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AH-64A Gunnery Performance: Implications for Gunnery Standards

David B. Hamilton
Anacapa Sciences, Inc.

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

This research evaluated the difficulty of establishing standards in the Army's helicopter gunnery manual (TC 1-140) for AH-64A crew gunnery qualification. In addition, the research identified variables that influence AH-64A gunnery performance. Thirty AH-64A crews from an operational cavalry brigade participated in three live-fire gunnery exercises during a 6-month period. Engagement time and target-effect measures were collected for 480 gun, 576 missile, and 470 rocket engagements. The results indicate that exposure time standards will be difficult for operational units to measure. Target-effect standards for gun and missile engagements can be achieved, but the standards for rocket engagements will be difficult to attain. The influence of several variables on gunnery engagement time and target-effect performance was estimated. Target distance had a major effect on gun performance. Also, the distribution of rocket impacts was shifted consistently to the right and short of the target. Finally, a method for establishing gunnery standards is recommended.

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Research Report 1605

AH-64A Gunnery Performance: Implications for Gunnery Standards

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Training Simulation

FOREWORD

The Army is revising its helicopter gunnery training manual (TC 1-140; USAAVNC, 1990). The manual explains the fundamentals of helicopter gunnery and provides a unit gunnery training program that progresses from the acquisition of individual skills, through crew skills and coordination, to team skills and coordination. The program includes tables that list gunnery tasks and standards for training and evaluating proficiency. The standards should be realistic and achievable; however, empirical data to demonstrate the timing and accuracy that Army aviators are capable of achieving with aerial weapon systems are lacking.

This research was performed within the Training Research Laboratory by the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, and was conducted in response to two taskings: One from the U.S. Army Aviation Center (USAAVNC) and one from the Department of the Army. The work was accomplished under the Memorandum of Agreement dated 17 November 1989 between ARIARDA and the Directorate of Training and Doctrine. The research also addresses questions raised by the Standards in Training Commission (STRAC) and the Department of Tactics and Simulation (DOTS).

This research describes the aerial gunnery performance of an operational AH-64A (Apache) unit. Performance is evaluated for different gunnery standards, and the influence of several factors on gunnery performance is quantified. Specific information is provided to the participating units on the performance of their weapon systems. Finally, a method is recommended for establishing gunnery standards.

This report will serve as a source of information about aerial gunnery performance and standards. Results were briefed to the USAAVNC Assistant Commandant, the Training and Doctrine Command (TRADOC) System Manager for Airborne Target Acquisition and Weapon Systems, the Apache Training Brigade Commander, and to representatives of the STRAC and DOTS. Other briefings to operational personnel were conducted from January through May 1991. The information in this report will be used to improve Army aerial gunnery training, performance, and evaluation.

Edgar M. Johnson

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The author wishes to express appreciation to several individuals from ARIARDA for their contribution to this research. Charles A. Gainer, Chief, ARIARDA, Fort Rucker, Alabama, served as the Contracting Officer's Technical Representative. Dennis Wightman (Technical Team Leader, Simulation Research Program), Major James Casey, Captain Chris Miller, and Captain Dale Weiler (Research and Development Coordinators), and Joan Blackwell (Research Psychologist) provided administrative assistance. Ms. Blackwell also frequently consulted on logistical issues. Larry Murdock (Data Processing Manager) ran the initial statistical analyses.

Several members of the Anacapa Sciences, Inc., staff also contributed to this project. Most notably, Catherine R. Kjellsen (Aviation Research Technician) was invaluable in the on-site data collection effort. Richard Weeter provided the initial project handover. George L. Kaempf, the designer of the original research effort, provided guidance and moral support. D. Michael McAnulty consulted on the design, analyses, and presentation of the data.

Finally, without the leadership and support of Colonel Thomas J. Konitzer (Commander, 6th Cavalry Brigade, Air Combat), this research project would not have been possible. In addition, the author wishes to express his appreciation to the unit commanders, operations officers, instructor pilots, and aviators who provided the leadership, coordination, instruction, and participation necessary to complete the research.

EXECUTIVE SUMMARY

This report describes the methods and results of research designed to measure AH-64A gunnery performance, to identify variables that influence performance, and to evaluate that performance with respect to the gunnery standards in the revised Army helicopter gunnery manual, TC 1-140. The research was conducted by the U.S. Army Research Institute Aviation Research and Development Activity.

Requirement:

One of the Army's goals is to provide unit commanders with a framework for aerial gunnery training and evaluation that is realistic and achievable. However, empirical data to describe the timing and accuracy that Army aviators are capable of achieving with AH-64A weapon systems are lacking. Gunnery standards have been established using information from other attack helicopters, the AH-64A manufacturing specifications, and the specifications of the ammunition. Total system performance depends on the interaction of the aircraft, its ammunition, its maintenance, and the skill and training of its crewmembers. Therefore, empirical data on gunnery performance taken from an operational unit is needed to establish realistic gunnery standards.

The research objectives for this project were (a) to obtain and describe measurements of AH-64A gunnery performance of Army aviators with experience levels that are typical of AH-64A units, (b) to analyze the gunnery performance data to determine the difficulty of different gunnery standards, and (c) to identify the major factors influencing gunnery performance.

Procedure:

An operational cavalry unit participated in three live-fire exercises over a 6-month period. Repeated measures of crew gunnery performance were collected for the Hellfire missile system, the 2.75-inch rocket system, and the 30-mm gun. The time to complete each engagement and the target effect of the rounds were measured for each engagement. The rocket and gun target-effect measures were obtained from an area weapon scoring system. The missile gunnery performance was evaluated using Hellfire training missiles; no actual Hellfire missiles were fired.

Findings:

The results of this research support five conclusions. First, the time standards expressed in terms of aircraft exposure time are difficult to measure. Second, the gun target effect is influenced significantly by target distance; engagements at less than 1700 meters are above standards and engagements at greater than 1700 meters are below standards. Third, the standards for missile target effect are inadequate to produce consistent evaluations of these engagements. Fourth, the target effect for rocket engagements supports the narrow cross-range width and elongated down-range length of the rocket boxes; however, the substantial reduction in the size of the boxes in TC 1-140 will significantly reduce the number of crews that attain the standards. Fifth, the distributions of rocket impacts show a consistent shift that indicates that most of the rockets land right and short of the targets.

Utilization of Findings:

The results of this research support four specific recommendations. First, exposure time standards should be changed to facilitate the collection of those measures. Second, a score sheet should be developed for the evaluation of Hellfire training missile engagements. Third, the size of the rocket boxes for the M274 rounds should be increased from 100 x 400 meters to 150 x 400 meters. Fourth, further research should be conducted (a) to determine the cause of the shifts observed in the distribution of rocket impacts and (b) to collect and analyze gunnery performance for AH-64A tasks not evaluated here and for aircraft other than the AH-64A.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAA	Army Audit Agency
AGL	Above Ground Level
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AQC	Aviator Qualification Course
ARIARDA	Army Research Institute Aviation Research and Development Activity
AWSS	Area Weapons Scoring System
BSS	Ballistic Scoring System
CMS	Combat Mission Simulator
COOP	Cooperative Rocket Mode
CPG	Copilot/Gunner
CSS	Computer Scoring Subsystem
CWEPT	Cockpit, Weapons, and Emergency Procedures Trainer
DA	Department of the Army
DOTS	Department of Tactics and Simulation
DSS	Detonation Scoring System
ETL	Effective Translational Lift
FARP	Forward Arming and Refueling Point
FM	Field Manual
HMD	Helmet Mounted Display
HMS	Helmet Mounted Sight
IHADSS	Integrated Helmet and Display Sighting System
IP	Instructor Pilot
JAAT	Joint Air Attack Team
LOAL	Lock-On-After-Launch
LOBL	Lock-On-Before-Launch
LRF/D	Laser Range Finder Designator
MPSM	Multipurpose Submunition
OIC	Officer in Charge
PLT	Pilot
PNVS	Pilot Night Vision System
SIP	Standardization Instructor Pilot
STRAC	Commission on Standards in Training
TADS	Target Acquisition and Designation System
TC	Training Circular
TSTT	TADS Selected Task Trainer
TEA	Training Effectiveness Analyses
TP	Target Practice
TP/PD	Target Practice/Point Detonating
TRADOC	Training and Doctrine Command
USAAVNC	U.S. Army Aviation Center
VRS	Video Recorder Subsystem

AH-64A GUNNERY PERFORMANCE:
IMPLICATIONS FOR GUNNERY STANDARDS

Introduction

The AH-64A Apache helicopter is the U.S. Army's newest attack helicopter. Its mission is to detect and engage enemy armor under day, night, and adverse weather conditions. To accomplish its mission, the helicopter is equipped with three weapon systems: the Hellfire laser-guided missile system, the 2.75 in. folding-fin aerial rocket system, and the 30 mm chain gun. In addition, the helicopter is equipped with a laser range finder/designator (LRF/D), a pilot night vision system (PNVS), and a copilot/gunner target acquisition and designation system (TADS). These systems improve the aircraft's daytime capabilities and allow the crew to operate the helicopter at night and under adverse weather conditions. The aircraft's firepower, range, target acquisition, and target tracking capabilities are much more effective than those of the Army's previous attack helicopter, the AH-1 Cobra.

The AH-64A (see Figure 1) is a twin engine, four-bladed helicopter with a maximum gross weight of 17,650 lbs and an approximate height, width, and length (excluding the rotor system) of 15 ft, 17 ft, and 49 ft, respectively. The two crewmembers, a pilot (PLT) and a copilot/gunner (CPG), are seated in tandem with the PLT behind and above the CPG. Each

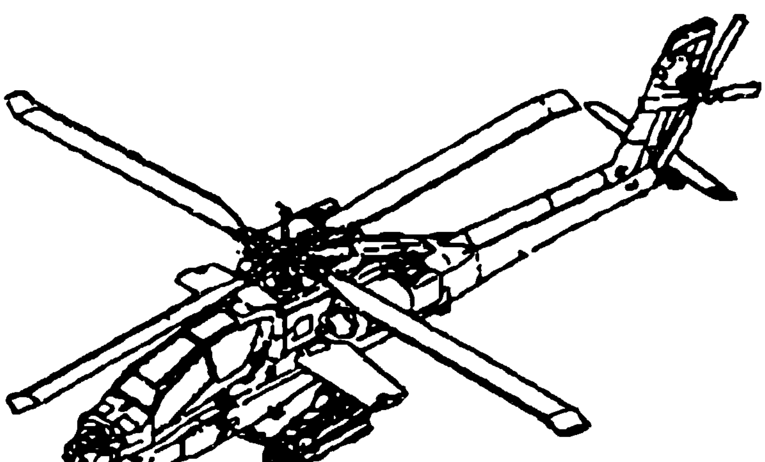

Figure 1. Diagram of the AH-64A helicopter.

crew station is equipped with an integrated helmet and display sighting system (IHADSS) consisting of a helmet mounted sight (HMS) and a helmet mounted display (HMD). The HMS allows the crewmember to use his line of sight for sensor pointing and weapons aiming. The HMD displays flight and weapons symbology and sensor imagery to the crewmember's right eye, permitting simultaneous viewing of video imagery and the outside world. Additionally, an on-board video recorder subsystem (VRS) can record the imagery and symbology being displayed by either the PNVS or TADS.

The crewmembers of the AH-64A helicopter can acquire and fire on targets in a variety of operating modes. Each crewmember can launch any weapon using one of several different procedures. Furthermore, each weapon system can be operated in one of several different modes. For example, the Hellfire missiles can be launched using two modes. In the lock-on-before-launch (LOBL) mode, the target is lased and the missile begins tracking reflected laser energy before it is launched. In the lock-on-after-launch mode (LOAL), the missile is launched before the target is lased. All the other modes of operation of the aircraft are described in the Operator's Manual for the AH-64A Helicopter (Department of the Army, 1984).

Army Aerial Gunnery Training

Army aviators receive basic flight skills training, a necessary prerequisite to gunnery training, and individual gunnery training at the U.S. Army Aviation Center (USAAVNC) at Fort Rucker, Alabama, in the AH-64A Aviator Qualification Course (AQC). After they complete the AQC and leave Fort Rucker, aviators are provided crew and team gunnery training based on the mission of their operational unit.

The munitions allocation for operational units to attain and sustain weapon proficiency is determined by the Standards in Training Commission (STRAC). STRAC publishes its recommendations for the types and quantities of ammunition for aviation weapon systems in chapter 7 of DA Pamphlet 350-38 (Department of the Army, 1990). Chapter 7 also specifies the percentage of aircrews that must be qualified for the training readiness condition of the operational unit. STRAC stresses making the maximum use of aids, devices, simulators, simulations, and subcaliber firing to achieve weapon proficiency.

To provide a guide for unit commanders to meet STRAC requirements and to ensure effective and efficient operation of all attack helicopters, the Department of Tactics and

Simulation (DOTS; formerly the Department of Gunnery and Flight Systems) publishes a helicopter gunnery training manual (FM 1-140; Department of the Army, 1986). The purpose of the information provided by FM 1-140 is to improve the ability of helicopter crews to place rounds on a target, rapidly and accurately, by improving crew skills in target detection, range estimation, weapon selection, and target engagement. FM 1-140 explains the fundamentals of helicopter ballistics, weapon delivery techniques, and ranges, and provides a notional unit gunnery training program.

The unit gunnery training program in FM 1-140 provides a structured framework for aviator gunnery training, progressing from the acquisition of individual skills, through crew skills and coordination, to team skills and coordination. The program includes tables that list gunnery tasks and standards for training or evaluating the use of the aircraft weapon systems in different modes of operation. The tables are numbered consecutively and are ordered to progress through the individual, crew, and team skills. The standards in the tables comprise two parts: the weapon accuracy or impact proximity referred to as target effect and time standards such as engagement time and exposure time.

Theoretically, there are at least two different methods for establishing standards for gunnery training and evaluation. One method bases the standards solely on the performance characteristics of the ammunition and the enemy threat. In this method, target effect criteria are established on the basis of the effective burst radius of the weapon. Exposure and engagement times are established on the basis of the time the enemy threat acquires and engages the helicopter. Using the characteristics of AH-64A ammunition and enemy threat performance to establish gunnery standards provides information to the AH-64A aviator about the absolute performance criteria that he must meet to be effective and survive on the battlefield. Unfortunately, using this method of establishing gunnery standards may produce standards that are difficult or impossible for the combination of the aircraft, weapons, and crew to obtain, especially under nonoptimal conditions of lighting, weather, or obscuration.

Another method for establishing standards for gunnery training bases the standards solely on the performance characteristics of the helicopter system, including its crew. Specifically, the target effect and time standards are based on performance norms taken from observed gunnery performance in an operational unit with the normal range of aviator experience using field-maintained weapon systems with various amounts of flight time. Although using this method to establish gunnery standards ensures achievable standards, aviators trained using them may not know the performance criteria needed to be effective and to survive on the battlefield.

The weapon standards published in FM 1-140 were established on the basis of data obtained from other attack helicopters, AH-64A operational tests, AH-64A manufacturing specifications, and ammunition specifications. Thus, the Army combined past attack helicopter performance with the performance of the AH-64A ammunition to produce the standards published in the first helicopter gunnery manual published after the fielding of the AH-64A. Because normative data could not be obtained for the AH-64A, there was little other information on which to base the gunnery standards.

In 1988, DOTS proposed revisions to FM 1-140 in response to increasing pressure to reduce the requirements for training ammunition. The coordinating draft of the revised helicopter gunnery manual (TC 1-140; USAAVNC, 1988) contained significant changes to the crew gunnery training requirements and standards for the AH-64A aircraft. DOTS proposed to reduce training ammunition requirements by conducting all AH-64A crew gunnery training and qualification in the AH-64A Combat Mission Simulator (CMS). No ammunition was provided for crew training and qualification; ammunition was provided only for training attack helicopter teams and conducting combined arms live-fire and joint air attack team (JAAT) exercises.

In TC 1-140, the gunnery tables were renumbered to be consistent with the gunnery tables in the tank gunnery manuals (e.g., FM 17-12-1; Department of the Army, 1986). The gunnery tasks in each table were also changed. The engagement time standards were removed, leaving only the exposure time standards. The target effect areas were made substantially smaller for gun and rocket engagements. The missile standard remained unchanged: a direct target hit. While considering the impact of these changes on gunnery training and evaluation, DOTS personnel identified the need for information on the AH-64A gunnery performance of typical Army crews and on the major factors that influence it.

Twenty-two months later, DOTS released the approved draft of the helicopter gunnery manual (TC 1-140; USAAVNC, 1990). In this version of TC 1-140, the proposal that all AH-64A crew gunnery be conducted in the CMS was dropped. The available training ammunition was redistributed among the gunnery tables, with more being allocated for the crew tables and less for the team tables. The gunnery standards in TC 1-140 remained substantially different and more difficult than those in FM 1-140.

AH-64A Crew Gunnery Standards

The crew tables in FM 1-140 and TC 1-140 (USAAVNC, 1990) are reproduced in Appendixes A and B, respectively. The TC 1-140 crew gunnery tables, published on pages K-20 through K-25 in TC 1-140, are referred to as Table VIII Day Intermediate Qualification Course (Crew) and Table VIII Night Intermediate Qualification Course (Crew). To simplify terminology, the tables are referred to collectively in this report as Table VIII. The target effect standards for each weapon system and the exposure time standards are described separately in the sections that follow. Specific changes from FM 1-140 to TC 1-140 are also described in each section.

Gun target effect standards. Table VIII contains 10 gun engagements: 5 under day conditions and 5 under night conditions (see Table 1). Thirty rounds of 30 mm ammunition are provided for each engagement. The targets range from 500 to 3000 m for day engagements and from 500 to 2000 m for night engagements. The engagements are fired both from hover fire and running fire modes. Hover fire is delivered when the helicopter is moving at velocities below effective translational lift (ETL). The helicopter may be stationary or moving, but the movement is always below ETL. Running fire is delivered when the helicopter is moving above ETL. For both day and night conditions, 3 of the 5 gun engagements are fired simultaneously with another weapon system. At least one engagement is fired using the IHADSS by each crewmember under both day and night conditions. The CPG also uses the TADS for two engagements during the day and for two at night. Finally, one day engagement is fired by the PLT with the gun fixed forward.

As for all target effect measures in Table VIII, the standards are designed to produce a binary (GO/NO-GO) rating. Target effect for each gun engagement is evaluated using one of two standards. For engagements using the LRF/D, a GO rating is awarded if the target is hit or 50% of the rounds impact within a 25 x 25 m box around the target; for engagements not using the LRF/D, a GO is awarded if the target is hit or 50% of the rounds impact within a 50 x 50 m box around the target. The engagements in Table 1 that have TADS in the engagement mode column use the LRF/D.

The target effect standards for the gun in Table VIII differ markedly from the standards published in FM 1-140. FM 1-140 used eight different standards for gun target effect (see Appendix A), none of which included target hits. Generally, FM 1-140 required a higher percentage of the rounds (66%) to fall in a larger box (e.g., 50 x 150 m).

Table 1

Gun Engagements in Table VIII

Number	Range (m)	Aircraft mode	Engagement mode	Crew-member	Rounds
		Day conditions			
1[a]	500-1000	Hover	IHADSS	PLT	30
3	1000 2000	Running	Fixed	PLT	30
5[a]	500-1000	Hover	IHADSS	CPG	30
6	2000-3000	Hover	TADS	CPG	30
8[a]	2000-3000	Running	TADS	CPG	30
		Night conditions			
1[a]	500-1000	Hover	IHADSS	PLT	30
3	500-1000	Running	IHADSS	PLT	30
5[a]	500-1000	Hover	IHADSS	CPG	30
7	1000-2000	Hover	TADS	CPG	30
8[a]	1000-2000	Running	TADS	CPG	30

Note. IHADSS = integrated helmet and display sighting system; PLT = pilot; CPG = copilot/gunner; TADS = target acquisition and display system.

[a]Fired simultaneously with another weapon system.

Missile target effect standards. Table VIII contains eight missile engagements: four under day conditions and four under night conditions (see Table 2). In Table VIII, the targets range from 3000 to 7000 m for day engagements and from 3000 to 7000 m for night engagements. All engagements are fired from a hover. For both day and night conditions, two engagements are fired simultaneously with another engagement using the LOBL mode, and two are fired as individual engagements using the LOAL mode.

Because the cost of the Hellfire missile prohibits proficiency training with live rounds, all missile engagements use the Hellfire training missile. The Hellfire training missile has an operational laser seeker that can search for and lock onto laser designated targets. The missile provides realistic cockpit indications, including

Table 2

Missile Engagements in Table VIII

Number	Range (m)	Aircraft mode	Engagement mode	Crew-member	Round
		Day conditions			
1[a]	3000-7000	Hover	LOBL	CPG	1
2	6000-7000	Hover	LOAL	CPG	1
5[a]	4000-5000	Hover	LOBL	PLT	1
6	6000-7000	Hover	LOAL	PLT	1
		Night conditions			
1[a]	3000-5000	Hover	LOBL	NS	1
2	6000-7000	Hover	LOAL	CPG	1
5[a]	3000-5000	Hover	LOBL	PLT	1
7	6000-7000	Hover	LOAL	PLT	1

Note. LOBL = lock-on-before-launch; LOAL = lock-on-after-launch; PLT = pilot; CPG = copilot/gunner; NS = not specified.

