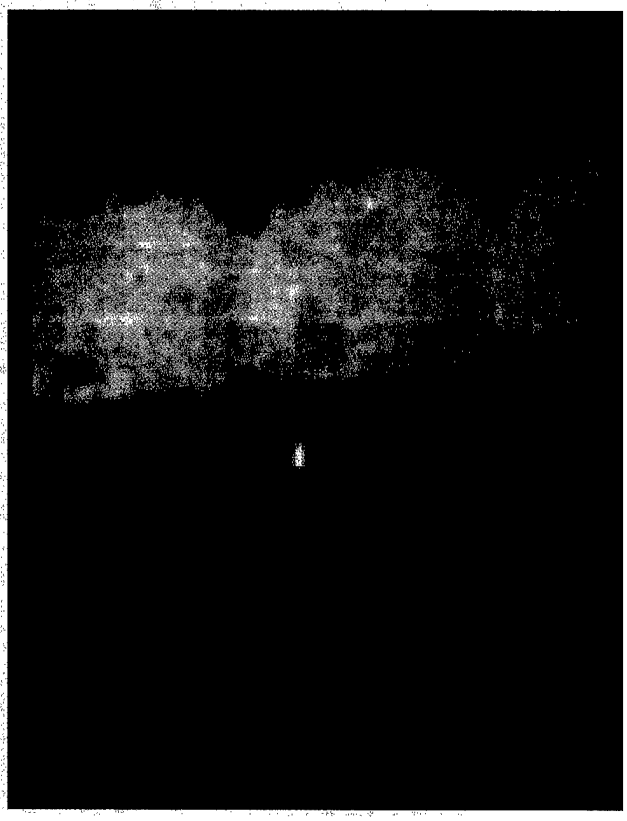
Training Assessments. ARI's most recent work with aiming lights and NVGs has been in the context of assessing training on government furnished equipment for platoons soon to be equipped with the Land Warrior system.[47] The AN/PVS-7B and AN/PVS-14 NVGs, and PAQ-4C and PEQ-2A aiming lights were used, as well as a borelight to "zero" the aiming lights. Three assessments were done over a two-year period. Boresighting aiming lights was found to work, when soldiers achieve a good boresight, adjust their NVGs properly, and use a stable firing position. More effective boresighting techniques evolved with each assessment (e.g., how to best stabilize the weapon, which boresight offset targets work best, and which procedures reduce overall boresighting time).

As our training assessments were being conducted, the USAIS was developing qualification standards for aiming lights. The goal was to have the night standard be the same as the day standard. However, it is well known that targets are difficult to detect with NVGs under poor ambient light. Some range configurations were found to produce very little target contrast, consequently lowering markmanship performance. ARI's training assessment results ultimately impacted the proposed qualification scenario developed for use with aiming lights and NVGs. In particular, the Army modified its qualification scenario and night performance standard to be more consistent with NVG capabilities, range configurations, and the ambient light conditions under which qualification firing would most likely be conducted.

Shooting with Thermal Sights

Thermal sights are not new to the Infantry, being integral to antitank weapons and the Bradley Fighting Vehicle. But they are new to most Light Weapons Infantrymen. These soldiers must now be taught how to make all the necessary adjustments to their

thermal sights. In contrast to using aiming lights, targets equipped with thermal blankets are much easier to detect with thermal sights.



A silhouette target equipped with a thermal blanket, as seen by a thermal camera.

ARI training assessments conducted with thermal sights involved the use of a borelight to boresight the thermal weapon sight (TWS) to a rifle, followed by live 25m zeroing.[47] If boresight procedures were done correctly, the TWS was properly adjusted, and the soldier was a good marksman, few shot groups were required to achieve zero. It was noteworthy that the probability of hit achieved with the TWS on the rifle qualification course at night was very similar to that achieved by the Close Combat Optic (CCO) during the day.

Soldier and Trainer Issues

The ARI training assessments were the first time four different aiming or optical devices, plus the borelight, had been trained simultaneously with the same soldiers.[47] Prior to that time, each device had been examined independently. Two major lessons emerged from these assessments. One lesson was that inconsistency in device design for windage and elevation adjustments created confusion for the soldier, led to errors, inefficient training, and wasted ammunition. The other lesson was that the diagnosis of shooting problems has become more complex for soldiers and trainers, because the number of potential causes for problems has increased almost exponentially.

