Technical Report 778

Effects of Degraded Mode Gunnery Procedures on the Performance of M1 Tank Gunners

Bob G. Witmer

ARI Field Unit at Fort Knox, Kentucky
Training Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

January 1988

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding

Technical review by

Donald Kristiansen
Margaret S. Salter

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POT, 5001 Eisenhower Ave., Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY --	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE --	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) --	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Technical Report 778
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Research Institute Field Unit - Fort Knox 6b. OFFICE SYMBOL (If applicable) PERI-IK	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences
6c. ADDRESS (City, State, and ZIP Code) Fort Knox, KY 40121-5620	7b. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600
8a. NAME OF FUNDING / SPONSORING ORGANIZATION -- 8b. OFFICE SYMBOL (If applicable) --	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER --
8c. ADDRESS (City, State, and ZIP Code) --	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 6.37.44.A PROJECT NO. 2Q263744 A795 TASK NO. 3.5.1 WORK UNIT ACCESSION NO. H.3
11. TITLE (Include Security Classification) Effects of Degraded Mode Gunnery Procedures on the Performance of M1 Tank Gunners	
12. PERSONAL AUTHOR(S) Bob G. Witmer	
13a. TYPE OF REPORT Final Report 13b. TIME COVERED FROM 07/86 TO 12/87	14. DATE OF REPORT (Year, Month, Day) January 1988 15. PAGE COUNT 116
16. SUPPLEMENTARY NOTATION --	
17. COSATI CODES FIELD / GROUP / SUB-GROUP	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Degraded Mode Gunnery, Degraded Conditions, Armor, Performance Measurement, Unit Conduct of Fire Trainer, M1 Tank, Tank Gunnery

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

The Unit Conduct of Fire Trainer (UCOFT) was used to determine the effects of using degraded mode gunnery procedures on the performance of 48 M1 experienced noncommissioned officers. Using the Gunnery Index (Witmer, 1986) as the measure of proficiency, gunnery performances under three different degraded conditions were compared to performances under fully operational conditions. Results suggest that using degraded gunnery procedures adversely affects the performance of experienced armor crewmen, with the most dramatic performance decrements occurring when degraded conditions require the use of the Gunner's Auxiliary Sight (GAS). Performance did not improve significantly under degraded conditions after a brief period of degraded gunnery practice on the UCOFT, suggesting the need for specialized degraded gunnery training programs.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Bob G. Witmer	22b. TELEPHONE (Include Area Code) (502) 624-6928 22c. OFFICE SYMBOL PERI-IK

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Technical Report 778

Effects of Degraded Mode Gunnery Procedures on the Performance of M1 Tank Gunners

Bob G. Witmer

ARI Field Unit at Fort Knox, Kentucky
Donald F. Haggard, Chief

Training Research Laboratory
Jack H. Hiller, Director

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

January 1988

Army Project Number
2Q263744A795

Training and Simulation

FOREWORD

Armor leaders recognize that their soldiers must be trained to fight under a wide range of battlefield conditions. On the battlefield, armor systems may malfunction or incur battle damage and not be quickly repaired. Armor crews may be required to continue operations despite problems with their equipment. The Army Research Institute at Fort Knox recognizes the requirement to prepare soldiers to fight under less than optimum conditions, and is conducting research designed to identify factors that may adversely affect gunnery performance, determine how these factors affect performance, and suggest solutions for reducing any performance deficiencies.

The present research investigates the effects of using degraded mode gunnery procedures on the gunnery performance of experienced M1 tank noncommissioned officers. This research was conducted under a Memorandum of Understanding, dated 22 June 1985, entitled "Future Battlefields Research," between the Army Research Institute and the U.S. Army Armor Center at Fort Knox. Results of the research were briefed to training development personnel at the Directorate of Training and Doctrine (16 June 1987) and to the Weapons Systems Department (29 June 1987). These training experts expressed a high degree of interest in how gunnery performance was affected by the degraded techniques. This research identified the degraded gunnery modes where soldiers exhibit their greatest deficiencies and those areas where specialized training is needed.

EDGAR M. JOHNSON
Technical Director

EFFECTS OF DEGRADED MODE GUNNERY PROCEDURES ON THE PERFORMANCE OF M1 TANK GUNNERS

EXECUTIVE SUMMARY

Requirement:

The sophistication of the M1 tank fire control system enables the gunner to engage targets with a high degree of precision. The M1 ballistic computer, in concert with the laser rangefinder, the stabilization system, and a host of sensors (e.g., lead-angle sensor, crosswind sensor), is largely responsible for the precision of the M1 fire control system. The loss of these primary components due to malfunction or battle damage necessitates the use of less accurate back-up systems. The back-up systems are not only less accurate than the primary fire control components, but also are less familiar to the gunners who must use them. While it is generally accepted that degraded mode gunnery procedures using back-up control components adversely affect gunnery performance, the relative amounts of performance degradation resulting from various failures of fire control systems have yet to be determined. This research makes that determination.

Procedure:

Forty-eight M1-qualified noncommissioned officers were tested as gunners under one of three degraded mode gunnery conditions or under fully operational conditions on the M1 Unit Conduct of Fire Trainer (UCOFT). Four surrogate tank commanders acted as tank commanders in testing the gunners. All soldiers performed the same UCOFT exercises but the engagement procedures they used varied as a function of type of malfunction simulated, tank-target movement, and target range. The malfunctions examined were stabilization failure, ballistic computer failure, GPS failure, and laser rangefinder failure. Malfunctions were simulated by appropriately setting fire control system switches in the M1 UCOFT and by requiring the use of alternate engagement procedures. Using a composite measure of gunner proficiency, the Gunnery Index (GI), performances of soldiers operating under the various degraded conditions were compared with performances of soldiers operating under fully operational conditions.

Findings:

The results indicate that performing under degraded conditions adversely affects gunnery performance. The poorest performances occurred when the gunners were required to use the Gunner's Auxiliary Sight (GAS) as the result of computer failure or when they engaged long-range moving targets without the benefit of the laser rangefinder. Failure of the stabilization system had

little effect on gunnery performance. Performance did not increase significantly across repeated trials of the degraded exercises, indicating that degraded gunnery performance may not improve with short periods of practice on the UCOFT, and suggesting the need for specialized degraded gunnery training programs.

Utilization of Findings:

This research clearly shows the degree to which the performance of experienced gunners is affected by using degraded gunnery engagement techniques. It identifies performance deficiencies as a function of malfunctions of specific types of fire control systems and indicates where additional training is needed. It also provides data that could be used by combat developers in designing back-up systems for a primary fire control system or by combat modelers in quantifying the loss of particular fire control components on the exchange ratio.

EFFECTS OF DEGRADED MODE GUNNERY PROCEDURES ON THE PERFORMANCE OF M1 TANK GUNNERS

CONTENTS

CONTENTS (Continued

LIST OF TABLES

LIST OF FIGURES

EFFECTS OF DEGRADED MODE GUNNERY PROCEDURES ON THE PERFORMANCE OF M1 TANK GUNNERS

INTRODUCTION

M1 Tank System Overview

The M1 tank constitutes a significant milestone in the development of armored vehicles. Among its features are a rapid, accurate firing capability, increased speed, high maneuverability, improved armor protection, a superior stabilization system for firing on the move, and an effective vehicle smoke-generating system for additional vehicle protection. The M1 tank is designed to fight under a variety of conditions. It is equipped with a Thermal Imaging System (TIS) for operation under the cover of darkness or during low visibility conditions. It also has a laser rangefinder for quickly and accurately determining target range. The M1 tank includes a variety of magnifying optics for acquiring targets and a variety of weapons for engaging those targets. Magnifying optics include the Gunner's Primary Sight (GPS), the Gunner's Auxiliary Sight (GAS), the Gunner's Primary Sight Extension (GPSE) for the commander, and the commander's fixed focus periscope for use with his .50 caliber machine gun. The M1 gunner and tank commander also have nonmagnifying unity sights or windows for searching the battlefield. A unity-power periscope is also used with the loader's machine gun. M1 weapons include a 105mm M68 main gun, two M240 7.62mm machine guns, and one .50 caliber M2HB machine gun. The main gun may be fired from either the gunner's or commander's station. The 7.62mm machine guns are fired by the gunner and loader and the .50 caliber machine gun by the tank commander. The inclusion of several sighting and weapon systems in the M1 tank provides increased capabilities for acquiring and engaging targets and some redundancy in case of battle damage or subsystem malfunctions.

M1 Fire Control System

The M1's fire control system consists of all equipment necessary for target acquisition, target identification, and target engagement with the main gun and coax machine gun (Headquarters Department of the Army [DA], 1986). The major functional components of the M1 fire control system are: (1) the ballistic computer system, (2) the laser rangefinder (LRF), (3) the gun/turret drive and stabilization systems, (4) the sighting systems, and (5) the weapons. These components are largely responsible for the precision and flexibility associated with the M1 tank.

A functional description of the major M1 fire control components is provided in the following paragraphs. Each component is described in its fully operational state to provide a framework for understanding the ensuing description of M1 degraded gunnery modes. An outline of M1 degraded gunnery modes is included to introduce the reader to M1 degraded gunnery modes and techniques and to illustrate their complexity. The outline also allows the reader to see the present research in its proper context as part of a larger set of degraded gunnery situations.

Ballistic Computer System. The ballistic computer system calculates and provides superelevation and lead correction, allowing the M1 gunner or commander to aim directly at the target center of mass, regardless of own tank or target movement, target range, and ammunition characteristics. Superelevation refers to the angle above the horizontal plane that the tank main gun must be elevated to compensate for the effects of gravity on a round of ammunition during its flight to the target, whereas lead refers to the angle that the gun must aim in front of a moving target to cause the round to strike the target. Superelevation and lead corrections are computed from a series of automatic and manually indexed inputs. Automatic inputs include cant information, wind sensor data, lead-angle sensor offsets, and target range. The cant unit measures the deviation of the gun trunions fror the horizontal when the tank is stationary and provides a signal to the computer to correct the error induced by this deviation. A crosswind sensor on a mast at the rear of the turret measures the crosswind velocity and the ballistic computer corrects for crosswind. Lead angle sensors detect target-tracking corrections from the power control handles for moving targets, offset the reticle horizontally, and the gun counter-rotates inducing automatic lead. The laser rangefinder fires a laser beam at a target and measures the time before the reflected beam is sensed at the tank. This time is converted to a range and sent to the computer through the rangefinder/computer interface. The computer retains the range until a new range is received. Range can also be entered manually into the computer by either the commander or gunner.

Among the inputs that can only be entered manually into the computer are ammunition propellant temperature, air temperature and atmospheric pressure, gun tube wear data, ammunition subdesignation, muzzle reference system (MRS) update, and battlesight range. Ammunition propellent temperature, as measured by a thermometer in the ammunition stowage compartment, should be corrected if it deviates by more than $10^{o}F$ from the value indexed in the computer. Air temperatures that deviate by more than $10^{o}F$ or barometric pressures that deviate more than one inch from indexed values should be reentered into the computer. Recommended standard inputs for temperature and barometric pressure by geographical area and by season may be found in FM 17-12-1, Tank Combat Tables, (Headquarters Department of the Army [DA], 1986). Gravitational or thermal forces may cause bending of the gun tube over time resulting in a loss of boresight. Performing an MRS update temporarily corrects this loss of boresight, reestablishing the relationship between the primary sight reticle and the main gun. The manual and automatic inputs to the computer are used to calculate a complete and unique ballistic solution for any given set of conditions, providing considerable firing precision when all M1 subsystems are operating fully.

Laser Rangefinder. The laser rangefinder (LRF) in the M1 tank is a Neodymium Yttrium Aluminum Garnet (YAG) laser transmitter coupled with a range receiver. The laser rangefinder is activated when the gunner or commander depresses the lasing buttons on the power control handles. The laser is aimed at the target by using one of the sighting systems, and reflections of the beam are received by the LRF receiver. The reception of multiple reflections or returns is evaluated via a return logic selector switch on the LRF control panel. The gunner selects either ARM 1ST RETURN or ARM LAST RETURN and the first return greater than 200 meters or the last return less than 4000 meters is fed automatically to the computer by the LRF. A bar above

the range displayed in the GPS warns the gunner and commander that more than one return was received. The gunner may then relase upon command, entering a new range into the computer or engage the target using the current range and ballistic solution. Range can also be entered manually into the computer from the gunner's or commander's position. The gunner manually indexes the range through the computer control panel (CCP). The commander, on the other hand, depresses the MANUAL RANGE BATTLE SGT button on the commander's panel, and then uses the ADD/DROP toggle switch to increase/decrease the range from its current setting to the desired range setting. Manual entry may be used when setting a battlesight range, when engaging targets at a known range, or when the LRF is inoperative.

Gun Turret Drive and Stabilization Systems. The gun turret drive and stabilization systems are electronically controlled and driven by an engine-powered hydraulic pump. A battery-powered auxiliary pump provides engine-off hydraulic power. Gyroscopes mounted in the hull, turret, main gun, and GPS sense errors in yaw, pitch, and gun position and generate signals to keep the gun and turret stable relative to the earth during own-tank movement. This stabilizes the target scene for the gunner and commander when firing on the move.

The gunner operating in NORMAL or EMERGENCY modes uses the gunner's power control handles to control gun turret movement for target acquisition and engagement. The drive system must be powered and the gunner must depress the palm switches on the power control handles to traverse the turret. The tank commander has a single power handle that overrides gunner control when the TC depresses the palm switch. Moving own tank stabilized gunnery is only possible in the NORMAL mode. The EMERGENCY mode must be relied upon when the stabilization system is not functioning. EMERGENCY mode operation requires the M1 to halt before firing and requires the gunner or commander to apply manual lead. Manual lead must be used because lead corrections are automatically mixed with stabilization inputs provided to the gun turret drive by the computer. Automatic lead capabilities are lost whenever the turret is not stabilized.

The MANUAL mode is used when turret power is lost. Neither the stabilization system nor the power control handles are available without turret hydraulic power. Therefore, the gunner or commander must use manual traverse and elevation hand cranks to traverse the turret and elevate the gun. Loss of stabilization in the manual mode requires the gunner or commander to apply manual lead.