[a]Fired simultaneously with another weapon system.

missile launch and time of flight messages. Unfortunately, the training missile does not provide any objective evidence of whether an actual missile would have hit the target, because the missile never actually leaves the aircraft.

The Table VIII target effect standard for all missile engagements is the same: "Proper Switchology (Use VRS when possible)." The proper switchology is not defined in the manual. Thus, no objective criteria for assessing the target effect for missile engagements is provided for the unit evaluator. Additionally, when the VRS is not available, the unit evaluator has no other source of information other than asking the aviators if they used proper switchology. Presumably, the appropriate switch actions and laser-on-target performance are known to all unit evaluators and do not need to be defined in Table VIII. The FM 1-140 missile target effect standard was a target hit.

Rocket target effect standards. Table VIII contains eight rocket engagements: four under day conditions and four under night conditions (see Table 3). Six to 10 rockets are provided for each engagement. The targets range from 1500 to 6000 m for day engagements and from 2000 to 6000 m for night engagements. The engagements are fired from hover fire and running fire modes. For both day and night conditions, three of the four engagements are fired by both crewmembers in a cooperative (COOP) mode. The fourth engagement is fired by the PLT using the IHADSS while the CPG simultaneously employs another weapon system.

The target effect for each rocket engagement is evaluated using one of two standards. For engagements using the M274 point-detonating ammunition, a GO rating is awarded if the target is hit or 50% of the rounds impact within a 100 x 400 m box around the target. For the engagements using the M267 multipurpose submunition (MPSM) ammunition (engagement 2 both day and night), a GO rating is awarded if the target is hit or 66% of the grenades impact within a 100 x 300 m box.

Table 3

Rocket Engagements in Table VIII

Number	Range (m)	Aircraft mode	Engagement mode	Crew-member	Rounds
		Day conditions			
2	4000-6000	Hover	COOP	Both	10
4	2000-3000	Running	COOP	Both	6
7	3000-5000	Hover	COOP	Both	6
8[a]	1500-2000	Running	IHADSS	PLT	6
		Night conditions			
2	4000-6000	Hover	COOP	Both	8
4	2000-3000	Running	COOP	Both	8
6	3000-5000	Hover	COOP	Both	6
8[a]	2000-3000	Running	IHADSS	PLT	8

Note. COOP = cooperative mode; IHADSS = integrated helmet and display sighting system; PLT = pilot.
[a]Fired simultaneously with another weapon system.

As was found with the gun standards, the TC 1-140 rocket target effect standards differ markedly from the FM 1-140 standards. There were 12 different standards for rocket target effect in FM 1-140 (see Appendix A); none of the standards mentioned target hits. The FM 1-140 rocket standards varied as a function of the sight and target distance and generally required 50% of the rounds to fall within a larger box (e.g., 300 x 500 m). The smallest target effect box in FM 1-140 (300 x 300 m) contained more than twice the area as the largest box in TC 1-140 (100 x 400 m).

Exposure time standards. The exposure time standards for Table VIII are scored using a point system for gun and rocket engagements. Missile engagements are not scored for exposure time because missile firing from a masked position is more common for Hellfire missiles than for gun or rocket engagements. Also, because of the extended range of the Hellfire missile system, intervisibility can exist between the target and the AH-64A without endangering the aircraft. The points awarded for gun engagements depend on the engagement mode used: one for engagements using the TADS or FIXED modes, one for PLT IHADSS, and one for CPG IHADSS (see Appendix B). The points awarded for rocket engagements depend on the rocket motors used: one for engagements using MK66 motors and one for engagements using MK40 motors (see Appendix B). In all the standards, the number of points awarded for each engagement depends on the number of seconds the aircraft was exposed to the target and the target distance. The longer the aircraft is exposed to the target, the fewer the points awarded. Additionally, for a given exposure time, the closer the aircraft is to the target, the fewer the points awarded.

The exposure time standards for Table VIII differ markedly from the FM 1-140 standards. First, the FM 1-140 exposure standards included measures of both engagement time and exposure time. Second, they did not depend on the engagement mode or rocket motor. Third, they were evaluated using a GO/NO-GO criteria in contrast to the points system used in Table VIII.

AH-64A Gunnery Performance Evaluation

One of the goals of DOTS and STRAC is to provide unit commanders with a framework for aerial gunnery training and evaluation that is realistic and achievable. However, they had insufficient empirical data to demonstrate the timing and accuracy that Army aviators were capable of achieving with the AH-64A weapon systems. Thus, the initial gunnery standards were established using information from other attack helicopters, the AH-64A manufacturing specifications, and the specifications of the ammunition. Because total system performance is dependent on the interaction of the aircraft, its ammunition, its maintenance, and the skill and training of its crewmembers, AH-64A gunnery performance measures from an operational unit are needed to evaluate the standards proposed in TC 1-140.

Objectives. The AH-64A gunnery performance evaluation was designed to accomplish two objectives. The first objective is to obtain and describe measurements of AH-64A gunnery performance taken from Army aviators with experience levels that are typical of Army AH-64A units. The second objective is to analyze the gunnery performance data to determine the difficulty of different gunnery standards and to identify the major factors influencing gunnery performance. The data obtained in this research can be used to evaluate the standards proposed in TC 1-140 and to establish future gunnery standards.

AH-64A CMS training effectiveness research. The research described in this report was conducted in conjunction with research designed to test the effectiveness of the AH-64A CMS for sustaining gunnery skills. In two audits of the SFTS, first in 1981 and again in 1984, the Army Audit Agency (AAA) recognized the lack of research documenting the effectiveness of simulators for sustaining helicopter flight and gunnery skills (U.S. Army Audit Agency, 1982, 1985). Specifically, both reports admonish the Army for the operational tests conducted on the SFTS and conclude that the Army had not adequately quantified the return on its investment in flight simulators procured for unit training. In 1986, the Department of the Army (DA) tasked the Army Research Institute Aviation Research and Development Activity (ARIARDA), through the Training and Doctrine Command (TRADOC), to plan and initiate postfielding training effectiveness analyses (TEAs) of each of the Army's flight simulator systems. The AH-64A CMS TEA research was one of several projects planned by ARIARDA in response to the DA tasking. The background and results of the AH-64A CMS TEA are fully described in Hamilton (1991).

Because the CMS TEA required that crew gunnery performance be measured on live-fire gunnery tables, DOTS and STRAC requested that ARIARDA evaluate the gunnery performance with respect to the standards published for the crew tables in TC 1-140. Therefore, the research plan that was developed to test the training effectiveness of the AH-64A CMS was modified to include an analysis of live-fire gunnery performance with respect to the standards proposed in Table VIII.

Method

The research was conducted in three phases. In Phase 1, AH-64A crew gunnery performance was evaluated during two initial live-fire exercises. During the exercises, the crews fired a set of crew gunnery engagements established by the participating brigade. The primary measures of gunnery performance collected during the exercises were target effect and engagement time. An area weapons scoring system (AWSS) was used during the live-fire exercises to provide the target effect measures for the gun and rocket engagements. In addition, the participating aviators completed a demographic survey describing their training and skill level at the initiation of the research.

In Phase 2, the crews received different types of gunnery training during a 6-month period to achieve the CMS TEA research objectives (see Hamilton, 1991). The frequency and type of gunnery training were recorded during this period.

In Phase 3, crew gunnery performance was measured during a final live-fire exercise. The gunnery performance of the crews during all three exercises was used to evaluate the gunnery standards in TC 1-140 (USAAVNC, 1990).

Materials

Demographic survey. The AH-64 aviator demographic survey (see Appendix C) was designed to collect personal, training, flight, and gunnery range experience data to describe the aviators who participated in the research. The survey was completed by all the aviators during the initial live-fire exercises.

Crew gunnery table. The brigade crew qualification table used in the experiment was designed for the Dalton-Henson Multipurpose Range Complex (see Table 4). The table contains 2 calibration and 18 normal engagements employing all three AH-64A weapon systems. It was used for both initial and final and day and night exercises. The engagements were fired from seven firing points toward 13 targets (see Figure 2). The target distance ranged from 975 m to 2575 m for the 30 mm gun, from 3450 m to 4500 m for the rockets, and from 2100 m to 4620 m for the missiles. All engagements were fired from a stationary hover, with the exception of the two gun engagements that were fired from a moving hover at firing points 5 and 6. The arrows in Figure 2 indicate the direction of movement of the targets and aircraft, if any occurred.

Table 4

Crew Gunnery Table

Firing point	Weapon system	Target number	Target distance	Rounds
1[a]	30 mm	1-7A,B	975	20
	Rockets	R3	3700	4
1	30 mm	1-7A,B	975	20
	Rockets	R3	3700	4
	Hellfire	R4	3835	1
2	30 mm	9A	1066	20
	Rockets	R2	3450	4
	Hellfire	R2	3450	2
3	30 mm	1-5A,B	1700	20
	Rockets	R3	4500	4
	Hellfire	R2	4350	1
4	30 mm	8A	1645	20
	Rockets	R2	4400	4
	Hellfire	R3	4620	1
5	30 mm	8B	1400	20
6	30 mm	9B	1100	20
7	Hellfire	43	3775	1
	Hellfire	32	2350	1
	Hellfire	31	2100	1
	30 mm	34	2575	20

Note. The 30 mm, rocket, and Hellfire ammunition were target practice (TP), target practice/point detonating (TP/PD) warheads with MK66 motors, and simulated, respectively.
[a]Calibration.

Personnel

The scoring personnel and the AH-64A aviators who participated in this research are described in the following two sections.

Scoring personnel. Target effect measures of gunnery performance were obtained during the live-fire exercises by nine individuals: four AWSS operators, three squadron standardization instructor pilots (SIPs), and two

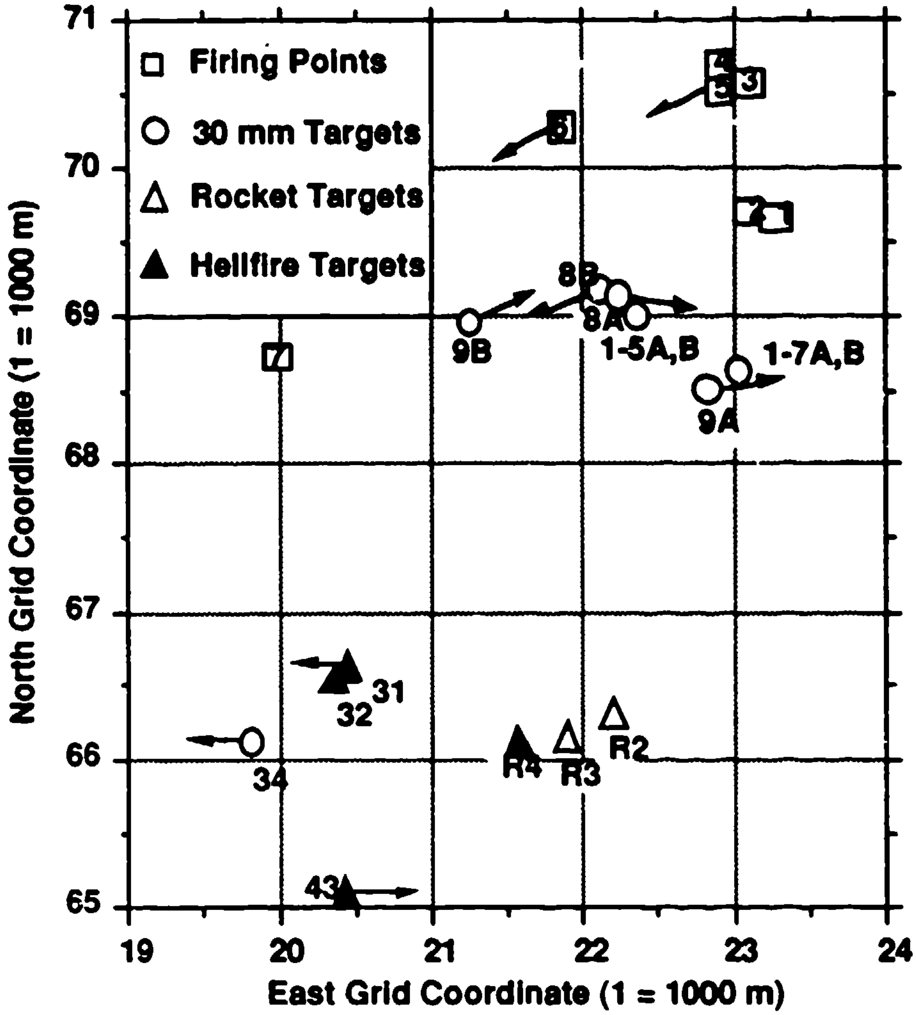

Figure 2. Configuration of the firing points and targets at the Dalton-Henson Multipurpose Range Complex, Fort Hood, Texas.

researchers. Two contract civilians operated the AWSS during the day exercises and another two during the night exercises. The missile target effect performance was evaluated by each squadron's SIP. The researchers monitored the range activities, collected the performance information from the AWSS operators, and entered the data into the project computer, one during the day exercises and the other during the night exercises. The on-site researcher obtained the engagement time measures after the live-fire exercises from the VRS videotapes.

AH-64A aviators. All crews from three squadrons of an operational cavalry brigade who were scheduled to remain in the unit for at least 6 months were selected to participate. Because Army policy restricts females from gunship operations, all aviators were male.

Initially, 30 qualified and current AH-64A crews (60 aviators) were selected to participate in the live-fire exercises. Three weeks before the final live-fire exercise, crew attrition was minimal (3 crews) and unrelated to crew performance (i.e., permanent change of station, medical grounding). However, an additional 9 crews were transferred to operational units of the Central Command before the final performance tests. Therefore, only 18 crews participated in the final live-fire exercises. After completing the final day run, however, one crew was unable to complete the night run because of an off-duty injury to one crewmember.

The demographic data for the 18 crews that completed both the initial and final live-fire exercises indicate a range of experience that is typical of AH-64 operational units (see Table 5). The aviators had two distinctly different backgrounds: those with previous career experience in other helicopters (predominantly the AH-1) and those who proceeded from Initial Entry Rotary Wing training to the AH-64 AQC. Across all indicators of experience, the PLTs were more experienced than the CPGs.

Gunnery Training

Presumably the gunnery performance of the participating brigade could be influenced by the types and frequency of gunnery training included in their training program. Therefore, five types of gunnery training were monitored over the course of the research to aid in the interpretation of the results. First, squadron operations officers provided information about major gunnery training activities. These reports indicated that 4 crews participated in a JAAT training exercise at Fort Hood, Texas, 2 months before the final live-fire exercises. No additional information is available about the type or amount of training they received.

Second, the on-site researcher reviewed the aviator flight records (Form 759) after the initial and final live-fire exercises to measure the amount of AH-64A flight time. The records indicated that the mean flight hours per crewmember during the experimental period was 113 (*SD* = 43.9). Third, the on-site researcher obtained the number of hours that the participating aviators used the cockpit,

Table 5

Aviator Demographic Data at the Initial Live-Fire Exercise

Measure	Quantity	Pilot (n = 18)	Gunner (n = 18)
Age (years)	median range	32 (23-47)	28 (22-40)
Months on active duty	"	125 (20-267)	81 (18-216)
Months since AQC	"	27 (3-60)	13 (2-30)
AH-64A flight hours	"	472 (148-788)	310 (149-638)
Total flight hours	"	1890 (312-5940)	829 (314-2011)
Readiness level	mean SD	1.1 (0.32)	1.4 (0.71)
Range experience	"	2.9 (1.80)	1.1 (1.35)

Note. AQC = Aviator Qualification Course.

weapons, and emergency procedures trainer (CWEPT) and the TADS selected task trainer (TSTT) from a computer data base maintained by personnel at the simulator facility. CWEPT records indicated the participating crews did not use the device very often (M = 1.3, SD = .5). Fourth, although the TSTT was available to participating crews during the initial stages of the research, it was removed approximately 3 months before the final live-fire exercises. Discussions with personnel managing the device indicated little or no use of the device by the participating crews.

Fifth, the amount of CMS training differed for the two groups. One half of the aviators received five 1.5-hour gunnery training sessions in the AH-64A CMS between the initial and final live-fire exercises. The other half of the aviators were restricted from gunnery training in the CMS and were allowed only to use the CMS for instrument and emergencies procedures training. Although one half of the participating aviators received CMS training and the other half were restricted from the CMS, there were no significant differences in gunnery performance between the two training groups (Hamilton, 1991). Therefore, the gunnery performance measures were collapsed across both training groups for the present analyses.

Area Weapons Scoring System

The Army has sponsored the development of the AWSS, a scoring system for attack helicopter live-fire training and evaluation. The AWSS used during the initial and final live-fire exercises to score AH-64A gun and rocket target effect performance was the proof-of-principle system installed on the Dalton-Henson Multipurpose Range Complex at Fort Hood, Texas.

The AWSS consists of the ballistic scoring system (BSS) for 30 mm projectiles, the detonation scoring system (DSS) for rockets, and the computer scoring system (CSS) for score calculation, display, and hard-copy production. The BSS (see Figure 3) uses special purpose, Doppler radar sensors to detect the rounds that penetrate a 15 m radius fan in front of each target. The 30 mm rounds that penetrate the Doppler fan are counted as hits; those outside the fan are counted as misses. No information about the exact location of the hits or misses is provided by the BSS, but AWSS personnel can detect when a target is struck by a burst.

Although the TC 1-140 gun standard describes the target effect area as a 25 x 15 m box around the target, the geometry projected on the ground by the BSS Doppler fan is not square or rectangular. The exact geometry changes depending on the altitude of the aircraft. Generally, it has a 30 m (15 m times 2) straight front and an elliptical rear. Because the Army has ordered several AWSS systems for use worldwide, the Doppler fan target effect area has the most relevance to future gunnery performance measurement. To simplify terminology, the Doppler fan target effect area is referred to as the fan in this report.

The DSS (see Figure 4) is an acoustical system that determines the geographic location of rocket impacts. It consists of 10 microphone sensors placed within 1000 m of the target. During a rocket engagement, each sensor transmits the acoustical signal that it receives to the CSS. Using the known position of the sensors and the physics of sound propagation, the CSS analyzes the signals from several sensors to compute the impact point, cross-range miss distance, and down-range miss distance for each rocket. The system can reliably determine the location of rocket impacts

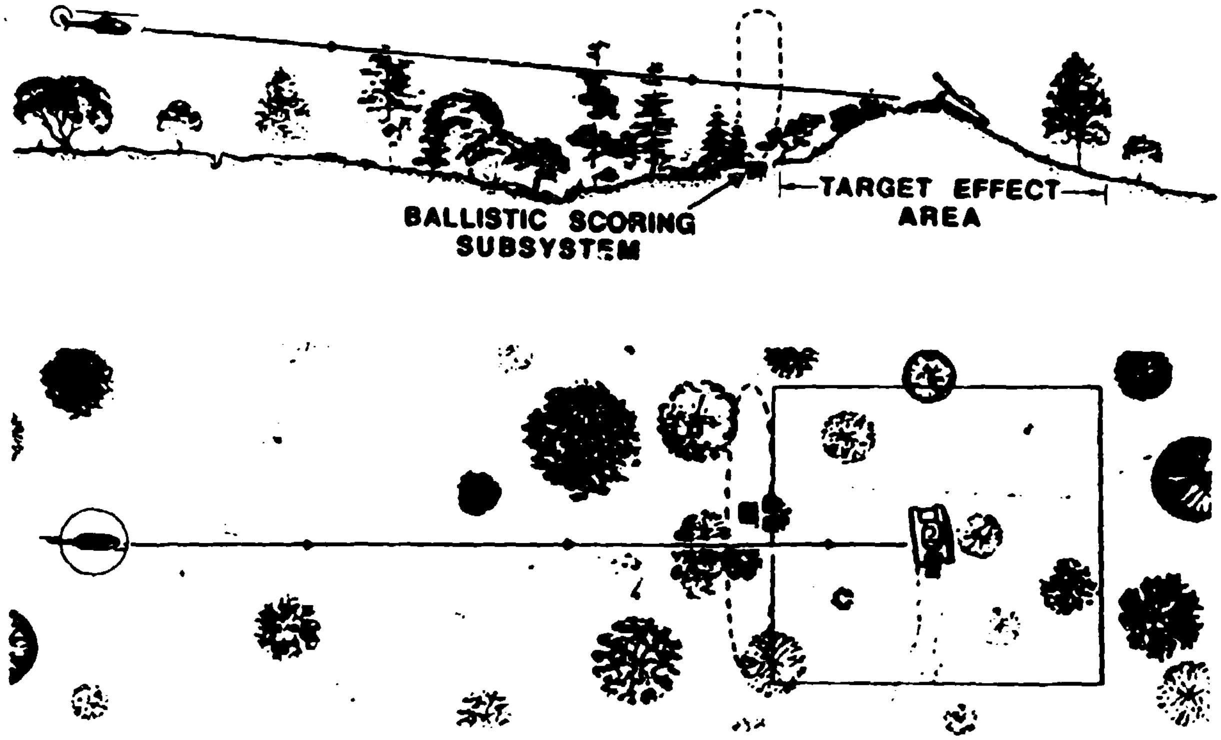

Figure 3. Diagram of the Ballistic Scoring System of the Area Weapons Scoring System.

