ARI Research Note 86-19

AD-A168 577

ANALYSIS OF M16A2 RIFLE CHARACTERISTICS AND RECOMMENDED IMPROVEMENTS

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TRAINING RESEARCH LABORATORY

U. S. Army
Research Institute for the Behavioral and Social Sciences

February 1986

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Note 86-19	2. GOVT ACCESSION NO. ADA 168 5??	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Analysis of M16A2 Rifle Characteristics and Recommended Improvements		5. TYPE OF REPORT & PERIOD COVERED Final Report October 82 - May 83 6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Arthur D. Osborne and Seward Smith		8. CONTRACT OR GRANT NUMBER(s) MDA 903-80-C-0345
9. PERFORMING ORGANIZATION NAME AND ADDRESS Mellonics Systems Development Division Litton Systems, Inc. P.O. Box 2086 Fort Benning, Georgia 31905-1098		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A794
11. CONTROLLING OFFICE NAME AND ADDRESS ARI Field Unit at Fort Benning, Georgia, P.O. Box 2498, Fort Benning, GA 31905		12. REPORT DATE February 1986 13. NUMBER OF PAGES 49
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

Seward Smith, contracting officer's representative

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aperture Sight	Battlesight Zero	Marksmanship	Zeroing
Assault Fire	Dispersion	Sight Adjustment	
Automatic Fire	Collinater	Tracer Ammunition	
Ball Ammunition	M16A1 Rifle	Servicability Checks	
Ballistics	M16A2 Rifle	Point of Aim/Point of Impact	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Based on five years of marksmanship-related research for the U.S. Army, the characteristics of the M16A2 rifle developed by the Marine Corps were analyzed to determine what impact new rifle features would have on Army marksmanship training and on combat effectiveness. It was found that use of the M16A2 rifle by the Army would be extremely problematic, a fact due, in part, to the vast differences between the marksmanship training philosophies of the Army and the Marine Corps. Numerous recommendations are presented which would result in simplified training and improved combat performance if adopted.

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 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

The Army Research Institute (ARI) Fort Benning Field Unit, Fort Benning, Georgia, has conducted an ongoing program of research directed towards development of cost and training effective methods for individual and collective training in M16 rifle marksmanship. The research includes all aspects of inquiry from problem assessment through instructional improvement to consideration of appropriate ranges, rifles, training aids, and devices. A detailed evaluation of M16A1 performance was conducted to determine adequacy, peculiarities, etc. The findings clearly indicated that the M16A1 was an adequate combat rifle; however, many shortcomings were identified that should be addressed in a new rifle or any rifle Product Improvement Program (PIP).

The M16A2 rifle was developed and tested by the U.S. Marine Corps. The purpose of this present analysis was to evaluate M16A2 rifle features as they relate to U.S. Army training and combat requirements. It was found that the M16A2 did not correct major shortcomings in the M16A1 and that many M16A2 features would be very problematic for the Army. Accordingly, this report provides several suggested rifle modifications which would improve training and combat performance.

ANALYSIS OF M16A2 CHARACTERISTICS AND RECOMMENDED IMPROVEMENTS

EXECUTIVE SUMMARY

Requirement:

The M16A2 rifle was developed by the U.S. Marine Corps. The requirement of this effort was to determine if M16A2 rifle features resulted in the best rifle for Army use and to suggest modifications as necessary to improve rifle design features.

Procedure:

The basis for this analysis was previous marksmanship and weapons research which had identified optimum rifle features to enhance Army marksmanship training and improve soldiers' combat performance. Each feature of the M16A2 was evaluated to determine its impact on Army training and mission accomplishment. The features considered desirable for an Army rifle, which were not incorporated into the M16A2, were discussed and the most desirable features were combined into a recommended Army rifle. Information on the M16A2 was obtained primarily from documentation resulting from operational testing conducted in late 1981 and supplementary testing conducted in 1982.

Findings:

This analysis revealed that the M16A2 design did not reflect consideration for Army training or combat requirements. The M16A2, without modification, will be extremely problematic for the Army.

Utilization of Findings:

This report is valuable to all weapons related Training Developers and Combat (Materiel) Developers. It reflects the need for better Army Training Development/Army Combat Development interface in future weapon/equipment development efforts. The findings of this report in the form of letters or memoranda have been provided to Army decision makers at all echelons and to Marine Corps project officers. These interim-type reports, submitted prior to various decision points in the M16 Rifle Product Improvement Program, were dated 25 February 1980, 16 November 1981, 15 July 1982, 22 October 1982, and 15 December 1982. Interim reports have already resulted in additional weapons testing and evaluation, and may result in an improved Army version of the M16A2.

ANALYSIS OF M16A2 RIFLE CHARACTERISTICS AND RECOMMENDED IMPROVEMENTS

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INTRODUCTION

During the past five years, the Army Research Institute (ARI) Fort Benning Field Unit, Fort Benning, Georgia, has been conducting an ongoing program of research directed towards development of cost effective methods for individual and collective training in M16 rifle marksmanship. The research included all aspects of training inquiry from problem assessment through instructional improvement to consideration of appropriate ranges, weapons, training aids, and devices. The research effort has been augmented by a resident contractor, Litton Mellonics, and has involved coordination with the Infantry School, Infantry Board, Army Marksmanship Unit, Training and Doctrine Command, Army Training Centers, and Forces Command.

During this period, 33 marksmanship related research products were produced by ARI/Litton. These reports are listed in the Reference or Bibliography sections. The research included the identification of individual and unit combat rifle requirements (Evans & Schendel, 1983). High priority and frequently performed combat rifle tasks were selected by closely analyzing all Infantry Army Training and Evaluation Program (ARTEP) missions and all doctrinal missions. To determine weapon capabilities and peculiarities associated with zeroing and combat firing, several firing tests were conducted, using 60 typical M16A1 rifles and 5000 rounds of typical M193 service ammunition (Osborne, Morey & Smith, 1980). Numerous field experiments were conducted to determine the influence of various training procedures on soldier shooting performance. (Evans & Osborne, 1983 and Smith, Osborne, Thompson & Morey, 1980). With this background, programs of instruction were developed for Basic Rifle Marksmanship (BRM), Advanced Rifle Marksmanship (ARM), and marksmanship in units. The development, testing, field validation, and implementation of these programs Army-wide has provided a broad experience base. This experience base allows various rifle features and their impact on Army training to be assessed.

This report discusses the features of the M16A2 rifle and the contrasting marksmanship training philosophies employed by the Army and the Marine Corps are outlined as they relate to rifle features. Army training requirements are discussed in detail from a training developer's prospective, and rifle improvements considered optimum for Army use while meeting Marine Corps requirements are combined into a recommended rifle.

BACKGROUND

Since its adoption as the standard service rifle, the M16 has been subjected to considerable criticism concerning its reliability and performance capabilities. Early in the research effort, it became obvious that a serious detriment to an effective rifle marksmanship program was a general lack of confidence in the M16A1 rifle. Therefore, a detailed evaluation of M16A1 performance was conducted to determine adequacy, peculiarities, etc. (Osborne, Morey & Smith, 1980). The findings clearly indicated that the M16A1 was an adequate combat rifle. Accordingly, to build necessary soldier confidence in the rifle, the positive aspects of the rifle were emphasized and training procedures were adjusted to minimize the negative characteristics. An Infantry article (Osborne, 1981) was written to help develop soldier confidence in the rifle. At the same time, it was clearly indicated that the M16A1 was not the best rifle that could be in the hands of the American soldier. Many shortcomings were identified that should be addressed in any rifle Product Improvement Program (PIP).

In September 1979, a Strategy Meeting was held at Headquarters, Marine Corps to review possible solutions to infantry weapons problems, including a product improvement proposal for a short-term solution to correct identified M16A1 deficiencies. Negotiations were initiated with Colt Industries, and in January 1980, a unilateral program was initiated by the Marine Corps which resulted in the testing of three improved M16s. In February 1980, a Joint Service Small Arms Program (JSSAP) meeting was held, and it was determined that enough interest existed to initiate a joint service program. Accordingly, the JSSAP management committee approved a plan to have Colt Industries build fifty M16 prototype rifles. The rifles were delivered in November 1981 and a Modified Operational Test (MOT) was conducted by the Marine Corps from 23 November 1981 to 11 December 1981. The MOT was conducted using thirty M16A1 rifles and thirty Product Improvement Program (PIP) rifles, designated M16A1E1 for testing. Test troops consisted of 20 marines and 10 soldiers from the 197th Infantry Brigade, Fort Benning, Georgia.

The PIP rifle, type classified in September 1982, and designated the M16A2, is currently being produced by Colt Industries for the Marine Corps. The Marines plan to purchase an average of approximately 40,000 M16A2 rifles per year for the next five years, with the total purchase projected at 264,000 rifles.

THE M16A2 RIFLE

The M16A2 is the result of a Product Improvement Program (PIP); however, it is, for all intents and purposes, a different weapon. The changes are:

- A new barrel--changed from 1:12 twist to 1:7 twist and somewhat heavier at the muzzle.
- A new muzzle compensated flash suppressor.
- A square front sight post for elevation adjustment.
- A differently shaped handguard of more durable material.

- A strengthened upper receiver, including a brass deflector rib, which supports a new rear sight. The rear sight has a horizontal wheel which is adjustable for ranges of 300 to 800 meters, using a 1-3/4mm aperture. While the sight is set for 300 meters, pushing the flip-type sight forward provides a 5mm aperture for ranges of 0 to 200 meters. A drum-type knob is used for windage adjustment.

- The "automatic" firing mode has been replaced with a "burst" mode which fires a maximum of 3 rounds for each trigger pull.

- The pistol grip has been remolded to provide for finger grooves and is constructed of a more durable material.

- The butt stock has been lengthened by 5/8 inch and is constructed of a more durable material. The butt plate is made of tougher material and designed to minimize slippage.

MARINE CORPS TEST FINDINGS

The Marine Corps test results (U.S. Marine Corps, 1982) stated the following advantages for the PIP rifle:

- Ease of training (handling and ease of sight movement).

- Improved safety (no hazard when adjusting elevation on the rear sight even with loaded weapon).

- Increased effectiveness at long ranges (more hits, better accuracy, and greater penetration).

- Improved handling characteristics and durability in hand-to-hand close combat.

- Reduced barrel jump and muzzle climb during automatic and rapid fire.

- Increased contrast and less glare with square front sight post.

- Stronger, more durable and improved grasping characteristics of front handguard.

- Stronger barrel with quicker twist to take advantage of increased effectiveness provided by new ammunition.

- Improved sighting characteristics providing quick target acquisition for moving targets and better detection of targets in low level light conditions at close ranges, and more accurate long range fire by use of two modified rear sight apertures.

- Increased ammunition conservation and more effective use of ammunition with burst control device.

- Conformity to human factors standards by lengthening stock (alleviating bruised eyebrows, noses, and lips).

- Stronger, more durable stock.

- Stronger, more durable buttcap which also reduces slipping on the shoulder during firing.

- More controllable and comfortable pistol grip contoured to the shape of the hand.

- Improved brass deflector which protects left handed shooters from hot ejected brass casings.

- Can use NATO type improved ammunition (XM855) which provides increased performance and penetration at long ranges.

The above list of advantages is very impressive. It appears that the rifle meets the primary requirements stated by the Marines:

- A sight adjustable to 800 meters.

- A bullet with better accuracy at 800 meters and the capability to penetrate all known helmets and body armor at ranges of 800 meters.

- A rifle with more durable plastic parts and barrel which will take a beating during bayonet training and extended field exercises.

- The replacement of the full automatic capability with a burst mode which fires a maximum of three rounds with each pull of the trigger.

The list, however, represents the objective and subjective evaluation of Marine Corps personnel who are emphasizing the most positive aspects of rifle characteristics as they pertain to envisioned Marine Corps requirements.

ARMY REQUIREMENTS NOT MET BY THE M16A2

An additional analysis was conducted by Litton/ARI from the point of view of Army trainers. It is not surprising that a different list of findings emerged. In fact, most findings are in the form of a disadvantage or shortcoming as the test results and rifle features relate to Army training and combat requirements. Also interesting to note is that there is very little direct conflict between items on the above list and the items listed below.

<u>25 Meter Setting</u>

The M16A2 does not have a sight setting for firing at 25 meters, where zeroing and most practice firing occurs. (Discussed on p. 21).

Battlesight Zero

The M16A2 does not have a setting for battlesight zero, i.e., 250 meters. (Discussed on p. 24).

Aperture Size

The M16A2 probably does not have an aperture suitable for the battlesight, e.g., the single aperture used for most marksmanship training, the record fire course, the primary aperture for combat, etc. The 5mm aperture used for 0-200 meters is probably too large and the 1-3/4mm aperture used for 300-800 meters is probably too small. (Discussed on p. 21).

Sighting System

The M16A2 sighting system is too complex, i.e., elevation is changed three different ways, leaving too much room for soldier error. (Discussed on p. 13).

Sight Movement

Sight movements on the M16A2 result in changing bullet strike by different amounts; .5, 1, 1.4, and 3 minutes of angle (MOA)*. The sights intended for zeroing, .5 and 1.4 MOA, are not compatible with old Army zero targets or the new targets being fielded. (Discussed on p. 13).

Zero Recording

The M16A2 does not have a sighting system which allows for easy recording of rifle zero. Also, the zero cannot be confirmed by visual inspection.

Returning to Zero

The M16A2 does not have a reliable procedure for setting an indivdual's zero after changing sights for any reason, e.g., using MILES or .22 rimfire adaptors.

Night Sight

The M16A2 does not have a low light level or night sight.

Protective Mask Firing

The M16A2 has not been designed to aid firing while wearing a protective mask.

Range Estimation

The M16A2 sight has not been designed to aid in the estimation of range.

*MOA is equal to 1 inch at 100 yards.

Lead for Moving Targets

The M16A2 sight has not been designed to simplify lead rules for the engagement of moving targets.

Front Sight

The M16A2 front sight is subject to bending, causing various amounts of change to windage adjustments when elevation adjustments are made.

Rear Sight

The M16A2 rear sight is subject to binding and must be kept clean and well lubricated.

Ammunition Compatibility

The new ammunition (XM855) cannot be fired accurately in the current rifle (M16A1).

Accuracy

The M16A2 is less accurate out to ranges of 500 meters. Independent testing conducted by the National Rifle Association, firing five groups of five rounds each at a range of 200 yards, resulted in the following average group sizes:

M16A1/M193 - 3.82"
M16A2/XM855 - 5.38"

The primary Marine test consisted of firing at ranges of 200, 300, 500, 600, 700, and 800 yards. The sum of extreme spreads at 200, 300, and 500 yards resulted in 50.3" for M193 ammunition and 55.8" for XM855 ammunition. While there are only small differences in accuracy to 500 meters, the sum of all firing data clearly indicates that the M16A1 firing M193 ammunition (current system) is more accurate than the M16A2 firing XM855 ammunition (new system). The test subjects who were qualified "expert" preferred the M16A1 due to its superior accuracy. The accuracy advantage of the new system has only been shown at 600, 700, and 800 meters. The Army has few ranges that would even permit firing at ranges greater than 300 meters.