With respect to their design, each device has adjusters or knobs that provide for windage and elevation adjustments. For example, if bullets are hitting high on the 25m zeroing target, an elevation knob on each device must be turned a particular amount (i.e., "clicks") and direction (i.e., clockwise or counterclockwise) so subsequent rounds will hit lower and closer to the target's center of mass. Unfortunately for trainers and users, the devices were not designed to accomplish these adjustments in the same manner. In addition, soldiers are faced with two 25m zero targets, one for the M16A2 rifle and one for the M4 carbine. However, these targets are not identical, with grid squares on the M4 target being larger than grid squares on the M16A2 target. Soldiers must also remember the amount of movement a "click" produces at a boresight distance

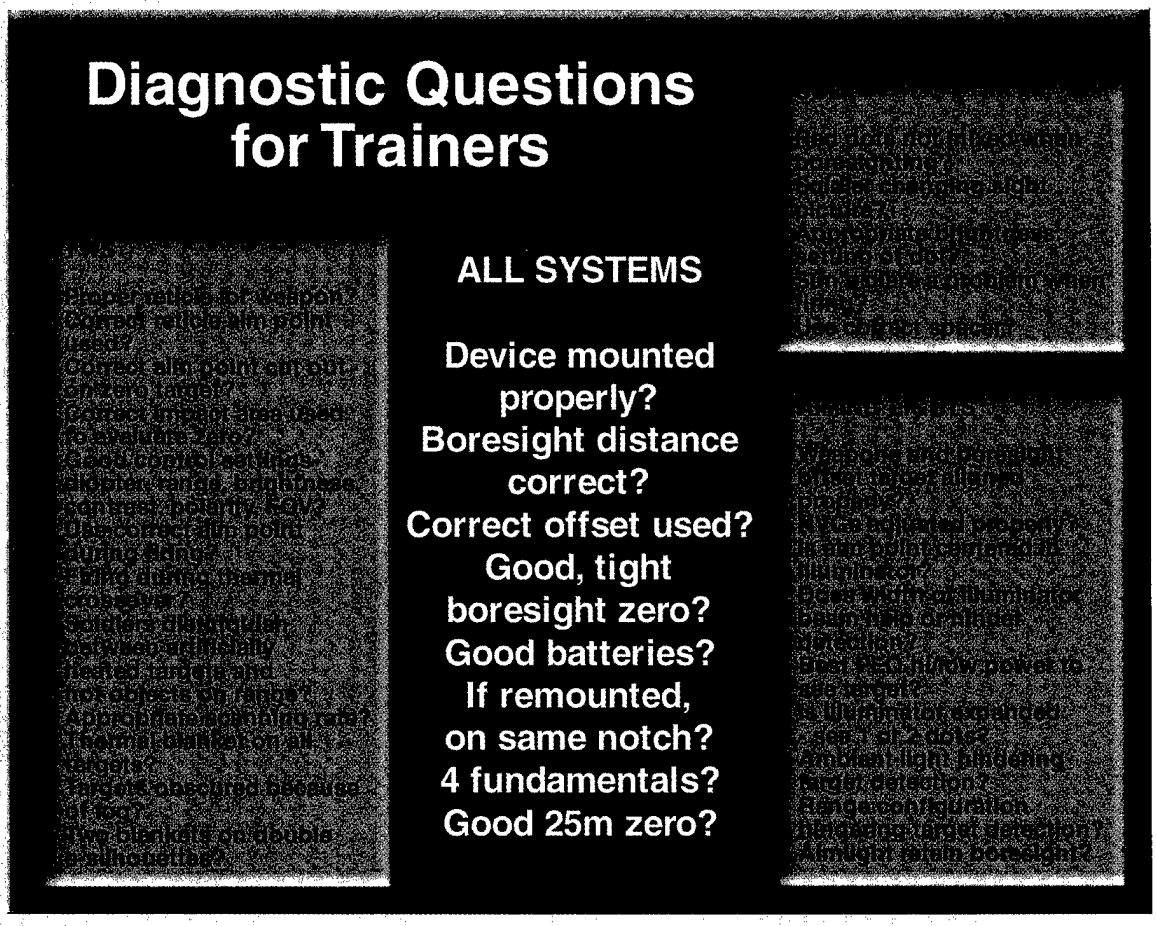
of 10m. It was not surprising that soldiers had trouble remembering which adjustments went with which device and what adjustments should be made when zeroing and boresighting. A summary of these device design differences is shown in Table 3.