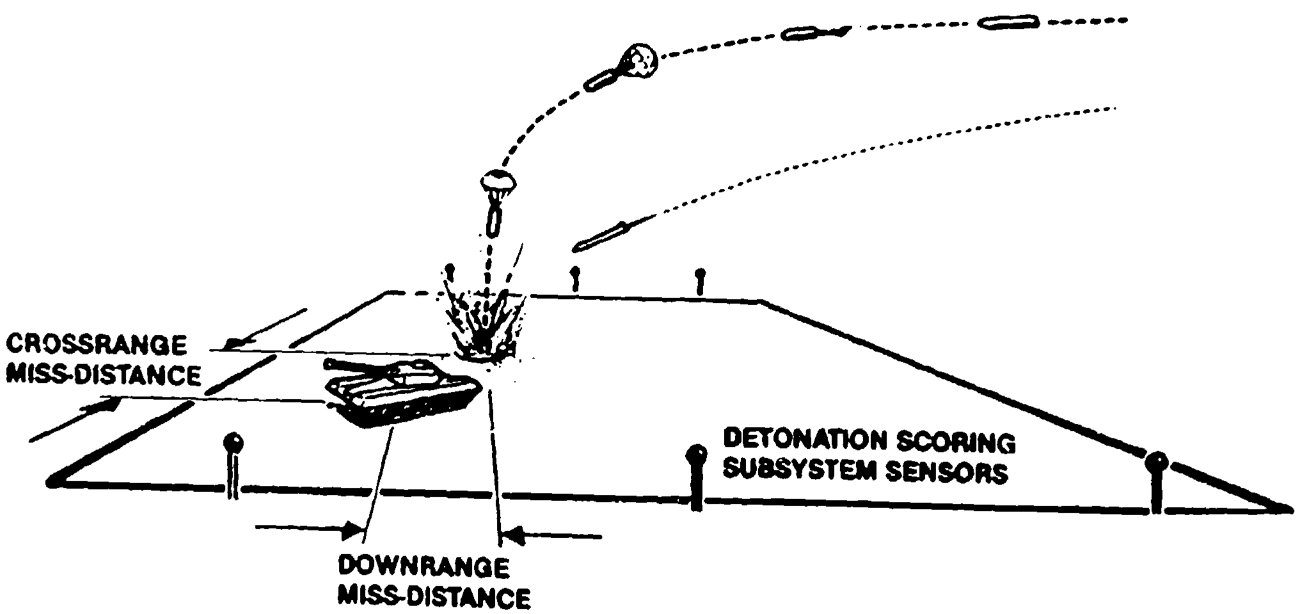

Figure 4. Diagram of the Detonation Scoring System of the Area Weapons Scoring System.

up to approximately 350 m from the target. Rockets falling beyond 350 m are either not detected or have large location errors.

The proof-of-principle DSS had three notable limitations that affected the conduct of the exercises. First, at the initiation of the project, the system was not reliably scoring rocket engagements using the M267 MPSM ammunition. Second, the system was not reliably scoring multiple rocket engagements. Third, the acoustically based DSS was susceptible to interference from other loud events such as the firing of the 30 mm gun. Because of these limitations, only TP/PD rockets were used, the rockets were fired individually with approximately 30 to 60 s between launches, and rocket and gun systems were not fired simultaneously.

Live-Fire Exercises

The initial and final live-fire exercises were conducted at the Dalton-Henson Multipurpose Range Complex at Fort Hood, Texas. The initial exercises were conducted at two different times. The first and second squadrons from the participating brigade completed the initial exercises over a 9-day period. The third squadron completed the initial exercises over a 5-day period approximately 2 months later. All three squadrons completed the final exercises over a 15-day period, 6 months after the first initial exercise. During both the initial and final exercises, only one squadron occupied the range at a time. The experimental protocol for the initial and final exercises was similar.

The gunnery exercises were controlled from the range operating tower. Each squadron provided one range safety officer and one officer in charge (OIC). The range operations office provided one civilian to operate the automated range. All targets were raised and lowered under the computer control of the range operator in the tower.

Each squadron established a forward arming and refueling point (FARP) within one mile of firing point 1. For the entire period that the squadron occupied the range, their personnel manned the bivouac for arming, refueling, maintaining, and staging aircraft. Performance of all the gunnery tasks in Table 4 and consequently, progress through all seven firing points was referred to as a run. Aircraft began and ended each run at the FARP. Each crew contacted the tower OIC when they were ready to start a run. When the range was clear of preceding aircraft, the aircraft were cleared by the OIC to move from the FARP to the first firing point.

Typically, a crew arrived on the range at firing point 1 and proceeded through the firing points to firing point 7 in sequential order. If equipment malfunction or other problems occurred, the crew was instructed to return to the FARP to repair or replace the aircraft. Subsequently, the crews returned to the range to complete the remaining engagements. Each crew completed one run under daylight conditions and one run under night conditions. During the initial exercises, crews were allowed to complete multiple runs to attain brigade standards for gunnery performance. Shortages of range time and ammunition during the final exercises limited each crew to a single day and a single night run.

All aircrews followed standard, out-front boresight procedures before firing the aircraft laser or weapons. Upon arriving at each firing point, the OIC acknowledged the aircraft's arrival at the firing position, cleared the crew to arm the weapon systems, instructed the crew to activate the VRS, and randomly selected one of the target engagements defined for that firing point. For each engagement, the OIC performed the following activities:

- requested that the range operator raise the target;
- requested that the aircraft establish the minimum safe altitude of 50 ft above ground level (AGL); and
- delivered a standard target handover including bearing, description, mode (stationary or moving), and weapon.

After receiving the target handover, the crew performed the following activities:

- established an altitude of 50 ft AGL,
- acknowledged the target handover,
- positioned switches for the engagement,
- unmasked the aircraft,
- acquired the target,
- delivered the ordinance,
- masked the aircraft, and
- called "weapons clear" to the OIC.

When all engagements were completed at a firing point, the OIC instructed the crew to deactivate the VRS and to place the weapon systems in the safe mode; he then cleared the crew to proceed to the next firing point. Each crew completed their day run before conducting their night run.

During the initial and final live-fire exercises, each crew was allowed to choose the weapon mode used to engage each target. However, the crews consistently used the same mode, which probably represented the consensus on the optimal weapon system mode for each engagement. The gun engagements were conducted by the CPG using the TADS and LRF/D. Rocket engagements were conducted in the cooperative mode: The CPG tracked the target with the LRF/D and TADS and the PLT maneuvered the aircraft to align the rocket symbology and fire the weapon. Missile engagements were conducted using the aircraft's simulated Hellfire training missiles by the CPG using the TADS and LRF/D in a normal LOBL mode with autonomous target designation.

Measures of Gunnery Performance

Four measures of gunnery performance were obtained during the live-fire gunnery performance tests. With the exception of engagement time, the measures differed from one weapon system to another. Each of the measures and their source are described in the following sections.

Engagement timing. FM 1-140 contained standards for both exposure time and engagement time. Exposure time is defined by the Army as the amount of time that the aircraft and the target have intervisibility during an engagement. Engagement time begins with the target handover, includes exposure time, and continues until the engagement is completed. In contrast to FM 1-140, TC 1-140 only contains standards for exposure time. After lengthy discussions with the operations officers and SIPs from the participating brigade, plans for measuring exposure time during the live-fire exercises were discontinued for two reasons. First, several of the firing points at the Dalton-Henson Multipurpose Range Complex always had intervisibility with the target. Second, an objective method of measuring intervisibility between the aircraft and target could not be identified by the researchers and the brigade personnel. Several methods using the VRS videotapes, range observers, the AH-64A crewmembers, and the known geometry of the firing points, terrain, and targets were considered and rejected. Because no acceptable method for acquiring exposure time measures was identified, only engagement time measures were collected.

Engagement time measures were obtained using hand-held stop watches and the VRS videotapes after the live-fire exercises. The videotapes were used to capture TADS displays and crew communications during each engagement. The range procedures were designed to utilize the 1-hour videotapes efficiently and to provide objective start (target handover) and finish (weapons clear) events to aid in measuring engagement time. The participating brigade did not include any timing standards in their crew qualification decisions; therefore, the crews were free to take the time necessary to maximize their target effect without practical consequence.

Gun target effect. Gun target effect was scored in three ways. First, if the BSS or range operator detected that any of the rounds struck the target, a target hit was recorded. Second, the number of rounds that passed through the BSS Doppler fan divided by the total number of rounds fired from the aircraft was computed for each engagement. The number of rounds passing through the BSS Doppler fan was provided by the BSS operator and the number shot was obtained from the rounds counter on the VRS videotape of the engagements. Thus, the ratio of detected rounds divided by the number shot is the percentage of rounds in the target effect area or fan. Finally, successful performance (GO ratings) were assigned to engagements when the target was hit or at least 50% of the rounds fell in the fan.

Missile target effect. The VRS videotapes were viewed immediately after each run by the squadron SIP and evaluated using the brigade standard for missile target kills. The information taken from the tapes was used to evaluate proper mode selection, switch settings, target acquisition, missile launch, and guidance. After evaluating an engagement, the squadron SIP recorded on brigade evaluations sheets his estimate of whether the target was killed.

As noted earlier, the standards for evaluating crew performance using the Hellfire training missile are not stated explicitly in FM 1-140 or TC 1-140. As such, some differences were noted among the squadrons in the evaluation of missile engagements. For the five factors evaluated, differences were noted in the relative contribution of the factors to the final rating and in the cutoff values at which the SIP awarded an unsuccessful rating.

Rocket target effect. Rocket target effect was scored in two ways. First, successful performance ratings were assigned to engagements when at least 50% of the impacts were within an unmarked rectangular box around the target. The down-range miss distance and the cross-range miss distance for each rocket impact were used to assess whether the impact fell within the box. Undetected rocket impacts were assumed to fall outside the 350 m radius around the target, where the DSS demonstrated good sensitivity, and were judged to be outside the box.

Second, the average miss distance for each engagement was computed using the miss distances from the individual firings. For each rocket impact sensed by the DSS, the cross- and down-range miss distances were used to compute the absolute miss distance using the Pythagorean theorem. However, miss distance could not be computed for undetected rocket impacts. Thus, two measures, miss distance and the percentage of undetected impacts, are required to fully describe rocket performance in any experimental condition. Because variations of two measures across conditions can make comparisons difficult to interpret, a single metric was desired. To produce a single metric of rocket performance that was influenced both by detected and undetected rocket impacts, the researcher assigned all undetected rocket impacts a 500 m miss distance. This assignment was made on the assumption that the missing impacts landed somewhere outside the 350 m sensitivity radius of the DSS.

Results

The main objectives of this research were to collect quantitative information on the gunnery performance of a typical AH-64A unit during crew gunnery exercises and to analyze that performance with respect to the gunnery standards published in TC 1-140. The analysis was also designed to identify the major factors influencing AH-64A gunnery performance to aid in the establishment of future gunnery standards. To meet the objectives, the engagement time and target effect data were analyzed for each weapon system and are described in separate subsections of the Results section. In addition, because the DSS provided cross-range and down-range miss distances for each rocket impact, in-depth analyses of rocket impact distributions, rocket distribution shifts, and rocket box standards are presented in the final three subsections of the Results section.

In the separate analyses of the weapon systems, five variables were evaluated to determine their influence on gunnery performance: light condition (day vs. night), squadron (first, second, third), target distance, aircraft mode (stationary vs. moving), and target mode (stationary vs. moving). The effects of light condition and squadron were evaluated using one-way analysis of variance (ANOVA) tests. If the effect of squadron membership was significant, Newman-Keuls tests were used to determine which squadrons were significantly different (Winer, 1971). The influence of target distance was evaluated using a regression analysis. If the regression analysis did not indicate a significant relationship between target distance and gunnery performance, the effects of aircraft and target mode were evaluated using one-way ANOVA tests. Otherwise, the effects of aircraft and target mode were evaluated with one-way analysis of covariance (ANCOVA) tests using target distance as the covariate. The ANCOVA tests provided the statistical control needed because of the confounding of aircraft and target modes with target distance in the set of measured engagements.

Gun Performance

Engagement time. Gun engagement time ranged from 10 to 542 s. The distribution was positively skewed (see Figure 5) with a median of 63 s (M = 70, SD = 43, n = 466). Of the five variables tested, light condition was the only one that significantly influenced gun engagement time, F (1, 464) = 9.23, p < .01. The average performance for night engagements (M = 76, SD = 54, n = 231) was approximately 12 s slower than for day engagements (M = 64, SD = 27, n = 235). The effect of light condition is probably larger than was estimated by this experiment because crews always fired the day engagements before the night engagements. Thus, the crews' night performance probably benefited from the live-fire experience of the day run.

Target effect. The percentage of rounds in the fan, target hits, and GO engagements were computed for 481 engagements using the gun. Across all engagements, performance was moderate. The mean percentages of rounds in the fan, target hits, and GO engagements were 52%, 29%, and 62%, respectively. Evaluation of the influence of the five variables on gun target effect identified five significant effects.

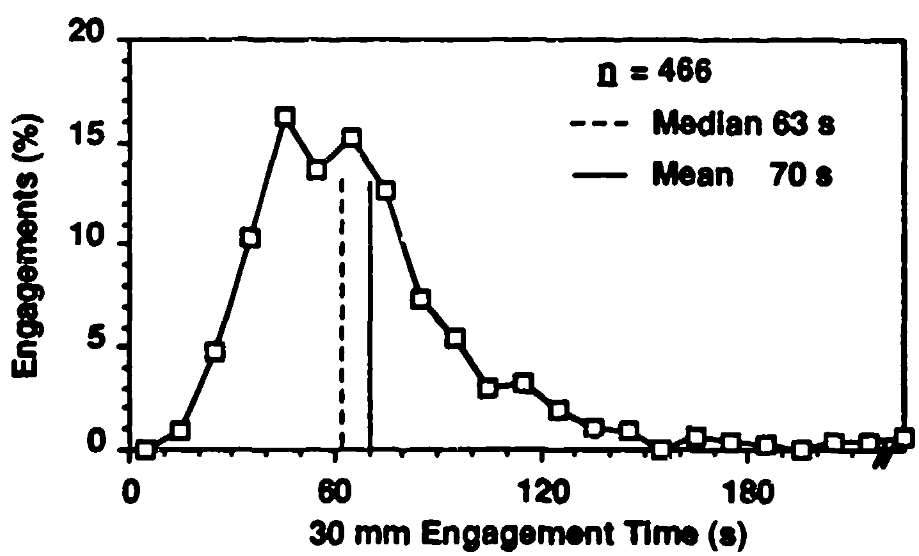

Figure 5. Distribution of engagement time for 466 engagements using the 30 mm gun.

Squadron membership and target distance influenced the percentage of rounds in the fan. The second squadron put a significantly higher number of rounds in the fan (59%) than the first and third squadrons (49%), F (2, 478) = 4.981, $p < .001$. The percentage of rounds in the fan generally declined the farther away the target was from the aircraft, $r = -.59$, $p < .001$; the regression equation (intercept = 107.5, slope = -.038) accounted for 35% of the variance in the percentage of rounds in the fan (see Figure 6). Light condition, aircraft mode, and target mode did not influence the percentage of rounds in the fan.

Target distance, aircraft mode, and target mode influenced the number of gun target hits. The number of hits generally declined the farther away the target was from the aircraft, $r = -.31$, $p < .001$. Exceptions to that trend were brought about by aircraft mode and target mode. Targets engaged from a moving hover (firing points 5 and 6) were more difficult to hit than those engaged from a stationary hover (see Figure 6), F (1,1,501) = 22.61, $p < .001$. In addition,

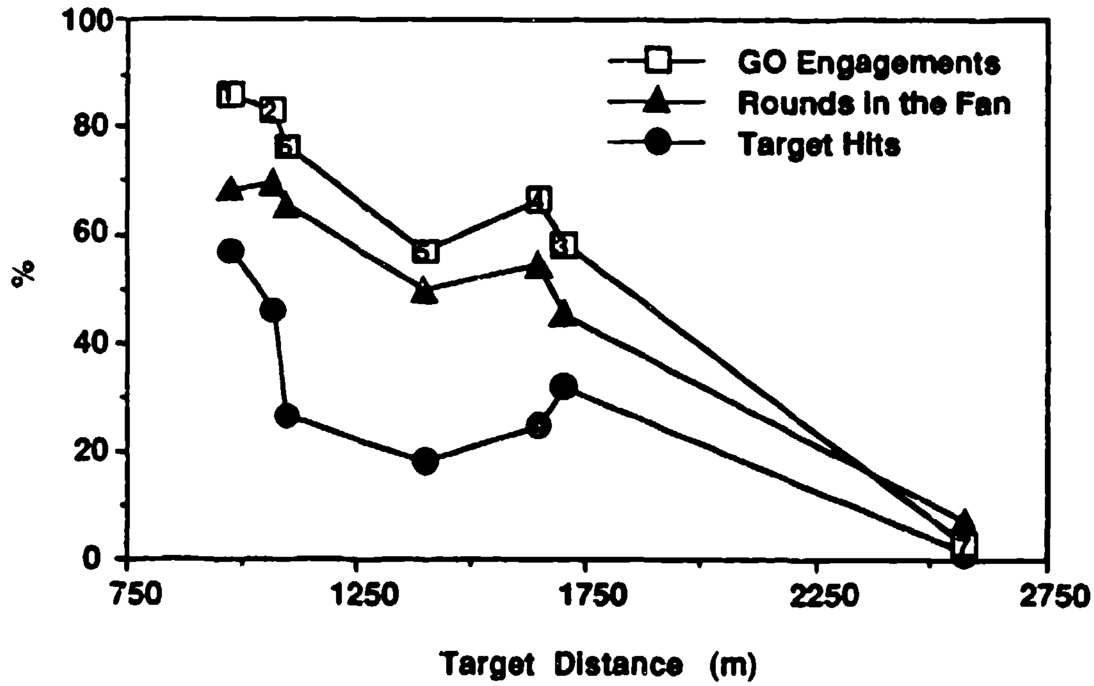

Figure 6. Percentage of 30 mm GO engagements, rounds in the fan, and target hits as a function of target distance. (The numbers in the GO engagement symbols indicate the firing point.)

moving targets (firing points 2, 4, 5, 6, and 7) were more difficult to hit than stationary ones (firing points 1 and 3), F (1,1,501) = 13.99, p < .001. Light condition and squadron membership did not influence target hits.

Each engagement was evaluated using the TC 1-140 standard for GO engagements. Engagements were given a GO rating if the target was hit (hit criterion) or if the percentage of rounds in the fan was 50% or higher (rounds criterion). The resulting GO engagements function was more similar to the rounds in the fan function than the target hits function (see Figure 6). For all GO engagements, 52% passed the rounds criterion without passing the hit criterion, only 9% passed the hit criterion without passing the rounds criterion, and 39% passed both criteria.

Missile Performance

Engagement time. Missile engagement time ranged from 14 to 300 s. The distribution was positively skewed (see Figure 7) with a median of 56 s (M = 66, SD = 42, n = 560). All missile engagements were fired from a stationary hover. There were significant differences among the squadrons, F (2, 557) = 7.3, p < .001. Engagement times for the first, second, and third squadrons was 66 s (SD = 43, n = 192), 57 s (SD = 29, n = 176), and 73 s (SD = 48, n = 192), respectively.

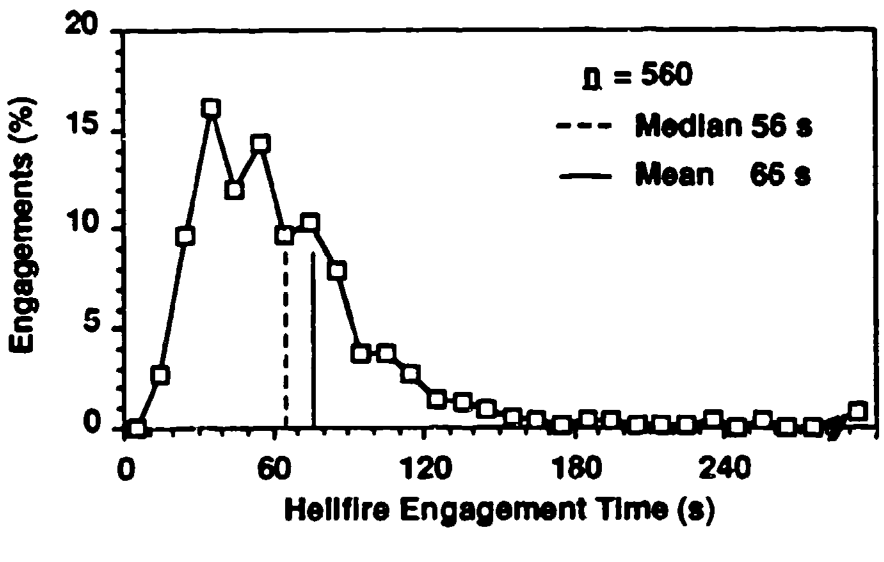

Figure 7. Distribution of engagement time for 560 Hellfire engagements.

Newman-Keuls tests indicated that engagement time was significantly shorter for the second squadron than for the first and third squadrons. There were no significant effects of light condition, target distance, or target mode on missile engagement time.