Sighting Systems. The day and thermal channels of the gunner's primary sight (GPS) provide the primary optics for the main gun and gunner's coaxial machinegun. The day channel includes a unity power vision block and a dual power periscope. The GPS unity power vision block is not magnified, has a field of view of 6 degrees vertically and 18 degrees horizontally, and may be used for close-in viewing. The periscope includes a low power (3X) wide angle (20^{o}) mode for acquiring targets and a high power (10X) narrow field of view (6.5^{o}) mode for identifying and engaging targets. The GPS thermal channel (TIS) also has 3X and 10X settings and while designed for viewing under low-visibility conditions, may be used under optimum daylight viewing conditions as well. In the NORMAL mode with all systems operational, rate information from the control handles in tracking a moving target causes the GPS

reticle to offset in azimuth when the gunner lases or enters a range. This rate information is also supplied to the gun turret drive system to counterrotate the turret in azimuth and maintain the reticle or target when reticle offset is applied. In the EMERGENCY mode, the GPS is slaved to the gun requiring the gunner to apply manual lead to engage moving targets. Manual lead is applied by using the mil line graduations on the GPS reticle. The Gunner's Auxiliary Sight (GAS) is a simple eight power, gun-mounted telescope that operates independent of the primary fire control system. The GAS is sometimes referred to as the 105D sight or telescope. It has a relatively narrow eight degree field of view, and serves as a rugged reliable backup to the GPS. The GAS provides selectable ballistic reticles for APDS and HEAT ammunitions. The GAS, like the GPS, is graduated in mil lines, but the GAS also has range lines in meters for providing superelevation to the gun for longer range targets. The commander GPS extension (GPSE) provides the commander with the same sight picture and symbiology as displayed by the GPS to the gunner. In addition the commander has the commander's forward unity periscope (FUP) for target acquisition during closed hatch operation. The FUP has a wide field of view. The commander's weapon station also includes a low power (3X) fixed focus periscope which provides lead lines graduated in mils and range lines graduated in meters for use with the commander's .50 caliber machine gun. The commander's periscope may be aligned with the main gun and rotated by traversing the turret, but can also be oriented independently of the turret by power or manual rotation of the commander's weapon station.

Tank-mounted Weapons. The primary weapon on the M1 tank is the 105mm M68 cannon, mounted in a combination gun mount. The combination gun mount provides mounting surfaces for the coaxial machinegun, the gunner's telescope and the auxiliary firing mechanism. The 105mm gun may be fired by depressing the trigger switches on the gunner's or commander's power control handles. The 105mm gun is fired via the manual elevation handle trigger in the MANUAL mode when there is no hydraulic power or by the MANUAL FIRING handle (blasting machine) when there is no turret electrical power. Secondary weapons include two M240 7.62mm machine guns and one .50 caliber M2HB machine gun. One 7.62mm machine gun is coaxially mounted on the main gun mount, while the other 7.62mm gun is mounted at the loader's station for use against enemy troops and aircraft. The .50 caliber machine gun mounts at the commander's weapon station.

M1 Degraded Modes

The foregoing discussion of the major functional components of the M1 fire control system refers to operation under MANUAL and EMERGENCY modes. These firing modes are used in response to malfunctions of or damage to M1 fire control system components and require the gunner and commander to apply specialized degraded gunnery techniques. Degraded gunnery techniques may also be necessary when firing in the NORMAL mode as when the LRF fails or when a faulty component is providing an erroneous input to the ballistic fire control computer (e.g., faulty crosswind sensor or cant sensor). The specific degraded technique employed by the gunner and commander and hence the firing mode used depends entirely on which component or components have failed. The large number of components that may fail singly or in combination precludes a comprehensive description of all possible degraded modes and

the required techniques for each. A broad, though brief, summary of degraded mode gunnery for the M1 tank is presented in Table 1. The table was derived from information included in ARI Research Product 84-12, M1 Degraded Mode Gunnery, (US Army Research Institute for the Behavioral and Social Sciences, 1984) and in FM 17-12-1 (Headquarters DA, 1986). The table lists possible system failures that lead to the use of degraded gunnery techniques, the symptoms suggesting that particular systems have failed, checks made to pinpoint the failure, and the necessary responses or techniques that an M1 crew must exhibit in order to engage targets if the checks indicate a system failure. Table 1 is not a procedures guide; it is an outline of M1 degraded modes and is presented to illustrate the range and complexity of M1 degraded mode gunnery.

Table 1

M1 Tank Degraded Gunnery Modes

System Failure	Symptoms	Checks	Suggested Response
Crosswind Sensor	- "F" in GPS - "3" in CCP - NO GO lamp on - Crosswind button flashes	- Laser Range Switch in SAFE - CB 22, 25, 27 on - Perform computer self test	- Report sensor failure - Press crosswind button - Enter "0" into CCP - Apply standard adjustment if round misses
Cant Sensor	- "F" in GPS - "2" in CCP - NO GO lamp on - Cant button flashes	- Laser Range Switch in SAFE - CB 22, 25, 27 on - Perform computer self test	- Report sensor failure - Press cant button - Enter "0" into CCP - Halt tank - Apply CANT correction (Aim 1 mil high and 1 mil in direction opposite of Cant per 1000 meters of target range)
Lead Angle Sensor	- "F" in GPS - No aim point offset after lasing - "4" in CCP - NO GO lamp on - Lead button flashes	- Laser Range Switch in SAFE - CB 22, 25, 27 on - Perform computer self test	- Report "malfunction, no lead" - Press lead button - Enter "0" into CCP - Apply manual lead for moving targets - Use GPS

Table 1 (Continued)

M1 Tank Degraded Gunnery Modes

System Failure	Symptoms	Checks	Suggested Response
Computer	- CCP Power light off with CCP power switch ON - "1" in CCP - NO GO lamp on	- Turret and hydraulic power on - CCP power switch on - Fire control mode switch in NORMAL - Perform computer self test	- Report Computer malfunction - Use GAS - Apply manual lead for moving targets
Laser Rangefinder	- "F" in GPS - No change in GPS range data after lasing - "8" in CCP - NO GO lamp on - Range button flashes	- Laser Range Switch in 1st or last return - Mode switch in NORMAL or EMERGENCY - Auto Range light in CCP off - Thermal Test Switch off - CB 25 on - Perform computer self test	- Determine range using alternate method - Index or toggle range into CCP or use battlesight range with GPS - GAS may be used in lieu of entering range into CCP
Stabilization	- View in the GPS/TIS jumps around - Gunner unable to keep aim point on the target	- Mode Switch in NORMAL	- Mode Switch to EMERGENCY - Halt Tank - Apply manual lead using reticle mil lead lines on GPS/GAS
GPS	- No view of outside area in 3X or 10X magnification	- CB 21 on	- Report "malfunction, no GPS" - Use TIS if available - If not, use GAS
GPS reticle	- No reticle image in GPS	- CB 21, 30 on - GPS reticle control is fully clockwise	- Report reticle is out - Use TIS if available - If not, use GAS

Table 1 (Continued)

M1 Tank Degraded Gunnery Modes

System Failure	Symptoms	Checks	Suggested Response
Thermal Imaging System	- No thermal images present in sight	- FLTR/CLR/SHTR switch in SHTR - Unit Test Pat-Pattern switch off - Fault light off - CB 22 on - Adjust contrast and sensitivity controls	- Report TIS is out - Day, use GPS/GAS - Night, use artificial light for direct fire or sketch card for indirect fire - Seek hull-down position
Image Control Unit/Electronic Unit	- No range numbers in GPS/TIS after lasing - No ready-to-fire symbol after lasing	- Time permitting gunner may check range displayed in CCP	- Report "malfunction, no symbols" - Engage target using GPS/TIS - If round misses, keep palm switches depressed and use reengage method of adjustment
Turret Power	- Turret or gun fails to move or stops	- CB 17, 30, 31 on - Turret traverse and elevation travel locks unlocked - Check turret/hull/gun shield for obstructions - Hydraulic power gauge above 1550 psi - Engine or Auxiliary Hydraulic power on - Gun/turret drive switch powered - Fire control malfunction light off	- Report turret power out - Use GAS and MANUAL mode - Use manual traverse and elevation hand-cranks to move gun - Apply manual lead for moving targets

Note: CCP = Computer Control Panel; CB = Circuit Breaker; TIS = Thermal Imaging System; GPS = Gunner's Primary Sight; GAS = Gunner's Auxiliary Sight.

Degraded Mode Gunnery Performance

Degraded mode gunnery is by definition less effective than gunnery with a fully operational tank because of the loss in firing precision attending the loss of primary fire control system components. Nevertheless, degraded gunnery modes, like those described in Table 1, may be essential to a crew's survival when a primary system fails. Further loss in firing precision and some loss in speed may occur in degraded modes due to lack of experience with degraded gunnery techniques or the necessary knowledge or skills to effectively apply those techniques. The extent to which gunnery performance is affected by the use of degraded mode techniques is largely unknown because no systematic effort has been made to quantify the resulting performance decrements. Data from investigations that included a degraded gunnery exercise suggests that gunnery performance may be adversely affected when degraded mode gunnery techniques are used.

On a test developed for the M1 Unit Conduct of Fire Trainer (Graham, 1986), inexperienced soldiers hit only 18 percent of multiple moving short range targets using the GAS with an inoperative ballistic computer, while the same soldiers hit 59 percent of the targets using the GPS on a similar fully operational tank exercise. Abel (1986), using an arcade style M60A1 gunnery trainer known as Battlesight, found less dramatic drops in gunnery performance for experienced and inexperienced gunners in switching from the M32E periscope to the 105D telescope. Average hit percentages over 100 engagements dropped from 31 percent with the periscope to 22 percent with the 105D telescope. Similarly first round hits dropped from 23 to 13 percent when switching to the telescope. In contrast, data representing Table VIII gunnery performance for more than 700 M1 tank crews suggests little or no performance decrements in using the GAS, with first round hit percentage averaging 90 percent for two short range targets - one stationary and one moving. Opening times on these targets averaged only 3.42 seconds (Unpublished memorandum, 1987). Smith and Graham (1987) included a degraded exercise involving an inoperative stabilization system for testing the firing skills of second lieutenants enrolled in Armor Officer Basic (AOB) training courses. The AOB students firing from the commander's station averaged a first round hit percentage of 55 percent and opening time of 16.2 seconds for stationary tank, moving target short range engagements. Smith and Graham, however, did not include a comparable fully operational exercise, so the effects of stabilization failure could not be assessed. Inferences about the effects of degraded modes on gunnery performance drawn from these investigations must be tentative, however, because target type, own tank movement, target movement, and target range were not controlled. None of these investigations were intended to evaluate degraded gunnery performance, and hence the necessary controls were not included.

Evaluating Gunnery Performance Under Degraded Modes

To properly evaluate the effects of the use of degraded modes on M1 gunner performance, factors such as target type, movement and range must be controlled. Additionally, the capability to reliably degrade selected components of the fire control system must be present. Finally, a sufficient number of rounds and target scenarios must be available to obtain an adequate

sample of gunnery performance under each degraded condition examined and under fully operational conditions. The M1 Unit Conduct of Fire Trainer (UCOFT), a high fidelity gunnery simulator for the M1 tank, meets all of these conditions and is the obvious choice for evaluating degraded mode gunnery performance. The M1 UCOFT has a large library of preprogrammed M1 gunnery exercises from which the evaluator can select the exercise that meets his immediate needs. Exercises simulating stationary and moving own tank and stationary and moving targets are available for short and long range engagements. Single and multiple target exercises, as well as day and night engagements, are available. In addition, degraded mode exercises for various types of fire control system malfunctions are available. Presently the M1 UCOFT includes at least seven different types of degraded mode commander/gunner exercises (General Electric Company, 1985). These "canned" degraded mode exercises were specifically designed for training soldiers in selected degraded gunnery techniques. Canned degraded exercises representing stabilization failure, LRF failure, GPS and ballistic computer failure, coax machinegun failure, and failure of the manual elevation handle trigger and/or the power control handles are included. Canned degraded exercises are not available for all combinations of target movement and target range for each of the seven degraded mode types. Fortunately, the various degraded modes can be simulated with fully operational mode exercises by the combined use of appropriate degraded gunnery procedures and proper positioning of fire control system switches. This permits an evaluator to use identical exercises under several degraded modes and under fully operational conditions. The use of switch settings to simulate degraded conditions in what would otherwise be fully operational exercises, however, does not allow the crew extra time for performing the degraded gunnery scenarios that some of the canned degraded exercises allow. Shorter times to complete the degraded gunnery scenarios could adversely affect degraded mode gunnery performance, even for experienced gunners.

Some characteristics of the UCOFT can be considered detrimental to the accurate evaluation of degraded gunnery performance on this device. Comments from armor trainers and crews suggest that the UCOFT stabilization system does not accurately portray the M1 tank stabilization system. The comments indicate that the UCOFT sight picture is too jittery with stabilization and too stable without stabilization. Stabilization loss in the UCOFT does require the simulated tank to halt and the gunner to apply manual lead - the same requirements attending stabilization loss in the M1 tank. The UCOFT also contains a bug in the software that requires target ranges announced by the commander to be adjusted downward 300-400 meters for all GAS engagements beyond Battlesight range. If the commander uses the ranges listed in the UCOFT manual for these GAS engagements and fails to use adjusted ranges, the gunner will miss targets despite using correct procedures. This problem is easily overcome by ensuring that the commander announces the adjusted target ranges. Another problem concerns the procedures to be used when the laser rangefinder (LRF) has failed. On the UCOFT, but not on the M1 tank, the commander must press the Battle Range button while the gunner is tracking to induce automatic lead for moving targets. This should not affect the gunner's performance as long as the commander consistently presses the Battle Range button on cue. The problems with UCOFT degraded modes gunnery are inconsequential if the required adjustments are made, but may invalidate the evaluation of degraded mode gunnery performance if they are not.

Present Research

The present research recognizes the problems associated with the measurement of degraded gunnery on the UCOFT and makes the necessary adjustments. The primary purpose of this investigation is to compare the effects various degraded gunnery modes on gunner performance to performance under fully operational conditions. A secondary purpose is to determine how target movement, range and own vehicle movement affect gunnery performance under different degraded conditions and under fully operational conditions. Other objectives include determining the effects of UCOFT gunnery practice under degraded conditions on degraded gunnery performance and identifying predictors of degraded gunnery performance.

This research is designed to systematically compare performance under several degraded conditions representing the failure of major fire control system components to performance under fully operational conditions. The effects of degraded modes on gunner performance are evaluated as a function of the degraded gunnery procedures required. No attempt is made to evaluate tank commander performance under these conditions. In fact the research is designed to control the tank commander's actions so that the commander's effect on the gunner's performance is minimal and constant for all gunners. All gunners receive the same engagements, but the gunners perform those engagements under different fire control system conditions, depending on a random assignment to subject groups. Gunners are not evaluated on their ability to identify a particular degraded condition from its symptoms, nor are they tested for their knowledge of the necessary procedures for any particular degraded condition. The degraded gunnery procedures to be used are provided to the gunners before each UCOFT exercise, and the gunners are tested only on their skill in executing the prescribed procedures. Their skill in executing the procedures is evaluated by measuring their speed and accuracy in applying these procedures to engage UCOFT targets.