Endurance

The following data from the Marine endurance and accuracy testing conducted with three rifles of each type from a distance of 200 meters shows the average extreme spread of shot groups measured at the start of the endurance test, after 3600 rounds had been fired through each rifle, and after 6000 rounds had been fired through each rifle.

	Start	3600 rounds	6000 rounds
M16A1 (M193)	19.03 cm	18.73 cm	17.73 cm
M16A2 (XM855)	27.43 cm	31.23 cm	62.23 cm

These data represent the only endurance firing conducted with the M16A2 and XM855 ammunition during the MOT. It is believed that bad ammunition was a major cause of this unsatisfactory performance. However, the fact remains that the system (rifle and ammunition) did not meet minimum endurance and accuracy standards.

Reliability

The M16A2 is less reliable. The primary Marine test resulted in the following firing failures:

Thirty M16A1 rifles firing 26,010 rounds of M193

Failures to fire - none

Failures to feed - 3 (Not locking magazine in place)

Thirty M16A2 rifles firing 26,010 rounds of XM855

Failures to fire - 52 (27 - bad ammunition)
(25 - mechnanical malfunctions)

Failures to feed - 3 (Improperly loaded magazines)

Upon completion of the primary test, the straightness gauge, (to indicate barrel bend) would not pass through 1 of 30 M16A1 rifles and would not pass through 14 of 30 M16A2 rifles. An investigation of this condition found that the barrels were not bent but that barrels contained metal foulings. Technical personnel suspected that jacket hardness, powder fouling, and the fast twist probably worked together as contributing factors.

During the cold weather test, the following failures were reported:

Five M16A1 rifles firing 30,000 rounds of M193

Failures to fire - 4

Weapon failures - None

Five M16A2 rifles firing 30,000 rounds of XM855

Failures to fire - 159

Weapon failures - 2

Again, many of these failures were blamed on bad ammunition and new parts associated with the burst control. However, the reliability of the new system was not demonstrated.

Automatic Fire

The M16A2 has less combat capability due to the elimination of full automatic fire. Full automatic fire enhances the ability of Army units to clear and defend buildings, to conduct final assaults on enemy positions, to defend against an enemy final assault, to conduct an ambush, to react to an enemy ambush, to engage an enemy helicopter or fast moving vehicle, etc. While the Marines claim greater accuracy and conservation of ammunition for the 3-round burst control, no data were generated during the test to support these contentions and no supportative data are known to exist. Also, it should be noted that room-to-room fighting was conducted with blanks, no close-in firing was conducted, no firing with short time limits was conducted, no firing at aircraft was conducted, etc. In other words, for all of the automatic/burst firing conducted during the test, a semi-automatic mode of fire would have probably resulted in a greater number of target hits. Finally, to be given very serious consideration, is the fact that the burst control requires nine (9) new parts in the lower receiver, evidently contributing to the large number of weapon malfunctions during testing of the M16A2. (Discussed on p. 25).

Heavy Barrel

The M16A2 "heavy barrel" is heavy in the wrong place. The problem with the M16A1 is a temporary bending of the barrel which occurs from the stress of various firing positions causing bullet strike to vary, e.g., the difference between a bipod firing position, and a position using a hasty sling will change the strike of the bullet at 300 meters by three to four feet or more. The "bending" takes place between the receiver and the sling swivel/bayonet stud. The M16A2 barrel is "heavy" only from the sling swivel to the muzzle--where it can have no effect on the bending problem. The Marines plan to test a new barrel which may correct this problem. (Discussed on p. 29).

Barrel Twist

The M16A2 barrel has a 1:7 twist (the bullet rotates once every seven inches) which was found to be appropriate for the squad automatic weapon (SAW). Available data indicate that a 1:9 twist would be more appropriate for the M16 rifle, improving accuracy and reliability. (Discussed at p. 29).

Stock Length

The M16A2 stock is too long for Army use. The decision to lengthen the stock was made after all portability tests (entering and exiting aircraft/vehicles/buildings, etc.) had been completed and without consideration for body armor, field jacket with liner, load bearing equipment, etc. This change results in the M16 trigger to butt plate length (the test report states 14 inches) being approximately one inch longer than the Springfield, M1, or M14. The Army problem was that the existing stock was already too long for many soldiers (mostly females). (Discussed on p. 31).

Rimfire Adapter

The M16A2 may not be able to accommodate the .22 rimfire adapter. The .22 long rifle bullet is designed to be fired in a 1:16 twist barrel. While there are many problems associated with firing the .22 bullet through the M16A1 barrel, fouling being one of them, it is a partially acceptable training alternative. It may not be possible to fire the .22 long rifle cartridge through the M16A2 barrel without excessive loss of accuracy or excessive fouling. The relatively soft body of a .22 bullet is approximately the same size as a 5.56 bullet, and it fits into the grooves of the rifle bore in a similar manner; therefore, since metal fouling is a problem with the hard military bullet, the .22 rimfire adapter should be tested for compatability with a 1:7 twist barrel.

Other Features

The M16A2 also does not include several needed features: improved serviceability checks, improved magazines, improved trigger or a system for obtaining a mechanical zero. (Discussed at pages 32 to 35).

MARINE TRAINING PHILOSOPHY VERSUS ARMY TRAINING PHILOSOPHY

More than 20 years ago the Army converted from Known Distance (KD) type ranges, firing at large bulls-eye targets at distances of 100, 200, 300, and 500 yards, to Trainfire ranges, firing at pop-up silhouettes at distances of 25 to 300 meters. The Marine Corps retained KD ranges for their primary marksmanship training and have continued to emphasize the competitive type shooting of a KD range.

The Marines are training a "few good men". They dedicate resources to this effort in the form of firing ranges which provide precise bullet location (essential for teaching shooting fundamentals) and a large number of highly trained instructor personnel. The ratio of trainers to recruits is seldom more than 1:2 on the firing line. They do an excellent job. The Army is training masses of men and women on ranges which provide at best only hit/miss feedback with a limited number of untrained instructors (the U.S. Army may be the only major military force in the world without a formal marksmanship instructor training program). The typical soldier receives no assistance during live fire. He shoots at the 300 meter target and at least 7 times out of 10 the bullet goes some place else. He does not know where. There should be no surprise that little learning occurs. One reason for drawing the above distinction is to make the point that the Marines dedicate resources to marksmanship which allow them to cope with a more complex training requirement, e.g., sighting system, than can the Army.

The Marines have clearly given priority to expected rifle targets in the 300 to 800 meter range band (the primary aperture on the A2 is designed for use only from 300 to 800 meters), and the Army has clearly demonstrated through current and planned range requirements that it is interested primarily in the range band of 15 to 300 meters. The Marines focus their marksmanship program on competitive type firing on a KD range (engaging targets to ranges of 500 meters) and the Army directs its marksmanship efforts to close-range, pop-up targets in a combat type environment (engaging targets to ranges of 300 meters).

While attending the Marine Corps Command and Staff College, Major Rex Wigney, Royal Australian Regiment, conducted marksmanship research. His report is a survey of rifle marksmanship in the U.S. Army, U.S. Marine Corps, United Kingdom, Canada, New Zealand, Federal Republic of Germany, Australia, Soviet Union, Israel, and Austria (Wigney, 1982). The U.S. Marine Corps program is unique in that it is the only program surveyed that requires individual riflemen to engage targets beyond 300 meters and is the only program which conducts sight changes on the firing line to allow for wind and gravity (all other programs use hold-off). Major Wigney states that the requirement to shoot at long range does not appear to have a doctrinal base, in that the Marine Corps official publication FMFM 1-3 states: "In the majority of cases, the range at which individual combat targets can be detected and effectively engaged will be less than 300 meters." He goes on to say that the requirement to shoot at 500 yards appears to have arisen from one of three possible sources: a competitive shooting background, the desire to exploit the ability to engage targets up to maximum effective range, or simply to build the Marine's confidence in his ability with his rifle.

Many of the differences between the Army and Marine approaches to marksmanship are reflected in the two primary courses of fire, KD and Trainfire. KD type firing is extremely good for teaching shooting fundamentals and for training competitive shooters. The training advantages of KD over Trainfire may be listed as follows:

- The precise location of each target hit can be seen.
- The precise location of most misses can be seen.
- Effects of various ranges on bullets can be observed.
- Effects of wind and gravity can be learned.
- A single shot or a shot group can be observed.
- Confidence can be developed in the ability of rifle and soldier to hit distant targets.

While these fundamentals are good for teaching shooting fundamentals, they also make the KD course easier to shoot than Trainfire in that: (1) a single target is presented at a known range; (2) it is clearly contrasted with a light-colored background; (3) it provides a precise point of aim; (4) the firer can establish a natural point of aim with a single rigid position; (5) small holes for the elbows or heels can be established since all shooting is at the same target; (6) the stockweld (spotweld) never has to be broken during rapid fire; (7) the effects of a bad zero are minimized because precise location of previous shots allows the firer to compensate; (8) the effects of wind and gravity are minimal because seeing the precise location of bullets allows the firer to compensate; and (9) the use of a loop sling provides for a very steady position.

The Trainfire range was designed to more clearly represent combat firing requirements. Trainfire requires a soldier to scan a sector of fire and perform many other tasks which are required to be an effective combat rifleman. The following Trainfire features reflect realistic combat shooting requirements. This vast difference in shooting requirements between KD and Trainfire results in different shooting techniques being employed and also results in different rifle requirements for optimum performance.

- Target range is unknown.
- Target location is unknown.
- Target is small (compared to KD scoring rings).
- Target blends with background.
- Target must be detected before it can be engaged.
- Target exposure time is short.
- Exact exposure time is unknown.
- Firing position must be adjusted after target is detected.
- More than one target may be presented at once.
- The quality of target hits is unknown.
- Weapon zero cannot be confirmed.
- Effects of wind and gravity cannot be observed easily.

The purpose of this comparison between Army and Marine training philosophies is not intended to indicate that one is better than the other, but to point out that they are very different. The Marine and Army marksmanship programs can each be justified based on uniquely different training considerations. However, this vast difference in training philosophy and expected combat employment dictates that rifle requirements may be quite different.

The M16A2 appears to have been developed without any consideration for Army training and combat requirements; therefore, an Army developed rifle may be expected to include different features.

CONSIDERATIONS FOR RANGE

At extended ranges, Army units generate combat power through the use of mortars, artillery, helicopter gunships, TacAir, and other available supporting weapons. However, these weapons, due to their dispersion, cannot be fully used as the soldier closes on an enemy position or as an enemy closes on the soldier's position. Therefore, as the soldier gets close to the enemy, the rifle must assume an ever-increasing role in the generation of suppressive and killing fire. Hence, the relative importance of the rifle at close range (0 to 300 meters) is much greater than at extended range (600 to 800 meters). Accordingly, if trade-off decisions become necessary during rifle development, the close range capability should be given priority.

The Marines may be able to justify an 800-meter setting on the rifle. The Army should not oppose an 800-meter setting on the rifle sights, but it should be considered in the proper perspective. Given that the typical soldier cannot hit a 300-meter stationary target under no wind conditions, a sight capable of being set on 800 meters may not be very useful. Assuming a soldier can properly hold on an 800-meter stationary target and get off a perfect shot, a 100-meter error in estimating range would cause the target to be missed by five feet. To compound things further, a walking target would move eight feet between the time the M16A2 rifle is fired and the bullet arrives, and a 10 mph crosswind would blow the bullet more than eight feet off target. The point is that teaching effective engagement of extended range targets for all soldiers is a very complex and difficult task and one that would take a major commitment of resources in the form of personnel, ranges, and target systems.

The M16A1 with standard sights can be effectively aimed at personnel targets to a range of 500 meters. All things considered, it is at least as effective as the M16A2 to that range. However, most combat units have equipped their rifles with the Low Light Level Sight System (LLLSS), which limits effective aiming to a maximum of 350 meters. All available test data and our own testing indicate the LLLSS degrades a unit's overall ability to hit targets. Accordingly, we have recommended that the use of the LLLSS be discontinued and that standard sights be installed on all rifles. This action would immediately add 43% to the range at which all soldiers can aim at targets.

The Rifleman/Sniper position which is part of new organizations is expected to utilize a telescopic sight, so this "master rifleman" will not have to rely on the standard sights.

The requirement to engage long-range targets with rifle fire has been emphasized in the after-action reports from training exercises in the Mid-East. While the opportunity to engage targets out to 800 meters appears to exist in training exercises, there is doubt that many opportunities will exist in combat when it will be appropriate for riflemen to engage targets at such extended ranges. Given an extremely low hit probability, it is doubtful that a rifleman's contribution to the generation of combat power would be sufficient to compensate for his reduced survivability. A rifleman who participates in the exchange of direct fire from 800 meters while being subjected to massive amounts of indirect fire, does not have a high probability of surviving the encounter. It may be advisable to keep the rifleman in a protected posture until the enemy is at a range which will allow his fire to be relatively effective.

The tactical employment of a rifle capable of firing to 800 meters should also be considered in light of current tactical doctrine, i.e., a rifleman's primary sector of fire is approximately 45 degrees to his front, which means the majority of an 800-meter range band would be fired in front of adjacent units.

To be given some consideration is the fact that combat infantry units, those units which have the highest probability of being in position to employ long-range small arms fire, have very few dedicated riflemen. A larger number of rifles may be employed by combat support and combat service support units.

After reviewing the state of Army marksmanship training, our training goals have been to improve hit probability on close range targets, developing soldier confidence that all life-threatening enemy targets can be hit. In other words, it may be better to have soldiers enter combat with the training experience of hitting all targets they can see out to 300 meters rather than missing almost all targets at 600 to 800 meters.

The intent of this discussion on the relative importance of shooting to 800 meters is to make a case for not giving up too much in the zero to 300 meter range band. Accuracy, terminal ballistics, reliability, endurance, and system simplicity are at stake.

RECOMMENDED RIFLE FEATURES

The recommended rifle reflects our best attempt to combine training and development considerations, making tradeoffs which seem to have the highest probability of resulting in optimum combat performance. There is good and supportable rationale for each recommended rifle feature; however, all features are presented as candidates for test and evaluation.

Recommendations are made as product improvements to the existing M16 rifle system.

Recommendations are made under the assumption that M855/M856 ammunition will be developed and matched to a barrel which will result in acceptable accuracy, terminal ballistics, reliability, and endurance. It is very important to note that, to date, none of these requirements have been demonstrated.