Target effect. Across 576 missile engagements, 88% were rated as a GO. Target distance had no influence on the percentage of GO engagements. However, light condition, squadron membership, and target mode all had significant effects on the percentage of GO ratings. GO engagements dropped from 93% (n = 288) during the day to 84% (n = 288) at night, F (1, 574) = 10.7, p < .001. The percentage of GO engagements was significantly different among the squadrons, F (2, 573) = 3.7, p < .05. GO engagements for the first, second, and third squadrons were 93% (n = 192), 84% (n = 192), and 89% (n = 192), respectively. Newman-Keuls tests indicated that the performance of only the first and second squadrons differed significantly. Finally, GO engagements dropped from 91% (n = 449) for stationary targets to 78% (n = 127) for moving targets, F (1, 574) = 17.7, p < .001.

Rocket Performance

Engagement time. Rocket engagement time ranged from 41 to 728 s. The distribution was positively skewed (see Figure 8) with a median of 152 s (M = 158, SD = 62, n = 440). All rocket engagements were fired from a stationary hover at stationary targets. There were no significant effects of light condition, squadron membership, or target distance on rocket engagement time.

Target effect. The mean miss distance and percentage of GO engagements for the TC 1-140 standard (hit or 50% in a 100 x 400 m box) were analyzed for 470 rocket engagements. Of the 1880 rockets fired during the 470 engagements, the DSS located 1121 or 59.5% of the impacts. The remaining 40.5% of the rockets were assumed to have been fired erratically and the impacts were outside the 350 m sensitivity radius of the DSS. No rockets were detected by the DSS or observed on the videotapes to directly impact the target. Across all engagements, the miss distance (M = 309 m, SD = 99) and GO engagements performance (16%) was low.

Miss distance was significantly dependent on light condition [F(1,4 68) = 12.32, p < .001], squadron membership [F(2, 467) = 3.66, p < .05], and target distance (r = -.14, p < .01). The mean miss distance was 32 m greater during the

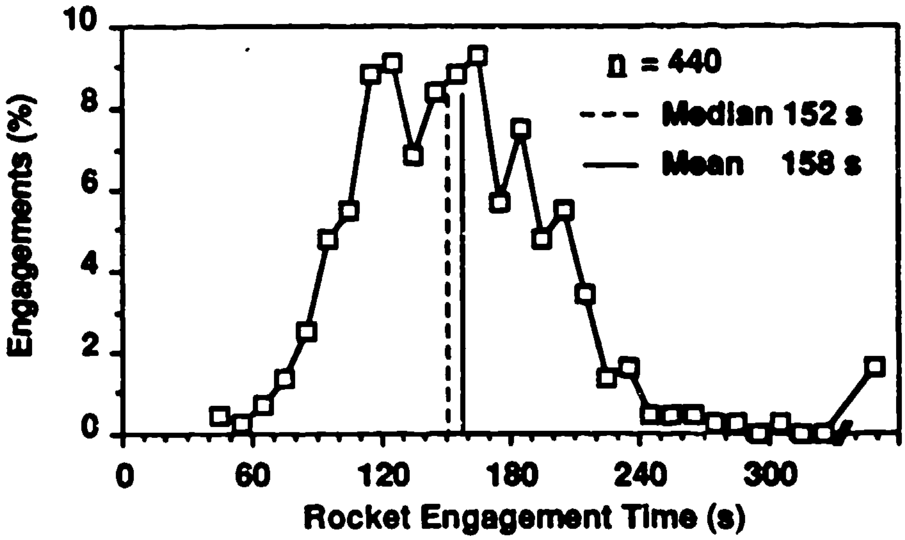

Figure 8. Distribution of engagement time for 440 rocket engagements.

day (_M_ = 322, _SD_ = 96, _n_ = 279) than at night (_M_ = 289, _SD_ = 101, _n_ = 191). The first, second, and third squadrons' mean miss distance was 322 m (_SD_ = 97, _n_ = 173), 292 m (_SD_ = 102, _n_ = 140), and 309 m (_SD_ =98, _n_ = 157), respectively. The 30 m difference between the first and second squadrons was statistically significant. Finally, mean miss distance generally decreased with target distance: 318 m (_SD_ = 94, _n_ = 120) at 3450 m, 328 m (_SD_ = 99, _n_ = 124) at 3700 m, 300 m (_SD_ = 97, _n_ = 105) at 4400 m, 288 m (_SD_ = 103, _n_ = 121) at 4500 m.

Similar effects were not found with the GO engagement measure. The disassociation was attributed to the effect of the rocket impacts outside the sensitivity of the DSS on mean miss distance but not on GO engagements. That is, the undetected impacts were assigned a value of 500 m in computing the mean miss distance but only rockets inside the sensitivity of the DSS could possibly contribute to the GO engagements. The effects of the three variables are reflected in the percentage of rockets detected: (a) 65.3% versus 55.7% for night and day conditions, (b) 55.6%, 58.9%, and 65.4% for the first, second, and third squadrons, and (c) 57.3%, 51.1%, 64.8%, 65.9% at 3450, 3700, 4400, and 4500 m, respectively.

Rocket Impact Distributions

The distribution of rocket impacts is described more fully in the following three subsections. The first subsection describes the distribution of rocket impacts observed in the overall data set, the second subsection describes the distribution of rocket impacts for a high performance subset of the data, and the third subsection describes the distribution of rocket impacts categorized by exercise and squadron. The overall analysis describes the current rocket performance of a typical Army unit, the high performance subset analysis describes the performance expected in the near future, and the subgroup analysis provides a reference of each squadron's performance during each exercise.

Overall analysis. The cross-range and down-range miss distances of the 1121 detected rocket impacts were analyzed to describe the dispersion of rocket impacts. Rocket engagements were fired from firing points 1 and 3 toward target 3 and from firing points 2 and 4 toward target 2 (see Figure 2). The distributions of impacts for the rockets fired from the four firing points were very similar (see Figure 9). The dispersion of the rockets fired from each firing point indicates more down-range dispersion than cross-range dispersion. Otherwise, the rocket impacts appear to be randomly distributed with no obvious differences between firing points or evidence of locations with abnormally high or low impact density. A regression analysis showed no significant relationship between target distance and impact dispersion, probably because of the limited range of distances for rocket engagements relative to the capabilities of the rocket system.

Because there were no obvious differences among the firing points, the data from firing points 1 and 3 were combined to plot the dispersion of impacts around rocket target 3, and the data from firing points 2 and 4 were combined to plot the dispersion of impacts around rocket target 2 (see Figure 10). Again, the dispersion of the rocket impacts around each target appeared to be randomly distributed with no obvious differences between targets or locations of abnormally high or low impact density, except for the greater down-range miss distances. Thus, the impacts around rocket target 2 and 3 were combined for analysis (see Figure 11).

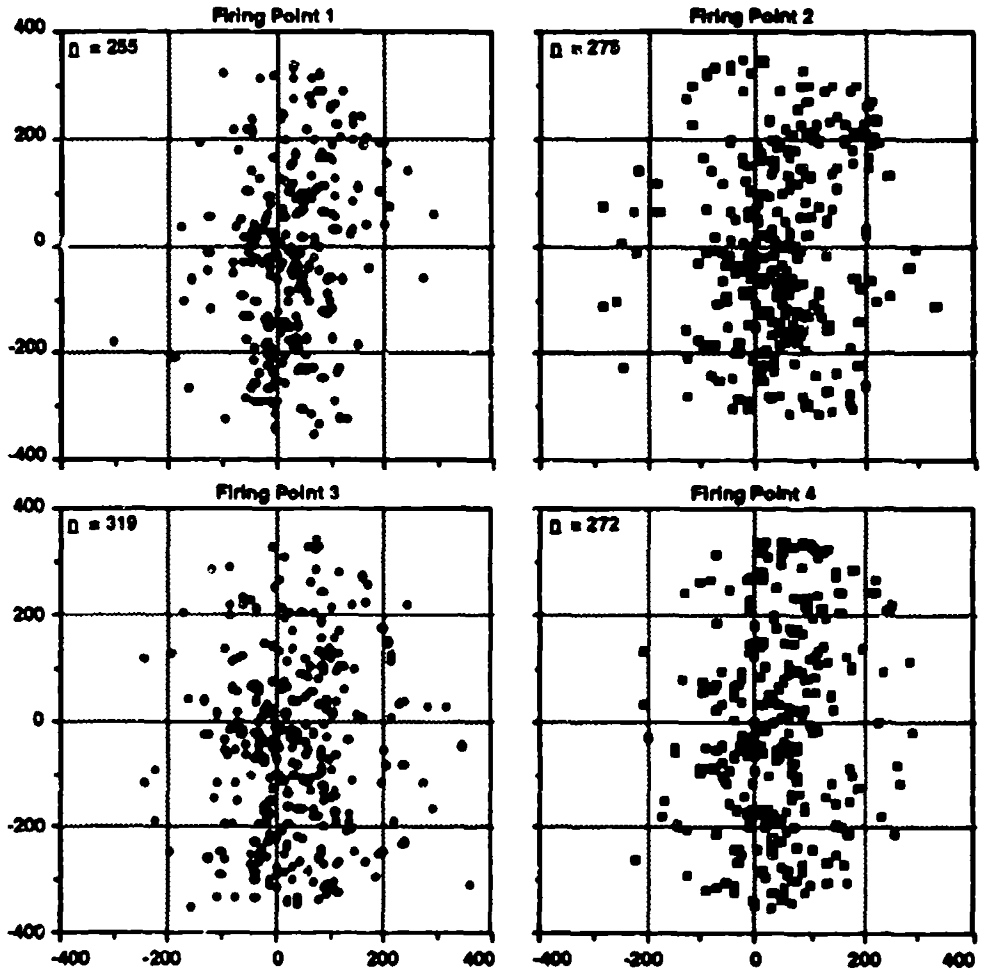

Figure 9. Dispersion in meters of observed rocket impacts fired from four firing points.

Analysis of the distribution of cross-range and down-range miss distances for the 1121 observed impacts (see Figure 12) revealed that the mean cross-range and down-range miss distances were shifted 36 m right and 19 m short of the target. Almost twice as many impacts were detected to the right of the target as to the left, while 25% more short impacts were detected than long impacts. Additionally, the analysis confirmed the observation that the down-range dispersion (SD = 176) was almost twice that of the cross-range dispersion (SD = 93) and that the impacts were approximately normally distributed.

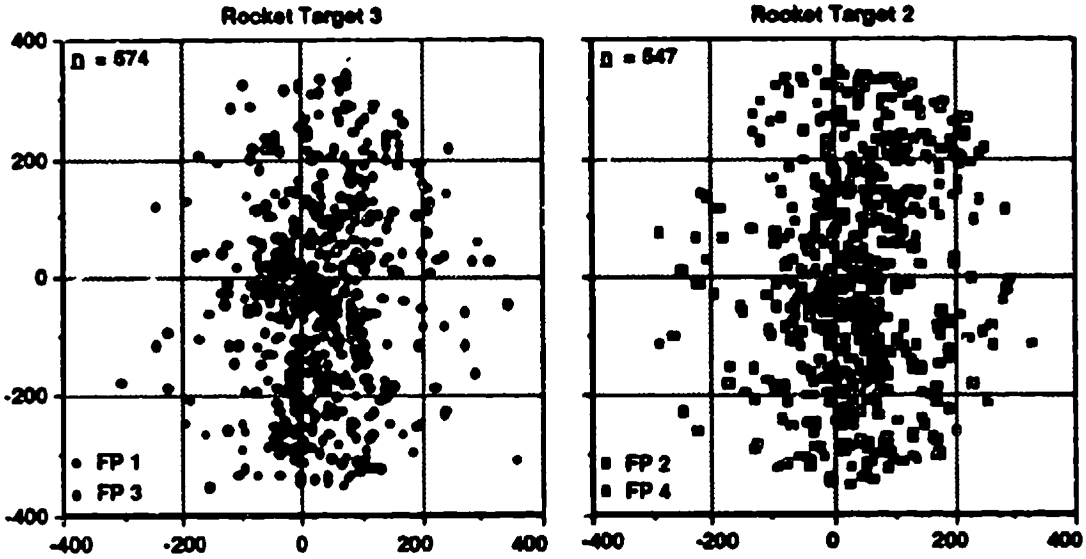

Figure 10. Dispersion in meters of observed rocket impacts for the two rocket targets.

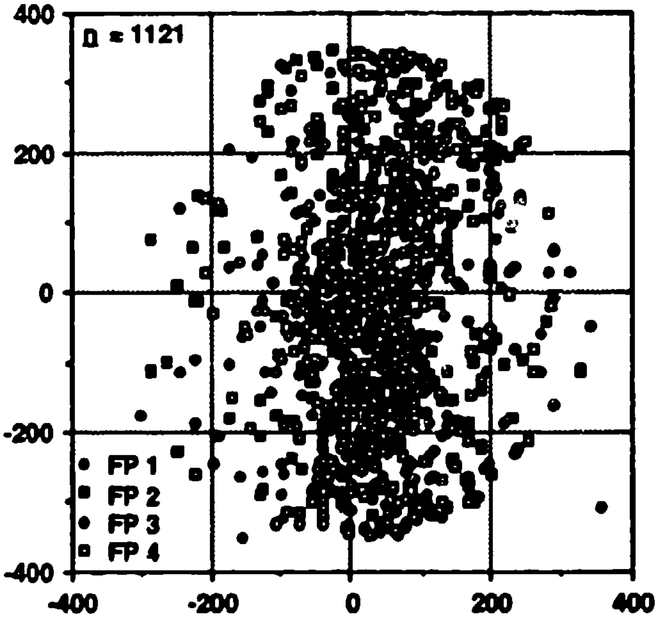

Figure 11. Dispersion in meters of all observed rocket impacts.

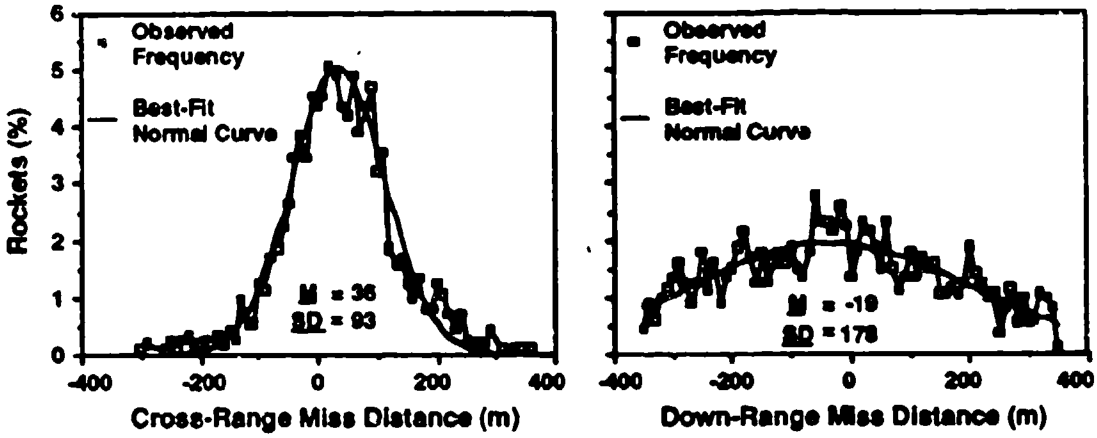

Figure 12. Cross-range and down-range distributions of rocket impacts with best-fit normal curves.

High performance subgroup analysis. At the completion of the overall analysis of the rocket performance described in the preceding paragraphs, AWSS scoring personnel reported that after the initial live-fire exercises and before the final live-fire exercises, the third squadron had initiated a set of rocket pod alignment procedures that had improved their target effect performance. Since that time, the USAAVNC obtained the maintenance procedures and implemented them at Fort Rucker to find a 90% increase in rocket target effect performance. Subsequently, the procedures were scheduled for incorporation into the Army AH-64A maintenance manuals. Because future rocket target effect performance may be best represented by this level of performance, the overall data set was analyzed for squadron specific increases in performance during the final live-fire exercises.

Initially, the mean miss distance for the initial and final live-fire exercises was examined for each squadron (see Figure 13). These data indicated that not only had the third squadron performed significantly better during the final exercise, but also that the second squadron's performance improvement was remarkably similar to the third squadron's improvement. Discussions with maintenance personnel from the second squadron provided no explanation for their increase in rocket performance.

Because the increases in performance for the second and third squadrons were equivalent, the distribution of rocket impacts was analyzed for 99 second and third squadron engagements from the final live-fire exercises (see Figure 14).

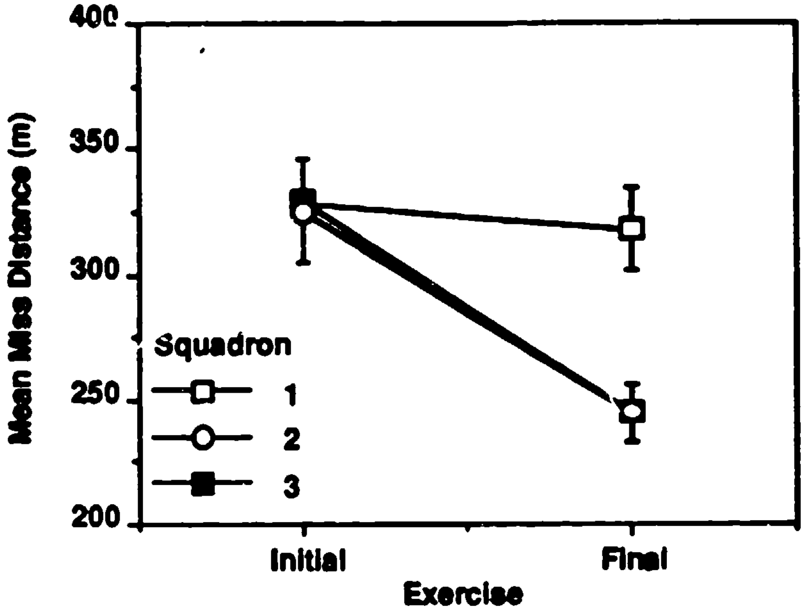

Figure 13. Mean rocket miss distance during the initial and final live-fire exercises for each squadron.

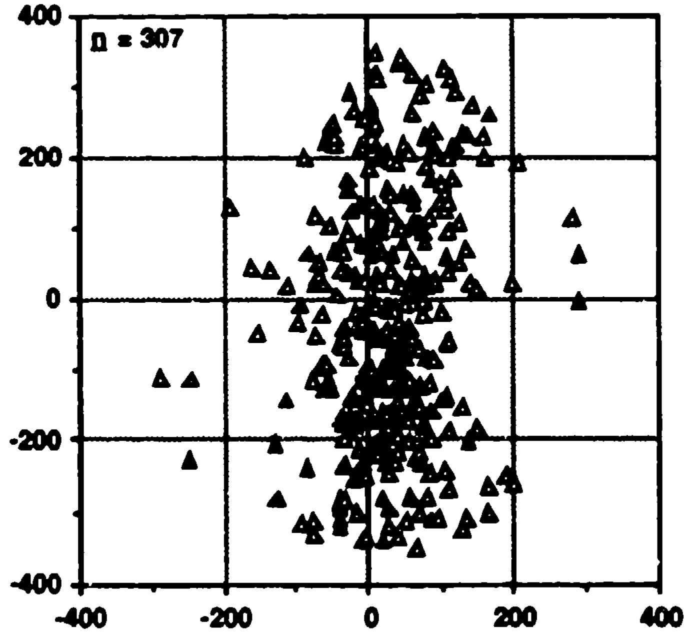

Figure 14. Dispersion in meters of all observed rocket impacts for the second and third squadrons during the final live-fire exercise.

Of the 396 rockets fired during the 99 engagements, the DSS detected 307 or 77.5% of the impacts.

The cross-range and down-range distribution shifts observed in the entire sample (36 m right and 19 m short), were also found in the subgroup. The mean cross-range miss distance was decreased slightly (30 m right) and the mean down-range miss distance was increased slightly (26 m short). More than twice as many impacts were detected to the right of the target as to the left, and 26% more short impacts were detected than long impacts.

The down-range dispersion (*SD* = 174, *n* = 307) for the second and third squadrons was quite similar to the overall down-range dispersion (*SD* = 176, *n* = 1121). The cross-range dispersion of the sample (*SD* = 77, *n* = 307) was relatively smaller than the overall cross-range dispersion (*SD* = 93, *n* = 1121). Thus, the decrease in the second and third squadrons' mean miss distances during the final live-fire exercises was a function of an 18% increase in the number of rockets that the DSS detected and a 17% narrowing of the cross-range dispersion.

Squadron by exercise subgroup analysis. To provide the participating squadrons with specific information about their performance during the exercises, the statistics for the performance sample size and the distribution shifts were computed separately for each squadron and each exercise (see Table 6). The breakdowns indicate that the number of engagements were roughly equal across squadrons and relatively fewer engagements were fired during the final exercise. The percentage of impacts scored by the DSS was the least for the second squadron during the initial exercises (52.1%) and the greatest for the third squadron during the final exercise (80.4%). The mean cross-range miss distance ranged from a minimum of 18 m right to a maximum of 64 m right and the mean down-range miss distance ranged from 4 m short to 54 m short. These shifts varied substantially across squadrons and between exercises.