METHOD

Subjects

The subjects for this investigation were 48 M1 qualified noncommissioned officers who were serving as instructors on M1 tank New Equipment Training Teams (NETT) at the US Armor Armor Center at Fort Knox. NETT instructors were selected because of their previous armor experience, UCOFT experience and knowledge of the M1 tank. These instructors averaged ten years in armor, two years as tank gunner and twenty hours of UCOFT time. Additional data on the subjects are presented in the results section.

Equipment and Materials

The primary equipment consisted of two M1 Unit Conduct of Fire Trainers (UCOFTs) designed and manufactured by the General Electric Company. The M1 UCOFT is a high fidelity gunnery trainer designed for training gunners and tank commanders to perform the individual and crew gunnery skills required during M1 tank gunnery engagements. Figure 1 depicts the major subsystems

constituting the UCOFT. These subsystems include an instructor/operator's station, an enclosed crew station, a special purpose computer and a general purpose computer (General Electric Company, 1985). The instructor/operator's station includes separate monitors for real-time monitoring of the performances of the gunner and commander, an instructor's control terminal, and a printer for permanently recording the crew's performance. The crew station (Figures 2 and 3) contains the Gunner's Primary Sight (GPS), the Gunner's Auxiliary Sight (GAS), the Gunner's Primary Sight Extension (GPSE) for the tank commander, the commander's Forward Unity Periscope (FUP), and nearly all of the switches and controls used by the gunner and tank commander for gunnery in the M1 tank. The UCOFT does not include the gunner's unity power vision block found in the M1 tank. The special purpose computer produces the full color, computer-generated scenes presented via the gunner's and commander's sights. The general purpose computer provides control of the other UCOFT subsystems and manages the UCOFT training and evaluation systems. Combat Vehicle Crewmen (CVC) helmets were provided for each gunner and TC. The crewmen used the CVC helmets to communicate with each other and with the instructor/operator (I/O).

An operator's guide containing the specific instructions for each UCOFT exercise was provided to the UCOFT instructor/operators (see Appendix A). The operator's guide also included instructions for the gunner regarding fire control procedures to be used in each fire control mode. The TCs were each given a copy of fire commands for each exercise (Appendix B). Other materials were general instructions to the subjects (Appendix C), a questionnaire for obtaining biographical data about the subjects (Appendix D), and a training strategies questionnaire for identifying any special strategies used in performing the degraded gunnery exercises (Appendix E).

Procedures

Key Personnel Training and Functions. This investigation required the assistance of instructor/operators (I/Os) to operate the UCOFT and surrogate tank commanders to issue fire commands and perform other commander functions for the subjects serving as gunners. I/Os and TCs received training in the necessary procedures before the investigation began. I/Os were trained to use the I/O guide in presenting UCOFT exercises to the gunners and to assist the TC in placing the reticle on the required landmark location before each engagement. The surrogate TCs were familiarized with degraded gunnery exercises and were trained to perform the required experimental procedures, including how to interact with the I/O and gunners. The TCs, who had previous UCOFT and tank commander experience, received this training over a three day train-up period preceding the investigation. The I/Os were five civilian research assistants and the surrogate TCs were four NETT instructors who were experienced on the UCOFT. Each instructor served as TC for 12 gunners, three gunners from each of four groups.

The objectives of this research require a standardized presentation of each target for all subjects. That is, each gunner must have an equal opportunity to identify and engage the targets. Engagements were standardized by designating a landmark feature (e.g., woodlines, rocks, barns) in each target

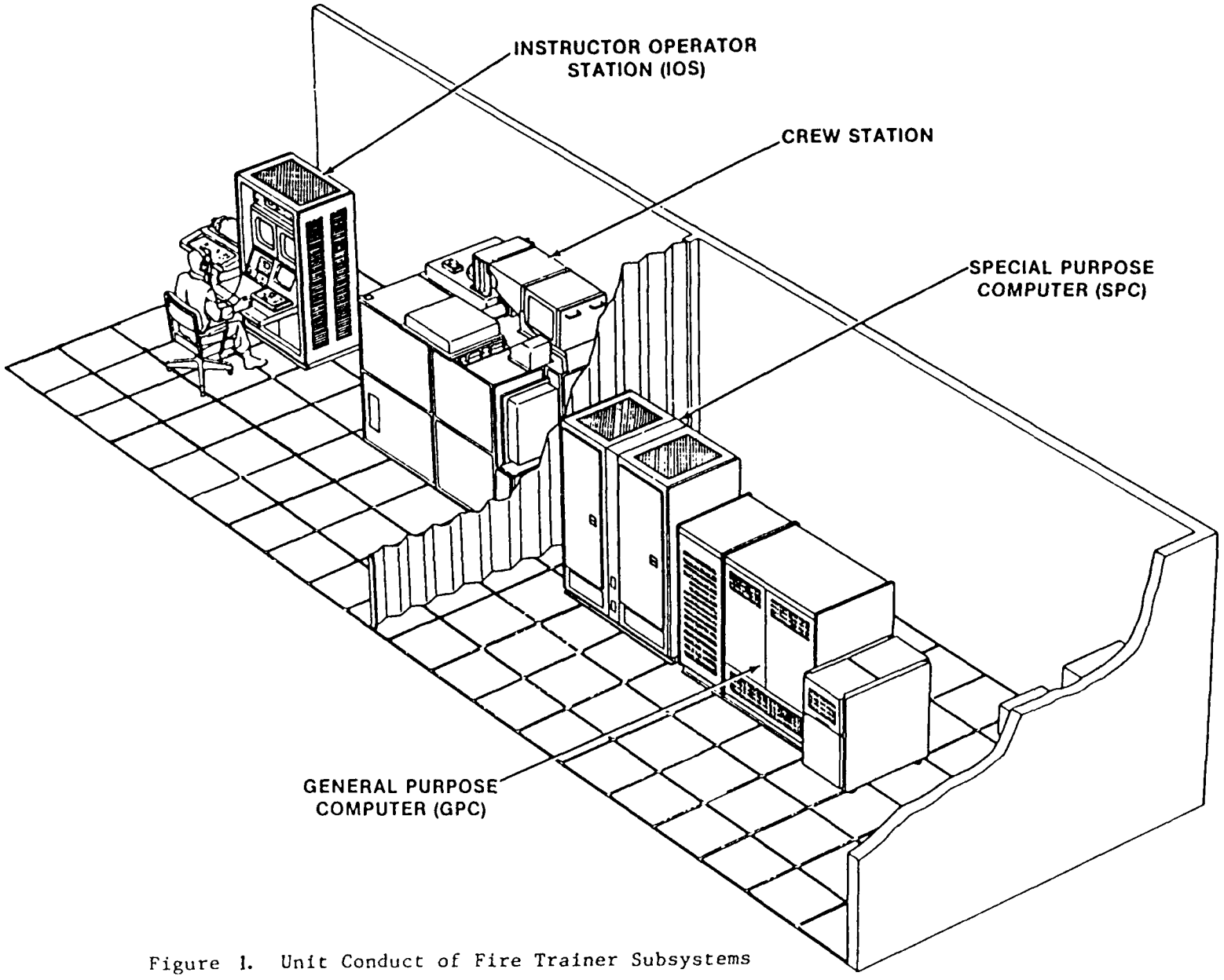
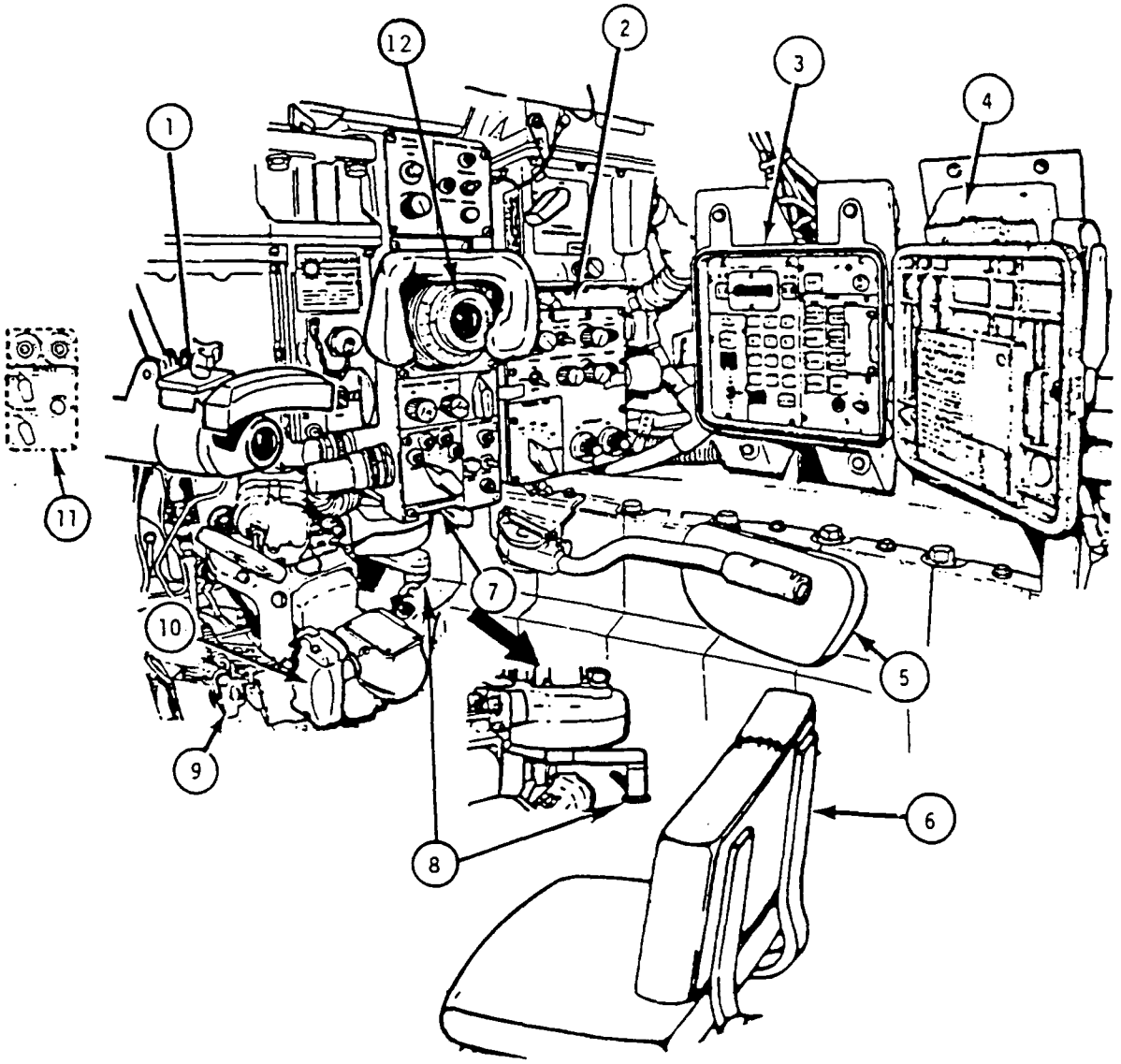
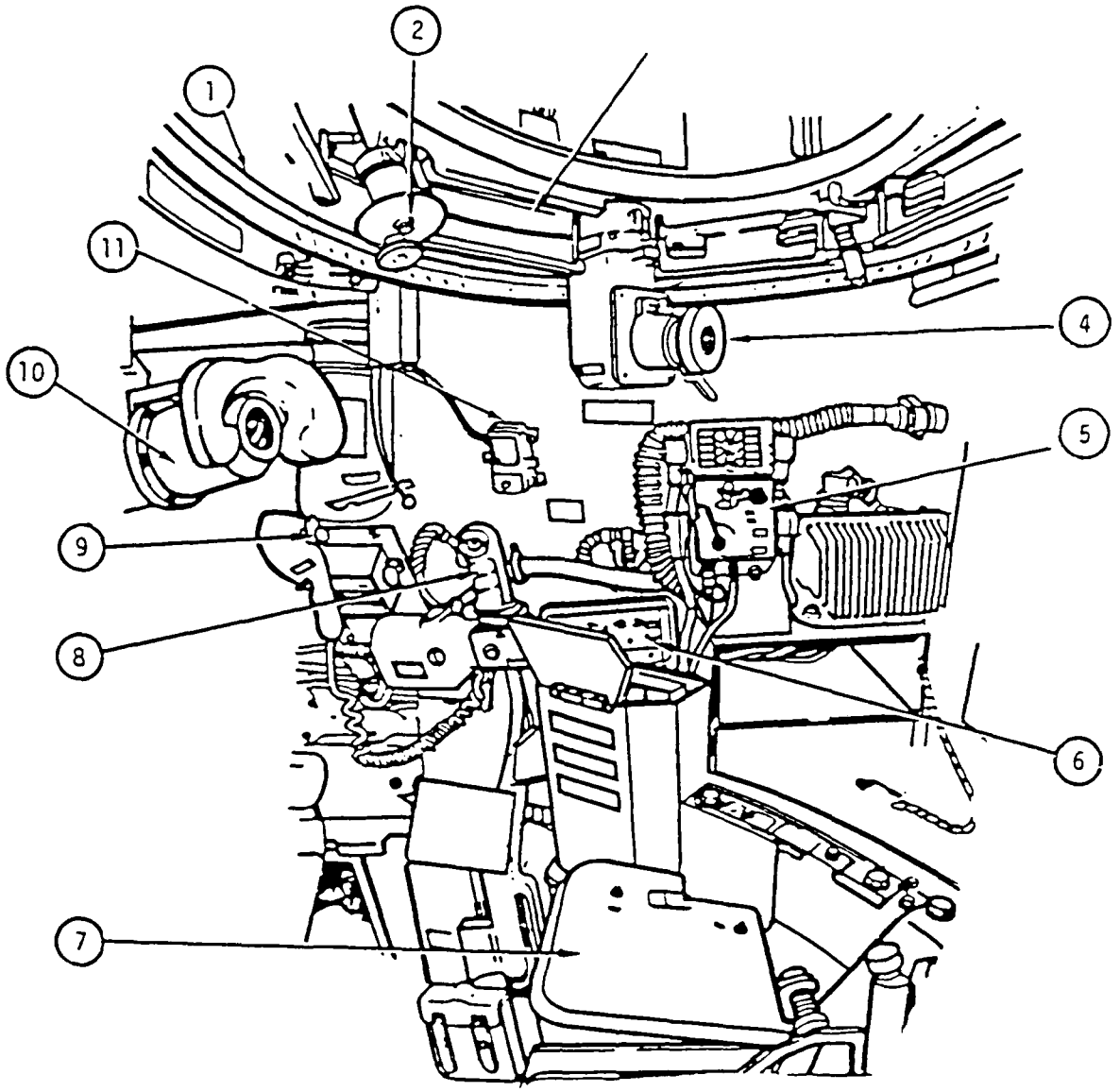


Figure 1. Unit Conduct of Fire Trainer Subsystems



1 GAS
2 TIS CONTROL PANEL
3 BALLISTIC COMPUTER CONTROL PANEL
4 INTERCOM CONTROL SET
5 CHEST REST
6 SEAT
7 GPS CONTROL PANEL
8 MANUAL TRAVERSE HANDLE
9 MANUAL ELEVATION HANDLE
10 GUNNER'S CONTROL HANDLE
11 GAS CONTROL PANEL
12 GPS

Figure 2. Unit Conduct of Fire Trainer Tank Gunner's Station



1 CWS MANUAL TRAVERSE RING
2 MANUAL ELEVATION CONTROL
3 FUP
4 CWSS
5 INTERCOM CONTROL SET
6 COMMANDER'S CONTROL PANEL
7 SEAT
8 COMMANDER CONTROL HANDLE
9 CWS CONTROL HANDLE
10 GPSE
11 DOME LIGHT

Figure 3. Unit Conduct of Fire Trainer Tank Commander's Station

scenario and determining the distance in degrees from this feature to the initial location of the target. An experienced UCOFT operator selected the landmark for each scenario; typically the operator selected landmarks that were four or five degrees to the left or right of the target's initial position. The procedure ensured that most targets would initially appear in the gunners 3X field of view and allowed all gunners to begin each engagement from a common reference point. Smith & Graham (1987) used this technique earlier in standardizing UCOFT engagements for testing the gunnery skills of second lieutenants enrolled in Armor Officers Basic Training.