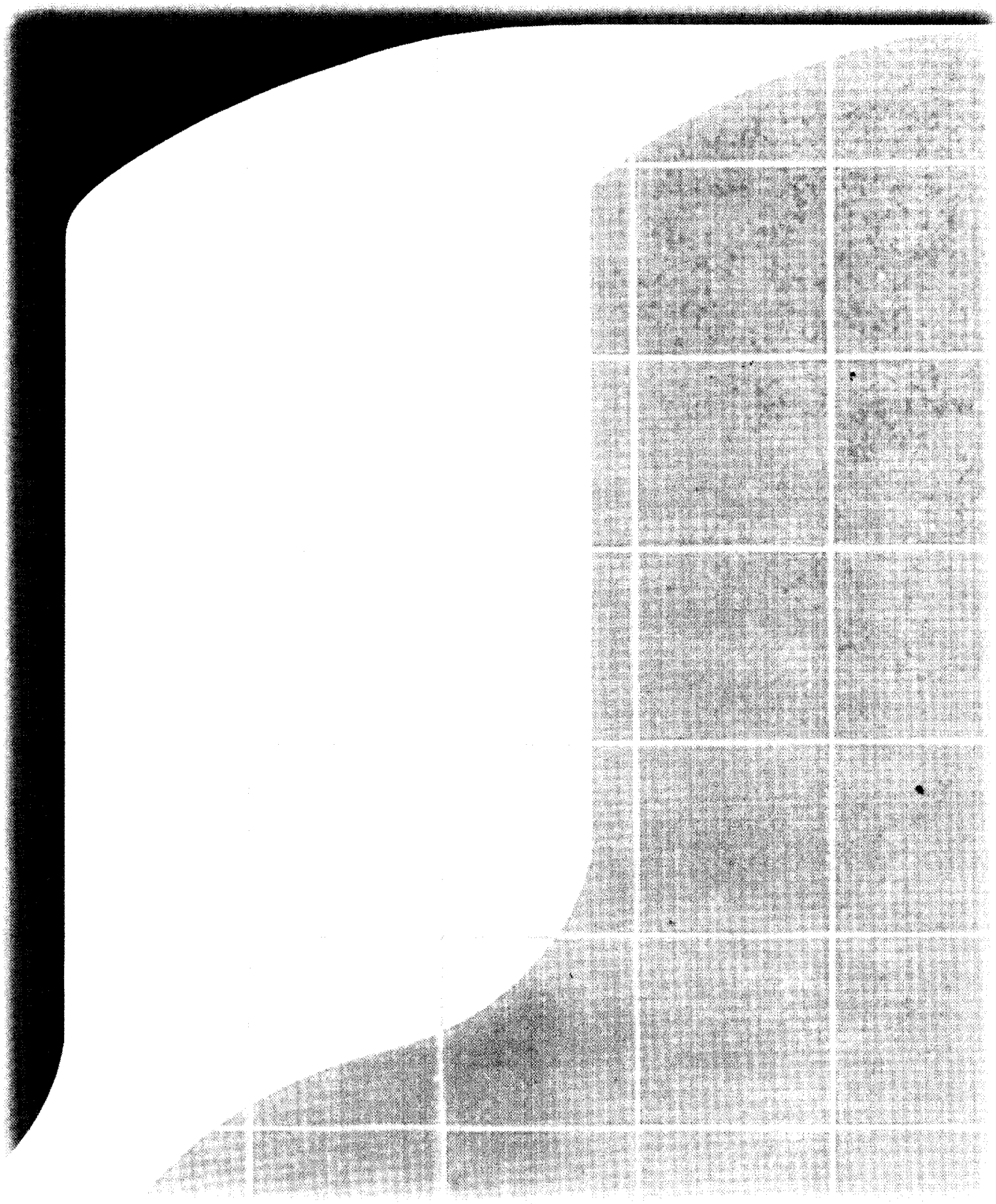
Table 3
System Adjustments for Windage, Elevation, and Distance During Zeroing and Boresighting

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	←	↓	10 mm	100%	71%
PEQ-2A Aimpoint Left side of M4	→	↓	10 mm	100%	71%
PEQ-2A Illuminator Left side of M4	→	↑	10 mm	100%	71%
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 borelight, a clockwise turn moves the barrel to the right and up.**

When soldiers miss targets with iron sights, the immediate reaction of a trainer is to check their application of the four marksmanship fundamentals (see Chapter 1). With the advent of aiming devices, optics, and borelights to the world of small arms, there are many more potential reasons why a soldier could be missing targets. The common core of probable causes has expanded beyond just the four fundamentals, and there is now a unique set of possible causes associated with each device. Trainers need to ask a host of diagnostic questions to determine why soldiers are missing targets. To effectively diagnose shooting problems, soldiers, trainers, and leaders must now fully understand each technology, how to use each device, and the complete collection of steps and procedures that result in effective rifle marksmanship performance, both during the day and at night.