Rocket Distribution Shifts

Consistent shifts in the distribution of rocket impacts is a tactical concern. Five possible explanations for the distribution shifts include:

- the sensitivity of the DSS was greater to the right of the targets than to the left,
- some aircraft were firing far right and short,

Table 6

Rocket Impact Sample Size and Distribution Shifts by Squadron

Measure	Exercise	Squadron First	Squadron Second	Squadron Third	Squadron Combined
		Sample size			
# Engagements	Initial	127	109	89	325
	Final	46	48	51	145
	Overall	173	157	140	470
# Rockets	Initial	508	436	356	1300
	Final	184	192	204	580
	Overall	692	628	560	1880
% Scored	Initial	54.1	52.1	56.7	54.2
	Final	59.8	74.5	80.4	71.9
	Overall	55.6	58.9	65.4	59.6
		Distribution shifts			
Mean cross-range miss distance (m)	Initial	18	42	64	39
	Final	32	33	27	30
	Overall	22	39	47	36
Mean down-range miss distance (m)	Initial	-12	-24	-4	-14
	Final	-30	-54	-4	-27
	Overall	-17	-35	-4	-19

- the AH-64A aircraft's fire control computer produced an incorrect ballistic solution,
- the M274 rockets had some mechanical or aerodynamic flaw, or
- the weather conditions and terrain at the Dalton-Henson Multipurpose Range Complex generated a consistent westerly wind that caused the rockets to deviate to the right.

The first explanation would be best described as a measurement bias rather than an actual shift in the rocket dispersions. However, the last four explanations would be classified as actual shifts. All five possibilities cannot be evaluated using the present data; however, the first two possibilities are evaluated in the following two subsections.

DSS analysis. The data collected during this research were used to evaluate the possibility that the consistent shifts observed in the distribution of rocket impacts were caused solely by a DSS sampling bias. If the cross-range distribution of rocket impacts was normally distributed and centered around the target, then one half of the rockets fell to the left of the target and one half fell to the right. If a situation was identified in which the undetected rocket impacts could not be distributed in any manner to balance the distribution around the target, then the possibility that the observed shifts were caused solely by a DSS sampling bias could be rejected.

The overall rocket impact data could not be used to reject the possibility of a DSS sampling bias because of the large percentage of rocket impacts that were not detected (see Table 7). If many of the undetected rockets fell to the left of the target but were undetected by the DSS, it could be possible that the dispersion of rocket impacts was centered around the target.

Because the high performance subgroup examined earlier had fewer undetected rockets, it was used to reject the possibility of a cross-range DSS sampling bias. If all the missing rockets fell to the left side of the target and were undetected by the DSS, this is not enough to balance the distribution of rockets around the target because greater than 50% of the rockets were detected to the right of the target (see Table 7). Furthermore, it is unlikely that every one of the undetected impacts fell to the left of the target because many of the missing rockets were known by the aviators and were observed by the researchers to be fired well outside the 350 m sensitivity radius of the DSS. Therefore, it must be concluded that the cross-range shifts were not solely the result of a DSS measurement bias but rather represent a shift in the rocket impacts. Unfortunately, the data available are insufficient to reject the possibility of measurement bias for the down-range shifts.

Aircraft analyses. To determine if the shifts were the result of the rocket systems on a small number of aircraft firing right and short, the distribution of rocket impacts was analyzed for each aircraft with more than 10 impacts detected by the DSS. The mean cross-range miss distance by aircraft ranged from 107 m right for aircraft number 241 to 5 m left for aircraft number 250 (see Figure 15). Of the 29 aircraft in the analysis, the mean cross-range miss distance

Table 7

The Distribution of Rocket Impacts

	Overall		Subgroup	
Position	n	%	n	%
Left of target	386	20.5	98	24.7
Right of target	735	39.0	209	52.8
Long of target	499	26.5	136	34.3
Short of target	622	33.0	171	43.2
Undetected by DSS	759	40.5	89	22.5

Note. The overall column is based on 1880 rockets fired by all squadrons during both exercises and the Subgroup column is based on 396 rockets fired by the second and third squadrons during the final exercises. DSS = detonation scoring system.

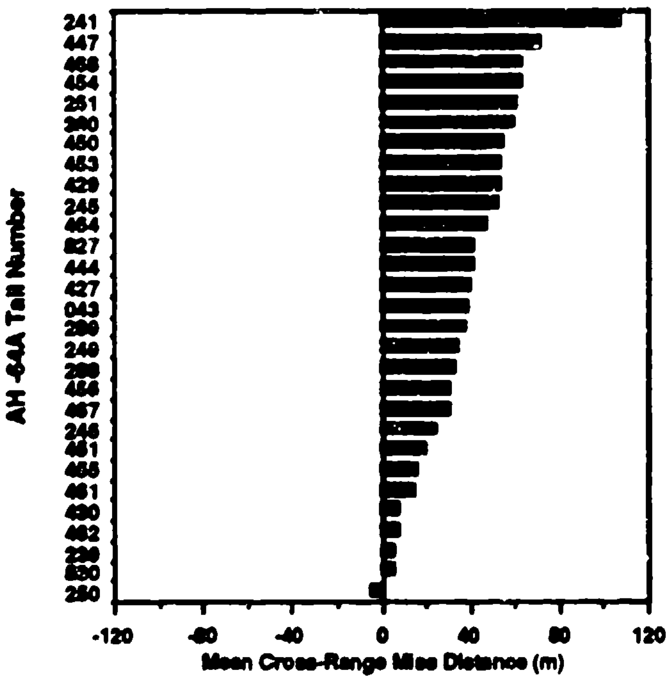

Figure 15. Mean cross-range miss distance of rocket impacts for each aircraft firing more than 10 rockets.

fell to the right of the target for 28 of them. For the same aircraft, the mean down-range miss distance by aircraft ranged from 84 m short for aircraft number 043 to 80 m long for aircraft number 827 (see Figure 16). The mean down-range miss distance fell short of the target for 21 of the 29 aircraft in the analysis. The aircraft analyses indicate that the cross-range and down-range shifts were not due to a small number of aberrant aircraft rocket systems.

Rocket Box Standards

The target effect performance of the 470 rocket engagements was evaluated using three different rocket boxes to determine the effect of different rocket standards on crew qualification. For each engagement, two (50%) or more of the observed impacts were required to fall within the box to receive a GO rating. The percentages of GOs were computed separately for each squadron, exercise, and box size (see Table 8). The 100 x 400 m box is the TC 1-140 standard and the two larger boxes represent FM 1-140 standards. To obtain a perspective of the size of these rocket box standards relative to the dispersion of rocket impacts, two of the

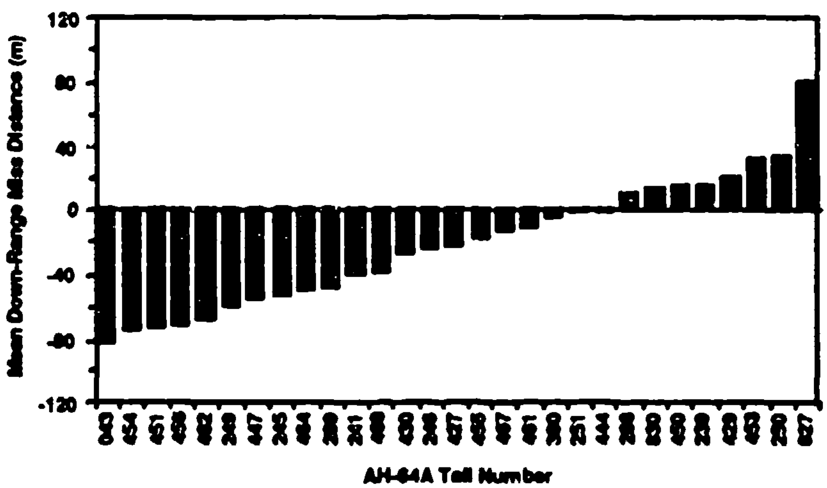

Figure 16. Mean down-range miss distance of rocket impacts for each aircraft firing more than 10 rockets.

Table 8

Percentage of GO Engagements for Different Rocket Box Sizes

		Squadron			
Box Size (m)	Exercise	First	Second	Third	Combined
100 x 400	Initial	12	16	9	12
	Final	15	25	33	25
	Overall	13	18	18	16
300 x 400	Initial	39	37	36	37
	Final	43	60	75	60
	Overall	40	44	50	44
300 x 500	Initial	46	45	43	45
	Final	52	71	90	72
	Overall	47	53	60	53

standards were superimposed on all the rocket impacts (see Figure 17). Across all box sizes and all squadrons, performance improved from the initial to the final exercises. Across squadrons, performance improved by 13%, 23%, and 27% from initial to final exercises for increasing box size. Across exercises, the third squadron had the best and the worst performance on all box sizes. The squadron's performance ranged from 9% for the smallest box during the initial exercise to 90% for the largest box during the final exercise. Across squadrons, when judged using FM 1-140 standards, the percentage of GO ratings ranged from 44% to 53% for the two box sizes. The percentage dropped to 16% using the TC 1-140 standards. Thus, the percentage of rocket engagements receiving GO ratings under FM 1-140 standards dropped by at least 28% under TC 1-140 standards.

To understand how the size of the rocket box influenced the number of GO engagements, DOTS personnel requested further analysis of the third squadron's final live-fire performance. Specifically, they requested that the percentage of engagements given GO ratings be plotted as a function of the width of a 400 m down-range box (see Figure 18). The analysis showed that the percentage of GO engagements was a monotonic function of the width of the box,

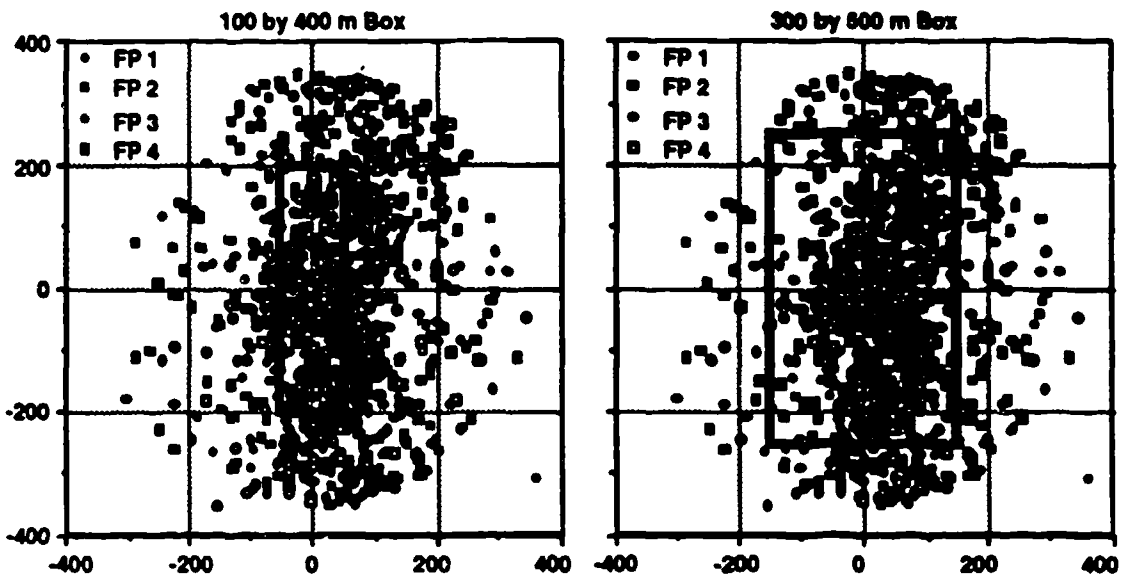

Figure 17. Comparison of two rocket box standards superimposed over all observed rocket impacts.

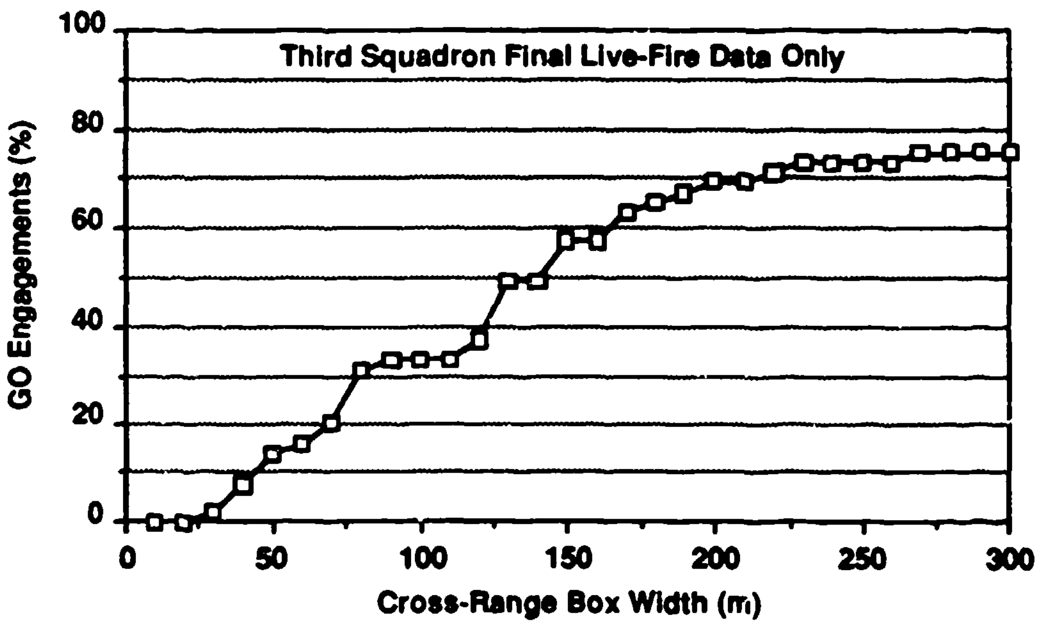

Figure 18. Percentage of GO engagements for a 400 m long box as a function of cross-range width.

with a minimum of 0% at 25 m or less and a maximum of about 74% at 265 m or more.

The function indicates that a box size of 130 x 400 m would produce crew qualification rates similar to those observed using the FM 1-140 standards. This prediction is based on two assumptions. First, it assumes that the third squadron's final live-fire performance is a good estimate of future performance. Second, it assumes that the initial sample combined across squadrons for the two larger boxes shown in Table 8 is a good estimate of crew qualification rates using FM 1-140 standards. Thus, the initial qualification rates (37% and 45%) produced for the two larger boxes are similar to the third squadron's final qualification rate (49%) for a 130 x 400 m box (see Figure 18).

The GO performance described above (Table 8 and Figure 18) was calculated by evaluating each observed 4-rocket engagement; however, TC 1-140 allocates 6 rockets to each engagement. To predict how performance is expected to change from 4-rocket to 6-rocket engagements, a probability method was used to predict performance for situations different from that measured. The cross-range and down-range distribution of rocket impacts is assumed to be the same for 4-rocket and 6-rocket engagements and normally distributed. Five parameters are used: four that describe the distribution of the detected rocket impacts and one that estimates the percentage of undetected rocket impacts. Using the area under the normal curve to estimate the probability of rockets landing in or out of the box, the means and standard deviations of the down-range and cross-range distribution and the percentage of rockets outside the DSS sensitivity radius were used to predict performance for different rocket box and engagement sizes.

To check the assumptions of the method, the expected percentage of engagements for each possible outcome in 4-rocket engagements was calculated for a 100 x 400 m box using the parameters from the third squadron's final exercise (see the graph on the left of Figure 19). GO ratings are given for two, three, or four rockets in the box; therefore, the percentage of GO ratings was predicted to be 32%, the sum of the expected percentages for two (24.7%), three (6.5%), and four (0.6%) rockets in the box. Because the predicted performance was within 1% of the observed performance (33%), the method was used to predict performance on 6-rocket engagements using the same parameters (see the graph on the right of Figure 19). The expected percentage of GO ratings (three, four, five, or six rockets in the box) is 22% on 6-rocket engagements, 10% lower than for 4-rocket engagements. Using the same method for prediction, a box size of 150 x 400 m was required to produce

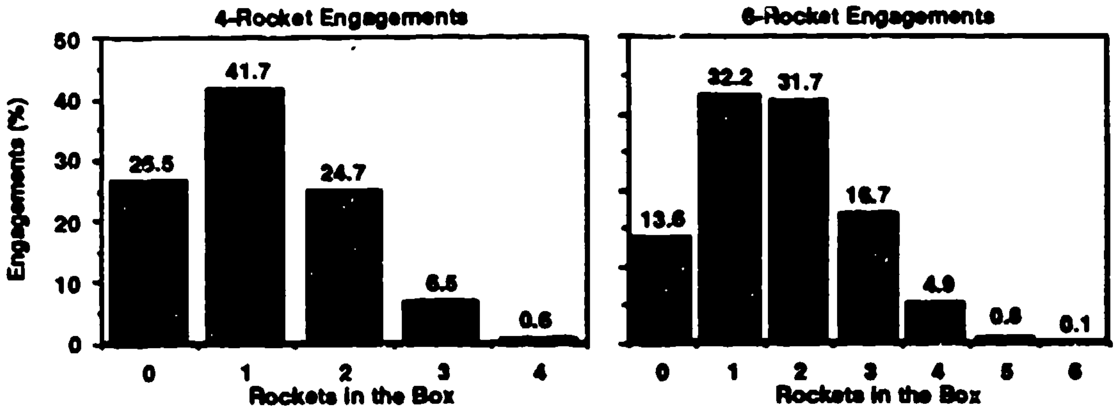

Figure 19. Expected percentage of engagements for all possible outcomes of 4-rocket engagements (left) and 6-rocket engagements (right) based on the parameters of the third squadron's final exercise.

crew qualification rates (44%) on 6-rocket engagements that were similar to those observed using the FM 1-140 standards. Unless the individual probability of firing a rocket in the box is above 60% (it is 28% here), any increase in the number of rockets allocated for each engagement is expected to lower the number of engagements receiving GO ratings, regardless of box size.

Summary and Discussion

The primary objectives of this research were to collect quantitative information on the gunnery performance of a typical AH-64A unit during crew gunnery exercises and to analyze that performance with respect to the gunnery standards published in TC 1-140. The analysis also sought to identify the major factors influencing AH-64A gunnery performance to aid in the establishment of future gunnery standards.

The research was conducted during three crew qualification live-fire exercises for operational AH-64A aviators. Measures of engagement time and target effect were collected for a set of gunnery tasks determined by the participating brigade. Although all the tasks in Table VIII (TC 1-140, USAAVNC, 1990) were not represented in the observed gunnery engagements, the information gathered from similar tasks provides an empirical data base to evaluate the difficulty of gunnery standards. In addition, separate analyses of the measures for each weapon system provides information about the major factors that influence gunnery performance.

In the subsections that follow, the factors found to influence AH-64A gunnery performance are summarized and the relative difficulty of the TC 1-140 gunnery standards is discussed. Finally, a method for establishing gunnery standards is presented before the final conclusions.

AH-64A Gunnery Performance

Engagement time. Engagement times for the gun and missile systems were similar and approximately 1 min in length. The engagement times for the rockets were substantially longer, averaging approximately 2.5 min. The longer rocket engagement time is probably unrealistic and is an artifact of firing one rocket at a time.

A number of factors were examined to determine if they had an impact on engagement time. Target distance, aircraft mode, and target mode were not found to influence engagement time. Night conditions were found to slow gun engagement times by an average of 12 s. Finally, there were significant differences among the squadrons for Hellfire engagement time. The second squadron had a significantly faster average engagement time than the first and third squadrons.

Target effect. The measures for target effect differed for each weapon system. Across all weapon systems, the factor that consistently generated significant differences was squadron membership. Though differences in gunnery performance among squadrons may be the result of a number of influences (e.g., different aircraft, training procedures, gunnery procedures, or maintenance procedures), the squadrons with high performance were identified as the first step in determining which factors contribute to superior gunnery performance.

Superior performance was found in the second squadron's gun performance, the third squadron's rocket performance, and the first squadron's missile performance. The methods for measuring missile target effect, however, were fundamentally different from the methods used to measure gun and rocket target effect. The gun and rocket measures were scored by the researchers and AWSS personnel using the same methods for each squadron. The missile engagements were scored by separate individuals from their respective squadrons. Because some differences were noted among the squadrons in the evaluation of missile engagements, a lower number of GO ratings for a squadron may be the result of poorer aviator performance or the application of more stringent scoring standards.

The largest impact on target effect was found in the gun analysis of target distance. Distance to the target was the major contributing factor in reducing the percentage of rounds in the fan from 68% at 975 m to 7% at 2575 m. Target distance did not produce significant differences in rocket or missile performance, but this may be because of the limited range of distances relative to the capabilities of the weapon systems found in those engagements: rocket engagements ranged from 3450 to 4500 m and missile engagements ranged from 2100 to 4620 m.

Light condition significantly influenced rocket and missile target effect. However, the effects were in different directions. Almost 10% fewer rockets fell within the 350 m sensitivity radius of the DSS during the day than at night. The increased number of impacts detected at night significantly reduced the average miss distance of night engagements. Conversely, performance for missiles was better during the day than at night: 9% more missile engagements received GO ratings during the day than at night. The day engagements in this experiment were always fired before the night engagements.

Finally, the aircraft mode (stationary vs. moving) varied only for gun engagements and was found to influence target hits but not rounds in the fan. Target mode (stationary vs. moving) varied for gun and missile engagements. Stationary targets were significantly easier to hit than moving targets with the gun and missiles.