Experimental Conditions. Subjects were randomly assigned to four groups of 12 subjects each. Three experimental groups were tested under degraded mode conditions while the fourth group, a control group, was tested in the fully operational mode. The three groups tested under degraded modes were: (1) a stabilization failure group; (2) an LRF failure group; and (3) a ballistic computer failure group. The ballistic computer failure group also had an inoperative GPS, LRF, and stabilization system. Before testing, all groups received 36 warm-up engagements (18 fully operational and 18 degraded mode) to familiarize them with the required procedures and to provide warm-up for the test. Thus, all soldiers received practice on both fully operational and degraded mode engagements on the UCOFT before being tested.

The test consisted of seven UCOFT exercises comprising 60 single-target engagements. Test exercises were selected on the basis of target range and own tank and target movement. Two target range classifications (i.e., short range targets less than 1500 meters and long range targets greater than 1500 meters) and three movement conditions were included. The movement conditions were: stationary own tank, stationary targets (SS); stationary own tank, moving targets (SM); and moving own tank, moving targets (MM). The combination of two ranges with three movement conditions yielded the following six engagement types: (1) stationary, stationary-short range (SS-S); (2) stationary, stationary-long range (SS-L); (3) stationary, moving-short range (SM-S); (4) stationary, moving-long range (SM-L); (5) moving, moving-short range, (MM-S); and (6) moving, moving-long range (MM-L). The UCOFT test exercises corresponding to each of the six types of engagement are shown in Table 2. The number of engagements constituting each exercise is also shown. The order of presenting the six engagement types was counterbalanced across trials. Within each group, the subjects were randomly assigned to the six orders so that only two subjects from each group received the exercises in the same order. The six orders of presenting the exercises are shown in Table 3. This counterbalancing procedure enabled the evaluation of practice effects across test trials.

Although the exercises listed in Table 2 were designed to be fired in the UCOFT under fully operational conditions, they can be fired in degraded modes as well. These exercises were degraded for the purposes of this investigation by setting the fire control switches to simulate the various degraded mode system failures. For example, placing the RANGE switch in SAFE on the M1 UCOFT disables the simulated laser rangefinder function. Stabilization system failure is simulated by placing the fire control mode switch in EMER-

Table 2

UCOFT Test Exercises with Type and Number of Engagements in Each.

UCOFT Exercise	Engagement Type	No. of Engagements
311110	SS-S	10
321110	SS-L	10
313110	SM-S	10
323110[a]	SM-L	10
315110	MM-S	10
325110[b]	MM-L	5
325111[b]	MM-L	5

[a]Although this exercise included 10 targets, target 8 was actually a short range target and was not included in the analyses.

[b]These five-engagement exercises are treated as a single exercise for analysis purposes.

Table 3

Latin Square used in Counterbalancing Engagement Type Across Trials for Each Subject Group

		TRIALS					
Order	n[a]	1	2	3	4	5	6
1	2	MM-S	SM-S	SS-L	SS-S	SM-L	MM-L
2	2	SM-S	SS-S	SM-L	MM-S	MM-L	SS-L
3	2	SS-S	MM-S	MM-L	SM-S	SS-L	SM-L
4	2	MM-L	SS-L	SS-S	SM-L	MM-S	SM-S
5	2	SM-L	MM-L	SM-S	SS-L	SS-S	MM-S
6	2	SS-L	SM-L	MM-S	MM-L	SM-S	SS-S

[a]The number of subjects in each group receiving a particular order.

GENCY. By setting the fire control switches to correspond to a particular type of degradation and by directing the soldiers to follow certain procedures, each of the degraded conditions was accurately simulated. This procedure permitted all subjects to fire the same engagements, regardless of engagement mode. That is, the same 60 target scenarios were presented to every subject in each of the four groups of subjects; only the type of degradation varied among the subject groups. This would not have been possible with the canned exercises.

Testing Sequence. Upon arriving at the test site, general instructions describing the purpose of the research and the experimental procedures were read to the subjects (see Appendix C). Each subject was paired with a surrogate TC and took the gunner's seat in the M1 UCOFT. Under the direction of the UCOFT instructor/operator and the TC, the gunner performed the 36 warm-up/familiarization engagements. The warm-up was followed by a 10-minute break. After the break, the subjects performed 30 test engagements under either fully-operational or one of three degraded mode conditions. Another 10-minute break was followed by the remaining 30 test engagements. After testing, a biographical questionnaire and a training strategies questionnaire were completed for each subject.

The Typical UCOFT Exercise. The typical warm-up/test exercise was performed in the following manner. The instructor/operator, using the I/O guide, announced the exercise to be performed, directed the gunner to place switches in their appropriate positions, and instructed the crew in which sights and engagement procedures to use for the exercise. The I/O checked that the crew was ready before starting the exercise. The I/O then directed the TC to move his sight reticle to a predetermined landmark location as the UCOFT was preparing each engagement. For example, the I/O might direct the TC to traverse right, cautioning the TC with STEADY as the landmark came into view, and tell the TC to lay on the top right of the barn. The TC used his Gunner's Primary Sight Extension (GPSE) to locate the designated landmark, except when a malfunctioning GPS dictated the use of the .50 cal sight for landmark location. The TC kept his reticle on the landmark until the target appeared, at which time he issued a fire command and released the palm switch on his commander's override, relinquishing control to the gunner. The gunner used the appropriate sight and gunner's control handles to search for and acquire the target, announcing IDENTIFIED upon locating the target. The I/O pressed the key labeled GUNNER IDENTIFIED at the I/O station when the gunner indicated he had identified the target. If the gunner failed to identify, the TC assisted by commanding ACTION LEFT or ACTION RIGHT. The gunner then layed on the target, tracked it if moving, and fired upon the TC's command after accounting for target range. Range determination methods varied across the different exercises and engagement modes. The TC instructed the gunner to CEASE FIRE after one round had been fired at the target. After firing the gunner was told to relax and wait for the next engagement. When the gunner completed all of the engagements in a particular exercise, the I/O pressed the FREEZE/UNFREEZE key to freeze the exercise and pressed the PRINT, PERF ANAL, PRINT keys in sequence to print the performance data.

Engagement Procedure by Exercise Type and Mode. Procedures performed by the I/O and crew change as a function of exercise and engagement mode. In

stationary own-tank exercises the I/O depresses the DRIVER STOP/GO key to move the tank from behind the berm when the TC commands DRIVER MOVE OUT, GUNNER TAKE OVER and again after the gunner fires to move the tank back behind the berm. The gunner must look through the GAS and command DRIVER STOP when the gun tube clears the berm, even for exercises in which the GPS will be used to engage the targets. Otherwise the gunner may fire the round into the berm instead of at the target. These procedures are not required for exercises in which the gunner's tank is moving. Procedures used in determining range and tracking targets as a function of exercise type and engagement mode are outlined in Table 4. Additional description of the procedures used for each engagement mode is included in the following paragraphs.

Fully Operational Fire Control System. The procedures employed in this investigation with a fully operational fire control system involve the use of precision gunnery techniques. In M1 precision gunnery the LRF is used for determining range and the GPS is used for tracking and firing. After identifying the target and with his tank in a firing position, the gunner must lay the GPS reticle on the target center of mass and track it if it is moving. The gunner then presses the lase button on the gunner control handles to activate the LRF. The TC commands FIRE if the LRF returns the correct range; otherwise the TC directs the gunner to RELASE. The gunner responds by relasing if necessary and firing a single main gun round from the GPS.

Inoperative Stabilization System. The stabilization system in the M1 tank compensates for hull and turret movement, keeping the turret and gun tube pointed in the same direction relative to the earth. This stabilizes the target scene for the gunner and TC. Without a working stabilization system, the gunner must operate in the Emergency Mode. In the Emergency Mode, the automatic lead function is inoperative and the tank must come to a halt before firing. That is, for all own-tank moving exercises, the TC commands DRIVER STOP before issuing the fire command. The I/O presses the DRIVER STOP/GO key on the operator's console in response to this command. For stationary targets the gunner aims his GPS reticle at the target center of mass, but for moving targets the gunner must lead the target several mils by placing the reticle slightly ahead of the target's center of mass. The amount of lead the gunner must apply depends on the speed of the target and the type of ammunition used. The lead required for targets in this research varied from zero to ten mils.

Inoperative Laser Range Finder (LRF). In the fully operational mode, the M1 laser rangefinder is used to determine the distance or range to a selected target. When used correctly the M1 LRF provides an accurate range determination. The range from the LRF is entered automatically into the fire control system when the gunner presses the lase button on the gunner's power control handles. A damaged LRF may provide no range information or return an incorrect range. Therefore the crew must use alternate methods for determining range and entering it into the fire control system. These methods vary from the simple, quick recognition method to the slower more complicated but accurate mil relation formula (Headquarters DA, 1986). In this investigation, the assumption was made that the TC had accurately determined target range using one of the alternate range determination methods. After determining the range, the TC announces the correct target range to the gunner in the

Table 4

Ranging and Tracking Procedures as Determined by Engagement Mode and Exercise Type.

Exercise Type	Engagement Modes			
	Fully Operational (Normal Mode)	Stabilization Out[a] (Emergency Mode)	LRF Out[b] (Normal Mode)	Computer, GPS, LRF, and Stabilization Out (Emergency Mode)
SS-S				
Ranging	LRF	LRF	Battle Range	Battle Range
Tracking	GPS/No Lead	GPS/No Lead	GPS/No Lead	GAS/No Lead
SS-L				
Ranging	LRF	LRF	Indexed	Range Lines
Tracking	GPS/No Lead	GPS/No Lead	GPS/No Lead	GAS/No Lead
SM-S				
Ranging	LRF	LRF	Battle Range	Battle Range
Tracking	GPS/Auto Lead	GPS/Manual Lead	GPS/Auto Lead	GAS/Manual Lead
SM-L				
Ranging	LRF	LRF	Indexed	Range Lines
Tracking	GPS/Auto Lead	GPS/Manual Lead	GPS/Auto Lead	GAS/Manual Lead
MM-S				
Ranging	LRF	LRF	Battle Range	Battle Range
Tracking	GPS/Auto Lead	GPS/Manual Lead	GPS/Auto Lead	GAS/Manual Lead
MM-L				
Ranging	LRF	LRF	Indexed	Range Lines
Tracking	GPS/Auto Lead	GPS/Manual Lead	GPS/Auto Lead	GAS/Manual Lead

[a]Tank always halts and fires from a stationary position with stabilization out.
[b]On UCOFT, but not on the M1 tank, TC must press Battle Range button while gunner tracks to induce Auto Lead for moving targets.

fire commands. The gunner then enters the range information into the fire control system. This requires the gunner to manually index target range into the ballistic computer for all targets beyond battlesight range. The battlesight range for SABOT is 1200 meters. In own-tank stationary exercises, the TC announces the range in the fire command and waits for the gunner to announce IDENTIFIED and manually index the range before commanding DRIVER MOVE OUT. The gunner indexes the range by pressing in sequence the RANGE key, the numbered keys corresponding to the range, and the ENTER key on the computer control panel. In own-tank moving exercises, the tank continues to move while the gunner indexes the range. For moving targets, the TC must press the BATTLE RANGE button after the gunner has tracked the target for at least .5 seconds. (Note: Pressing the BATTLE RANGE button on LRF out, moving target exercises is idiosyncratic to the M1 UCOFT and is not a necessary procedure on the M1 tank.)

Inoperative GPS, Ballistic Computer, Stabilization System, and LRF. The failure of the GPS and Ballistic Computer requires the use of the Gunner's Auxiliary Sight (GAS) for engaging targets. An inoperative LRF means that alternate range determination methods must be used. Again it is assumed that the TC is able to determine an accurate range despite the failure of the LRF, and the TC announces the range to the gunner in the fire command. For targets at ranges beyond battlesight range the gunner uses the appropriate range line on the GAS reticle. The gunner aims center of mass for stationary targets but must lead moving targets because there is no automatic lead. Because the stabilization system is inoperative, the TC must command DRIVER STOP to halt the tank before the gunner engages a target.

Battlesight Engagements. Targets within battlesight range may be engaged using battlesight gunnery techniques. In battlesight gunnery, the battlesight range (1200 meters for SABOT) is preindexed into the computer or the 1200 meter aiming circle/line GAS SABOT reticle is used if the computer is inoperative. Battlesight techniques may be used for engagements where speed of response is a critical factor, such as when a threatening target appears suddenly at close range. These techniques are especially useful in situations in which the LRF is damaged or malfunctioning. In battlesight engagements the TC alerts the gunner in the fire command that battlesight techniques should be used. The TC presses the BATTLE RANGE button to enter the battlesight range into the system before commanding the gunner to FIRE. The TC need not press the BATTLE RANGE button if the computer is out. Because the system uses the battlesight range, the gunner neither needs to index a range before firing nor use the LRF. He simply aims the GPS reticle or uses the 1200 meter mark on the GAS reticle and fires on command.

Measures

Three measures of gunner accuracy and one measure of gunner speed were selected for evaluation purposes. The accuracy measures include average hit percentage, azimuth aiming error and elevation aiming error. The speed measure is average opening time. These measures were calculated separately for each UCOFT exercise/engagement type. Average hit percentage for each exercise was calculated by dividing the number of targets hit by the number of

targets presented. Average azimuth and elevation aiming errors were computed by separately summing the azimuth and elevation aiming errors across each exercise and dividing the azimuth and elevation sums by the number of targets engaged. Opening times is defined as the time elapsing between the target's first appearance and the firing of the first round. Average opening time was found by summing the opening times for an exercise and dividing by the number of rounds fired.