Chapter 4
Research Questions

As weapons and simulation technologies continue to evolve, the need for additional rifle marksmanship research will remain throughout the decade. Chapter 4 briefly explores future training issues and associated research needs in three broad areas: the improved integration of existing systems, the development of training programs for new systems, and the need for an overall strategy to effectively harness advances in simulation technology.

Systems Integration

A service rifle equipped only with iron sights is almost passe. Now soldiers use a rifle on which a variety of separately-engineered optical devices is mounted. Thus, the M16A2 rifle and M4 carbine have each increasingly become a "system of systems". Unfortunately, the improved capabilities resulting from these additional systems have come at a price, namely more difficulty in zeroing and in staying zeroed. Table 3 outlined many of the incompatible design features among these optical devices, which collectively make boresighting and zeroing tasks much more complex. These problems are further compounded when weapons must be separately zeroed for tactical engagement simulation (TES) training (e.g., MILES or Simunitions®).

It is becoming painfully apparent to most units that a greater percentage of available marksmanship training time is being spent on zeroing and boresighting tasks. Because more time and ammunition are being spent for these tasks, it becomes increasingly important for each zero setting to remain relatively permanent, far longer than just a single period of training. To overcome this problem, weapons racks need to be redesigned so rifles can be safely stored with optical devices attached. Additional space is also limited in many of today's arms rooms, so outdated rifle racks are only part of the problem. As illustrated in Table 3, the complete array of different adjustment procedures is really more than we can expect soldiers to remember. The need exists to incorporate all of the different boresighting, zeroing, and adjustment procedures into an updated job aid or document tailored to a soldier's weapon.

With the increasing number of devices and optics that a soldier must use, it is important to know whether skill with one transfers to the others. Is the transfer sufficiently high so that training on only one is required, with only minimal training on the others? Or is there little transfer, with the skills being sufficiently different, thus requiring substantial training on all? The need exists to address these questions, as they impact how the Army trains and help us better understand the marksmanship skills needed for the different systems that soldiers must employ on today's battlefield.

New Systems Training

Scheduled for initial fielding in 2007, the Objective Individual Combat Weapon (OICW) could radically affect the development of future doctrine and training within active Infantry units and Infantry OSUT. Simply stated, the OICW combines a 5.56mm carbine and a 20mm weapon that fires air-bursting fragmentation rounds, delivered using a complex fire control system.[48, 49, 50] This fire control system incorporates a laser range finder and ballistic computer to calculate the range to a target and to transfer targeting data to the electronic fuse built into the 20mm round. In addition, the OICW's sighting system will have a video tracking capability for moving targets and a thermal module for night operations.

Although the OICW may eventually reduce the need to train selected ARM, M203 grenade launcher, and M249 squad automatic weapon tasks, the overall training resource burden associated with OICW fielding will be high, at least initially. Due to the greater relative costs of its 20mm ammunition, simulation will likely have an even more important role in the OICW's overall training strategy than it has in current small arms training.[50] Developing effective and affordable systems for marksmanship simulation and tactical engagement simulation will be a challenge. Further, procedural tasks appear more complex in the OICW than in current weapon systems. Overall, OICW tasks appear to be more cognitive and less psychomotor in nature, with numerous situational (if-then) contingencies. The amount of training needed to rapidly execute such tasks under conditions of extreme stress may be much greater than presently realized.