TC 1-140 Gunnery Standard Evaluation

The crew gunnery standards in TC 1-140 differ qualitatively and quantitatively from those in FM 1-140. In the subsections that follow, the impact that these changes may have on crew gunnery qualification is discussed separately for exposure time and target effect standards.

Exposure time. As described earlier, the only timing standard in TC 1-140 is exposure time. Unfortunately, the researchers and the staff from the participating brigade could not identify a satisfactory method for measuring the exposure time during this experiment. Thus, the engagement time measures are limited for directly evaluating the exposure time standards in TC 1-140. However, examination of the engagement time measures may be useful because exposure time is a major component of engagement time.

As described earlier, the exposure time standards in TC 1-140 are dependent on target distance. The standards allow longer exposure times for farther target distances. Although the rationale for incorporating target distance into the standards may have more to do with the performance of the threat than with the AH-64A, no relationship was found in this experiment between target distance and engagement time.

The difference found between gun engagements fired during the day and at night was not incorporated into the TC 1-140 exposure time standards. Presumably, the 12 s difference was the result of longer target acquisition time, which is part of exposure time. The exposure time charts (see Appendix B) show that if a crew at 1000 m achieved a 5 s exposure time, it would receive a perfect 100 point score. If the crew's 5 s exposure time was increased to 17 s because of night conditions, its score would be reduced to 30 points. Thus, if exposure time increases as engagement time did in this experiment, crew qualification under the standards given in TC 1-140 would be substantially more difficult at night.

Target effect. The standards for target effect in TC 1-140 are different for each weapon system and will be evaluated separately.

As described earlier, there are two target effect standards in TC 1-140 for the 30 mm gun depending on whether the laser range finder is used. Because all the gun engagements in this experiment used the laser and the fan was of comparable size, the data can be used only to evaluate the TC 1-140 laser standard for gun engagements: a target hit or 50% of the rounds in a 25 x 25 m fan. Overall, the percentage of GO ratings for all gun engagements was 62%; therefore, the standard may be adequate on the average. However, the prediction equation predicts that performance at distances less than 1700 m will be better than 50% and at distances greater than 1700 m will be worse than 50%. Therefore, if the effects of target distance are not incorporated into the gun standards, the standards will be much easier to attain for the shorter engagements than for the longer engagements.

Probably the most conspicuous change in the standards from FM 1-140 to TC 1-140 was in the size of the rocket boxes. TC 1-140 has two rocket standards depending on the type of rocket used (M267 and M274). The M274 rocket was the only rocket used in this experiment and the TC 1-140 standard for this rocket is a target hit or 50% of the rounds in a 100 x 400 m box. As already mentioned, this box contains less than half the area of the FM 1-140 standards. Based on the overall rocket performance data collected during this experiment, the percentage of rocket engagements receiving GO ratings should drop by 28% with the fielding of the TC 1-140 standards. The rocket standards in TC 1-140 are unequivocally more difficult in terms of the percentage of GO engagements. If the overall rocket performance found in this experiment was similar to past AH-64A gunnery performance, crews evaluated under the FM 1-140 standards probably achieved an average of 53% GOs. If the third squadron's final live-fire performance is similar to future AH-64A gunnery performance, crews evaluated under the TC 1-140 standards would only be expected to achieve an average of 33% GOs. Thus, in the best possible analysis, GO ratings can be expected to drop 20% for M274 rocket engagements.

The standards in FM 1-140 for missile engagements did not change in TC 1-140. Both manuals lack explicit criteria for IPs and SIPs to use in evaluating missile engagement performance. The percentage of missile engagements receiving GO ratings has been high in the past and is expected to be high using the TC 1-140 missile engagement standards. The lack of explicit criteria to judge missile engagements allows units to apply different criteria to crew evaluations.

Establishing Effective Gunnery Standards

Depending on the rationale, a number of methods may be employed to establish gunnery standards, each of which generates a different set of standards. Before making the final recommendations from this research, a method for establishing gunnery standards is proposed to guide the application of the research results.

The method presented below produces standards with four desirable attributes. First, the gunnery standards are explicit and objective. Second, the standards provide information to the aviators about the envelope of an effective engagement for each weapon system. Third, the standards are achievable given the current capabilities of the aircraft and the level of aviator training. Fourth, the standards are field measurable.

Time standards. Improved gunnery time standards can be establish in three steps. First, adopt the general form of the standards now in use. The exposure time graphs already meet the first and the second criteria in that they are objective and educate the aviator in the critical period of exposure time for aircraft survivability. The major flaw in the TC 1-140 exposure time standards is that the standards are difficult to measure in the field. Unfortunately, the difficulty in measuring exposure time has contributed to some unit commanders' decisions to drop all time standards for crew qualification.

Second, determine the constant amount of time that could be added to exposure time to translate exposure time to engagement time. This would allow the critical measure of exposure time to be translated into a measure that is easier to obtain in the field. If the standard continued to be expressed as a function of exposure time, the aviators would continue to be trained in the critical time aspects of engagements.

Third, other factors that influence engagement time should be incorporated into the standards (e.g., light conditions). The graphical format may need to be dropped, however, if other factors are incorporated. An equation or formula format that produces the number of points based on the raw time and other relevant parameters may be the simplest and most efficient method of conveying the standard.

Gun and rocket target effect. Improved aerial gunnery target effect standards for the gun and rocket engagements can be establish in three steps. First, adopt the general form of the standards now in use. The gun and rocket engagement standards are composed of two parts: the target effect area or box and the percentage of rounds that are required to hit inside the box. These types of standards already have the first and the fourth attributes in that they are objective and AWSS field measurable.

Second, set the size of the box such that a round in the box is effective in suppressing, damaging, or destroying the target. With the box size set to define the effective radius of each weapons system, an aviator is informed about the physical characteristics of effective engagements each time he participates in a crew qualification exercise.

Third, adjust the percentage of rounds required in the box for each engagement to make the engagements similar in difficulty and achievability on the basis of current system performance. The probability method described in the Results section could be used to predict performance on any sized box and to adjust the percentage of rounds in the box for GO ratings. The percentage of required rounds would then be modified when changes in the aircraft or aviator training enhanced total system performance or possibly when the characteristics of a particular range were well known and different from the standard. The percentage might also be adjusted for different readiness levels of training. The box size would be modified only when characteristics of the ammunition changed.

Hellfire training missile target effect. Because the training missile does not provide any objective evidence of whether an actual missile will hit the target, SIP evaluation of engagements that use this device will be subjective by nature. Subjective evaluations, however, can have a high degree of interrater reliability, if the criteria for the evaluation is stated explicitly and is composed of a number of subtasks that can be evaluated objectively. Thus, if each of the criteria for a successful missile engagement (e.g., proper target selected, missile launch message received, target lased, etc.) are compiled on a structured evaluation worksheet and provided in the gunnery manual, the scoring of Hellfire training missile engagements will be more consistent across evaluators and less open to evaluator interpretation.

Conclusions

The results of this research support five conclusions. First, the exposure time standards for engagements in TC 1-140 are difficult to measure. Second, the gun target effect performance is greatly influenced by target distance; however, the TC 1-140 standards for gun target effect do not vary as a function of target distance. Subsequently, engagements at less than 1700 m are above the standard and engagements at greater than 1700 m are below the standard. Third, the standards for missile target effect evaluation in TC 1-140 are inadequate to produce consistent evaluations of these engagements. Fourth, the target effect performance for rocket engagements supports the narrow cross-range width and elongated down-range length of the rocket boxes. However, a substantial reduction in the size of the boxes will significantly reduce the number of crews that attain the TC 1-140 standards. Fifth, the distributions of rocket impacts had consistent shifts, indicating that the majority of the rockets landed right and short of the targets.

Recommendations

The data collected in this research provided important information about AH-64A gunnery performance and led to the identification of four desirable attributes for gunnery standards. A method for establishing gunnery standards was presented in the Discussion section of this report. However, excluding a complete revision of the standards, three specific recommendations are proposed here. First, it is critical to the survival of AH-64A crews on the battlefield that all crew gunnery exercises be conducted with some form of time pressure on the participants. Therefore, the exposure time standards in TC 1-140 should be changed to facilitate the collection of those measures in the field or engagement time standards should be stipulated.

Second, the size of the rocket boxes for the M274 rounds should be increased from 100 x 400 m to 150 x 400 m to produce crew qualification rates similar to those observed using the FM 1-140 standards. This recommendation is based on the probabilities of 6-rocket engagements and assumes that future AH-64A rocket performance is best estimated by the third squadron's results during the final live-fire exercise.

Third, a score sheet should be developed and published in TC 1-140 to guide in the evaluation of Hellfire training missile engagements. The sheet should list each subtask necessary for a successful missile engagement that can be evaluated objectively. The score sheet will aid in standardizing the evaluation of these types of engagements.

Future Research Needs

Further research designed to collect and analyze gunnery performance information is needed in three areas. First, research should be conducted to determine the cause of the shifts observed in the distribution of rocket impacts. The distribution of impacts that resulted in the highest rocket performance averaged 27 m right and 4 m short of the target. These shifts not only reduce crew performance during gunnery training, but also reduce the war fighting capability of the AH-64A.

Second, gunnery performance should be measured and described for aircraft other than the AH-64A. Although some results may generalize to other attack helicopters, the relationship between AH-64A gunnery performance and the gunnery performance of other helicopters remains unknown. Objective information about the gunnery performance of all the Army's attack helicopters will not only be valuable in evaluating the gunnery standards of the individual aircraft, but it also can be used to identify the systems and training that produce superior gunnery performance.

Third, research should be conducted for AH-64A gunnery tasks that were not analyzed here. The number of modes of fire examined in this research was far fewer than the total number of alternatives available in the aircraft. Although the set of gunnery tasks examined probably does represent the most common modes of fire, several of the types of tasks found in Table VIII of TC 1-140 were not examined in this research. Thus, further research is required to describe typical gunnery performance on tasks including the use of the

IHADSS, pairs rather than single rockets, the full range of target distances, and target engagement without the use of the LRF/D.

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APPENDIX A

FM 1-140 GUNNERY STANDARDS

This appendix contains the explanation of the gunnery tables and the crew gunnery tables from FM 1-140. Pages A-2 to A-5 present section 4-10, which appears on pages 4-14 to 4-17 of FM 1-140. Pages A-6 to A-13 present the AH-64 Crew Gunnery Tables (Table 4-18), which appear on pages 4-69 to 4-76 of FM 1-140.

4-9. JOINT AIR ATTACK TEAM

JAAT operations epitomize synchronization on the battlefield. There are usually three elements involved in JAAT operations. These elements are Air Force close air support aircraft (usually A-10s), Army attack helicopters, and field artillery. When these elements combine to attack enemy forces, the result is a synergistic effect which is greater than if each system were operating independently. For a detailed discussion of JAAT operations, refer to FM 1-111.

4-10. EXPLANATION OF GUNNERY TABLES

The gunnery tables are designed to allow commanders flexibility in conducting gunnery exercises. To allow for differences in range facilities and target array availability, a variety of arrays are shown at ranges from 500 to 6,000+ meters.

a. Use of Gunnery Tables.

(1) In developing a strategy for gunnery training, the commander should identify an array in the gunnery tables that best represents an available target array. Troop silhouettes can be fabricated locally and placed at various ranges, as shown in the tables.

(2) The range to the selected array must be identified. To allow for differences in range facilities, ranges in gunnery tables are flexible.

(3) The mode of flight and target condition may be selected based on the tactical scenario and the target array layout. When available, moving targets should be engaged. The commander should plan at least 50 percent of all his engagements at moving targets. On ranges that do not have moving targets, stationary targets in column or line formations should be used.

(4) The selection process as described in paragraphs *(1)*, *(2)*, and *(3)* above constitutes one engagement. Table 4-1 outlines the minimum number of successful engagements at various ranges required for qualification. For example, the commander selects target array 1 on Table 4-9. Local target array resembles this array. This array has a range of 3,000 meters and has targets in a stationary column. By selecting one item from each of the columns, commanders can custom-make their gunnery program and maximize gunnery training on ranges with limited facilities.

b. Target Effect.

(1) Target effect is a measurement of destroyed or disabled vehicles and personnel casualties. Target effect is expressed as a percentage of the target array affected. Disruption of enemy movement, force deployment, tactical confusion, or target suppression to aid in escape is a function of target effect.

(2) The standard for target effect is determined by the following criteria (explained further in paragraph *e* below):

- Desired effect on target—suppression, neutralization, or destruction.
- Target area coverage as defined in Table 4-2.
- Maximum engagement time per target array.
- Maximum exposure time per engagement.
- Percent of successful engagements per table category as defined in Table 4-1.
- Percent of ammunition not expended.

c. Types of Tables. Distinctive tables, tailored to various unit missions, are provided for attack, cavalry, and light infantry (attack and cavalry) units. The categories in each table are commanders, crew, team (unit), and combined arms/JAAT. Each category is explained in paragraph 1-4.

(1) Attack helicopter unit tables stress using TOW and Hellfire against tank and assorted armored targets. Engagements may vary from 500 to 3,750 meters using TOW and out to 5,000+ meters using rockets in the indirect mode.

(2) Cavalry unit tables stress hipshoot gunnery at assorted lightly armored targets and dismounted infantry. TOW engagements are required but not highly stressed because of the cavalry's unique reconnaissance and security missions. The cavalry tables call for close-in engagements at targets of opportunity and indirect engagements at targets in excess of 5,000 meters.

(3) Light infantry division helicopter tables are designed for low- to mid-intensity conflict scenarios. These tables emphasize dismounted infantry, machine gun nests, MOUT, and so forth. Although some are furnished, hard targets are held to a minimum. The light infantry's mission is to fight in a low-intensity setting and retain utility in the mid- to high-intensity environment.

d. Simulation Tables. In addition to the tables listed above, simulation tables are provided to increase training on the aircraft's main gun. These tables show TOW and Hellfire engagements at various ranges and conditions (hovering or moving flight, stationary or moving target). TOW and Hellfire engagements can be conducted in the following manner:

- Live fire (realizing that resources will continue to be limited for these weapon systems).
- FWS and CMS, where available.
- MILES/AGES in a force-on-force scenario.

e. *Scoring Criteria.* As stated in paragraph *b* above, several factors must be considered when assessing target effect. An in-depth definition of each standard is shown below. A suggested scorer/evaluator training program is outlined in Appendix C.

(1) Suppression of a target limits the enemy's ability to engage or return fire in the target area. Firing high-explosive ammunition creates apprehension or surprise and causes tanks to button up. Also, dismounted infantry seeks cover, thereby reducing their combat effectiveness. The effect of suppressive fires usually lasts only as long as fires continue. Suppressive fire usually requires little ammunition to produce the desired effects. Table 4-2 gives both the target effect criteria for each weapon system and the target area coverage. Table 4-3 shows the maximum rounds to be expended per target during any engagement.

(2) Neutralization tasks take a target out of the battle temporarily. The unit again becomes effective when casualties are replaced and damage is repaired. A force is neutralized when ten percent of its equipment is damaged or ten percent of its personnel become casualties.

(3) Destruction occurs when the target is taken out of action permanently. Casualties or materiel damage of 30 percent or more normally renders a unit ineffective. Destruction missions usually require large amounts of ammunition.

(4) Maximum engagement and exposure times represent the satisfactory (GO/NO-GO) times. These are shown in Chart 4-1.

(a) Exposure time is computed from the time the helicopter unmasks, the rounds impact on the target, and the helicopter remasks. It may be advantageous during direct rocket firing at long distances to remask after firing and unmask again. It may also be advantageous to have another source give corrections and target effect.

(b) Engagement time is computed from target handoff in the battle position to the time that the desired target effect is achieved or contact is broken. Engagement time depends on target array, posture, and the number of aircraft in the team.

(5) Commanders at all levels should stress to their aircrews the importance of ammunition management. Conservation of ammunition resources during combat may well be the key to ultimate success. Ammunition shown in the gunnery tables reflects the maximum per target array. If crews satisfy target effect standards with less ammunition than shown, the remaining ammunition should be returned to the rearm point. Under no circumstances should a crew who has successfully engaged a target array fire the remaining ammunition for practice or aviator proficiency. The commander may allot the remaining ammunition to aviators who failed to achieve the standards using the prescribed ammunition.

f. *Modes of Fire and Modes of Flight.*

(1) Modes of fire and modes of flight will be determined by the tactical scenario, by ammunition loading, and by weather conditions. Except when the situation (indirect fire or diving fire) dictates, the commander may determine the mode of flight. Firing weapon systems of the AH-1S(MC); AH-1S(ECAS); AH-1S(MOD) and AH-1S(PROD); AH-1G; UH-1B, UH-1C, and UH-1M; and AH-64 are found in Appendixes D, E, F, G, H, and I, respectively.

(2) Many tables require the crew to engage targets using two weapon systems simultaneously. Using the turret along with another system (TOW or 2.75-inch FFAR), most of these divergent shots require rapid suppressive fire on an unexpected enemy. This type of target array requires increased crew coordination and confidence in the weapon subsystems.

Table 4-1. Standards of engagement

RANGE	ATTACK	CAV	LT INF (ATK)	LT INF (CAV)
<1,999	2 of 3	4 of 5	2 of 3	4 of 5
2,000-2,999	5 of 6	4 of 5	5 of 6	4 of 5
3,000-3,999				
4,000-4,999				
>5,000	2 of 3	1 of 2	2 of 3	1 of 2

NOTE: Qualification is based on 9 successful engagements out of 12 for targets at various distances. A successful engagement is determined by comparing desired effect on target from gunnery tables with the target effect criteria in Table 4-2. For example, in an attack helicopter unit, two of three engagements must be successful at distances less than 1,999 meters, five of six from 2,000-4,999 meters, and two of three beyond 5,000 meters to satisfy qualification requirements.

Table 4-2. Scoring criteria

AH-1/UH-1C/M WEAPON SYSTEM	RANGE(M)	TARGET EFFECT
SS-11	500-2,900	Hit
TOW	500-3,750	Hit
20-mm	Up to 1,500	1/2 rounds in 50m x 100m target area
7.62-mm	Up to 1,500	2/3 of rounds in 100m x 200m target area
40-mm	Up to 900	2/3 of rounds in 100m x 200m target area
2.75-inch FFAR	1,000-1,999	1/2 of rounds in 300m x 700m target area
	2,000-2,999	1/2 of rounds in 300m x 600m target area
	3,000-3,999	1/2 of rounds in 300m x 500m target area
	4,000-4,900	1/2 of rounds in 300m x 400m target area
	5,000	1/2 of rounds in 300m x 300m target area

AH-64 WEAPON SYSTEM	RANGE(M)	TARGET EFFECT (NONLASER/LASER)
Hellfire	500-8,000	Hit
30-mm	IHADSS-Up to 1,999	2/3 rounds in 100m x 200m/NA
	IHADSS-2,000 to 3,000	2/3 rounds in 100m x 300m/NA
	TADS-500-1,499	2/3 rounds in 25m x 175m/25m x 125m
	TADS 1,500-2,499	2/3 rounds in 50m x 150m/50m x 100m
	TADS 2,500-3,000	2/3 rounds in 75m x 125m/75m x 75m
2.75-inch FFAR	IHADSS 1,000-1,999	1/2 rounds in 300m x 700m/NA
	IHADSS 2,000-2,999	1/2 rounds in 300m x 600m/NA
	IHADSS 3,000-3,999	1/2 rounds in 300m x 500m/NA
	IHADSS 4,000-5,000	1/2 rounds in 300m x 400m/NA
2.75-inch FFAR	TADS 2,000-2,999	1/2 rounds in 300m x 600m/300m x 500m
	TADS 3,000-4,999	1/2 rounds in 300m x 500m/300m x 400m
	TADS 5,000-6,999	1/2 rounds in 400m x 400m/300m x 300m
	TADS 7,000-9,000	1/2 rounds in 500m x 500m/400m x 400m

NOTE: AH-64 criteria for 2.75-inch FFAR based on estimation.

Table 4-3. Rounds per target

WEAPON SYSTEM	ROUNDS PER TARGET
7.62-mm	400
20-mm	32
30-mm	20
40-mm	20
2.75-inch FFAR	4
TOW	1
SS-11	1
Hellfire	1

g. STRAC Resources. STRAC provides a viable program for management of training ammunition. Commanders must understand how the STRAC program works and have a firm grasp of the unit's ammunition allocations.

h. Simulation Tables. Simulation tables stress crew coordination and simulated weapons firing. These tables also emphasize TOW engagements in various modes and ranges. Simulation tables may be conducted using the flight weapon simulator. The tables also may be conducted using the MILES/AGES in a force-on-force scenario or by using dry firing in a maneuver area. To fine-tune crew skills and to ensure valuable range time is not wasted, simulation tables should be accomplished before team or combined arms/JAAT live-fire exercises.

i. Target Condition. The target conditions column of the gunnery tables (Tables 4-4 through 4-21) give commanders maximum flexibility when selecting target arrays available on local ranges. As shown in the gunnery tables, the threat array may be configured in numerous formations, either moving or stationary. Recommended distance between each target in the array is no less than 15 meters and no greater than 50 meters.