A modified version of the Gunnery Index (Witmer, 1986) was used in analyzing the data. The Gunnery Index (GI) is a composite measure of gunnery performance that combines various measures of accuracy and speed into a single measure of gunnery proficiency. The Gunnery Index was computed for each exercise by combining weighted averages of opening times with average aiming errors and hit percentages. Opening times were used in lieu of hit times in this investigation because opening times tend to be more reliable, especially for those exercises where few hits (and therefore few hit times) are recorded. A brief description of the Gunnery Index as used in this investigation appears in Appendix G.

Measures of experience and ability from the biographical questionnaire include age, military grade or rank, education level, General Technical (GT) score, military service time, armor service time, time as a gunner, time since last gunnery practice, and hours of experience on the UCOFT. GT is a composite score from the Armed Services Vocational Aptitude Battery (ASVAB) consisting of verbal and arithmetic reasoning components. GT is one criterion used in selecting soldiers for Officers Candidate School. Separate measures of time as an M1 gunner and time as a gunner on other armor vehicles were obtained.

Analyses

MANOVA procedures from the Statistical Packages for the Social Sciences (SPSS-X) were used to determine the effects of degraded mode gunnery on gunner proficiency. The between subjects variable was engagement mode (4 levels) and the within-subjects factors were target range (2 levels) and tank -target movement (3 levels). That is, each subject was tested under only one of the four engagement modes but under all of the range by the tank/target movement combinations. Because this research focused on different types of system degradation, an overall comparison between degraded and fully operational performance was of less interest than were specific comparisons among the groups. Four pairwise and one non pairwise comparison were used in evaluating the effects of engagement mode on gunner proficiency. The first three pairwise comparisons were selected to contrast performance under each of three degraded mode conditions with performance under fully operational conditions. The fourth comparison, a pairwise contrast between two of the degraded modes, was chosen to determine if use of the GAS produces significant performance decrements. The non pairwise comparison was included to compare fully operational performance with the combined effects of degraded mode operation. The Gunnery Index was used as the measure of gunner proficiency. A per experiment error rate of 0.05 was used in evaluating the nonorthogonal comparisons and within-subjects factors. This per experiment error rate corresponds to a .00217 per comparison error rate.

As described earlier and shown in Table 3, the engagement types were administered in six counterbalanced orders so that all types were equally represented in each of the six trials. This procedure permitted the evaluation of a TRIALS effect, despite the fact that individual subjects had different types of engagements on each trial. The TRIALS effect was evaluated in an SPSS-X MANOVA with engagement mode (four levels) as the between subjects factor and TRIALS (six levels) as the within-subjects factor. A significant trials effect would suggest that performance under fully operational or degraded conditions improves with practice under those conditions.

An analysis of performance during the warm-up/familiarization was conducted to determine if the groups of subjects randomly assigned to the various degraded and fully operational engagement modes were performing at the same level prior to testing. Inclusion of equal numbers of fully operational and degraded warm-up/familiarization engagements allowed the pretest comparison of groups in both degraded and fully operational modes. Separate measures of GI under fully operational and degraded modes were compared across the four groups using SPSS-X MANOVA procedures.

Correlations between biographical measures and gunnery performance during the warm-up/familiarization and on the test were computed to explore possible relationships between biographical predictor variables and gunnery performance. Predictors of gunnery performance under fully operational and degraded conditions were computed separately in the analyses. The analyses used Pearson correlation and stepwise regression procedures from the SPSS-X statistical package.

RESULTS AND DISCUSSION

Major Results

The primary question to be answered by this research is how fire control system component failures that necessitate the use of back-up systems and/or alternate procedures affect gunnery performance. This question is addressed by comparing the UCOFT performance of soldiers operating under various degraded modes to the performance soldiers operating under fully operational conditions. Converging results from both the warm-up/familiarization trials and the test trials indicate that performance is adversely affected under degraded mode operations. Significant performance differences between fully operational engagements and degraded mode engagements during the warm-up/familiarization trials suggest that degraded engagement conditions substantially reduce gunnery performance ($F_{1,44}$= 244.66, p<.0005). Soldiers subsequently assigned to the various degraded test groups and those assigned to the control group did not significantly differ from one another ($F_{3,44}$=.77, p>.51) in their performance on the warm-up/familiarization trials. This result demonstrates the effectiveness of random assignment in minimizing baseline performance differences.

Figure 4 shows comparisons between the test performance of each of the groups performing under degraded mode conditions and that of a control group

performing in the fully operational mode. Test scores as measured by the Gunnery Index are plotted as a function of tank-target movement and range. The figure shows decrements in the performance of soldiers operating under degraded conditions. The figure also shows that performance varies as a function of engagement type with moving and long range targets producing poorer gunnery performance. Finally, the figure suggests that the size of the performance decrements depends on which fire control components fail. For example, ballistic computer failure appears to produce more severe performance decrements than other fire control system failures. Figure 4 is based on data included in Table F-1 in Appendix F. Additional measures of gunner speed and accuracy by degradation condition may be found in Tables F-2, F-3, F-4, and F-5. The information provided in Tables F-2 through F-5 may be useful to combat modelers for determining accurate estimates of man-in-the-loop M1 gunnery performance under various system failure conditions. These tables present mean values for speed and accuracy measures for each degraded mode tested and for the fully operational mode.

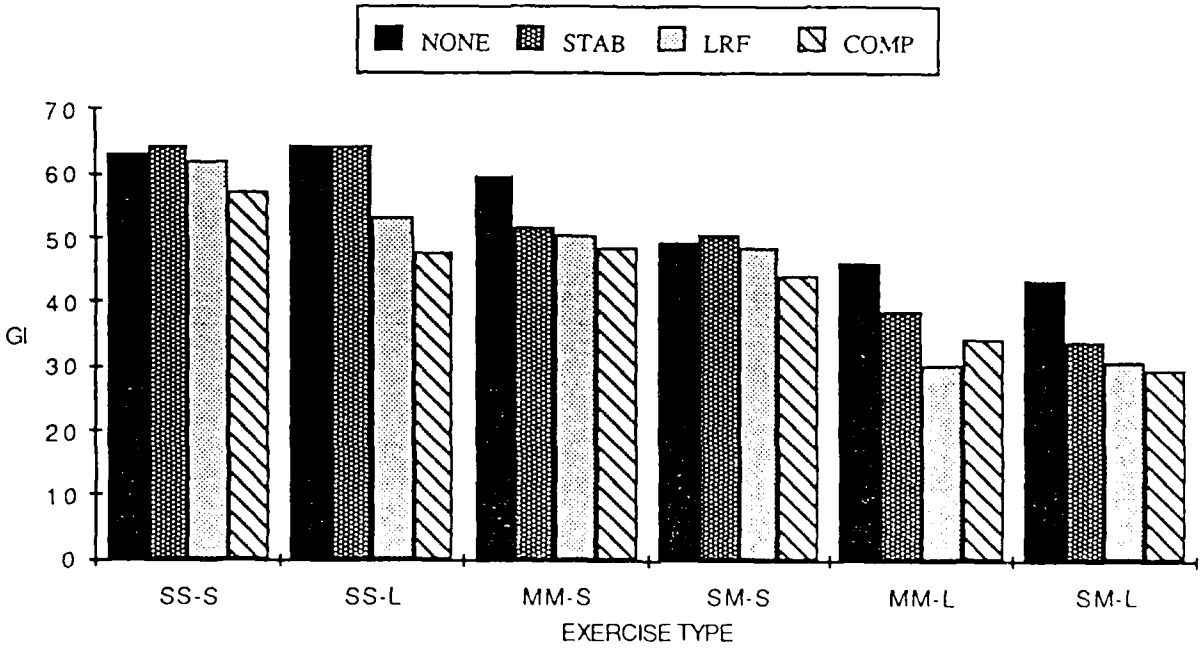


Figure 4. Effects of M1 fire control system components failure on M1 UCOFT gunnery performance.

Table 5 shows how the gunnery index changes as a function of engagement mode, tank-target movement and target range. Comparisons between pooled degraded performances and performance under fully operational conditions show significant effects for tank-target movement, range, and the interaction of these variables. Table 5 also presents pairwise nonorthogonal contrasts that

compare performances in the degraded modes with performances exhibited under fully operational conditions. The loss of the stabilization system does not produce reliable decreases in the level of gunnery performance. Other degraded mode conditions do result in reliable performance decrements, however, as evidenced by significant mode effects for each of the remaining contrasts. Contrasts between the fully operational condition and the LRF degraded mode yield a significant MODE X RANGE interaction suggesting that performance differences between these modes are a function of target range. The paragraphs that follow discuss each of the effects displayed in Figure 4 and Table 5.

Fully Operational Versus Inoperative Stabilization System

The M1 stabilization system permits the M1 gunner to engage targets while moving. Without stabilization, the tank must come to a complete halt before the gunner can accurately fire a round. An inoperative stabilization system requires the gunner to place the fire control system in the Emergency mode. In the Emergency mode, the gunner must apply manual lead when engaging moving targets. A fully operational fire control system does not require manual lead; the lead is automatically entered into the system as the gunner tracks the target. The nonsignificant performance differences between the fully operational and stabilization failure conditions suggests that requirements to halt before firing and to apply manual lead do not result in reliable performance decrements for experienced soldiers. Inspection of Figure 4, however, suggests that the likelihood of finding significant decrements in performance for stabilization system failure may be greater for stationary-moving long range and moving-moving engagements than for other engagement types.

Fully Operational Versus Inoperative LRF

Under fully operational conditions the gunner presses the lase button on the gunner's control handles to determine target range and enter it into the fire control system. An inoperative LRF requires using alternate methods for range determination, and manually keying the range in the system for long-range targets or employing battlesight techniques for short range targets. The data in Figure 4 and Table 5 suggest that LRF failure produces a significant adverse effect on gunnery performance that increases with target range. The largest performance decrements occur for long range targets where the gunner must manually index the target range.

Table 5

Effects of Engagement Mode on M1 UCOFT Gunnery Index Scores as Evaluated by Planned Nonorthogonal Contrasts

Contrast[a]	Effect[b]	F	df	Prob[c]
F.O. vs STAB	MODE	2.64	1,44	N.S.
	MODExTTM	5.89	2,43	N.S.
	MODExR	1.37	1,44	N.S.
	MODExTTMxR	4.67	2,43	N.S.
F.O. vs LRF	MODE	15.96	1,44	.0005
	MODExTTM	4.66	2,44	N.S.
	MODExR	13.70	1,44	.001
	MODExTTMxR	.83	2,44	N.S.
F.O. vs COMP	MODE	27.54	1,44	.0005
	MODExTTM	.37	2,43	N.S.
	MODExR	5.75	1,44	N.S.
	MODExTTMxR	2.45	2,43	N.S.
STAB vs COMP	MODE	13.12	1,44	.001
	MODExTTM	4.06	2,43	N.S.
	MODExR	1.50	1,44	N.S.
	MODExTTMxR	3.26	2,43	N.S.
F.O. vs DEGRAD	MODE	19.69	1,44	.0005
	TTM	167.85	2,43	.0005
	R	207.98	1,44	.0005
	MODExTTM	4.19	2,43	N.S.
	MODExR	8.81	1,44	N.S.
	TTMxR	21.57	2,43	.0005
	MODExTTMxR	2.91	2,43	N.S.

[a]F.O. = Fully Operational; STAB = Inoperative Stabilization System; LRF = Inoperative Laser Rangefinder; COMP = Inoperative Computer, LRF, Stabilization, and GPS; DEGRAD = STAB, LRF, and COMP pooled.

[b]MODE = Target Engagement Mode, TTM = Tank, Target Movement, R = Range to Target.

[c]All contrasts tested at the = .00217 level, which corresponds to a .05 per experiment error rate.

This research did not require the use of alternate range determination methods, but rather employed a technique whereby the TC announced the correct range in the fire command. This technique was used in order to test the gunner's ability to perform procedures required of the gunner (e.g., manually indexing range) for an LRF failure condition without the possible confounding from errors in the TC's range determinations. Had the TC and gunner been required to use alternate range determination methods, the performance decrements would likely have been greater than those observed in this experiment. Nevertheless, the loss of the LRF produced a significant decrement in gunner performance that increased with increasing target range. The significant MODE by RANGE interaction demonstrated that the loss of the LRF becomes more critical for longer range targets. LRF loss increases the difficulty of engaging long range targets relative to that of engaging short range targets because of the additional requirement to manually index the range for long range targets.

The tank commander may also manually enter ranges into the ballistic computer in the event of LRF failure. In fact FM 17-12-1 (Headquarters DA, 1986) states that entry by the TC is the preferred method for manually inducing range into the system. The commander enters the range with a toggle switch that increments or decrements the range in 10-meter steps until the desired range is reached as displayed in the GPSE. This procedure is simpler and faster than the method of entering numbers from the computer control panel as the gunner must do, suggesting that the gunner should have a similar system for manually indexing range. When the LRF fails and the commander is occupied with other tasks (e.g., firing his machinegun), the gunner will be required to index range manually. A simple quick method for the gunner to manually induce range should be provided.

Fully Operational Versus Inoperative Ballistic Computer, LRF, GPS, and Stabilization

The loss of the computer, GPS, LRF, and stabilization systems requires the gunner to operate in the emergency mode from the Gunner's Auxiliary Sight (GAS). The TC announces the range and the gunner uses the GAS range lines to lay the gun in elevation and applies manual lead for moving targets. The gunner must also wait until the tank halts before firing. As might be expected, this combination of fire control component failures produces the largest decrements in gunnery performance. Performance decrements occur for each of the six engagement types (see Figure 4) and do not vary significantly with target range. The large significant performance decrements for the combined computer, LRF, GPS, stabilization system failure may be attributed primarily to the requirement to use the GAS to fire all engagements.

Inoperative Stabilization Versus Inoperative Ballistic Computer, LRF, GPS, and Stabilization

Comparing performance under stabilization system failure to performance when the computer, GPS, and LRF also fail lends further support to the conclusion that the use of the GAS degrades gunnery performance. The significant MODE effect in comparing these conditions is particularly important because the only difference between the procedures performed by the gunner

for these degraded modes is the sight used for firing. The gunner uses the GPS when the stabilization system fails, but must use the GAS when the GPS and ballistic computer fail. The fact that poorer performance occurs when the GAS is used leads to the inescapable conclusion that the GAS has a significant adverse impact on the gunnery performance of experienced armor soldiers.

Fully Operational Versus Pooled Degraded Conditions

The performances of soldiers assigned to each of the previously discussed degraded conditions were pooled and compared to performance under fully operational conditions. This comparison identifies overall differences resulting from operating in degraded modes. The significant MODE effect suggests that operating in degraded modes produces reliable decrements in gunnery performance. This between groups effect is consistent with the within groups effect for engagement mode found on the warm-up/familiarization exercises. The significant difference in test performance as a function of engagement mode also suggests that decrements due to degraded conditions do not quickly disappear with practice under these conditions, (i.e., given that soldiers had both the warm-up and the test exercises in which to improve).