The information in Figure 1 provides a brief comparison of features among the M16A1, the M16A2, and a recommended Army rifle. The recommended features are discussed in some detail in the following paragraphs.

The Sighting System

A reasonable measure of a unit marksmanship program may be to assure that every soldier has his rifle zeroed. There are several methods for recording zeroes; unfortunately, none of them work for the M16A1. The only positive way to check the zero is to move to a range and fire a shot group. Checking the first shot group fired by each soldier will indicate that major sight changes are required unless it is an exceptional unit. Why are soldiers not zeroed? A lack of training can always be blamed, but complexity in rifle design can also be a major factor. When the soldier goes down range today to inspect his zero target and finds he needs to make an elevation change, depending upon which sight/target combination is being used, one click of the front sight will move the bullet 1/2 square, 3/5 square, 3/4 square, 1 square, or 1-1/4 squares on the zero target, and when he turns the sight "up", it goes "down" to move the bullet strike "up", and all of this is dependent upon the availability of an 8-penny nail. It is impossible for most soldiers to keep track of the positive and negative numbers of sight changes. Even if they do not lose count of clicks, which are made from some unknown point, there is no practical way to confirm a sight setting. If fingernail polish or some other marking is used to identify a flush starting position, the real zero is

ITEM	M16A1	M16A2	RECOMMENDED
Front Sight (Standard)	Adjustable round post .065" wide. 1 click = 1 MOA.*	Adjustable square post .070" wide. 1 click = 1.4 MOA.	Fixed blade, .090" wide.
Front Sight (Low Light Level)	Adjustable round post .095" wide with luminous vial in center of post. 1 click = 1.25 MOA. Must be turned 2 clicks for vial to show = 2.5 MOA.	None.	A luminous dot on each sightguard.
Rear Sight (Standard)	Flip-type peep. Back is 2mm peep used for 250-m zero. Forward, marked L, is 2mm used for 25-meter firing (zeroing with point-of-aim/point-of-impact) and a zero for 375 meters. Windage adjustment is made with a flat slotted wheel, 1 MOA per click.	Flip-type peep. Elevation drum built into carrying handle has 25 clicks (1 MOA ea.) of elevation adjustment and markings for 3, 4, 5, 6, 7, and 800 meters. Back flip sight is 1-3/4mm and used for 300 through 800-meter firing. The forward flip is 5mm and is used from zero to 200 meters, with the drum set for 300 meters. Windage adjustments are with a drum-type knob, .5 MOA per click.	A single 2mm peep. A single elevation knob marked for 200, 250, 300, 25, 400, 500, 15, 600, 700, and 800 meters. Windage knob at rear. Each click equal to 1 MOA.
Rear Sight (Low Light Level)	Flip type peep. Back is 7mm peep used for low light level firing. Forward is 2mm peep marked L, which is the regular sight for 250-meter zero. Windage adjustment is made with a flat slotted wheel, 1 MOA per click.	None.	Two luminous dots on upper portion of receiver (or a single flip-up luminous dot located forward of the carrying handle) are aligned with front dots for shooting at night.

*A minute of angle (MOA) is equal to one inch at 100 yards or .7 cm at 25 meters.

Figure 1. Comparison of features among the M16A1, the M16A2, and a recommended Army rifle.

ITEM	M16A1	M16A2	RECO[illegible]
Recording of Zero	Almost impossible.	Very difficult.	Simple.
Visual inspection of Zero	Impossible.	Impossible.	Simple.
25-m Setting (Standard Sights)	Not by design.	None.	Yes.
25-m Setting (Low Light Level Sights)	None.	N/A.	Yes.
Mechanical zero can be placed on the rifle.	No.	No.	Yes.
Battlesight (A sight setting for 250 meters)	Yes.	No.	Yes.
Firing Mode	Semi and Auto.	Semi and 3 round burst.	Semi and Auto.
Barrel	Light weight 1:12" twist.	Heavy at muzzle end. Light weight at receiver and mid-barrel. 1:7" twist. (Heavy barrel currently being tested.)	Slightly heavier at receiver and mid-barrel. 1:9" twist.
Handguard	Triangular in shape. Left and right sections different. Held in place with a difficult-to-move slip ring.	Round in shape and constructed of more durable material. Upper and lower sections identical. Held in place by an easy to move slip ring.	Same as M16A2 except held in place with a securely fastened ring nut to provide rigidity.
Butt Stock	Standard.	Constructed of more durable material. 5/8" longer.	Same material as M16A2. Same length as M16A1. Option for adjustable length.

Figure 1. (continued)

destroyed when the sight is turned back to the flush position. This means that the quality of the zero is dependent upon the soldier's ability to accurately count clicks and not on his last firing performance. The zero needs to be verified because the sight has to be changed to align the sights with the MILES laser, to clean the front sight for inspection, to use .22 Rimfire Adapter, etc. The point is that a simple weapon design can contribute greatly to combat readiness. Things are already too complex. In its current form, the M16A2 will add to the problem. In the above example of changing a front sight (standard or LLLSS) with any of three zero targets currently in the field, the M16A1 results in five different amounts of movement as it relates to squares on zero targets. The M16A2 would add 1-2/5 squares, 1-1/8 squares, and something less than 3/4 square to the possible combinations. The new targets being fielded and our recommended sights will result in all sight movements of one click moving the bullet one square on the new zero target or one inch at 100 yards.

Front Sight

The adjustable front sight is the source of many problems. It should be a fixed blade. The size of the front sight blade should facilitate aiming, but it should also serve other purposes, e.g., assist the soldier to estimate range, establish lead on moving targets, hold-off for wind, etc. The .090 inch recommendation used in this paper would, of course, be adjusted to best accommodate all factors, after ballistic information has been confirmed.

Range Estimation

As a guide to assisting in the difficult task of estimating range, when a man appears to be the same width as 1/2 the sight post width, i.e., when the sight post will cover two men, it is the zero range of 250 meters; when it appears that the target is larger than one-half the sight width, it means the target is closer than 250 meters, and when the target appears smaller than one-half the sight width, it is at a greater range. The sight covers one man at 125 meters, two men at 250 meters, and three men at 375 meters. This sight/target relationship is shown in Figure 2.

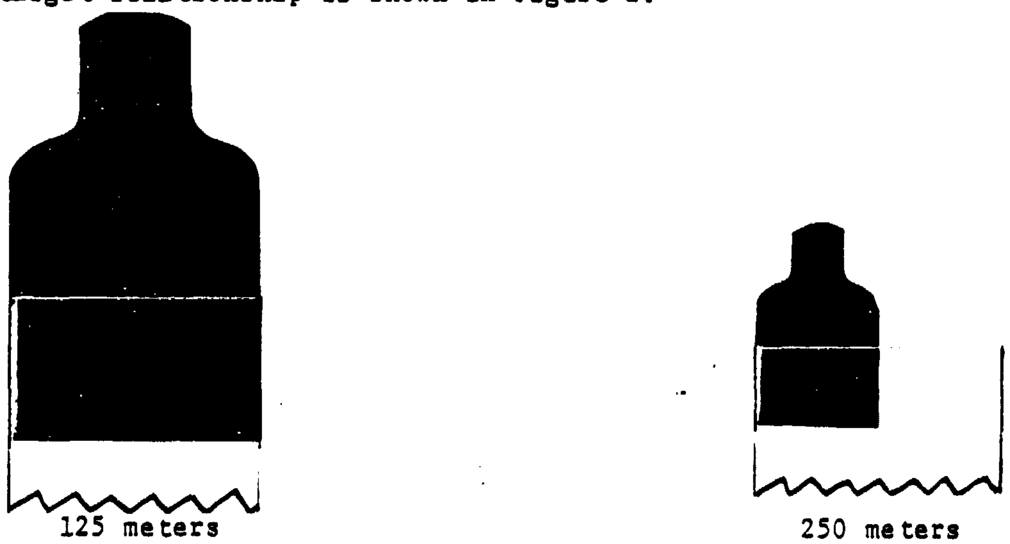

Figure 2. When the sight post is .90 inch wide, it will appear the same size as a man-size target at 125 meters and a man-size target will cover one-half of the sight at the battlesight zero range of 250 meters.

Moving Targets

Current plans call for the world-wide installation of moving target ranges within the next few years. These Remoted Target System (RETS) ranges, including an overwhelming scenario of moving and stationary targets, were initially planned to be used for BRM qualification and annual qualification for all soldiers. While final decisions have not been made concerning the use of RETS ranges, it is clear that simplified training procedures must be developed. The current lead rules are too complex: For a walking target 0 to 300 meters or for a running target 0 to 100 meters, split the front sight post with the leading edge of the target (A). For a running target 100 to 200 meters, place the trailing edge of the front sight post against the leading edge of the target (B). Leading the target by 1/2 of a sight post has been taught for medium range targets with considerable lateral movement (C). If the target is running at a distance of 200 to 300 meters, lead the target the same distance as the perceived width of the front sight post (D). This sight/target relationship is shown in Figure 3. This is too much for a soldier to remember and may be the reason that some moving target training results in decreased performance.

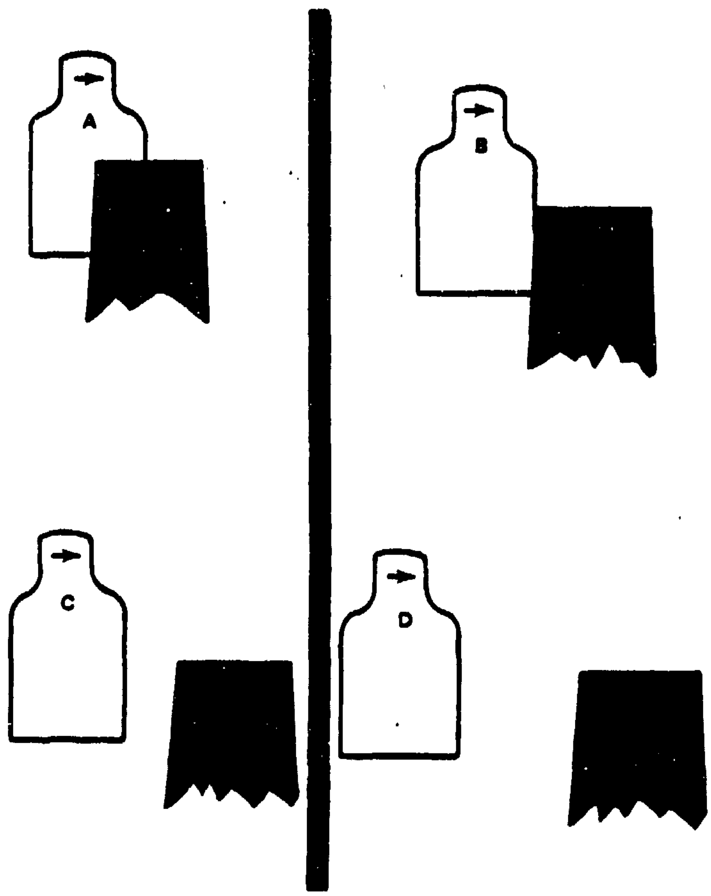

Figure 3. Previous rules for the engagement of moving targets.

The recommended .090 inch wide sight post will allow the teaching of one sight rule for all laterally moving targets at all ranges, walking or running, with no decrease in hit probability: Place the trailing edge of the sight at target center. This rule is shown in Figure 4.

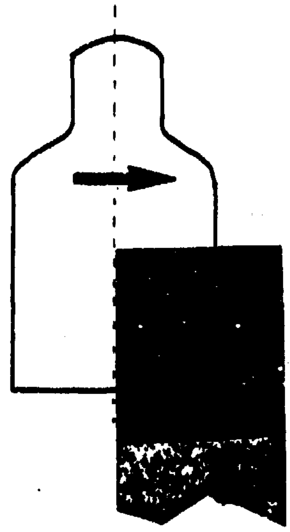

Figure 4. A single lead rule, place the trailing edge of the sight post at target center, results in good hits on most combat targets.

This rule causes lead to automatically increase as range to target increases. The perceived width of the target at various ranges provides for proper lead, e.g., at 15 meters, the center of the sight is one inch in front of target center, and at 150 meters, it is 11 inches in front, providing for good hits on most moving targets. This sight/target relationship is shown in Figure 5.

Rear Sight

Windage and elevation adjustments should be made with friction drums on the rear sight with numbers clearly indicated so the weapon's zero can be visually verified. Each click for windage or elevation should equal one minute of angle. When adjusting sights from the rear of a weapon, both windage and elevation adjustments are made in the direction of desired bullet strike. This sight, shown in Figure 6, will greatly simplify the zeroing process. To move the bullet left, the windage knob is turned left, moving the sight and the bullet strike left. To move the bullet up, the elevation knob is turned up, moving the sight and bullet strike up. Upon completion of zeroing at 25 meters, a tool is used to align the windage knob on "Ø" and the elevation knob on "25". Following this adjustment, the elevation is set at 250 meters, and all subsequent sight changes are made simply by clicking the knobs, e.g., when the MILES laser is used, the windage and elevation knobs are turned to align rifle sights with the laser beam and at the completion of MILES training, the individual is assured of having the correct zero on his rifle by turning the windage knob back to zero and the elevation knob back to 250 (for field firing) or 25 (for 25 meter range firing).