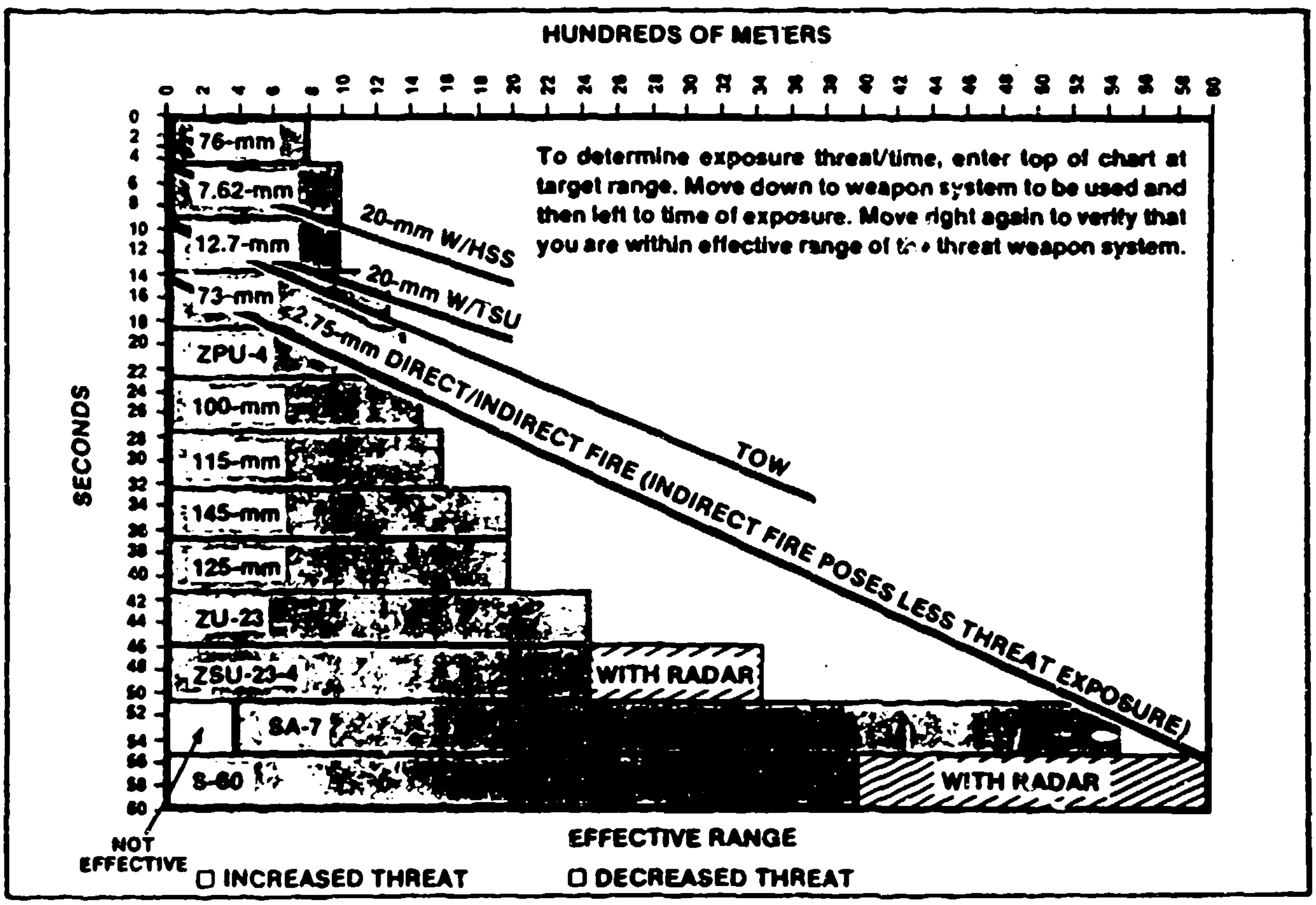

Chart 4-1. Exposure time

Table 4-18. AH-64 crew gunnery tables

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (1st Day)					
1 Tank 4 Tanks	3,000-5,000	1 Hellfire/Simulated (LOBL-Norm) 10 2.75 (COOP-Dir)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2
AH-64 Crew (2d Day)					
1 Lt Armored Veh 2 Lt Armored Veh	1,000-1,500 1,500-2,500	40 30-mm (IHADSS-CPG) 6 2.75 (IHADSS-P)	Terrain Flight	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY

DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (3d Day)					
2 Lt Armored Veh	1,500-2,500 2,000-3,000	60 30-mm (TADS) 8 2.75 (IHADSS-P)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2
AH-64 Crew (4th Day)					
2 Tanks	4,000-6,000	12 2.75 (COOP-Indir)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (5th Day)					
2 Lt Armored Veh	2,000-3,000	60 30-mm (TADS)	Hover	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2
4 Tanks	4,000-7,000	4 Hellfire/Simulated (LOAL-Dir-P)			
AH-64 Crew (6th Day)					
20 Troops	500-1,000	40 30-mm (IHADSS-P)	Terrain Flight	From a Forward or Concealed Position	Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (7th Day)					
4 Assorted Armored Veh	4,000-6,000	1(2.75 (COOP-Dir)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
AH-64 Crew (8th Day)					
4 Tanks	500-1,500	4 Hellfire/Simulated (LOBL-RIPL)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit From a Forward or Concealed Position	Destroyed IAW Para 4-10e(3) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
20 Troops	3,000-6,000	40 30-mm (IHADSS-P)	Divergent Engagement		Suppressed IAW Para 4-10e(1) and Table 4-2

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (9th Day)					
4 Tanks	3,000-5,000	4 Hellfire/Simulated (LOBL-Norm-Rapid)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
AH-1 Crew (10th Day)					
2 Tanks	500-1,500	2 Hellfire/Simulated (LOBL-LO-P)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2
1 Lt Armored Veh	4,000-7,000	40 30-mm (IHADSS-CPG)			Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (1st Night)					
4 Tanks	3,000-5,000	4 Hellfire/Simulated (LOBL-RIPL)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
AH-64 Crew (2d Night)					
1 Lt Armored Veh	500-1,000	40 30-mm (IHADSS-P)	Terrain Flight	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY					
DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (3d Night)					
1 Tank 1 Lt Armored Veh	500-1,500 3,000-4,000	1 Hellfire/Simulated (LOBL-Norm) 40 30-mm (IHADSS-P)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
AH-64 Crew (4th Night)					
2 Lt Armored Veh	1,500-2,500 2,000-3,000	60 30-mm (TADS) 8 2.75 (IHADSS-P)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2

Table 4-18. AH-64 crew gunnery tables (continued)

TARGET ARRAY DESCRIPTION	RANGE(M)	AMMUNITION	MODE	TARGET CONDITION	TARGET EFFECT
AH-64 Crew (5th Night)					
2 Tanks 1 Lt Armored Veh	500-1,500 4,000-6,000	2 Hellfire/Simulated (LOAL HI-P) 40 30-mm (IHADSS-CPG)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Destroyed IAW Para 4-10e(3) and Table 4-2 Neutralized; Coverage of Target Area IAW Para 4-10e(2) and Table 4-2 Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1
AH-64 Crew (6th Night)					
4 Tanks	3,000-5,000	12 2.75 (COOP-Dir)	Hovering	Moving Column, Attacking Line, Stationary Column, or Stationary Assembled Unit	Total Engagement Time IAW Para 4-10e(4)(b) Total Exposure Time Per Engagement IAW Para 4-10e(4)(a) and Chart 4-1 Suppressed IAW Para 4-10e(1) and Table 4-2

APPENDIX B

TC 1-140 GUNNERY STANDARDS

This appendix contains the crew gunnery tables and exposure time standards from TC 1-140 (1990). Pages B-2 to B-4 present Table VIII, AH-64 Day Intermediate Qualification Course (Crew), which appears on pages K-20 to K-22 of TC 1-140. Pages B-5 to B-7 present Table VIII, AH-64 Night Intermediate Qualification Course (Crew), which appears on pages K-23 to K-25 of TC 1-140. Pages B8 to B-13 present an explanation of the exposure time standards and the exposure time standards relevant to the AH-64A. This information appears on pages L-1 to L-4 and pages L-8 and L-9 of TC 1-140.

TABLE VIII. AH-64 DAY INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:________ CP/G:________

AIRCRAFT:__________ UNIT:_____ _____ DATE/TIME:___________

TASK NO DESCRIPTION	TASK TYPE	CONDITION RANGE	CONDITION MODE	CONDITION WPN SYS	CONDITION SIGHT SYS	STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
1 ENGAGE MULTIPLE TARGETS	ARMOR	3,000-7,000m	HOVER	HELLFIRE TNG MSL	LOBL (G)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
SIMULTANEOUSLY	INF TROOPS	500-1,000m		30mm	IHADSS (P)	HIT OR 50 % OF RNDS WITHIN 50m x 50m BOX	30 RDS	GO NO-GO
		30mm EXPOSURE TIME:_____ SCORE: ________				ENGAGEMENT TOTAL SCORE: ________		
2 ENGAGE MULTIPLE TARGETS	ADA	6,000-7,000m	HOVER	HELLFIRE TNG MSL	LOAL (G)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
SEQUENTIALLY	WHEELED VEHICLES	4,000-6,000m		RKTS	COOP	HIT OR 66 % OF GRENADES WITHIN 100m x 300m BOX	10- RKTS M267	GO NO-GO
		RKTS EXPOSURE TIME _____ SCORE _____				ENGAGEMENT TOTAL SCORE: _______		
3 ENGAGE STATIONARY TARGET	LT ARMOR VEHICLE	1,000-2,000m	RUNNING	30mm	FIXED (P)	HIT OR 50 % OR RNDS WITHIN 50m x 50m BOX	30 RDS	GO NO-GO
		30mm EXPOSURE TIME _____ SCORE _____				ENGAGEMENT TOTAL SCORE: _______		

TABLE VIII. AH-64 DAY INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:________ CP/G:________

AIRCRAFT:__________ UNIT:__________ DATE/TIME:____________

TASK NO	DESCRIPTION	TYPE	CONDITION RANGE	MODE	WPN SYS	SIGHT SYS	STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
4	ENGAGE MOVING TARGET	LT ARMOR	2,000-3,000m	RUNNING	RKTS	COOP	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	6 - RKTS M274	GO NO-GO
			RKTS EXPOSURE TIME _____		SCORE _____		ENGAGEMENT TOTAL SCORE: ______		
5	ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY	ARMOR	4,000-5,000m	HOVER	HELLFIRE TNG MSL	LOBL (P)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
		INF TROOPS	500-1,000m		30mm	IHADSS (G)	HIT OR 50 % OF RNDS WITHIN 50m x 50m BOX	30 RNDS	GO NO-GO
			30mm EXPOSURE TIME _____		SCORE _____		ENGAGEMENT TOTAL SCORE: ______		
6	ENGAGE MULTIPLE MOVING TARGETS SEQUENTIALLY	ARMOR	6,000-7,000m	HOVER	HELLFIRE TNG MSL	LOAL (P)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
		ADA	2,000-3,000m		30mm	TADS	HIT OR 50 % OF RNDS * WITHIN 25m x 25m BOX	30 RNDS	GO NO-GO
			30mm EXPOSURE TIME _____		SCORE _____		ENGAGEMENT TOTAL SCORE: ______		

TABLE VIII. AH-64 DAY INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:__________ CP/G:__________

TASK			CONDITION				STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
NO	DESCRIPTION	TYPE	RANGE	MODE	WPN SYS	SIGHT SYS			
7	ENGAGE MOVING TARGET	WHEELED VEHICLES	3,000-5,000m	HOVER	RKTS	COOP	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	6 - RKTS M274	GO NO-GO
			RKTS EXPOSURE TIME _____ SCORE _____				ENGAGEMENT TOTAL SCORE: _____		
8	ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY	LT ARMOR VEHICLE	2,000-3,000m	RUNNING	30mm	TADS	HIT OR 50 % OF RNDS WITHIN 25m x 25m BOX *	30 RDS	GO NO-GO
		INF TROOPS	1,500-2,000m		RKTS	IHADSS (P)	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	6 - RKTS	GO NO-GO
	30mm EXPOSURE TIME _____		SCORE _____	RKTS EXPOSURE TIME _____		SCORE _____	ENGAGEMENT TOTAL SCORE: _____		

RATING: GO NO-GO
(Circle appropriate rating)

AMMUNITION: 18 RKTS M274
10 RKTS M267
150 RNDS 30mm

POINTS: _____

EVALUATED BY: __________

NOTES:

1. Engagement points for each task are based on applying exposure time to the appropriate point calculation sheet.
2. All rocket engagements will be fired as pairs.
3. * Increase standards to 50m x 50m when ranging without laser.

STANDARD: Crew must achieve a GO rating in 10 of 13 tasks and 630 out of 900 points to receive an overall GO rating on Table VIII Day.

TABLE VIII. AH-64 NIGHT INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:________ CP/G:________

AIRCRAFT:________ UNIT:________ DATE/TIME:________

TASK NO. DESCRIPTION	TASK TYPE	CONDITION RANGE	CONDITION MODE	CONDITION WPN SYS	CONDITION SIGHT SYS	STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
1 ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY	ARMOR	3,000-5,000m	HOVER	HELLFIRE TNG MSL	LOBL	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
	INF TROOPS	500-1,000m		30mm	IHADSS (P)	HIT OR 50 % OF RNDS WITHIN 50m x 50m BOX	30 RDS	GO NO-GO
		30mm EXPOSURE TIME:____	SCORE:____			ENGAGEMENT TOTAL SCORE:____		
2 ENGAGE MULTIPLE TARGETS SEQUENTIALLY	ADA	6,000-7,000m	HOVER	HELLFIRE TNG MSL	LOAL (G)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
	WHEELED VEHICLES	4,000-6,000m		RKTS	COOP	HIT OR 50 % OF GRENADES WITHIN 100m x 300m BOX	8 - RKTS M267	GO NO-GO
		RKTS EXPOSURE TIME ____	SCORE ____			ENGAGEMENT TOTAL SCORE:____		
3 ENGAGE STATIONARY TARGET	LT ARMOR VEHICLE	500-1,000m	RUNNING	30mm	IHADSS(P)	HIT OR 50% OR RNDS WITHIN 50m x 50m BOX	30 RDS	GO NO-GO
		30mm EXPOSURE TIME ____	SCORE ____			ENGAGEMENT TOTAL SCORE:____		
4 ENGAGE MOVING TARGET	LT ARMOR VEHICLE	2,000-3,000m	RUNNING	RKTS	COOP	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	8 - RKTS M274	GO NO-GO
		RKTS EXPOSURE TIME ____	SCORE ____			ENGAGEMENT TOTAL SCORE:____		

TABLE VIII. AH-64 NIGHT INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:________ CP/G:________

TASK		CONDITION				STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
NO DESCRIPTION	TYPE	RANGE	MODE	WPN SYS	SIGHT SYS			
5 ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY	ARMOR	3,000-5,000m	HOVER	HELLFIRE TNG MSL	LOBL (P)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
	LT ARMOR VEHICLE	500-1,000m		30mm	IHADSS (G)	HIT OR 50 % OF RNDS WITHIN 50m x 50m BOX	30 RNDS	GO NO-GO
		30mm EXPOSURE TIME ____		SCORE ____		ENGAGEMENT TOTAL SCORE: ____		
6 ENGAGE MOVING TARGET	WHEELED VEHICLES	3,000-5,000m	HOVER	RKTS	COOP	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	6-RKTS M274	GO NO-GO
		RKTS EXPOSURE TIME ____		SCORE ____		ENGAGEMENT TOTAL SCORE: ____		
7 ENGAGE MULTIPLE MOVING TARGETS SEQUENTIALLY	ARMOR	6,000-7,000m	HOVER	HELLFIRE TNG MSL	LOAL (P)	PROPER SWITCHOLOGY (USE VRS WHEN POSSIBLE)		GO NO-GO
	LT ARMOR VEHICLE	1,000-2,000m		30mm	TADS	HIT OR 50 % OF RNDS WITHIN 25m x 25m BOX	30 RNDS	GO NO-GO
		30mm EXPOSURE TIME ____		SCORE ____		ENGAGEMENT TOTAL SCORE: ____		

TABLE VIII. AH-64 NIGHT INTERMEDIATE QUALIFICATION COURSE (CREW)

AIRCRAFT CREW: P:__________ CP/G:__________

TASK NO DESCRIPTION	TYPE	CONDITION RANGE	MODE	WPN SYS	SIGHT SYS	STANDARD	AMMO REQD	CIRCLE GO/ NO-GO
8 ENGAGE MULTIPLE TARGETS SIMULTANEOUSLY	LT ARMOR VEHICLE	1,000-2,000m	RUNNING	30mm	TADS	HIT OR 50 % OF RNDS WITHIN 25m x 25m BOX *	30 RDS	GO NO-GO
	ADA	2,000-3,000m		RKTS	IHADSS (P)	HIT OR 50 % OF RKTS WITHIN 100m x 400m BOX	8 - RKTS M274	GO NO-GO

30mm EXPOSURE TIME _____ SCORE _____ RKTS EXPOSURE TIME _____ SCORE _____ ENGAGEMENT TOTAL SCORE: _______

RATING: GO NO-GO
(Circle appropriate rating)

AMMUNITION:
8 RKTS M267
24 RKTS M274
150 RNDS 30mm

POINTS: ______

EVALUATED BY: __________

NOTES:
1. Engagement points for each task are based on applying exposure time to the appropriate point calculation sheet.
2. All rocket engagements will be fired as pairs.
3. * Increase standard to 50m x 50m when ranging without laser.

STANDARD: Crew must achieve a GO rating in 10 of 13 tasks and 630 out of 900 points to receive an overall GO rating on Table VIII Night.

APPENDIX L

EXPOSURE TIME STANDARDS

Figures L-1 through L-8 are provided to allow the scorer to assess points for each target engagement. They are based on the weapon system, type of threat, time of flight of the rounds, and human responses. To use them, the scorer enters the figure at the top left, goes down to the raw time obtained from the score sheet, moves right to the range of the target engaged, and then moves right (diagonally) for the actual score. To properly score exposure time, the scorer should start the time when intervisibility exists between the firing aircraft and the target. He should stop the time when intervisibility is broken either by aircraft remasking or target effect. Repeated exposure to the target from the same firing point will result in cumulative times. If the firing aircraft is repositioned to another firing point or range constraints require simulated repositioning, then the scorer restarts the exposure time.

The gunnery tables incorporate exposure time scoring as a method of assessing the crew's probability of survival during a series of target engagements. Since the use of standoff ranges increases the probability of survival, exposure times are not used for engagements beyond 4,000 meters. Because of the subjective nature of assessing this probability, a GO/NO-GO score is not given for each engagement but is totaled in a cumulative score for that table. This score shows the relative amount of risk a crew takes to engage all targets. Although a crew may receive a GO for each target engaged, they will receive a NO-GO for that table if their exposure score is below the minimum standard listed in the table.