Tank-Target Movement and Target Range

Gunnery performance is significantly affected by the various own tank movement, target movement combinations ($F_{2,43}=167.85$, $p<.0005$). Similarly target range significantly affects gunnery performance ($F_{1,44}=207.98$, $p<.0005$), with better performance exhibited for shorter range targets. The range effects are attributable in part to the differences in gunnery procedures for short and long range engagements in degraded modes. For example, battlesight gunnery techniques are used for short range but not for long range engagements whenever the LRF is inoperative. This tends to simplify the short range engagements compared with the long range engagements. It should be noted however that performance on short range engagements exceeds that on long range engagements for fully operational and inoperative stabilization modes where the engagement procedures do not change as a function of range (see Figure 4). Range also interacts with tank-target movement to produce a significant range by tank-target movement interaction ($F_{2,43}=21.57$, $p<.0005$). The nature of this interaction may be seen by inspecting Figure 5. The figure shows that the effects of target range are greater for stationary-moving and moving-moving engagements than for stationary-stationary engagements. Thus range has a greater effect on gunnery performance for moving targets than for stationary targets.

The magnitude of effects of tank-target movement and target range are large compared to the effects of engagement mode. That is, tank-target movement and target range may influence gunnery performance more than operating in degraded modes. This result should not be construed as diminishing the importance of mode of engagement as a determinant of gunnery performance. It simply suggests that skill deficiencies exist in engaging long range moving targets as well as in performing under degraded modes.

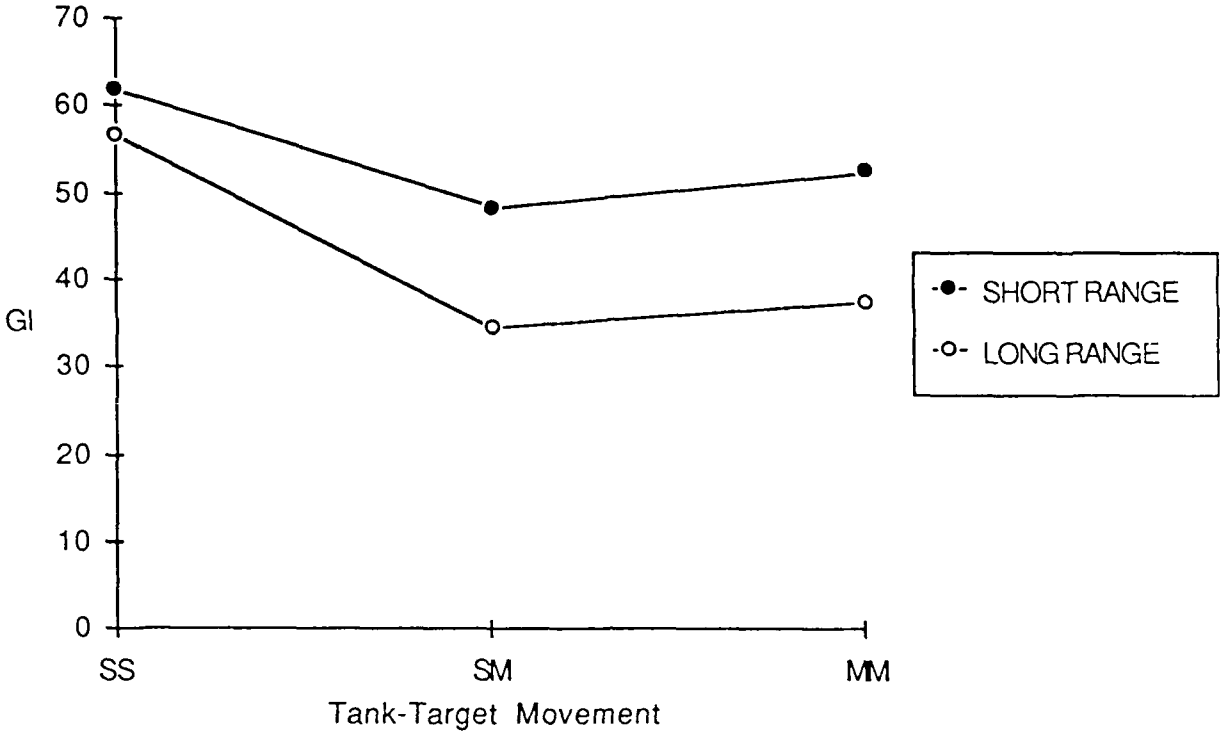


Figure 5. Gunnery index scores as a function of target range and own tank-target movement

Trial Effects

Each exercise constitutes a trial in this research. The evaluation of trial or practice effects is complicated by differences in the difficulty level of the exercises; for example, a moving-moving long range exercise is more difficult than a stationary-stationary short range exercise. Counterbalancing the order of exercise presentation so that all exercises are equally represented on every trial, however, allows the evaluation of trial effects without confounding due to exercise difficulty. The nonsignificant trial effect ($F_{5,40}=.95$, $p>.85$) over the six test trials suggests that gunnery performance does not improve over six UCOFT exercises. The MODE x TRIAL interaction is also nonsignificant ($F_{15,110}=.93$, $p>.99$) which suggests that the trial effect does not vary as a function of engagement mode. Soldiers do not improve their gunnery performance across the six test trials for either fully operational or degraded mode gunnery. The hypothesis that performance improves with practice for degraded mode gunnery was not supported by this research. Apparently the small amount of degraded gunnery practice given or the lack of specific effective instruction in engaging targets under degraded conditions was responsible for the absence of a trials effect. This explanation suggests that UCOFT degraded gunnery training requires either a large number of practice trials or special degraded gunnery training techniques. Performance in degraded modes is significantly below fully operational mode performance and requires the attention of armor trainers and training researchers to increase the performance levels under degraded modes.

Degraded Mode Gunnery Techniques and Training Strategies

Gunners were instructed before each exercise to use engagement techniques that were appropriate for the conditions under which the exercise would be fired. Some gunners found it necessary to deviate from the recommended procedures or adopted other special techniques in firing the UCOFT degraded exercises. Results from the Degraded Gunnery Training Strategies Questionnaire suggest that roughly 30 percent of the gunners used special techniques in engaging the targets. The most frequently mentioned technique was to apply extra lead for moving targets. Five of forty-eight gunners reported using more than the 2 1/2 mil standard lead recommended for SABOT rounds, and three other gunners suggested that extra lead should be used. Most of those who reported using extra lead were in the inoperative computer group. No one in the stabilization failure group reported using extra lead, although the requirement to apply additional lead was present for that group as well. One gunner in the stabilization failure group, however, did report estimating target speed to figure lead, indicating that he was varying how much lead he applied based on target speed. Two gunners in the stabilization failure group and one in the inoperative computer group admitted using the ambush technique. In the ambush technique, the gunner places the reticle ahead of the moving target and fires when he thinks the target is the required distance from this reticle. No attempt is made to track the target in the ambush technique. The ambush technique may be useful for some gunners in situations where they must fire quickly and there is no automatic lead. Generally this technique should not be used, particularly when the fire control system is fully operational. Two gunners operating without the LRF used one hand for operating the gunner control handles, leaving the other hand free to enter the target range as they tracked. Another gunner in the stabilization failure group used the GAS to make the precise lay on the targets, but his reasons for using this technique were unclear since the simpler GPS is available in the case of stabilization failure.

Gunners were also asked for their recommendations regarding techniques that could be used in engaging targets under degraded conditions. Two gunners in the stabilization failure group recommended estimating lead, firing the first round, and adjusting the second round on the basis of the impact of the first round. This technique was not available to gunners in this investigation because only one round per target was allowed. Two gunners in the inoperative LRF condition recommended special gunnery techniques. One gunner suggested engaging targets with the GAS when the LRF fails because in using the GPS the target may be lost while the range is being indexed into the computer. Another gunner suggested dumping lead after acquiring a target, but this procedure seems questionable since the ballistic computer on the M1 tank continually updates the lead solution even when the LRF is malfunctioning.

Few, if any, of the techniques recommended by the experienced noncommissioned armor officers are likely to substantially improve performance under degraded conditions. While extra manual lead is required for the stabilization and computer failure conditions for fast moving long-range targets like those presented on the UCOFT, determining exactly how much lead is needed is a difficult task. Likewise, adjusting fire on the basis of the first round strike may be useful, but only if additional rounds are available. Using the

GAS instead of indexing range may be useful in the inoperative LRF condition but only if the gunner is skilled in using the GAS. Similarly using one hand to track and the other to enter range when the LRF malfunctions could be useful but may be very difficult to learn. Recommendations on how to train the suggested techniques ranged from "cannot train" and "verbal instruction" to the old standby, "more practice." No unique training strategies were described.

Biographical Data

Table 6 shows the biographical profile of the soldiers who participated in this experiment as M1 gunners. The biographical data show that the soldier's who were the gunners for this research are older and more experienced than soldiers who typically serve as M1 gunners. Average time in armor and average service time are 10 and 12 years, respectively. The amount of gunner experience previous to this experiment varies widely among the soldiers, but the average time as gunner is two years. Fifteen percent of the soldiers tested have no previous gunner experience and seventy-nine percent have no previous M1 gunner experience. Seventy-seven percent have experience on the UCOFT, averaging 20 hours per instructor.

Predictors of M1 UCOFT Gunnery Performance

Examination of the relationship between the biographical measures and gunnery performance measures provides little evidence that biographical variables can reliably predict gunnery performance (see Table 7). Only six of a possible forty-four correlations between biographical variables and performance measures are significant. Four of these six correlations involves age of the soldier as the predictor of performance. Age successively predicts performance under both fully operational and degraded conditions, with younger soldiers exhibiting better gunnery performance. Service time is negatively correlated with performance on the degraded warm-up/familiarization exercises, and time elapsing since last gunnery sustainment training is negatively correlated with degraded gunnery test performance. When all the possible biographical predictor variables are entered in a stepwise linear regression, only age significantly predicts gunnery performance.

Table 6

Biographical Profile of M1 NETT Instructors who Served as Gunners in this Experiment.

Measure	Mean	Std Deviation	Range
Age (yrs)	32.23	4.95	22 - 43
Grade	6.40	0.68	E5 - E7
Education Level	3.29	1.09	2 - 5
GT Score[a]	109.48	14.28	84 - 160
Time in Service (yrs)	12.36	4.03	3.5 - 19.5
Time in Armor (yrs)	10.09	3.85	2 - 19.5
Time as Tank Gunner (mos)	23.77	21.47	0 - 120
Time as M1 Gunner (mos)	2.27	5.28	0 - 20
Last Gunnery Sustainment (mos)	27.87	20.32	1 - 108
UCOFT Firing Occasions	8.04	17.15	0 - 87
Hours on UCOFT	20.48	46.32	0 - 261

[a] General Technical Score, a composite of scores on verbal and arithmetic reasoning subtests from the Armed Services Vocational Aptitude Battery.

Table 7

Biographical, Experiential, and Performance Measures as Predictors of Degraded Gunnery Test Performance.

Predictor Variable	GIC[a] (n=48)	GID[b] (n=48)	TGI(C)[c] (n=12)	TGI(D)[d] (n=36)
Age	-.36*	-.43**	-.69*	-.45**
Grade	-.09	-.17	-.42	-.03
Education Level	-.28	-.05	.39	-.14
GT Score	-.03	-.02	-.15	-.02
Time in Service	-.21	-.35*	-.45	-.29
Time in Armor	.05	.05	.43	-.15
Time as Tank Gunner	.18	.16	.26	.12
Time as M1 Gunner	.13	-.23	.53	-.09
Last Gunnery Sustainment	-.16	-.15	-.70*	.08
UCOFT Firing Occasions	.23	.10	-.05	-.13
Hours on UCOFT	.12	.07	.03	-.16
GIC	-	.69***	.47	.61***
GID	.69***	-	.69*	.64***

[a]GIC is the gunnery index on the warm-up exercises under fully operational conditions.

[b]GID is the gunnery index on the warm-up exercises under degraded conditions.

[c]TGI(C) is the gunnery index on the test under fully operational conditions.

[d]TGI(D) is the gunnery index on the test under degraded conditions.

*$p<.05$. **$p<.01$. ***$p<.001$

The negative relationship between age and gunnery performance was not expected. In fact, because increases in armor experience typically accompany increases in age, a positive relationship between age and gunnery performance might be expected. On the other hand, psychomotor abilities necessary for gunner proficiency may decline with increasing age. Considering that the mean age of the subjects tested is 32 years, decline in psychomotor abilities is a very real possibility. Psychomotor abilities as the critical factor is supported by data that shows the speed component of GI declining with age, but not the accuracy component. Another possibility is that because of a longer time period since they were gunners, older soldiers may have lost gunnery skills in comparison to soldiers whose gunner experience is more recent. Greater acceptance of gunnery simulators as useful training devices by younger soldiers could account for better performance by these soldiers on the UCOFT. Negative attitudes of older soldiers towards simulation may adversely affect UCOFT performance. Negative attitudes might be expected to affect accuracy measures as much as they affect speed measures, however. The present data suggest that only speed is affected, an observation that fails to support the hypothesis that negative attitude towards the UCOFT is responsible for the age performance decrement.

The best predictors of fully operational and degraded UCOFT test performance are UCOFT performances on the warm-up/familiarization exercises. That is, the best predictor of one UCOFT gunnery performance is another measure of UCOFT gunnery performance. Table 7 shows that degraded mode test performance TGI(D) is best predicted by performance on the warm-up familiarization exercises. Degraded mode test performance is predicted by either degraded or fully operational mode warm-up measures. Test performance under fully operational conditions, TGI(C), is reliably predicted by degraded mode performance on the warm-up exercises, but not by fully operational warm-up exercise performance. The low reliability in the latter case may be related to the small number of observations ($\underline{n}$=12) for that case.

Summary and Conclusions

Soldiers required to perform both fully operational and degraded engagement exercises do not differ from each other in their initial gunnery performance. Assignment to degraded gunnery conditions tends to decrease the performance of soldiers relative to that of soldiers assigned to fully operational conditions. The size of the performance decrement varies with type of degradation, with the largest decrements occurring when a failed LRF requires the gunner to index range or a failed computer requires the gunner to use the GAS. The adverse effects of LRF or computer failure may have been even greater had accurate ranges not been provided to the gunner. Stabilization system failure appears to have little effect except possibly for long range moving targets.

Attempts to increase degraded mode gunnery performance through brief periods of degraded gunnery practice were unsuccessful. Attempts to identify techniques for reducing decrements in degraded mode gunnery also met with little success. These results suggest that performance decrements associated with degraded mode gunnery are not easily eliminated. They suggest that

significant improvements in degraded mode gunnery performance may require either extensive practice under degraded conditions or the use of special, and at present unidentified, degraded gunnery training techniques.