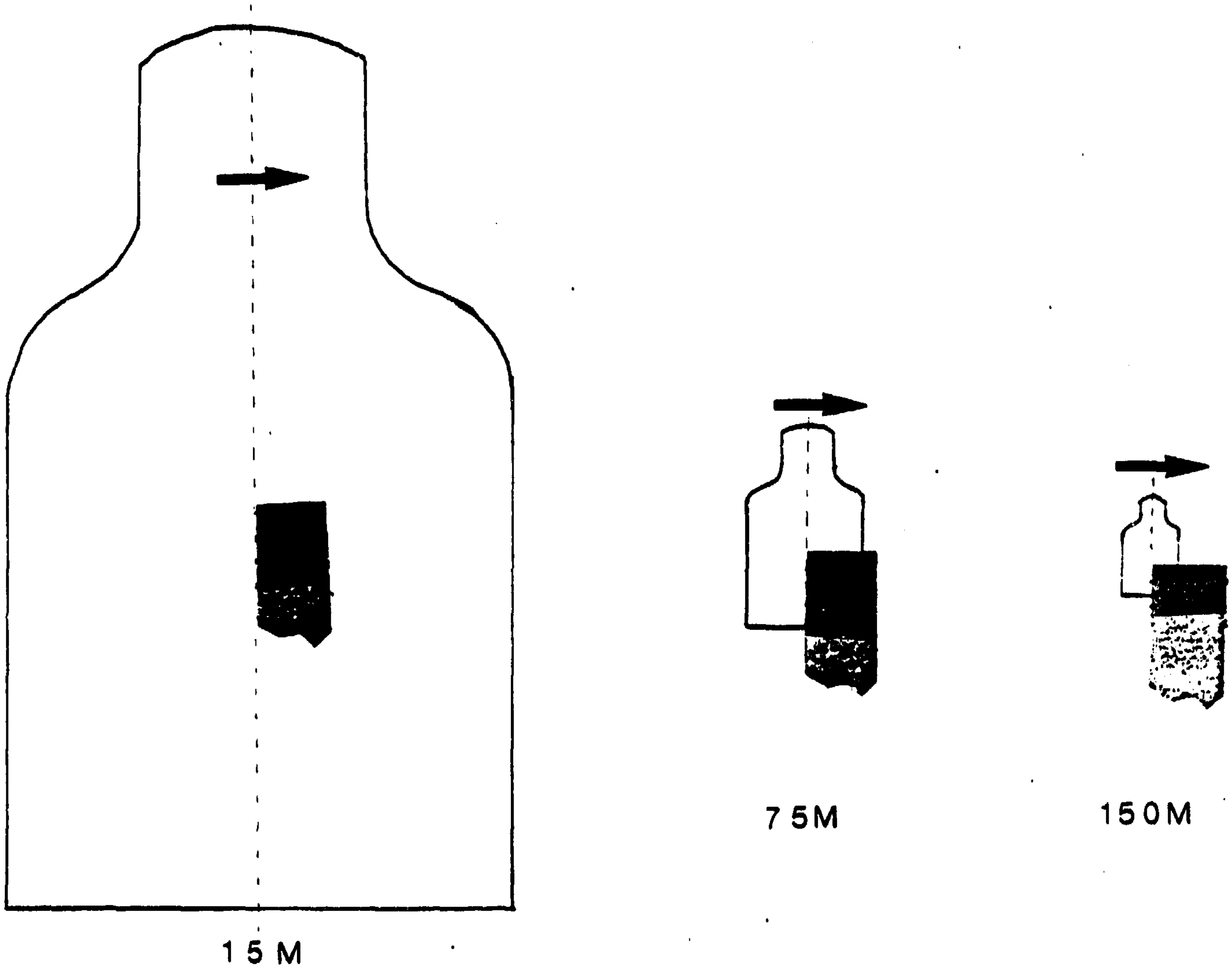

Figure 5. Placing the trailing edge of the front sight at target center provides a lead of a little over one inch at 15 meters, about five and one-half inches at 75 meters, and about 11 inches at 150 meters.

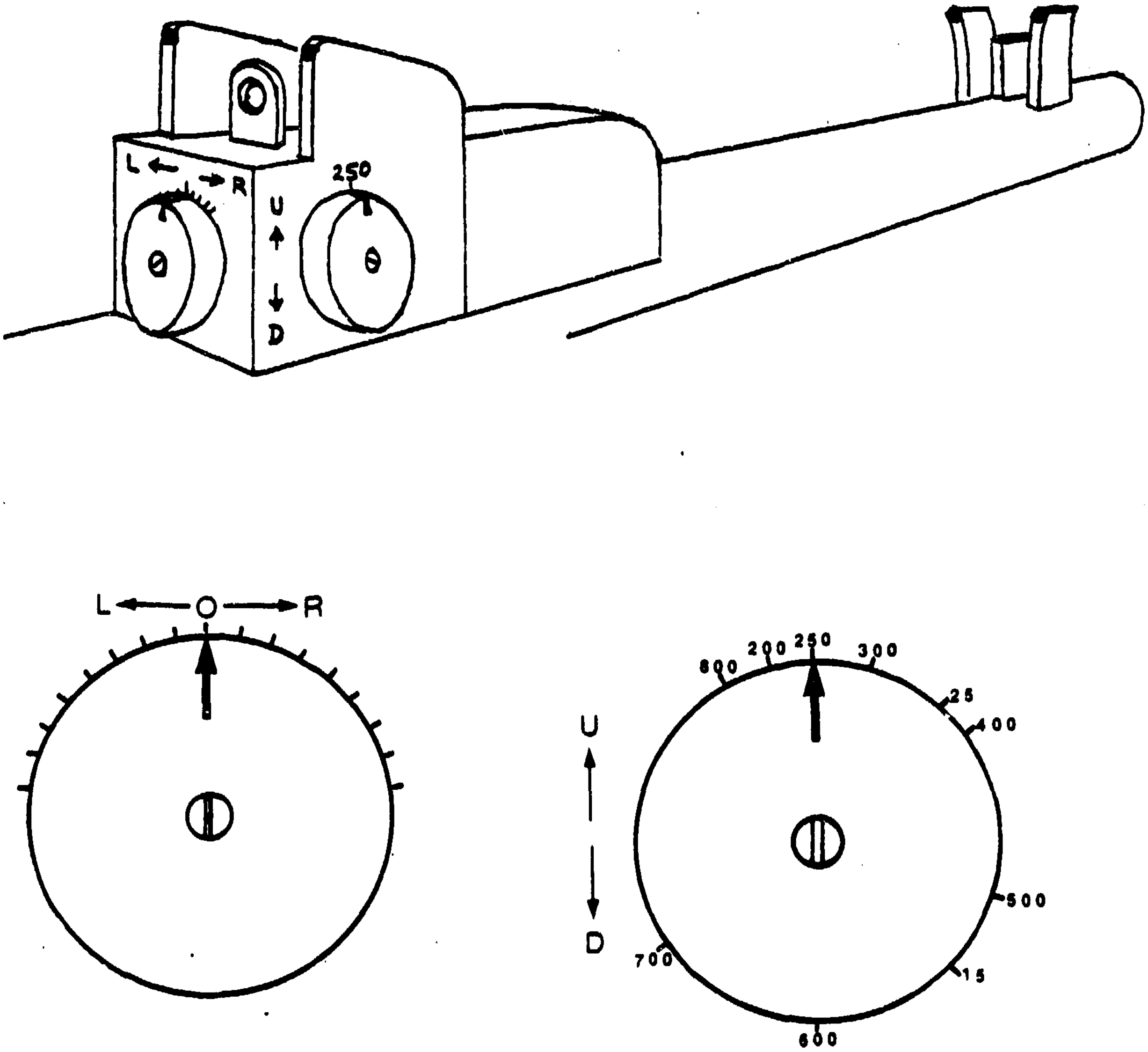

Figure 6. This sketch shows the location of the windage knob (rear of the receiver), elevation knob (right of the receiver), and luminous dots for rifle alignment at night (front sight guards and above the rear sight).

Peep Sight. The Marines plan to use a 5mm peep sight from zero to 200 meters, and a 1-3/4mm peep sight for ranges from 300 to 800 meters. The proposed sighting system uses a single peep sight and retains the 2mm aperture used on the M16A1. It is significant that the Army and Marines teach different uses of the peep sight. The Marines align the front sight within the aperture. The Army looks through the aperture at the front sight, relying on the natural centering ability of the eye for alignment. Our tests determined that the 2mm aperture provides an adequate field of view and good accuracy under a broad range of light conditions.

25 Meter Setting. While the Marines conduct limited training at 15 and 25 maters, the only primary Army ranges which provide precise feedback of bullet location are 25 meter ranges, and many targets have been developed and proven training-effective which allow for point-of-aim/point-of-impact at 25 meters for purposes of zeroing, skill practice, scaled silhouette firing, etc.

The Army's old and new zero targets are shown in Figure 7. The old zero target was confusing, difficult to use, and provided no indication of down range performance. Throughout the research effort on marksmanship, the complexity of information presented to the trainee was of concern. Using the Canadian bull zeroing target required that sights be adjusted so bullets would hit 2.4 cm below point of aim at 25 meters. Many soldiers were confused by this procedure. Some confusion could obviously be eliminated if the initial firings were conducted so that bullet impact was the same as point of aim. It was quite by accident we discovered that using the M16A1 long-range sight at 25 meters, and adjusting the bullet impact to coincide with point of aim, would produce a good 250 meter battlesight zero with the regular sight. The sketch in Figure 8 depicts the bullet trajectory.

The ability to shoot at scaled silhouette targets and hit where the rifle is aimed has an important training implication. The use of the new zero target allows the role of the 25 meter range to be expanded beyond that of merely providing for the zeroing of weapons. Several additional exercises have been developed based on scaled silhouette targets, which are designed to provide the same visual perception when viewed at 25 meters as actual targets viewed at actual range. For example, the six-silhouette target shown in Figure 9 represents targets at ranges of 75, 175, and 300 meters. It is used on the 25-meter range in a transitional role prior to subsequent field firing where only hit/miss feedback is available. It is also a valuable diagnostic tool at this stage of training. If a soldier cannot hit scaled silhouettes at 25 meters, additional training is indicated rather than advancing to the limited feedback environment of field firing. The silhouette targets can be used without the point of aim/point of impact capability, but the inherent confusion can be seen in the target in Figure 10 which was developed for use with the Low Light Level Sight System (LLLSS).

A capability is needed on the rear sight which allows for obtaining a zero by firing point-of-aim/point-of-impact at 25 meters. The recommended sighting system (shown in Figure 6) does this by providing a 25 meter setting on the elevation knob. When firing on a 25 meter range with a zeroed rifle, turning the knob to the 25 meter setting will provide for simple and effective skill practice training--the bullet will hit where the rifle is aimed.

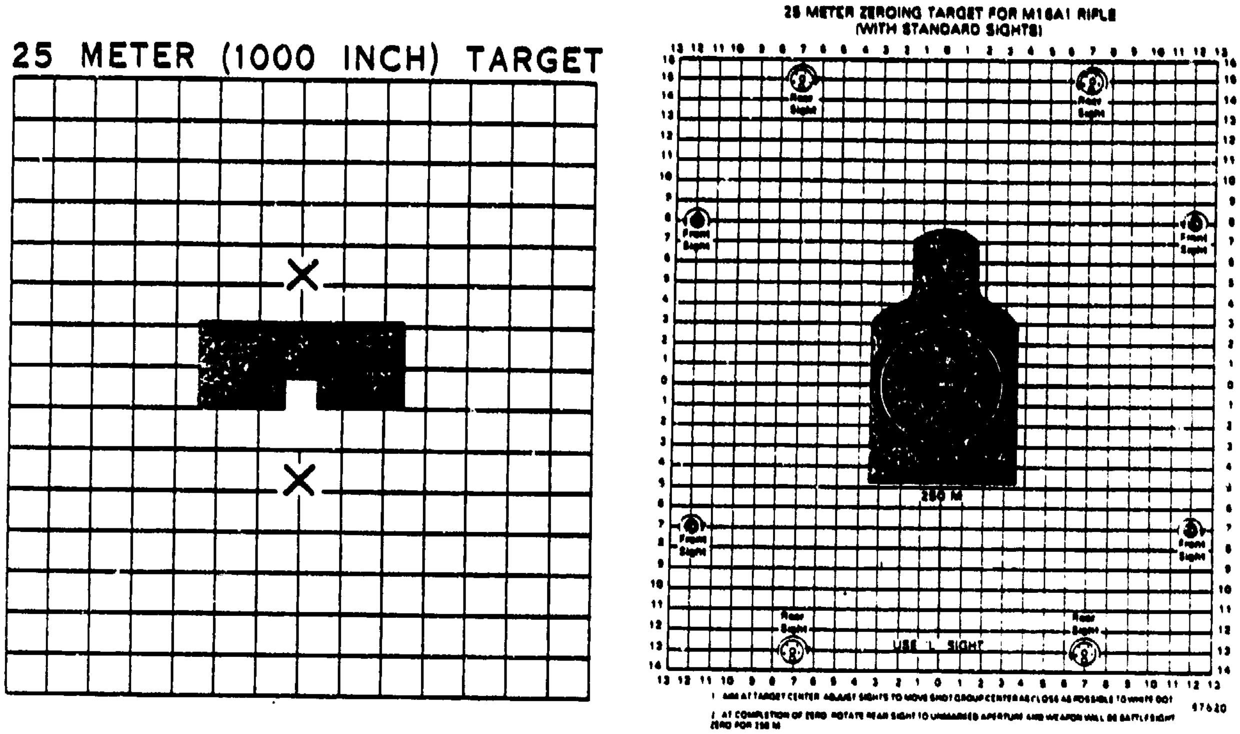

Figure 7. The old zeroing target (Canadian Bull) is shown on the left and the new silhouette zeroing target is shown on the right.

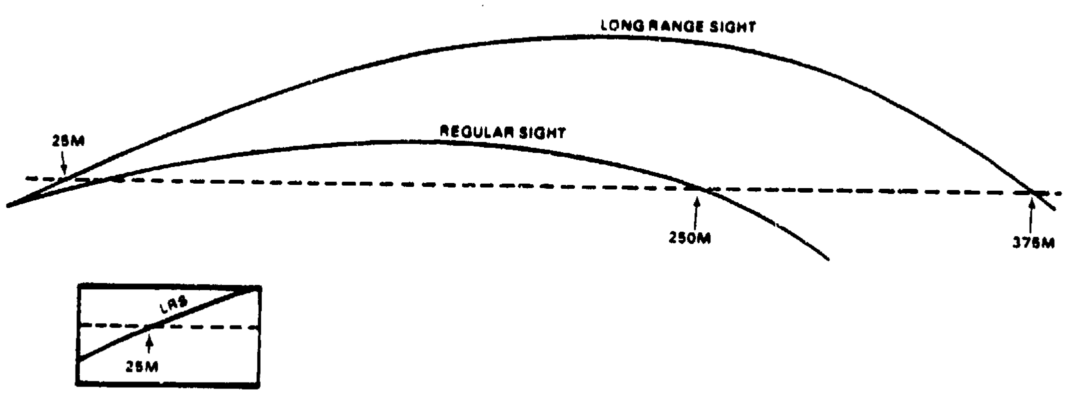

Figure 8. M16A1 trajectory, showing point-of-aim (dotted line) and the trajectory of the long range sight (top solid line) are the same at 25 meters.