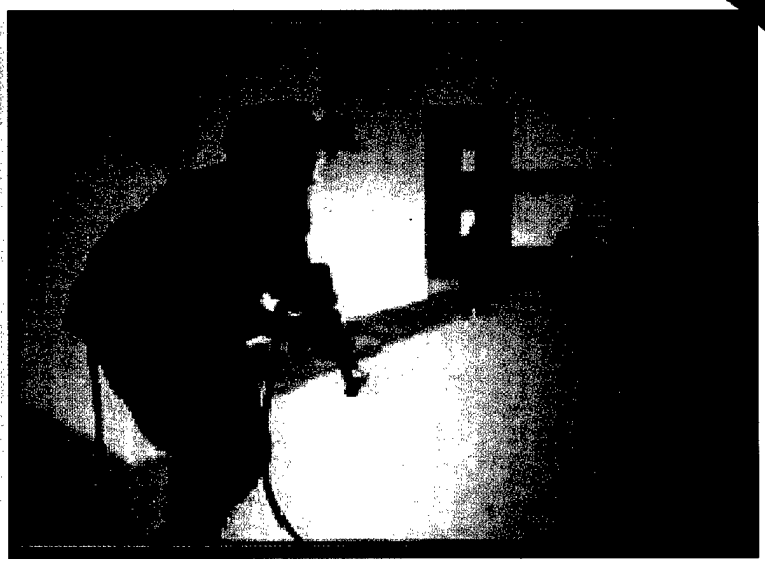
Objective Individual Combat Weapon.

Simulation Training Strategy

Three new or upgraded marksmanship training devices are expected to be introduced within the near future. These devices are the MACS 2000, EST 2000, and LMTS (see Chapter 2). Each has its own unique set of advantages within an overall training program. Though a part-task trainer, MACS probably has the best instructional design features and doesn't require the constant presence of an instructor. EST provides training on the widest range of marksmanship tasks, including collective ones. Finally, the LMTS appears well-suited to provide preparatory marksmanship training on a relatively large scale. Despite everyone's best intentions, the introduction of any new training device is almost always accompanied by problems like software errors, lack of trainer familiarity, and initial uncertainty about the best way to incorporate its use within an existing training program. Focusing on issues such as these in the latter stages of

training device evaluation can help to minimize the inevitable period of adjustment after fielding.

Marksmanship trainers always want to have the best training devices available to do their job. Unfortunately, the perfect marksmanship simulator has yet to be designed. If it existed, it would probably have the best features of the three devices just mentioned. Yet, even the most advanced marksmanship device today, the EST 2000, cannot do everything. For example, it presently has no capability for thermal imagery, it cannot accommodate moving firing points, and it does not offer dynamic scenarios in which targets realistically react to the specific actions of firers. In contrast, a completely different line of R&D is beginning to tackle some of these shortcomings. Specifically, research in virtual reality environments is beginning to achieve limited success in simulating force-on-force tactical engagements for dismounted forces.[51] Within this decade, the training development community will likely need to decide whether it is more cost effective to spend its limited resources on making existing devices more virtual, or whether marksmanship training features should be added to the virtual systems being developed. Training effectiveness research should have a large role in that decision.



A soldier prepares to engage virtual targets in the Soldier Visualization Station.

A simulation training strategy must also seek a proper balance between simulated exercises and live firing. For practical reasons, some units are even seeking to replace live qualification with simulated qualification. At present, it is unclear whether such a position is prudent or foolhardy. Nevertheless, answers that are part of an overall training strategy need to be sought and validated, recognizing that a single answer may not fit the training needs of everyone.

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) October 2000	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) May-August 2000
4. TITLE AND SUBTITLE Shooting Straight: 20 Years of Rifle Marksmanship Research		5a. CONTRACT OR GRANT NUMBER
		5b. PROGRAM ELEMENT NUMBER 62785
6. AUTHORS Kenneth L. Evans, Jean L. Dyer, and Joseph D. Hagman		5c. PROJECT NUMBER A790
		5d. TASK NUMBER 204
		5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences Infantry Forces Research Unit P.O. Box 52086 Fort Benning, GA 31995-2086		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600		10. MONITOR ACRONYM ARI
		11. MONITOR REPORT NUMBER Special Report 44

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT (Maximum 200 words):

The U.S. Army Research Institute (ARI) has developed numerous research products for rifle marksmanship training over the past 20 years. This report highlights ARI marksmanship research efforts during this period of time, focusing on those contributions that continue to influence soldier training today. ARI marksmanship contributions have included program evaluation, instructional development, the design of training materials for students and instructors, systems research, training device development, and training device evaluation. Future marksmanship research questions are discussed in the areas of system integration, new systems training, and simulation training strategies.

15. SUBJECT TERMS

Training Rifle Marksmanship Simulation Training Devices Night Operations

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON (Name and Telephone Number)
16. REPORT Unclassified	17. ABSTRACT Unclassified	18. THIS PAGE Unclassified	Unlimited		Dr. Ken Evans (706) 545-2565