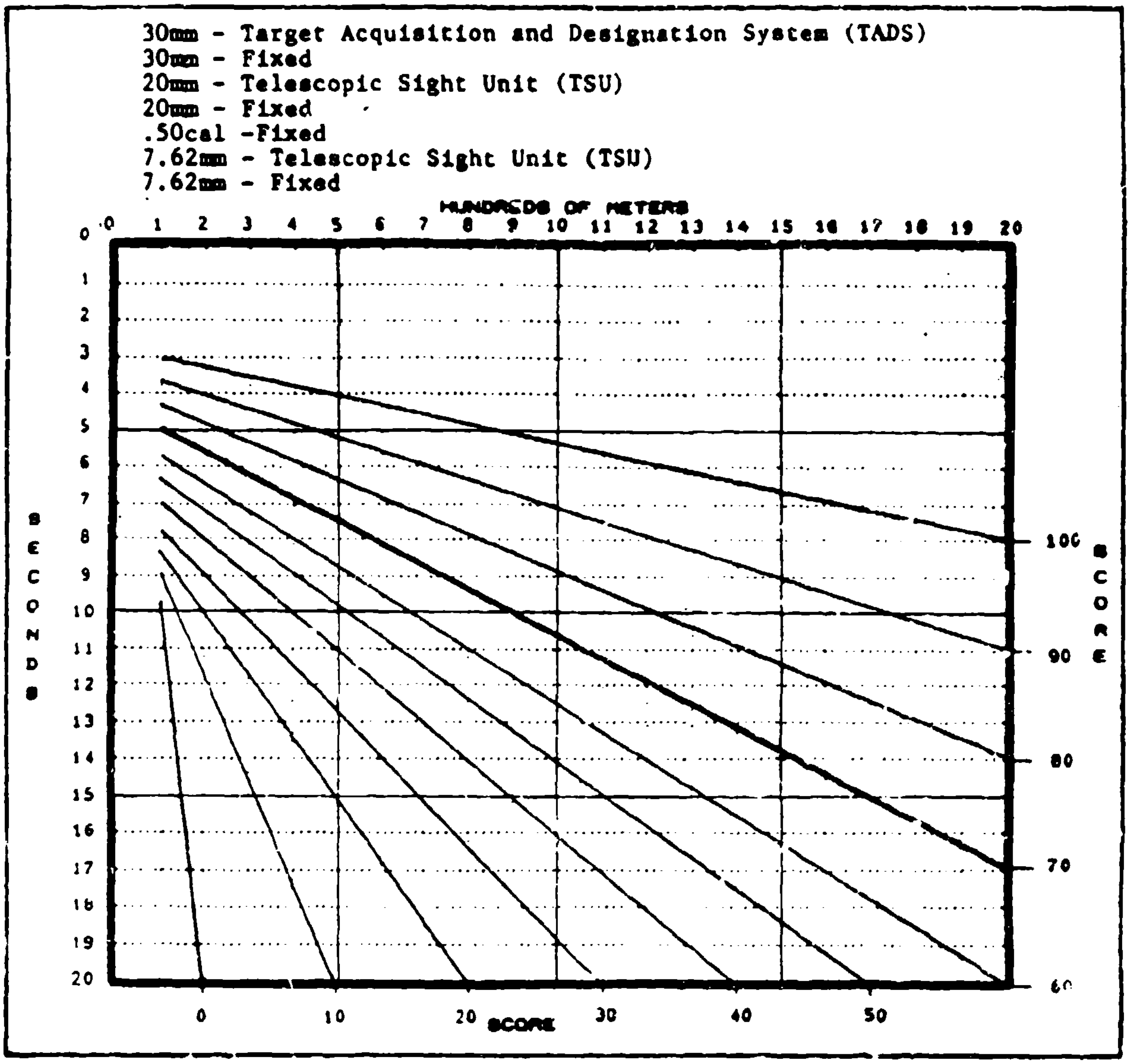

Figure L-1. Exposure times for 30-millimeter TADS/fixed, 20-millimeter TSU/fixed, .50-caliber fixed, and 7.62-millimeter TSU/fixed

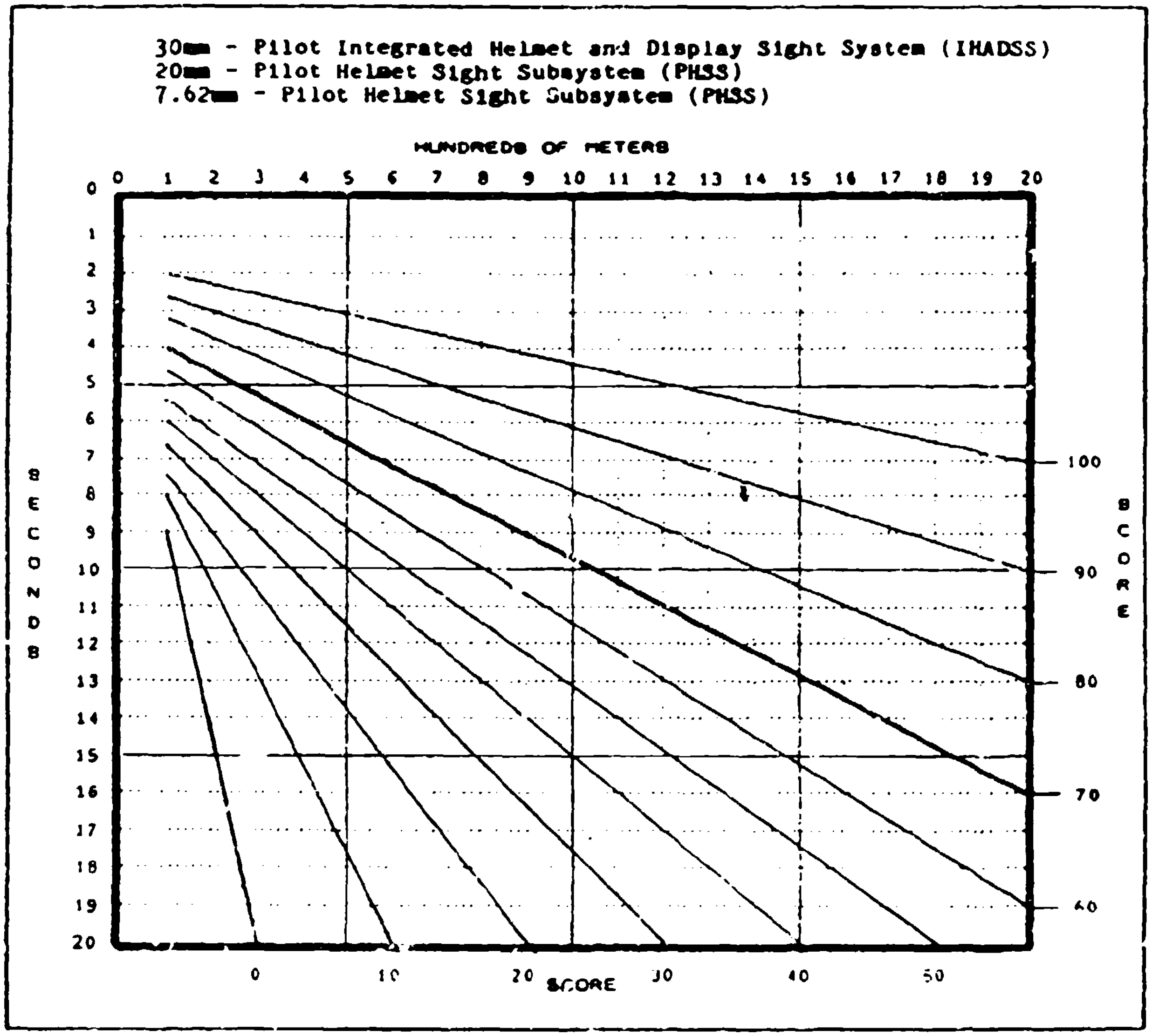

Figure B-2. Exposure times for 30-millimeter IHADSS, 20-millimeter PHSS, and 7.62-millimeter PHSS

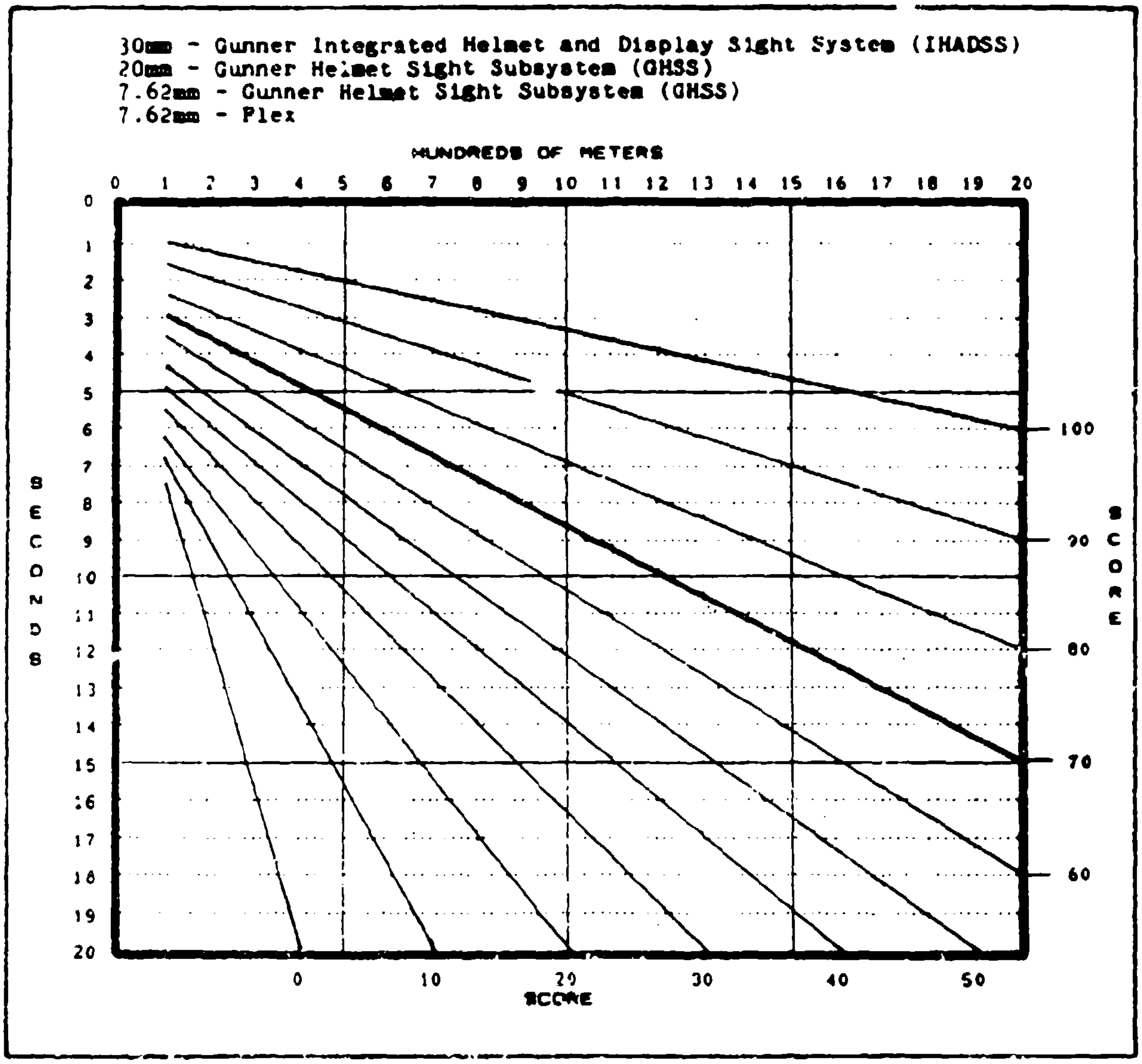

Figure L-3. Exposure times for 30-millimeter IHADSS, 20 millimeter GHSS, and 7.62-millimeter GHSS

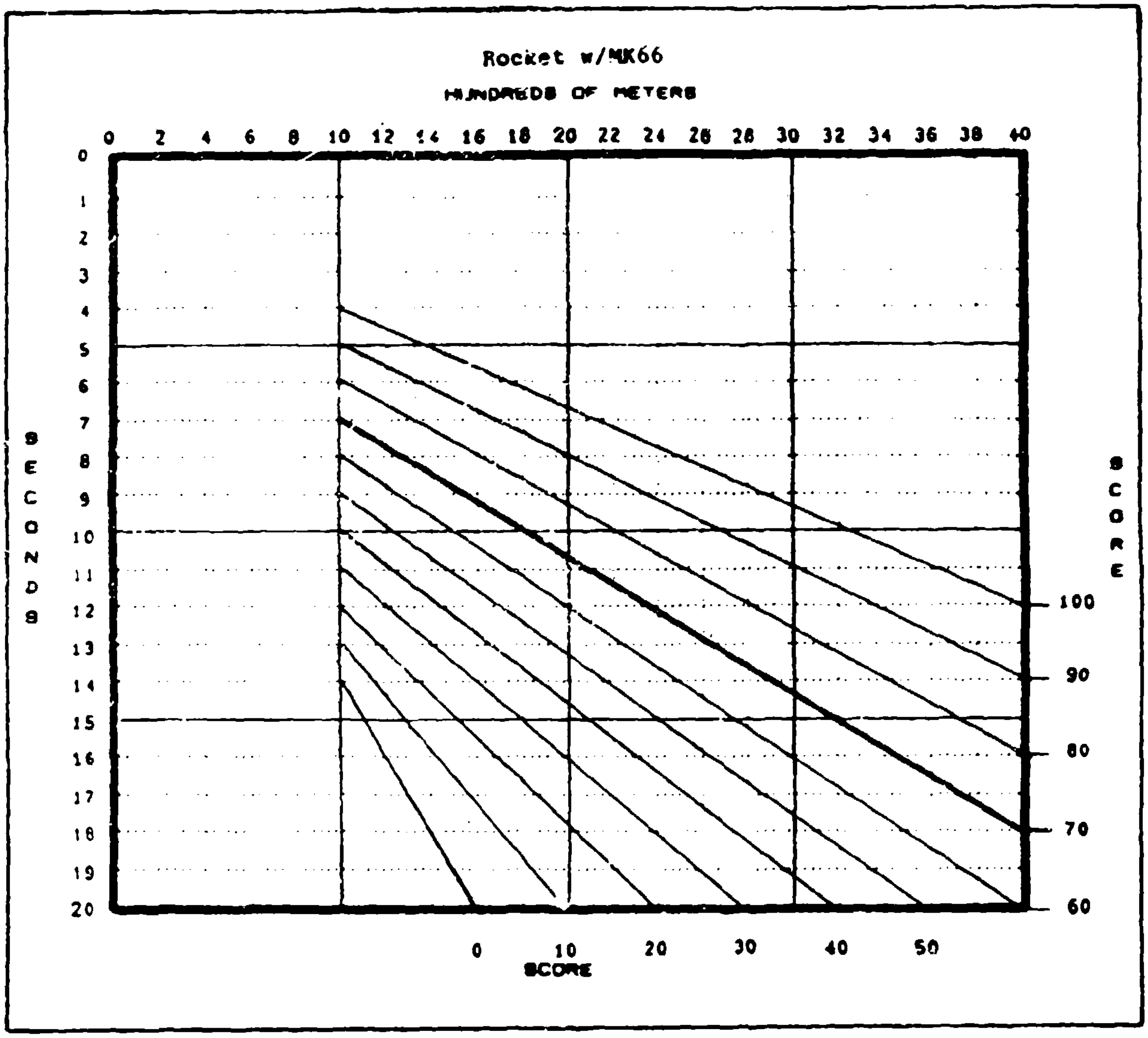

Figure L-7. Exposure time for rocket with MK66

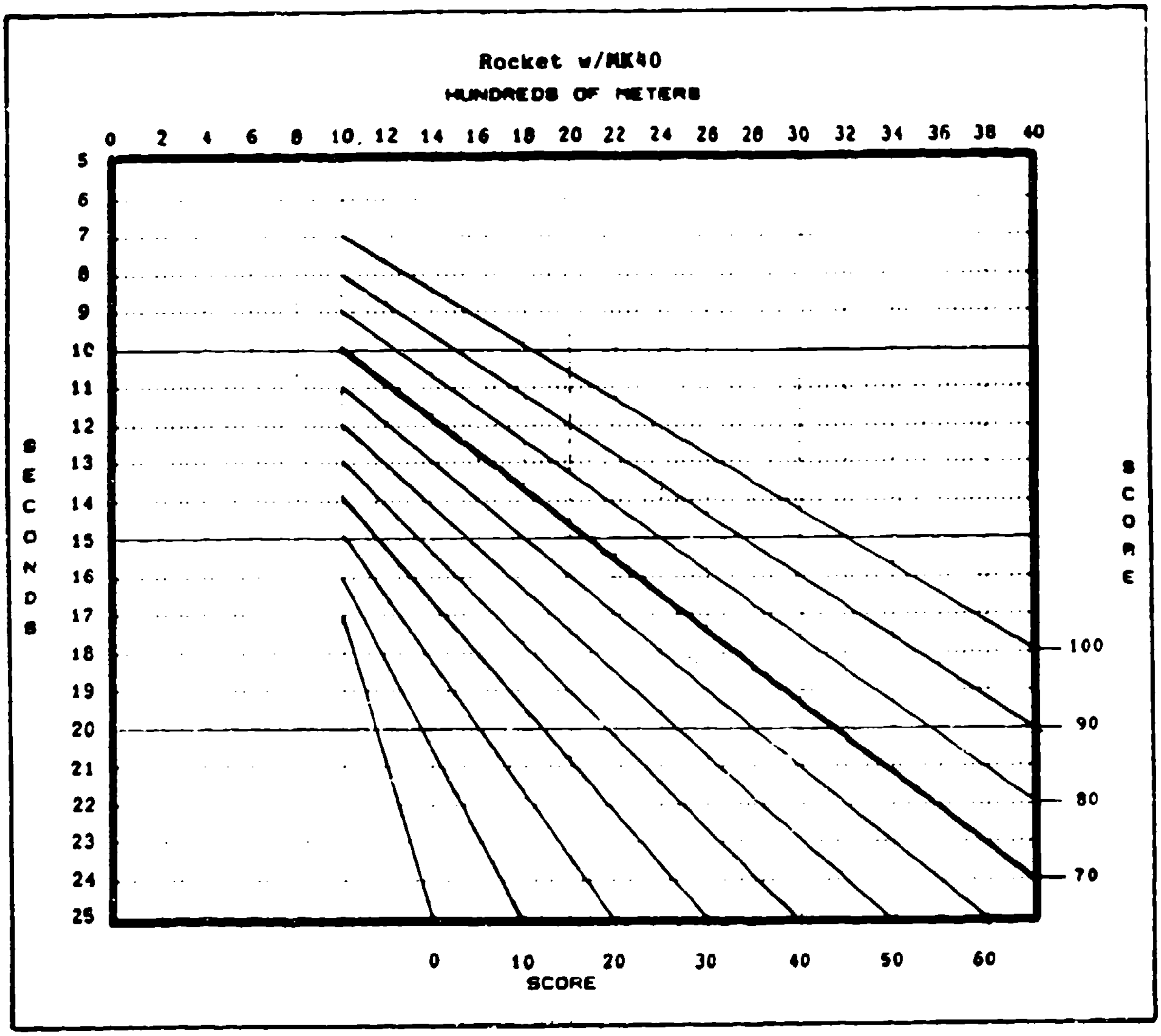

Figure L-8. Exposure time for rocket with MK40

A P P E N D I X C

AH-64 CMS GUNNERY RESEARCH PROGRAM
DEMOGRAPHIC SURVEY

AH-64 CMS GUNNERY RESEARCH PROGRAM
DEMOGRAPHIC SURVEY

PART A INSTRUCTIONS: Part A consists of questions that provide information about your personal background and experience. Answer each item that applies to you by checking in the appropriate bracket [√] or by printing the required information in the space provided. When answering items about flight hours, you may refer to records, if available, or you may estimate the flight hours as closely as possible. Your responses will be used for research purposes only.

1. Name: ______________________________________
   Last First Middle

2. Social Security Number: ___ ___ ___ - ___ ___ - ___ ___ ___ ___

3. Today's Date: ______________________________
   (Month) (Day) (Year)

4. What is your age ?
   ________ Years

5. What is your current rank?

[ ] WO1	[ ] 2LT
[ ] CW2	[ ] 1LT
[ ] CW3	[ ] CPT
[ ] CW4	[ ] MAJ
	[ ] LTC
	[ ] COL

6. To which unit are you assigned?
   Unit: ________________ Squadron ________________ Troop

7. How long have you been assigned to your present troop?
   ________ years and ________ months

8. Do you anticipate reassignment prior to October 1990?

[ ] Yes

[ ] No

If yes, give expected date and location of reassignment________________

____

9. Currently, what is your primary duty position in the unit?

____

10. What additional duties do you perform in your unit?

____

____

____

11. How long have you been on active duty military service?

________ years and ________ months of active service

12. How long has it been since you graduated from initial Army flight training?

________ years and ________ months

13. How long has it been since you graduated from the AH-64 AQC?

________ years and ________ months

14. Were you an IERW turnaround student in the AH-64 AQC?

[ ] Yes

[ ] No

If no, what was your primary aircraft before entering the AH-64 AQC?

____

15. Indicate the total number of flight hours you have logged in each of the following aircraft. Also, check [√] the highest duty category you have held in each aircraft.

a. Military Rotary Wing

			PI	PC	UT	IP	SI	IE
AH-64:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
AH-1:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
OH-58:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
UH-1:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

(Specify other aircraft)________________________________

b. Military Fixed Wing

UH-21:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
C-12:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
OV-1:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other:	________	hours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

(Specify other aircraft)________________________________

16. How many flight hours have you logged in each seat of the AH-64?

Front Seat: __________ hours

Back Seat: __________ hours

17. How many flight hours have you logged in each seat of the AH-64 CMS?

Front Seat: __________ hours

Back Seat: __________ hours

18. How many flight hours have you logged in each seat of the AH-64 CWEPT?

Front Seat: __________ hours

Back Seat: __________ hours

19. How many <u>night</u> flight hours have you logged in each seat of the AH-64?

Front Seat: __________ hours

Back Seat: __________ hours

20. If you were an AH-1 pilot previously, how long has it been since you completed the AH-1 Crew Gunnery Tables?

_______ years and _______ months

21. After arriving at your present unit, what was your original crew station designation?

[ ] AH-64 front seat

[ ] AH-64 back seat

[ ] Other (explain) ________________________________

22. How many training hours were required for you to attain RL2 and RL1 status in your originally designated seat? (Check here [ ] if you did not attain RL2 or RL1 in your originally designated seat.)

__________ flight hours to RL2 from RL3

__________ CMS hours to RL2 from RL3

__________ flight hours to RL1 from RL2

__________ CMS hours to RL1 from RL2

23. What is your current crew station designation?

[ ] AH-64 front seat

[ ] AH-64 back seat

[ ] Both seats (explain) ____________________________.

24. What is your current Readiness Level?

RL Front	RL Back
[ ] RL1 in the front seat	[ ] RL1 in the back seat
[ ] RL2 in the front seat	[ ] RL2 in the back seat
[ ] RL3 in the front seat	[ ] RL3 in the back seat

25. Excluding IP evaluations, how many crewmembers have you flown with since entering the 6th CBAC?

__________ crewmembers

26. Have you been assigned to a fixed crewmate?

[ ] Yes

[ ] No

27. If you are a member of a fixed crew, how many hours has your crew trained together?

___________ flight hours

___________ CMS hours

28. How many of your flights, if any, have been delayed or rescheduled due to the unavailability of an appropriately trained (i.e., current in the required seat) crewmate?

___________ flights have been delayed or rescheduled

29. How many times have you participated in gunnery exercises at the Dalton/Henson range complex?

___________ times flying the AH-64A

___________ times flying other aircraft

END

FILMED

DATE: 2-92

DTIC