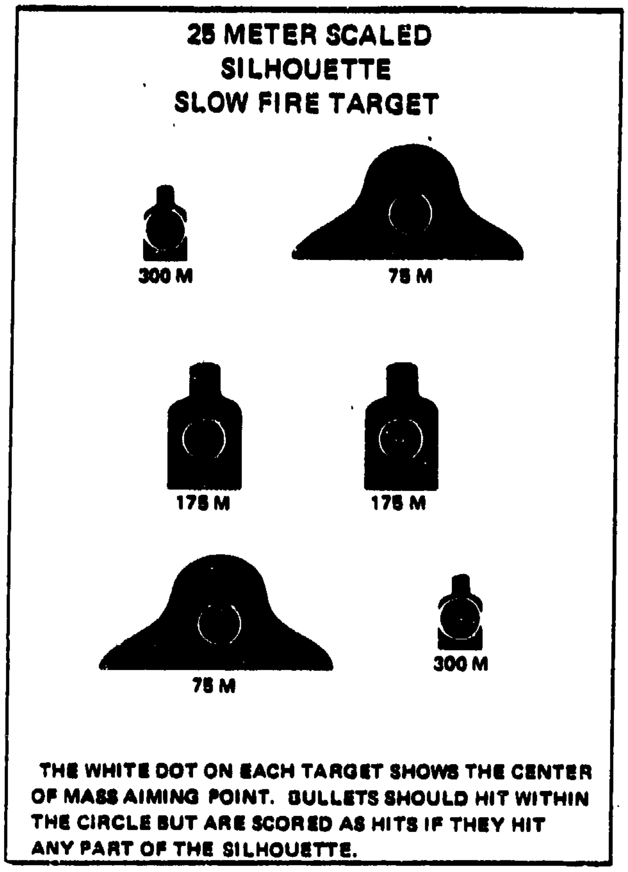

Figure 9. This is one of several scaled silhouette targets developed for training at 25 meters.

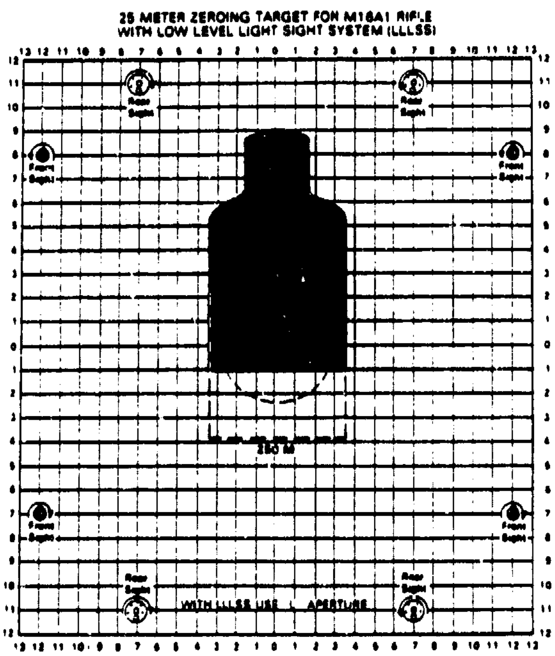

Figure 10. This target was developed to allow a scaled silhouette to be used for zeroing when rifles are equipped with the Low Light Level Sight System (LLLSS).

15-Meter Setting. Many Reserve and some Active Component units use the standard 50-foot indoor range for marksmanship training. The recommended sight provides a 15-meter setting (approximately 11 clicks from the battlesight zero) which allows for point-of-aim/point-of-impact training on the indoor range and a positive return to the battlesight zero.

Battlesight Zero. The Army has a requirement for a battlesight zero setting on the rear sight, i.e., a setting which provides a high probability of target hit with center-of-mass aiming out to the maximum allowable range, a zero of 250 meters, which will allow for the engagement of targets out to 300 meters with minimum adjustment of the aiming point. The recommended rifle has a clearly marked battlesight setting—the setting which will always be on the rifle unless a special target is being engaged. The idea of making numerous sight changes during the course of a battle has no support from available data.

Night Sight. An effective night sight should be developed concurrently with the new rifle. Peep sights are inappropriate for use at night (5mm or 7mm) and luminous sights which must be placed on the target (LLLSS) tend to obscure the target. One idea that ARI plans to test uses luminous dots. A system which provides for luminous dots on the front sight guards can be used to align the front of the rifle with the target and luminous dots on the rear of the rifle (See Figure 6) can be used to align with the front dots, bringing the rifle into proper alignment while keeping line of sight between the eye and the target completely clear of sighting devices or luminious material. The resulting sight picture is shown in Figure 11. Another version of this night sight uses one dot for rear alignment, placed high at the forward portion of the receiver and flipped-up for use. It may also prove useful when wearing a protective mask, eliminating some or all of the parallax caused by rifle cant.

Figure 11. Rifle alignment at night is accomplished by aligning the two front dots in line with the two rear dots and putting the target in the center.

AUTOMATIC FIRE

The elimination of automatic fire is considered to be a mistake. It solves no problem and creates many. There should be a very careful analysis conducted to determine just what the issues are.

One of the reasons the M16 was acquired was because soldiers in combat felt they were being outgunned by an enemy armed with an automatic AK47. Many times it is a very close call as to which side has fire superiority. The psychological impact of fully automatic fire can often make the difference in the unit's perception of how effective their fire is. There are also some data to suggest that a soldier is more willing to expose himself and return fire if he has a fully automatic weapon, as opposed to a more controlled way of delivering fire. It has been well established that, during World War II and Korea, a large percentage of soldiers failed to fire their semi-automatic weapons during some enemy contacts. In Vietnam, armed with a fully automatic weapon, almost all soldiers returned fire. Much of the Vietnam firing was "wasted", i.e., it didn't hit anybody, however, it was a rare exception when individuals or units got into trouble because they had expended all of their available ammunition. The point can be made that there is nothing wrong with firing a lot of bullets if ammunition stocks are retained at safe levels. Considerable ammunition is conserved when 85% of a unit fails to fire their weapons, and considerable ammunition is expended when all unit members engage targets with full automatic fire. While good training and good leadership should keep the Army between these two historical extremes, the question of which alternative is wiser should be addressed.

Reliability is perhaps the most important feature of a combat rifle. The "problem" with the M16 in Vietnam was reliability--it would not shoot every time the trigger was pulled. The burst control mechanism degrades reliability -- a serious problem.

The soldiers in Vietnam, including leaders, were not trained to employ rifle fire effectively. But it was not a one-bullet-for-one-kill environment. Most firing was directed at unseen targets, and in small unit rifle versus rifle contacts, the fully automatic rifle may be what gave our soldiers the edge. Whether or not the fully automatic rifle really made any difference, soldiers thought it did. And accordingly, they went into fire-fights with full confidence that they would prevail, and they did. There must also be careful consideration of the fact that all potential enemies have individual weapons with fully automatic capabilities.

An extensive analysis of the Infantry and Mechanized Infantry ARTEP's has been conducted to determine rifle requirements associated with each task within each ARTEP mission. There are numerous situations identified within the ARTEP and within the doctrinal manuals where fully automatic fire would seem to be the most appropriate and effective mode of fire--clearing buildings and defending buildings in MOUT environments, final stages of an assault on an enemy position, the enemy's final assault on friendly positions, ambush requirements, reaction to ambush, engagement of aircraft, placing effective suppressive fire on enemy ATGM gunners, placing effective fire on exposed masses of troops (when the first burst will disperse the target), placing effective fire on exposed vehicle drivers/commanders when they are moving rapidly and visible for brief periods, etc.

During the limited research we have conducted in automatic fire--experimenting with burst size, various holding positions, etc.--we are finding that three-round bursts may not be the optimum burst size. In the majority of bipod-supported automatic fire holding positions, firing up to five and ten round bursts, the third round will many times find the limit of the group size, with subsequent rounds moving back in toward and around the initial aiming point (see Figure 12). Therefore, an increased hit probability may occur with a five or six round burst on target, as opposed to two three-round bursts. Also, some targets do not stay around for a second burst, and sometimes the firer is not around for a second burst.

Heckler & Koch, Inc. has recently developed a new rifle which fires caseless ammunition, designated the G-11. This rifle incorporates a three-round burst control which appears to accomplish the intended purpose of a three-round burst control, i.e., it distributes three rounds into a man-sized area, which may compensate for aiming error and may result in higher hit probability for three rounds on a given target than for three single rounds. This is accomplished because the rifle has very low recoil and a cyclic rate of 2000 rounds per minute that has been timed to the recoil pattern to provide optimum dispersion of three rounds in a single burst. Because this works on the G-11, is no indication that it works on the M16, which has much more recoil and a much slower cyclic rate of fire. Also of some significance is that the G-11 has a fully automatic setting.

It also is important to note that the proposed three-round burst control on the M16A2 does not recycle, i.e., if one or two rounds are fired because the trigger is not held long enough, a magazine change is required, or in the event of a stoppage for any other reason, the next pull of the trigger will not result in a three-round burst, but will result in one or two shots being fired. In other words, even when the burst control is properly working, it may result in the firing of one, two, or three shots. This is a frightening consideration for the soldier who must burst through a doorway to face a couple of waiting enemy soldiers.

There are two primary arguments for the three-round burst control--it is more accurate and it conserves ammunition. The first claim (more accurate) is not true. The second claim (conserve ammunition) is not supported by data. Using the assumed rationale, a two round burst would always be more accurate and conserve more ammunition than a three-round burst and firing single rounds would be a significant improvement in accuracy and conservation of ammunition. Accuracy and conservation of ammunition should be discussed as separate issues. If a three-round burst is more accurate than a five-round burst, that must mean that there is a higher probability of hitting a given target with a three-round burst than with a five-round burst. That is not true, because, all things being equal, the first three rounds of a five-round burst will strike the same place as the rounds from a three-round burst--since the third round departs the barrel before the fourth round is fired. As for conserving ammunition, a thirty-round burst will result in the expenditure of thirty rounds in a little less than 2 1/2 seconds, and ten 3-round bursts can result in the expenditure of thirty rounds in five seconds. The time difference in these two modes of fire is very small, resulting in the expenditure of a similar amount of ammunition for a given engagement. This assumes that a soldier who would hold the trigger for the duration of a thirty-round

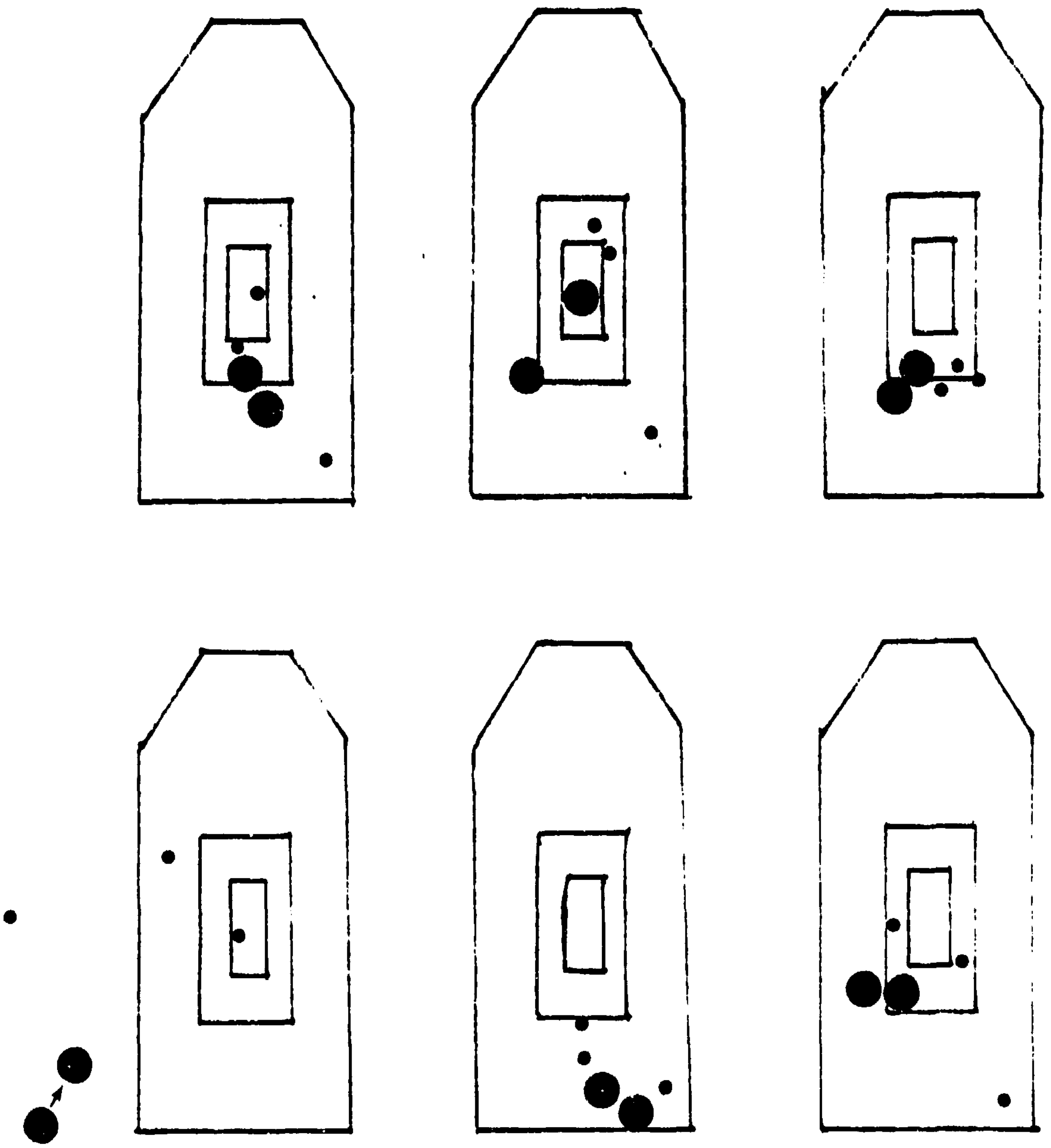

Figure 12. These targets were fired with a bipod supported M16A1 using 5-round burst at distances of 50 and 100 meters. Projectile location equipment was used to accurately plot the firing sequence and location of each round. The first three rounds of each burst are represented by the small dots and rounds four and five are represented by the large dots.

magazine (fully automatic) would also fire a full magazine (burst control) as fast as he could pull the trigger. As discussed previously, this may not be a valid assumption because the soldier may elect not to expose himself and/or his position to fire one, two, or either three rounds per trigger pull. While ammunition expenditure in each mode of fire may be similar for a given engagement, there may be a vast difference in the effectiveness of the fire. During close-in fighting, fully automatic fire can be used as a very effective means of walking fire into a target or to quickly saturate an area with fire. The burst control can serve to reduce both speed and accuracy.

It is the responsibility of the combat leader to control burst size and conserve ammunition, and that responsibility cannot be delegated to a mechanism in the rifle. When troops are frightened and are convinced that fully automatic or burst fire will offer them greater protection, they can expend a thirty-round magazine every few seconds. Additionally, if the three-round burst control causes the commander to be less diligent in his responsibilities, then actually more ammunition could be expended. Improved training in the employment of fire is probably a better solution.