Biographical variables were not reliable predictors of degraded gunnery performance. Correlations of ability measures such as education level, grade, and GT score with degraded gunnery performance were uniformly low and not significant. Experience measures such as time in armor and time as a tank gunner also did not predict degraded mode gunnery performance. Age was significantly correlated with performance but negatively, perhaps because of declining psychomotor abilities for older gunners. The best predictor of degraded gunnery test performance appears to be performance on the fully operational or degraded warm-up exercises. That performance on a fully operational UCOFT exercise can predict performance on a degraded gunnery UCOFT exercise is interesting in that it suggests the best gunners under fully operational conditions also make the best gunners under degraded conditions.

REFERENCES

Abel, M. (1986). Performance of soldiers on the battlesight tank gunnery video game. (ARI Technical Report 710). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences. (AD 178 446)

General Electric Company, Defense Systems Division, Simulation and Control Systems Department (1985). Instructor's utilization handbook for the M1 unit conduct of fire trainer (UCOFT). Orlando, FL: Naval Training Equipment Center, US Army Program Manager Training Devices.

Graham, S.E. (1986). The unit conduct of fire trainer (UCOFT) as a medium for assessing gunner proficiency: Test reliability and utility. (ARI Research Report 1422). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences. (AD A169 196)

Headquarters Department of the Army (1986). FM 17-12-1, tank combat tables. Fort Monroe, VA: Author.

Morrison, J. (March 5, 1987). Grafenwoehr gunnery data. Unpublished memorandum, Human Resources Research Organization, Fort Knox, KY.

Smith, E.P. & Graham, S.E. (1987). Validation of psychomotor and perceptual predictors of armor officer M1 gunnery performance. Technical Report 766.

US Army Research Institute for the Behavioral and Social Sciences (1984). M1 degraded mode gunnery: Booklet 1, M1 gunnery system. (ARI Research Product 84-12-A). Alexandria, VA. (AD A156 802)

Witmer, B.G. (1986). Gunnery indices as measures of gunnery proficiency. Paper presented at the 28th Annual Conference of the Military Testing Association, Mystic, Connecticut.

APPENDIX A

I/O GUIDES AND INSTRUCTIONS

The procedures used by the UCOFT Instructor/Operator (I/O) and by the gunner and commander varied as a function of exercise type and engagement mode. Providing a guide for the I/O detailing the procedures for each exercise to include instructions to the gunner and commander ensured that the correct procedures were used. Guidelines and instructions were provided for each exercise and for each engagement mode or degraded condition.

The I/O guides include the following elements: (1) exercise number, (2) exercise type, (3) fire control mode, (4) special notes to the I/O, (5) target number and type, (6) the reference landmark on which the commander makes the initial lay, (7) the distance (in degrees) and direction from where the target initially appears to the reference landmark, (8) a reminder to the I/O to print the data after the last target has been engaged, and (9) exercise instructions to be read to the gunner and commander. The I/O guides were useful in training the surrogate tank commanders and I/Os to perform the correct research procedures during the train up phase and also served as procedural guides for use during the conduct of the research. These guides ensured that all I/Os, TCs and gunners consistently used the appropriate procedures in accordance with fire control mode and exercise type.

WARM-UP/FAMILIARIZATION EXERCISES

Stationary Own Tank, Stationary Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Warm-up Exercise 31211(O) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TANK	L4	Top left of near woods
2	TANK	R4	Top of pine tree
3	APC	L4	Bottom right of house

*Wait until target #4 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) When the TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears gunner should move to the Gunner's Primary Sight (GPS).

3) Fire only one round per target.

4) After one round, TC should command DRIVER MOVE BACK.

Warm-up Exercise 31251(O) LRF OUT; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TANK	R4	Right side of hedges
2	TANK	L4	Bottom right of bottom barn
3	APC	L4	Bottom left of barn

*Wait until target #4 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Set the RANGE Switch to SAFE.

2) With the LRF out, Gunner must use Battlesight techniques or key range into the computer upon TC's command.

Stationary Own Tank, Stationary Targets; Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Warm-up Exercise 32211(O) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TANK	L5	Bottom left of bottom woodline
2	TANK	R4	Right side of hedges
3	APC	R5	Bottom left of top barn

*Wait until target #4 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL and the RANGE switch to LAST RETURN.

2) When the TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears gunner should move to the Gunner's Primary Sight (GPS).

3) Fire only one round per target.

4) After one round, TC should command DRIVER MOVE BACK.

Warm-up Exercise 32211(O) LRF OUT; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TANK	L5	Bottom left of bottom woodline
2	TANK	R4	Right side of hedges
3	APC	R5	Bottom left of top barn

*Wait until target #4 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Set the RANGE Switch to SAFE.

2) With the LRF out, Gunner must use Battlesight techniques or key range into the computer upon TC's command.

Stationary Own Tank, Moving Targets; Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Warm-up Exercise 32331(1) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TRUCK	L4	Bottom right of barn
2	TRUCK	L4	Right side of very top shack
3	CHOPPER	R5	Bottom left of barn

*FREEZE. Read Instructions for next exercise at bottom of page. When GNR & TC are ready go to target #4.
*Do NOT PRINT until Targets 4, 5, 6 have been presented.

1) Place FIRE CONTROL MODE Switch in NORMAL and the RANGE switch to LAST RETURN.

2) When the TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears gunner should move to the Gunner's Primary Sight (GPS).

3) Fire only one round per target.

4) After one round, TC should command DRIVER MOVE BACK.

Warm-up Exercise 32331(1) STAB OUT; EMERGENCY MODE

Target #	Type	Degree	Landmark Location
4	TANK	R6	Bottom left of woodline
5	CHOPPER	L6	Left side of rock
6	TANK	L6	Left side of large rock

*Wait until target #7 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place the FIRE CONTROL MODE SWITCH in EMERGENCY.

2) No auto lead; gunner must apply manual lead.

Stationary Own Tank, Moving Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Warm-up Exercise 31331(1) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	TRUCK	R8	Right side of middle rock
2	TRUCK	L4	Bottom right of barn
3	CHOPPER	L7	Left side of bottom rock

*Freeze. Read Instructions for next exercise at bottom of page. When GNR & TC are ready go to target #4.
*Do NOT PRINT until Targets 4, 5, 6 have been presented.

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) When the TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears gunner should move to the Gunner's Primary Sight (GPS).

3) Fire only one round per target.

4) After one round, TC should command DRIVER MOVE BACK.

Warm-up Exercise 31331(1) STAB OUT; EMERGENCY MODE

Target #	Type	Degree	Landmark Location
4	TANK	R4	Left side of hedges
5	CHOPPER	R5	Right side of bottom rock
6	TANK	R5	Bottom right of barn

*Wait until target #7 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place the FIRE CONTROL SWITCH in EMERGENCY.

2) No auto lead; gunner must apply manual lead.

Moving Own Tank, Moving Targets, Short Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Warm-up Exercise 31531(O) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	Tank	R4	Bottom left of trees
2	Tank	L3	Bottom right of trees
3	APC	R4	Top right of barn

*Freeze. See next page for additional instructions.
Do NOT PRINT until Targets 4, 6, 7 have been presented

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) After each engagement, gunner should release the palm switches and relax until the TC is told to move the gun tube.

3) When the TC is told to move, gunner should depress the palm switches and continue to hold until the target has been engaged.

4) Fire only one round per target.

Moving Own Tank, Moving Targets; Short Range

Special I/O Notes: Direct TC to use the 50 Cal. Sight for making the initial lay. About 10 to 15 seconds before the target appears, help the TC to orient the 50 Cal. in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Warm-up Exercise 31531(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Target #	Type	Degree	Landmark Location
4	Helicopter	L5	Right side of clump of trees
5	Truck	SKIP	
6	Tank	R5	Right side of woodline
7	Truck	L7	Left side of barn

*Wait until target #8 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Computer and GPS are out; Apply Manual Lead.

3) STAB Out; TC must command DEGRADED DRIVER STOP before issuing fire command.

4) After each engagement, gunner should release the palm switches until the TC issues the fire command.

5) LRF and GPS are out. Use battlesight gunnery techniques or the appropriate range lines on the 105D sight (GAS).

6) Fire only one round. After firing TC must tell DRIVER to MOVE OUT.

Moving Own Tank, Moving Targets; Long Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Warm-up Exercise 32531(O) FULLY OPERATIONAL; NORMAL MODE

Target #	Type	Degree	Landmark Location
1	Helicopter	R4	Bottom left of trees
2	Tank	L5	Top right of back barn
3	APC	R5	Left corner of trees (next to barn)

*Wait until target #4 appears. Then FREEZE and Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL, the RANGE switch in LAST RETURN, and the FLTR/CLR/SHTR switch in CLR..

2) After each engagement, gunner should release the palm switches and relax until the TC is told to move the gun tube.

3) When the TC is told to move, gunner should depress the palm switches and continue to hold until the target has been engaged.

4) Fire only one round per target.

Moving Own Tank, Moving Targets; Long Range

Special I/O Notes: Direct TC to use the 50 Cal. Sight for making the initial lay. About 10 to 15 seconds before the target appears, help the TC to orient the 50 Cal. in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Warm-up Exercise 32531(1) *COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE*

Target #	Type	Degree	Landmark Location
1	Helicopter	R6	Left corner of rock
2	Tank	R5	Right side of woodline
3	Helicopter	L4	On the pine tree

*Wait until target #4 appears. Then Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in EMERGENCY, the RANGE switch in SAFE, the THERMAL MODE switch in OFF, and the FLTR/CLR/SHTR switch in SHTR.

2) Computer and GPS are out; Apply manual lead.

3) STAB Out; TC must command DEGRADED DRIVER STOP before issuing fire command.

4) After each engagement, gunner should release the palm switches until the TC issues the fire command.

5) LRF and GPS are out. Use appropriate range lines on the 105D sight (GAS).

6) Fire only one round per target. After firing TC must tell DRIVER to MOVE OUT.

I/O Note: When this exercise is completed, tell Gunner to place the RANGE switch in LAST RETURN and the FLTR/CLR/SHTR switch in CLR.

GROUP ONE TEST EXERCISES (FULLY OPERATIONAL)

Test Exercise 31111(O) FULLY OPERATIONAL; NORMAL MODE

Stationary Own Tank, Stationary Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L7	Left side of house
2	TANK	R5	Right side of tree line
3	TANK	R5	Bottom right of treeline
4	TANK	R4	Left corner of rock
5	TANK	L5	Left corner of rock
6	TANK	R5	Right corner of treeline
7	TANK	L5	Left corner of rock
8	TANK	R6	Left corner of rock
9	TANK	L5	Bottom right of house
10	TANK	R7	Right side of hedges

*Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 31311(O) FULLY OPERATIONAL; NORMAL MODE

Stationary Own Tank, Moving Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Bottom left of barn
2	TANK	L4	Bottom right of woods
3	APC	L5	Bottom left of woods
4	TANK	L4	Right side of barn
5	CHOPPER	L5	Bottom right of woods
6	TANK	R4	Bottom left of woods
7	TRUCK	R5	Left side of bottom rock
8	TRUCK	R5	Bottom right of barn
9	CHOPPER	R4	Left side of rock
10	TANK	L3	Bottom right of barn

*Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 31511(O) FULLY OPERATIONAL; NORMAL MODE

Moving Own Tank, Moving Targets; Short Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Right side of shack
2	TANK	L5	Left side of shack
3	APC	L5	Right corner of right treeline
4	TANK	L6	Left corner of back barn
5	CHOPPER	L7	Left side of shack
6	TANK	R7	Bottom right of trees
7	TRUCK	R3	Bottom left of barn
8	TRUCK	L6	Left corner of (near) woods
9	CHOPPER	L5	Bottom left of left trees
10	TANK	L9	Bottom left of back woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Moving own tank, single moving targets.

3) After each engagement, gunnery should release the palm switch and relax until the TC is told to move the gun tube.

4) When the TC is told to move, gunner should depress the palm switch and continue to hold until the target has been engaged.

5) Fire only one round per target.

Test Exercise 32111(O) FULLY OPERATIONAL; NORMAL MODE

Stationary Own Tank, Stationary Targets, Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L4	Bottom right of woodline
2	TANK	R5	Right side of shack
3	TANK	L4	Left corner of bottom rock
4	TANK	L3	Left corner of rock
5	TANK	L5	Top left of barn
6	TANK	R4	Right corner of woodline (by hedge)
7	TANK	L5	Left corner of woodline
8	TANK	R3	Left corner of hedges (by woodline)
9	TANK	R4	Left side of middle rock
10	TANK	L5	Left side of tree

*Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 32311(O) FULLY OPERATIONAL; NORMAL MODE

Stationary Own Tank, Moving Targets; Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R4	Left of woods
2	TANK	L5	Right side of bottom rock
3	APC	L5	Right side of bottom rock
4	TANK	L4	Right side of top woods
5	CHOPPER	L6	Right side of rock
6	TANK	R5	Right side of rock
7	TRUCK	L5	Right side of far woods
8	TRUCK	R5	Bottom right of woods
9	CHOPPER	L5	Right side of bottom rock
10	TANK	R3	Bottom left of woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 32511(0) & 32511(1) FULLY OPERATIONAL; NORMAL MODE

Moving Own Tank, Moving Targets, Long Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Target #	Type	Degree	Landmark Location
32511(0)			
1	TANK	R4	Left side of trees
2	TANK	L5	Left side of back barn
3	APC	R4	Right side of barn
4	CHOPPER	R5	On pine tree (right of woodline)
5	CHOPPER	R2	Bottom left of left woods
*Press PRINT, PERF ANAL, & PRINT *			
32511(1)			
1	TANK	L5	Left side of tree
2	TANK	R5	Bottom right of barn
3	CHOPPER	L6	Left corner of clump of trees (right of barn)
4	APC	R5	Far back pine tree
5	TANK	L3	Far back pine tree
*Press PRINT, PERF ANAL, & PRINT *			

1) Place FIRE CONTROL MODE Switch in NORMAL.

2) Moving own tank, single moving targets.

3) After each engagement, gunner should release the palm switch and relax until the TC is told to move the gun tube.

4) When the TC is told to move, gunner should depress the palm switch and continue to hold until the target has been engaged.

5) Fire only one round per target.