In May/June 1982, an experimental Advanced Rifle Marksmanship (ARM) program was implemented at Fort Benning for the Infantryman in OSUT training. Primary additions to the program include these periods: Rapid Semi-Automatic Fire, Suppressive Fire, Quick Fire, and Engagement of Moving Targets. A principle focus of ARM is to improve skills beyond the BRM level in the rapid application of basic shooting fundamentals, to allow an aimed shot to be placed in a target area every one or two seconds--resulting in a large volume of very accurate fire with maximum conservation of ammunition. Supppressive fire is taught on a scaled landscape target to begin teaching how to shoot at unseen targets, e.g., when enemy fire is being received but no enemy can be seen and fires must be directed at a fence line, wood line, building, puff of smoke, etc. Automatic fire is used on one target, fired in three-round bursts, to demonstrate the superior accuracy of rapid semi-automatic fire. The intent is not to show that automatic fire is ineffective, but to develop an appreciation for the relative accuracy of various types of fire. When the soldier's life is threatened and he believes that deliberately aiming each shot or that rapid semi-automatic fire is the optimum way to expend available ammunition, the combat leader will have a manageable job of controlling fires and conserving ammunition. On the other hand, there are special situations when a five- or ten-round burst will save the soldier's life and assist in unit mission accomplishment.

This mis-utilization of automatic rifle fire is reflected in every qualification course. To improve scores, just flip the selector to semi. It appears logical that if automatic fire was being properly employed in a realistic setting, automatic fire would result in a higher score than semi-automatic fire. Currently, all rifle training is designated as automatic or semi-automatic and the soldier is not required to select a mode of fire to fit the situation. Consideration should be given to the development of a rifle course of fire which will vary the nature of targets, tactical situations, ammunition availability, etc., and will result in the highest possible score being obtained when the most effective firing techniques are employed, e.g., well aimed shots, rapid semi-automatic fire, quick fire, or automatic fire.

The issues associated with automatic fire are complex. The collection of valid data is complicated due to a void of information concerning automatic fire feedback. The Army does not have adequate feedback capabilities for semi-automatic or automatic fire. The Marines have excellent facilities for semi-automatic fire but no capability for recording automatic fire. Projectile location equipment which shows the precise location of each round and the sequence of each round in a burst would provide a basis for making more valid decisions concerning automatic fire. Adding to the information void is that no alternatives were evaluated for the M16A2; one muzzle compensated flash suppressor was coupled with a three-round burst control and the majority of rounds fired were lost. In the absence of objective data, it may be appropriate to survey combat veterans as to which they would prefer for their personal defense weapon during close combat--automatic or burst control (none of the thirty Marine test subjects had combat experience).

The results of a combat veteran survey coupled with the existing data (the burst control adds no capability to the rifle, the burst control requires nine new parts, the burst control requires additional training, and the burst control was the cause of several weapon malfunctions during testing), and a test which could not be won with semi-automatic fire would probably result in retaining the M16A1 lower receiver which has been refined into a dependable and reliable system during 15 years of combat and training.

THE BARREL

Heavy Barrel. The light weight barrel of the M16A1 is prone to external pressure, and our firing tests have revealed large differences in bullet strikes based on these stress extremes, i.e., a hasty sling as opposed to a bipod position with downward pressure (see Figure 13). It is proposed that only sufficient weight be added to the barrel at the receiver and mid-barrel to help the barrel bend problem and that this be coordinated with a more securely fastened handguard to help provide rigidity while retaining light weight. A heavy barrel has been tested and there may be plans to incorporate it as a preplanned product improvement if it proves to be adequate; however, the goal is not a heavy barrel, but the elimination of serious bullet displacement resulting from various holding positions. Another consideration must be to retain sufficient cooling air space, already reduced, between the barrel and the handguard.

Barrel Twist. The SAW has a 1:7 twist, because it was reported that this amount of twist was required to stabilize the tracer round at extended ranges. No alternative to a 1:7 twist has been tested for the rifle. The general rule seems to be that, for bullets of the same diameter, more twist is required to stabilize a round in flight as the length of the round increases. Our measurements indicate the following lengths:

- Current ball (M193) - 19 mm
- Current tracer (M196) - 22-1/2 mm
- New ball (XM855) - 23 mm
- New tracer (XM856) - 29-1/4 mm

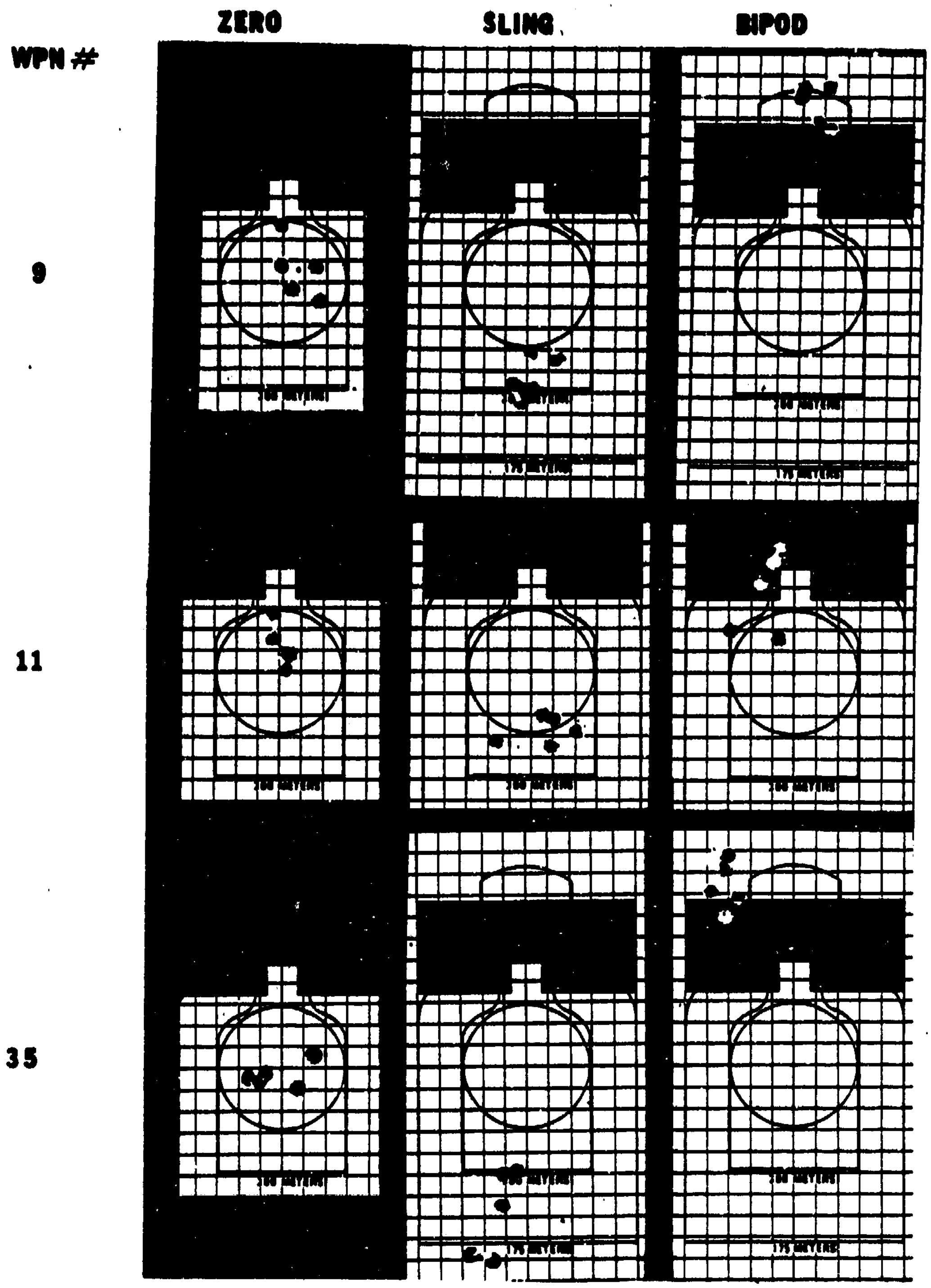

Figure 13. These targets were fired with three different rifles, using the same aiming point for all three targets--no pressure for zero, a tight hasty sling, and a bipod with downward pressure on the stock.

While any alternative must be tested, previous firing tests have confirmed that a 1:9 twist will provide for stability of a bullet similar to the new ball round. Reducing barrel twist to 1:9 will result in less stress on the bullet, barrel life will be improved, and barrel fouling will be reduced. While this twist may not fully stabilize the tracer round to maximum range, the rifle tracer is normally used as a marking round at extended ranges and precise accuracy is not required.

The M16A1 has one twist (rifling) for each 12 inches of barrel length and it has very effective terminal ballistics against personnel targets. It is generally accepted that less bullet stability will enhance terminal ballistics. Therefore, the increased twist of the M16A2, one twist in seven inches, should be tested against a one in nine twist barrel, which would probably produce better terminal ballistics against personnel targets.

A very important consideration is that reducing twist to 1:9 will probably improve accuracy at all ranges, particularly at 25 meters and in the primary range band out to 300 meters. A general rule is that minimum twist should be used to stablilize the round. Any additional twist will increase variability, causing the bullet to move in a corkscrew-type pattern at closer ranges. With the Army dependence on 25-meter ranges, this factor is much more important to the Army than the Marine Corps. An example of appropriate twist may be seen in the Army Marksmanship Unit rifles which have a 1:10 twist for firing at ranges up to 1000 yards. When the same type rifle and ammunition is used for 300-meter competition, the twist is reduced from 1:10 to 1:14 to obtain greater accuracy. From reviewing available firing data and giving consideration to terminal ballistics, employment ranges, barrel fouling, accuracy, and compatibility with M193 ammunition, a 1:9 twist appears optimum for the Army rifle.

Tapered Slip Ring. The tapered slip ring has been designed to allow easy removal of handguards; however, M16 rifles could probably go through a complete war without handguards being removed and weapons reliability and accuracy would not be affected. It does appear that a very secure slip ring, perhaps even one that screws securely and tightly into position, could assist in providing some rigidity to the barrel, eliminating some of the sensitivity to stress while retaining light weight. In other words, shooting accuracy should be increased at the expense of easily removed handguards.

Muzzle Compensator. The muzzle compensator was developed to allow for more effective automatic firing; however, no variations have been tested and the muzzle compensator has been used only for firing three-round bursts. It would appear logical to determine the type of fire to be employed and the primary firing positions to be used and then modify the muzzle compensator for optimum results. Also a close look at the effectiveness of flash suppression is warranted, because a portion of the suppressor has been closed.

STOCK LENGTH

The stock should not be increased in length. Many smaller soldiers, mostly female, cannot comfortably position their eyes close enough to the rear sight now. The longer stock is appropriate for males on the KD firing range. However, with consideration for normal soldier activities associated with personnel carriers, fighting vehicles, helicopters, and fighting in cities, the current length should be retained, with consideration for an adjustable option.

The stock length issue involves an important difference in how the Army and Marines teach aiming. The Marines place emphasis on the precise alignment of three items; the target, the front sight, and the rear sight. The Army teaches a simplified aiming procedure which is faster and more accurate for close-in, short-exposure, pop-up targets; alignment of only two items--the front sight and the target. With the eye focused on the tip of the front sight, the natural and instinctive ability of the eye to center objects and to seek the point of greatest light (which is the center of the aperture) will result in correct sight alignment. But for this simple aiming procedure to work, the eye must be placed close to the rear sight.

UNIFORM CONSTRUCTION

A problem with the M16A1 is that variability among weapons makes it impractical to have a common starting point from which to zero weapons. Accordingly, all soldiers (trainees especially) start firing with a weapon which may not hit the zero target, even if sights are properly aligned and proper firing techniques are employed. Therefore, target misses normally result in the rotating of difficult to move sights. In effect, the new soldier is forced to zero the rifle before he learns how to shoot--resulting in wasted ammunition, lack of confidence, and a frustrating training experience.

To overcome this, we have experimented with various collimater devices which would allow a mechanical zero (alignment of the sights to the bore) to be placed on the rifle prior to rifle training, but we have not found one accurate enough for use on the M16. More uniform construction of weapons would assist the zeroing problem and the zeroing of Starlight scopes, but a requirement should be established to produce a collimater, improving weapon construction as necessary to obtain necessary accuracy. This capability would allow initial marksmanship training to focus on the teaching of shooting fundamentals, with refinement of individual zeroes undertaken after shooting skills have been developed.

The advantage of going to the range (or combat) with a mechanical zero on the rifle was demonstrated during an experiment involving twenty subjects firing on the Weaponeer, the Multi-Purpose Arcade Combat Simulator (MACS), and firing live bullets at a 200-meter silhouette target. Of the twenty subjects, thirteen had little or no shooting experience, five were experienced shooters, and two were world-class shooters. The same M16A1 rifle with the same sight setting was used for all shooters. Ten shooters received precise feedback, using Locaton of Miss and Hit (LOMAH) equipment, for each of the first ten rounds fired. This allowed them to adjust their aiming point after the first round; therefore, only the first round each person fired from the rifle is shown in Figure 14. It is interesting to note that every person hit the 200-meter target with the first round fired, and the average of the ten shots is very close to target center.

The other ten shooters received only hit/miss feedback for their first ten shots; therefore, they had no reason to adjust point of aim unless they missed the target. Their targets are shown in Figure 15. It should be noted that only 13% of the bullets missed the 200-meter target, and the shot groups indicated no sight change necessary for at least seven of the ten shooters.

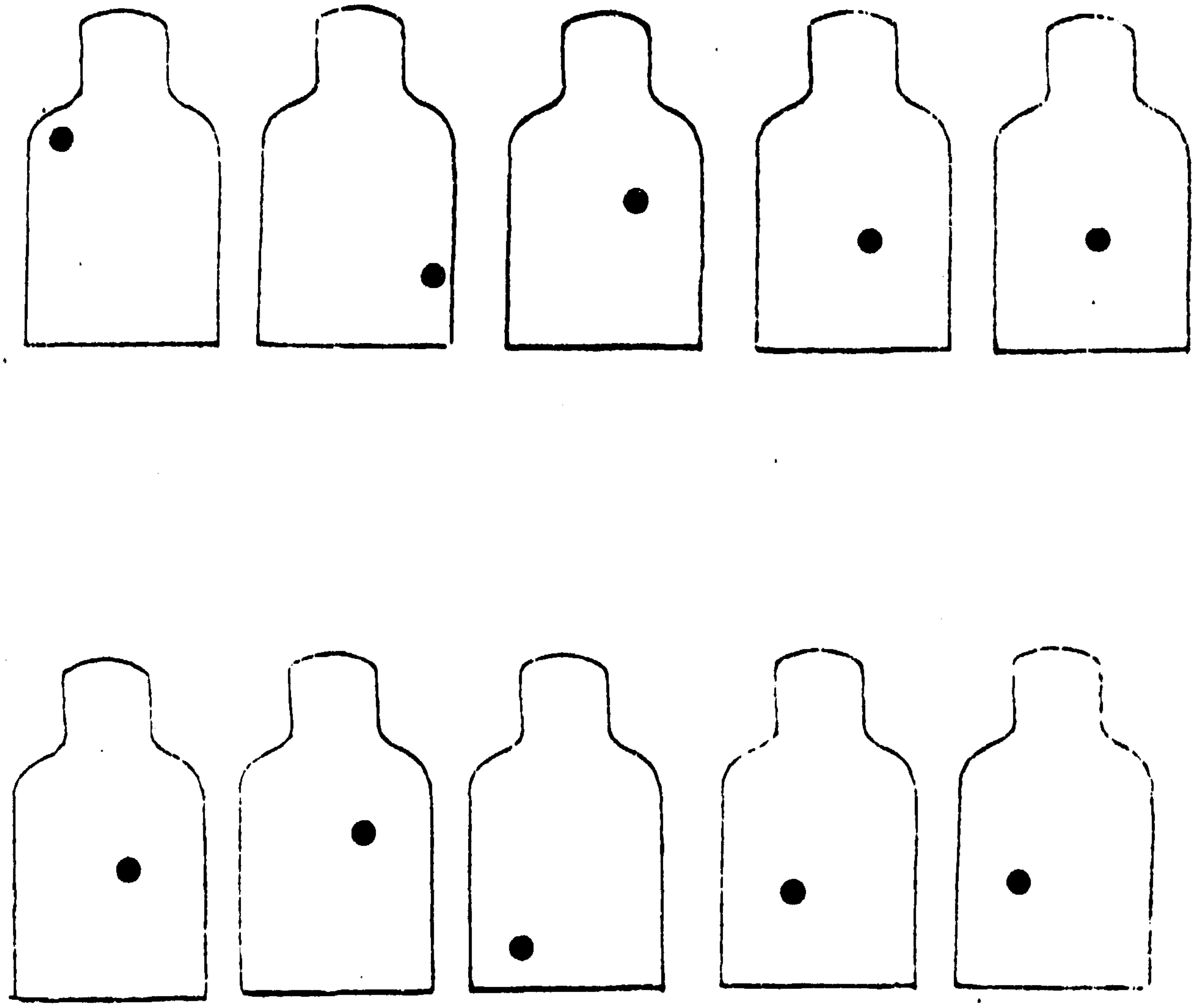

Figure 14. A target at a distance of 200 meters was engaged by 10 different people, using the same M16A1 rifle and the same sight setting. The first round fired by each person is shown. For six of the subjects, this was the first round ever fired from an M16 rifle and for three of the subjects, this was the first time they had fired a real weapon. However, all subjects had received limited training on the Weaponeer and the Multipurpose Arcade Combat Simulator (MACS). Note that each person hit the target and that the average placement of the 10 shots is near target center.

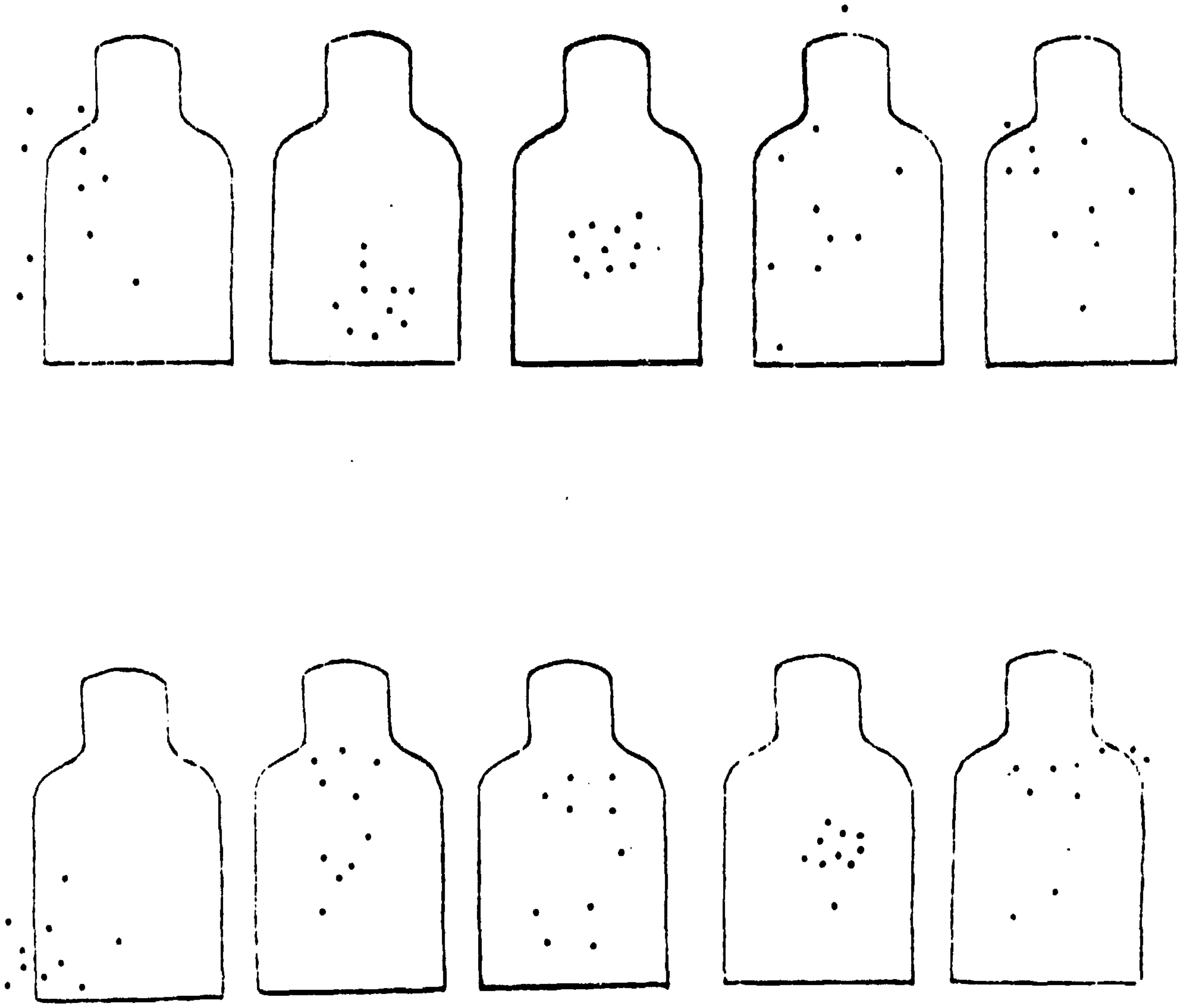

Figure 15. A target at a distance of 200 meters was engaged by 10 different people, using the same M16A1 rifle and the same sight setting. Only hit/miss feedback was provided during the firing of 10 rounds each. Five of these subjects had little or no previous shooting experience, but had received limited training on Weaponeer and the Multipurpose Arcade Combat Simulator (MACS). Note that 87% of the bullets were target hits and that sight changes are not needed for at least seven of the ten firers.

The capability to align all new or newly issued rifles to closely match the rifle used in this test has important training implications. For example, a major problem at all Army Training Centers (ATC) is getting trainees zeroed. Too many soldiers fire fifty to sixty rounds and still cannot zero. For an individual who has learned basic shooting fundamentals, the zeroing process is fast and simple, requiring only a few rounds of ammunition. For an individual who has not acquired basic shooting skills, who cannot shoot tight shot groups, and cannot place shot groups in a consistent location, zeroing is impossible, e.g., trainees who cannot zero with eighteen rounds. It is also illogical that the soldier is required to perform the most difficult shooting task within the BRM Program (the zero requirement equates to hitting a 300-meter target every time) as the first shooting task. Some soldiers arrive on the record fire range without having a good zero. A rifle which can be mechanically zeroed has potential for making significant improvements to the marksmanship program. It would allow learning to occur in a logical sequence--learning how to shoot and then zeroing.

OTHER FEATURES

Magazines. Numerous weapon malfunctions occur because of bad magazines. There is no effective procedure for getting bad magazines out of the system, or to be certain that a magazine has been the cause of the problem. Consideration should be given to building a sturdier magazine, a more positive operating magazine, and/or one that fits more securely into the magazine well. This appears to be a very serious problem, and it deserves attention during the development and testing of the new rifle.

Trigger. Trigger pull can be improved. Many M16 rifles have been observed to have a hard, creepy trigger pull. The trigger should maintain a clean, crisp break during its useful life. Additionally, the burst control cam on the M16A2 results in a different trigger weight/feel for each of the three cam positions.

Serviceability Checks. Available serviceability checks for the M16A1 will eliminate unserviceable rifles; however, the passing of all serviceability checks is no indication of rifle shooting quality (see Figure 16). Development efforts for the new rifle should include built-in serviceability checks which will ensure that accurately firing weapons can be turned out of the maintenance units.

Weapon Protection. Consideration should be given to providing necessary items to prevent dirt and sand from entering the weapon. For safety reasons, the weapons many times are carried with dust covers open, bolts to the rear, magazines removed, and without a muzzle cover. Features should be considered such as: a dust cover which is spring-loaded to stay closed except for ejection, rubber plugs or bands to protect the magazine well and other potential entry points from dirt and grime, etc.

Telescopic Sights. It has been proposed that telescopic sights should be mounted on all combat rifles to improve the soldier's combat firing performance. This idea has face validity in that the telescope provides a single focal plane (simplifies teaching of aiming), improves target acquisition, and

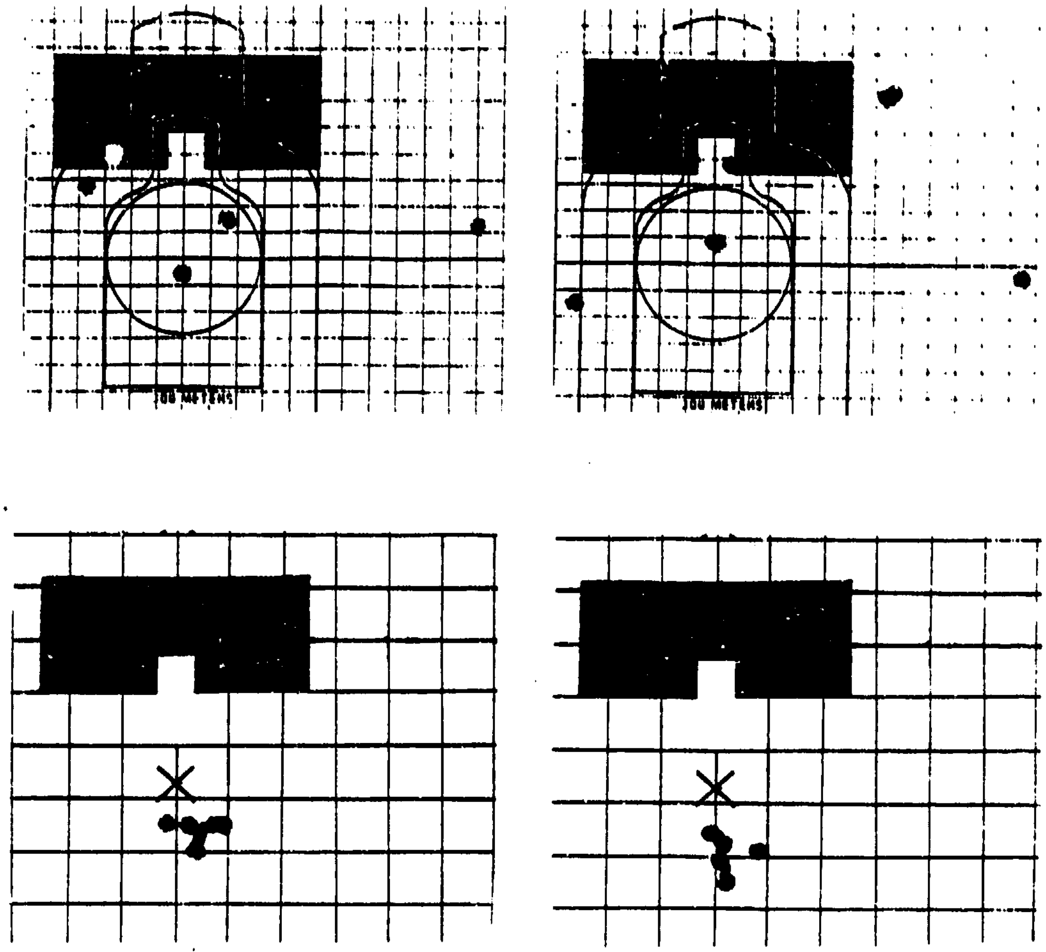

Figure 16. Serviceability firing checks. These four targets were fired by tha same firer with the same rifle from the same supported position on a 25 meter range. Before firing the top two five-round groups, the rifle passed basic serviceability checks: barrel straightness, headspace, bore erosion, muzzle erosion, and trigger pull. Additionally, a physical measurement of the bore, a check of torque readings, and the recording of muzzle velocity for several rounds found those measures to be well within specifications. The bottom two five-round groups were fired after the upper receiver was replaced. With knowledge that the rifle would not shoot accurately, the decision to replace the upper receiver was a judgment call.

reduces aiming error. However, in addition to the obvious problems of cost, durability, requirements for rifle re-design, etc., the scope may not improve shooting performance against what is considered to be the primary enemy threat (represented by the Remoted Target System Defense Test Range). Therefore, performance improvement should be demonstrated before serious attention is given to telescopic sights. The term "aiming error" is often used to describe "total system error." Therefore, it may be assumed that a telescope will eliminate much of the "total system error." In fact, it will not correct the soldier error responsible for most target misses -- improper trigger control. However, the major factor to be considered in a decision to install telescopes on combat rifles is the impact of directed energy weapons (DEW). Future battlefields will probably contain high power laser weapons which will put all direct view optics into serious jepardy. Magnifying optics compound the eye's vulnerability to laser damage. Given these considerations, telescopic sights offer no panacea to the problems with rifle sights.

Additional Items. Additional items that should be checked during the test and evaluation for the new rifle are: use of MILES equipment, use of .22 rimfire adapter, and firing while wearing a protective mask.

DISCUSSION AND CONSIDERATION OF ALTERNATIVES

The rifle which has been type classified and designated the M16A2 is considered to be unsuitable for Army use, and purchase under any circumstances is not recommended.

Time was a major factor with the Marine development effort. They were short a large number of rifles and had to purchase new rifles. It did not make sense to puchase old rifles when new rifles were ready for testing. Therefore, they decided to purchase new rifles and stepped up the tempo of testing activities accordingly, taking what Colt had available on-the-shelf and conducting a quick Modified Operational Test (MOT). When the system (M16A2 firing XM855 ammunition) failed to meet requirements for major portions of the test, it would seem appropriate to have delayed testing and new weapon purchases until the system could undergo successful operational testing. But under time pressure, the Marines have ordered combat rifles which failed to meet minimum standards for accuracy, durability, or reliability.

It is desirable for all services to use the same rifle; however, there is no firm requirement that Marine and Army rifles be exactly the same. One alternative is to develop an Army rifle with a minimum number of parts different from the M16A2 and with all major parts interchangeable with the Marine rifle.

If a requirement exists for the Army to purchase new rifles now, the only low-risk alternative is to purchase M16A1 rifles. This would allow time for the development of the rifle we recommend, time to develop appropriate targets, time to develop appropriate training literature, and time to develop appropriate ranges.

New M16A1 rifles could be ordered with plastic parts made of the new material, and new plastic parts could be purchased as replacement items. This would solve any parts breakage problem while the ammunition, sights, and barrel are being developed. It is believed that refinements to the sighting system can only be made after the ammunition has been developed and theoretical ballistic information has been confirmed through actual firing.

An immediate decision to eliminate the Low Light Level Sighting System (LLLSS) would increase the effective aiming range of most combat rifles by 43% (from 350 to 500 meters). Adding sniper positions to combat units would provide an immediate long-range rifle capability.

There appears to be little rationale for current plans to arm combat support and combat service support units with fully automatic rifles while arming combat units with rifles which fire a maximum of one, two, or three rounds per trigger pull.

Primary requirements for the PIP rifle were: a more durable rifle for bayonet fighting, a rifle with better performance at ranges of 600 to 800 meters, and a rifle which would result in conserving ammunition. While these goals appear admirable, a closer look reveals that these rifle characteristics are inconsistent with frequently performed combat tasks.

o No attempt is made here to present hard data, but there is probably general agreement that less than 1% of enemy (rifle) casualties are expected to be caused from bayonet wounds. (Bayonet training is justified through other considerations). Also, the number of casualties resulting from deliberately aimed service rifle fire at ranges in excess of 500 meters would probably be less than 4% of enemy casualties inflicted by rifle fire. Accordingly, the PIP rifle has been developed to address less than 5% of combat rifle requirements, while operational testing showed a degradation in performance which relates to more than 95% of all high priority combat rifle requirements.

o Through the years, infantry combat leaders have been plagued with the problem of getting soldiers to fire their weapons during the fear and stress of close combat. A major goal of the PIP rifle is to restrict the number of bullets a soldier will fire in combat. The apparent incompatibility of these observations should be given careful study before a new rifle is accepted by the Army.

Some consideration must be given, however remote, to the possibility that the M16A2/M855 system will never undergo successful testing or cannot be developed in time to meet mobilization requirements. Some consideration should also be given to the fact that American soldiers were sent to Vietnam with a rifle/ammunition system which did not work.

An important consideration is to evaluate the loss of combat rifle capability resulting from a delayed purchase of new rifles. In fact, the following points indicate that replacing the M16A1 rifle with the M16A2 rifle will complicate training, will complicate logistical support, will degrade unit readiness, and will result in a rifle which is less reliable and which has reduced combat capabilities.

o If the M16A2 has any clear advantage over the M16A1, it is probably accuracy and terminal ballistics at ranges of 600 to 800 meters. Given the standard Army marksmanship training program, which may provide precise bullet location feedback at only 25 meters, and the engagement of targets to only 300 meters, soldiers will not be trained to utilize a 600 to 800 meter capability. If soldiers were to receive extensive training, expecting the M16A2 to perform at the upper limits of what would be expected of a high-quality sniper rifle is unrealistic. All known Threat analyses indicate the majority of combat rifle targets will be within 300 meters, with the bulk of targets at closer ranges. The maximum effective range of the M16A2 has been listed at 550 meters, short of the range where it has an advantage over the M16A1. The point is that if the M16A2 is not used to engage enemy soldiers in the 600 to 800 meter range band, it has no significant advantage over the M16A1.

o Given that the M16A1 has been demonstrated to be more effective to ranges of 500 meters, the only reason remaining for converting to the M16A2 is to have a rifle which will fire the same ammunition as the SAW. However, SAW ammunition comes in a separate box, is ordered by a different identification number, and is linked. Only in emergency situations would ammunition be exchanged between the rifle and the SAW. That would still be possible because M193 can be fired in the SAW with little performance degradation out to ranges of 600 meters, and M855 can be fired in the M16A1--with considerable loss of accuracy, but suitable for a close-in emergency situation.

o The ammunition issue is very serious. For the next 10 years the Army plans to have two M16 rifles which will not fire the same ammunition. The M16A2 seems to fire M193 as well as it fires M855. However, the M16A2 is not designed to fire M193 ammunition, so the long term use of M193 may not be advisable. The M16A1 will fire M855, but, as shown in Figure 17, with a significant loss of accuracy. A more simple Army-wide solution seems to have all rifle bullets in clips and all SAW bullets in links. It also appears very risky to be committed to the SAW and the M16A2 without the demonstrated ability to produce adequate amounts of M855 ammunition for training and combat.

o With current emphasis on light Infantry, the M16A2 is longer and 15% heavier than the M16A1. It is true that many knowledgeable shooters would report that the longer stock and the barrel which is heavy on the end gives the rifle a better "feel." The Infantryman who carries the rifle all day may not appreciate the better feel--he may even experience times when he would prefer to have the weight in 40 extra rounds of ammunition rather than the extra weight on the rifle.

o The M16A2 has 20% more parts than the M16A1, which is an indication the M16A2 will be more difficult to maintain.

o The new plastic parts of the M16A2 are reported to be very rugged, but the most fragile and problematic part of the two rifles may be the rear sight of the M16A2.

o As discussed in the body of this report, the elimination of automatic fire, the unnecessarily complex and inappropriate sighting system, reduced weapon reliability, and the failure to conduct an operational test which includes production weapons and production ammunition combine to make the M16A2 unacceptable as a replacement for the M16A1.

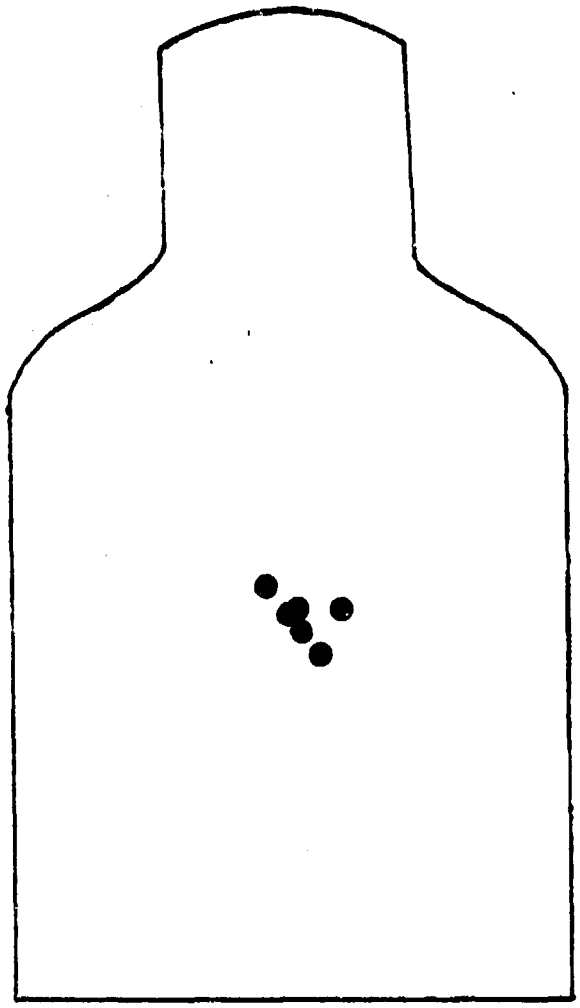

Figure 17. These two six-round shot groups were fired at a distance of 100 yards by an experienced firer from a supported position, using the same M16A1 rifle. The three-inch group on the left was fired with current ammunition (M193) and the twelve-inch group on the right was fired with the ammunition developed for the M16A2 and SAW.

o The established requirements for the Advanced Combat Rifle (ACR) should provide an indication of what the most desireable rifle features are. It is interesting to note that if the Army was required to select between the M16A1 and the M16A2 to meet ACR requirements, the M16A1 would be selected.

o A change in rifles from the M16A1 to the M16A2 will certainly not result in soldiers hitting more targets. Without a major breakthrough in rifle design, a better training program is the most promising solution. However, adequate training ranges are not available and inadequate ammunition allocations are being reduced while many millions of dollars are being spent for rifle replacement. The Army is paying 48 cents a round for SS109/M855 ammunition while new M193-type ammunition can be purchased locally for 14 cents a round. Given M16A1 rifles, adequate amounts of training ammunition, adequate ranges, and emphasis on a good marksmanship training program, combat performance of the soldier can be improved.

CONCLUSION

If the M16A1 is going to be replaced, it should be replaced with a rifle which will enhance training and improve combat performance. The recommended rifle features in Figure 1 are presented for development, testing, and evaluation. They reflect Army training and combat requirements with a view toward overall combat effectiveness. This design was accomplished without the normal organizational limitations which focus efforts into confined areas of responsibility. A study of training standards and tactical doctrine, coupled with five years of field research and contact with the majority of Active and Reserve Component units, has provided a unique perspective from which to evaluate the relative importance of various rifle features. The recommended rifle takes advantage of the new 5.56mm bullet while minimizing the problems to be expected with a new system. It is compatible with current rifles, ammunition, and new targets which are being fielded. It provides for optimum trade-offs which results in a reliable rifle capable of effectively engaging long-range stationary targets or close-in moving targets under all light conditions. While meeting all Army training and combat requirements, it also exceeds all stated requirements of the Marine Corps.

REFERENCES

Evans, K. L. & Osborne, A. D. (1983). The development and implementation of basic, advanced, and unit M16A1 rifle marksmanship training programs (ARI Research Report in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Evans, K. L., & Schendel, J. D. (1983). Development of an Advanced Rifle Marksmanship Program of Instruction (ARI Research Product in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D., Morey, J. C., & Smith, S. (1980). Adequacy of M16A1 rifle performance and its implications for marksmanship training (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D. (1981). The M16 Rifle: bad reputation, good performance. Infantry, 71(5), 22-26.

Smith, S., Osborne, A. D., Thompson, T. J., & Morey, J. C. (1980). Summary of the ARI-Benning research program on M16A1 rifle marksmanship (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

U.S. Marine Corps. (1982, April). Final report: Test results, analysis, and recommendations of testing conducted on the M16A1E1* service rifle, Firepower Division, Development Center, Marine Corps Development and Education Command, Quantico, VA 22]34.

Wigney, R. (1982, May). Small Arms Weapons Training: An Examination of Selected Countries' Training Systems, U. S. Marine Corps Command and Staff College (The information presented is the opinion of Major Rex Wigner, Royal Australian Regiment, and does not necessarily represent the views of the Marine Corps.)

*later designated M16A2

BIBLIOGRAPHY

Evans, K. L., Thompson, T. L., & Smith, S. (1980). FORSCOM/U.S. Army Marksmanship Unit M16A1 rifle and .45 caliber pistol marksmanship training evaluation (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Heller, F. H., Thompson, T. J., & Osborne, A. D. (1981). Basic rifle marksmanship shooter's book (ARI Research Product in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Klein, R. D. (1977). M16A1 Rifle, Analysis of factors affecting the development of threat oriented small arms training facilities (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Klein, R. D., & Maxey, J. L. (1980). Analysis of threat oriented marksmanship training capabilities of the Infantry Remoted Target System (IRETS) (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Klein, R. D., & Tierney, T. J. (1978). Analysis of factors affecting the development of threat oriented small arms training facilities (ARI Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Maxey, J. L., & Dempster, J. R. (1978). Survey of M16A1 basic rifle marksmanship--current procedures and practices (ARI Draft Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Maxey, J. L., & George, J. D. (1977). Analysis of current training: M16A1 rifle, analysis of M16A1 basic rifle marksmanship (ARI Draft Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Maxey, J. L., Klein, R. D., & Dempster, J. R. (1980). Comparison of rifle defeatable threat criteria and the Infantry Remoted Target System (IRETS) (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Maxey, J. L., & Sweezy, R. W. (1977). Training effectiveness analysis research: instructional approaches for individualizing basic rifle marksmanship training (ARI Draft Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D. (1979). Human factors research: Training effectiveness and training extension course (ARI Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D. (1979). Training extension course validation (includes M16A1 rifle lessons) (ARI Draft Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D. (1980). Basic rifle marksmanship trainer's guide (ARI Research Product published by the U.S. Army Infantry School, Fort Benning, GA).

Osborne, A. D., Evans, K. L., Lucker, H. A., & Williams, G. P. (1982). Development of a rifle marksmanship training program for units (ARI Research Product in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D., & Morey, J. C. (1979). Basic rifle marksmanship training program (ARI Research Product published by the U.S. Army Infantry School, Fort Benning, GA).

Osborne, A. D., Schroeder, J. E., & Heller, F. H. (1980). Evaluation of the basic rifle marksmanship program of instruction (ARI Research Report 1364). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Osborne, A. D., & Smith, S. (1983). Unit rifle marksmanship training guide (ARI Draft Research Product in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Rosen, M. H. & Behringer, R. D. (1979). M16A1 Rifle Marksmanship Training Development (Litton Mellonics Research Report) Litton Mellonics, 1001 West Maude Avenue, Sunnyvale, California.

Schendel, J. D., Heller, F. H., Finley, D. L. & Hawley, J. K. (1983). Use of Weaponeer Marksmanship Trainer in predicting M16A1 rifle qualification performance (ARI Draft Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Schendel, J. D., & Johnston, S. D. (1982). A study of methods for engaging moving targets (ARI Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Schendel, J. D., Osborne, A. D., & Lucker, H. A. (1981). Aid to Improved Marksmanship (ARI Research Product in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Schroeder, J. E. (1982). The relationship between the moving target rifle marksmanship training (MTRMT) and the multipurpose arcade combat simulator (MACS) (ARI Draft Research Note). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Smith, S., & Osborne, A. D. (1981). Troubleshooting rifle marksmanship. Infantry, 71(4), 28-34.

Smith, S., & Osborne, A. D. (1981). Experimental evaluation of the Superdart projectile location system (ARI Research Report in preparation). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Smith, S., Thompson, T. J., Evans, K. L., Osborne, A. D., Maxey, J. L., & Morey, J. C. (1980). Effects of down range feedback and the ARI zeroing target in rifle marksmanship training (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Taylor, C. J., Dyer, F. N., & Osborne, A. D. (1983). Effects of rifle zero and size of shot group on marksmanship scores (ARI Draft Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Thompson, T. J. (1982). Range estimation training and practice: A state-of-the-art review (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Thompson, T. J., Morey, J. C., Smith, S. & Osborne, A. D. (1981). Basic rifle marksmanship skill retention: Implications for retention research (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Thompson, T. J., Smith, S., Morey, J. C. & Osborne, A. D. (1980). Effectiveness of improved basic rifle marksmanship training programs (ARI Research Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.