GROUP TWO TEST EXERCISES (STABILIZATION FAILURE)

Test Exercise 31111(O) STAB OUT; EMERGENCY MODE

Stationary Own Tank, Stationary Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L7	Left side of house
2	TANK	R5	Right side of tree line
3	TANK	R5	Bottom right of treeline
4	TANK	R4	Left corner of rock
5	TANK	L5	Left corner of rock
6	TANK	R5	Right corner of treeline
7	TANK	L5	Left corner of rock
8	TANK	R6	Left corner of rock
9	TANK	L5	Bottom right of house
10	TANK	R7	Right side of hedges

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 32111(O) STAB OUT; EMERGENCY MODE

Stationary Own Tank, Stationary Targets, Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L4	Bottom right of woodline
2	TANK	R5	Right side of shack
3	TANK	L4	Left corner of bottom rock
4	TANK	L3	Left corner of rock
5	TANK	L6	Top left of barn
6	TANK	R4	Right corner of woodline (by hedge)
7	TANK	L5	Left corner of woodline
8	TANK	R3	Left corner of hedges (by woodline)
9	TANK	R4	Left side of middle rock
10	TANK	L5	Left side of tree

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 31311(O) STAB OUT; EMERGENCY MODE

Stationary Own Tank, Moving Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Bottom left of barn
2	TANK	L4	Bottom right of woods
3	APC	L5	Bottom left of woods
4	TANK	L4	Right side of barn
5	CHOPPER	L5	Bottom right of woods
6	TANK	R4	Bottom left of woods
7	TRUCK	R5	Left side of bottom rock
8	TRUCK	R5	Bottom right of barn
9	CHOPPER	R4	Left side of rock
10	TANK	L3	Bottom right of barn

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY. No auto lead; gunner must apply manual lead.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 32311(O) STAB OUT; EMERGENCY MODE

Stationary Own Tank, Moving Targets, Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R4	Left of woods
2	TANK	L5	Right side of bottom rock
3	APC	L5	Right side of bottom rock
4	TANK	L4	Right side of top woods
5	CHOPPER	L6	Right side of rock
6	TANK	R5	Right side of rock
7	TRUCK	L5	Right side of far woods
8	TRUCK	R5	Bottom right of woods
9	CHOPPER	L5	Right side of bottom rock
10	TANK	R3	Bottom left of woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY. No auto lead; gunner must apply manual lead.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) Fire only one round per target.

5) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 31511(O) STAB OUT; EMERGENCY MODE

Moving Own Tank, Moving Targets; Short Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location. When the TC commands DEGRADED DRIVER STOP or when the TC begins the ALERT element of the fire command, depress the DRIVER STOP key on the panel. After the crew has fired one round at the target, move the driver out.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Right side of shack
2	TANK	L5	Left side of shack
3	APC	L5	Right corner of right treeline
4	TANK	L6	Left corner of back barn
5	CHOPPER	L7	Left side of shack
6	TANK	R7	Bottom right of trees
7	TRUCK	R3	Bottom left of barn
8	TRUCK	L6	Left corner of (near) woods
9	CHOPPER	L5	Bottom left of left trees
10	TANK	L9	Bottom left of back woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY. No auto lead; apply manual lead.

2) Moving own tank, single moving targets. STAB is out; TC must command DEGRADED DRIVER STOP before issuing fire command.

3) After each engagement, gunner should release the palm switches and relax until the tank halts in response to the TC's command. When the tank halts, TC should release his override.

4) Fire only one round per target. After firing, TC must tell DRIVER to MOVE OUT.

Test Exercise 32511(0) & 32511(1) STAB OUT; EMERGENCY MODE

Moving Own Tank, Moving Targets, Long Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location. When the TC commands DEGRADED DRIVER STOP or when the TC begins the ALERT element of the fire command, depress the DRIVER STOP key on the panel. After the crew has fired one round at the target, move the driver out.

Target #	Type	Degree	Landmark Location
32511(0)			
1	TANK	R4	Left side of trees
2	TANK	L5	Left side of back barn
3	APC	R4	Right side of barn
4	CHOPPER	R5	On pine tree (right of woodline)
5	CHOPPER	R2	Bottom left of left woods
*Press PRINT, PERF ANAL, & PRINT *			
32511(1)			
1	TANK	L5	Left side of tree
2	TANK	R5	Bottom right of barn
3	CHOPPER	L6	Left corner of clump of trees (right of barn)
4	APC	R5	Far back pine tree
5	TANK	L3	Far back pine tree
*Press PRINT, PERF ANAL, & PRINT *			

1) Place the MODE Switch in EMERGENCY. No auto lead; apply manual lead.

2) Moving own tank, single moving targets. STAB is out; TC must command DEGRADED DRIVER STOP before issuing fire command.

3) After each engagement, gunner should release the palm switches and relax until the tank halts in response to the TC's command. When the tank halts, TC should release his override.

4) Fire only one round per target. After firing, TC must tell DRIVER to MOVE OUT.

GROUP THREE TEST EXERCISES (LRF FAILURE)

Test Exercise 31111(O) LRF OUT, NORMAL MODE

Stationary Own Tank, Stationary Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L7	Left side of house
2	TANK	R5	Right side of tree line
3	TANK	R5	Bottom right of treeline
4	TANK	R4	Left corner of rock
5	TANK	L5	Left corner of rock
6	TANK	R5	Right corner of treeline
7	TANK	L5	Left corner of rock
8	TANK	R6	Left corner of rock
9	TANK	L5	Bottom right of house
10	TANK	R7	Right side of hedges

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) LRF is out. Gunner must use battlesight gunnery or key in range upon TC's command.

5) Fire only one round per target.

6) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 32111(O) LRF OUT; NORMAL MODE

Stationary Own Tank, Stationary Targets, Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L4	Bottom right of woodline
2	TANK	R5	Right side of shack
3	TANK	L4	Left corner of bottom rock
4	TANK	L3	Left corner of rock
5	TANK	L6	Top left of barn
6	TANK	R4	Right corner of woodline (by hedge)
7	TANK	L5	Left corner of woodline
8	TANK	R3	Left corner of hedges (by woodline)
9	TANK	R4	Left side of middle rock
10	TANK	L5	Left side of tree

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) LRF is out. Gunner must use battlesight gunnery or key in range upon TC's command.

5) Fire only one round per target.

6) After one round, TC should command DRIVER MOVE BACK.

Test Exercise 31311(O) LRF OUT; NORMAL MODE

Stationary Own Tank, Moving Targets; Short Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Bottom left of barn
2	TANK	L4	Bottom right of woods
3	APC	L5	Bottom left of woods
4	TANK	L4	Right side of barn
5	CHOPPER	L5	Bottom right of woods
6	TANK	R4	Bottom left of woods
7	TRUCK	R5	Left side of bottom rock
8	TRUCK	R5	Bottom right of barn
9	CHOPPER	R4	Left side of rock
10	TANK	L3	Bottom right of barn

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) LRF is out. Gunner must use battlesight gunnery or key in range upon TC's command.

5) Fire only one round per target.

6) After one round, TC should command DRIVER MOVE BACK.

7) TC must press BATTLE RANGE button after gunner has tracked for 1/2 second.

Test Exercise 32311(O) LRF OUT; NORMAL MODE

Stationary Own Tank, Moving Targets; Long Range

Special I/O Notes: With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R4	Left of woods
2	TANK	L5	Right side of bottom rock
3	APC	L5	Right side of bottom rock
4	TANK	L4	Right side of top woods
5	CHOPPER	L6	Right side of rock
6	TANK	R5	Right side of rock
7	TRUCK	L5	Right side of far woods
8	TRUCK	R5	Bottom right of woods
9	CHOPPER	L5	Right side of bottom rock
10	TANK	R3	Bottom left of woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Stationary own tank, single moving targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm. When the gun tube clears, gunner should go to GPS.

4) LRF is out. Gunner must key in range upon TC's command.

5) Fire only one round per target.

6) After one round, TC should command DRIVER MOVE BACK.

7) TC must press BATTLE RANGE button after gunner has tracked for 1/2 second.

Test Exercise 31511(O) LRF OUT; NORMAL MODE

Moving Own Tank, Moving Targets; Short Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Right side of shack
2	TANK	L5	Left side of shack
3	APC	L5	Right corner of right treeline
4	TANK	L6	Left corner of back barn
5	CHOPPER	L7	Left side of shack
6	TANK	R7	Bottom right of trees
7	TRUCK	R3	Bottom left of barn
8	TRUCK	L6	Left corner of (near) woods
9	CHOPPER	L5	Bottom left of left trees
10	TANK	L9	Bottom left of back woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Moving own tank, single moving targets.

3) After each engagement, gunner should release the palm switches and relax until the TC is told to move the gun tube.

4) When the TC is told to move, gunner should depress the palm switches and continue to hold until the target has been engaged.

5) LRF is out. Gunner must use battlesight gunnery or key in range upon TC's command.

6) Fire only one round per target.

7) TC must press BATTLE RANGE button after gunner has tracked for 1/2 second.

Test Exercise 32511(O) & 32511(1) LRF OUT; NORMAL MODE

Moving Own Tank, Moving Targets, Long Range

Special I/O Notes: About 10 to 15 seconds before the target appears, help the crew to orient the gun in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location.

Target #	Type	Degree	Landmark Location
32511(O)			
1	TANK	R4	Left side of trees
2	TANK	L5	Left side of back barn
3	APC	R4	Right side of barn
4	CHOPPER	R5	On pine tree (right of woodline)
5	CHOPPER	R2	Bottom left of left woods
*Press PRINT, PERF ANAL, & PRINT *			
32511(1)			
1	TANK	L5	Left side of tree
2	TANK	R5	Bottom right of barn
3	CHOPPER	L6	Left corner of clump of trees (right of barn)
4	APC	R5	Far back pine tree
5	TANK	L3	Far back pine tree

*Press PRINT, PERF ANAL, & PRINT *

1) Place MODE Switch in NORMAL and the RANGE Switch in SAFE.

2) Moving own tank, single moving targets.

3) After each engagement, gunner should release the palm switches and relax until the TC is told to move the gun tube.

4) When the TC is told to move, gunner should depress the palm switches and continue to hold until the target has been engaged.

5) LRF is out. Gunner must key in range upon TC's command.

6) Fire only one round per target.

7) TC must press BATTLE RANGE button after gunner has tracked for 1/2 second.

GROUP FOUR TEST EXERCISES (BALLISTIC COMPUTER FAILURE)

Test Exercise 31111(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Stationary Own Tank, Stationary Targets; Short Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay on the landmark. With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L7	Left side of house
2	TANK	R5	Right side of tree line
3	TANK	R5	Right side of treeline
4	TANK	R4	Left corner of rock
5	TANK	L5	Left corner of rock
6	TANK	R5	Right corner of treeline
7	TANK	L5	Left corner of rock
8	TANK	R6	Left corner of rock
9	TANK	L5	Right side of house
10	TANK	R7	Right side of hedges

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm.

4) LRF and GPS are out. Use battlesight techniques or the appropriate range lines on the 105D sight (GAS).

5) Fire only one round per target. After firing TC must tell DRIVER TO MOVE BACK.

Test Exercise 31311(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Stationary Own Tank, Moving Targets; Short Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay on the landmark. With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R6	Left side of barn
2	TANK	L4	Right side of woods
3	APC	L5	Left side of woods
4	TANK	L4	Right side of barn
5	CHOPPER	L5	Right side of woods
6	TANK	R4	Left side of woods
7	TRUCK	R5	Left side of bottom rock
8	TRUCK	R5	Right side of barn
9	CHOPPER	R4	Left side of rock
10	TANK	L3	Right side of barn

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Computer and GPS are out; Apply Manual Lead.

3) Stationary own tank, single stationary targets.

4) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm.

5) LRF and GPS are out. Use battlesight techniques or the appropriate range lines on the 105D sight (GAS).

6) Fire only one round per target.

7) After one round, TC should command DRIVER TO MOVE BACK.

Test Exercise 31511(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Moving Own Tank, Moving Targets; Short Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay. About 10 to 15 seconds before the target appears, help the TC to orient the 50 cal. in degrees as shown below. *After a few seconds more the landmark* will appear, at which point you will guide the crew to the specific landmark location

Target #	Type	Degree	Landmark Location
1	TANK	R6	Right side of shack
2	TANK	L5	Left side of shack
3	APC	L5	Right corner of right treeline
4	TANK	L6	Left corner of back barn
5	CHOPPER	L7	Left side of shack
6	TANK	R7	Right side of trees
7	TRUCK	R3	Left side of barn
8	TRUCK	L6	Left corner of (near) woods
9	CHOPPER	L5	Left side of left trees
10	TANK	L9	Left side of back woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Computer and GPS are out; Apply Manual Lead.

3) Moving own tank, single moving targets. STAB OUT, TC must command DEGRADED DRIVER STOP before issuing fire command.

4) After each engagement, gunner should release the palm switches until the TC issues the fire command.

5) LRF and GPS are out. Use battlesight techniques or the appropriate range lines on the 105D sight (GAS).

6) Fire only one round per target. After firing TC must tell DRIVER TO MOVE OUT.

Test Exercise 32111(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Stationary Own Tank, Stationary Targets, Long Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay on the landmark. With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	L4	Right side of woodline
2	TANK	R5	Right side of shack
3	TANK	L4	Left corner of bottom rock
4	TANK	L3	Left corner of rock
5	TANK	L6	Left side of barn
6	TANK	R4	Right corner of woodline (by hedge)
7	TANK	L5	Left corner of woodline
8	TANK	R3	Left corner of hedges (by woodline)
9	TANK	R4	Left side of middle rock
10	TANK	L5	Left side of tree

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Stationary own tank, single stationary targets.

3) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm.

4) LRF and GPS are out. Use the appropriate range lines on the 105D sight (GAS).

5) Fire only one round per target. After firing TC must tell DRIVER TO MOVE BACK.

Exercise 32311(O) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Stationary Own Tank, Moving Targets; Long Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay on the landmark. With own tank stationary be sure that driver moves out. After the crew has fired one round, move the driver back and quickly guide the crew to the next landmark location.

Target #	Type	Degree	Landmark Location
1	TANK	R4	Left of woods
2	TANK	L5	Right side of bottom rock
3	APC	L5	Right side of bottom rock
4	TANK	L4	Right side of top woods
5	CHOPPER	L6	Right side of rock
6	TANK	R5	Right side of rock
7	TRUCK	L5	Right side of far woods
8	TRUCK	R5	Right side of woods
9	CHOPPER	L5	Right side of bottom rock
10	TANK	R3	Left side of woods

*Press PRINT, PERF ANAL, & PRINT *

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Computer and GPS are out; Apply Manual Lead.

3) Stationary own tank, single moving targets.

4) When TC commands DRIVER MOVE OUT, GUNNER TAKE OVER, gunner should look through the 105D sight (GAS) and command DRIVER STOP when the gun tube clears the berm.

5) LRF and GPS are out. Use battlesight techniques or the appropriate range lines on the 105D sight (GAS).

6) Fire only one round per target. After firing TC must tell DRIVER TO MOVE BACK.

Test Exercise 32511(O) & 32511(1) COMPUTER, LRF, STAB, GPS OUT; EMERGENCY MODE

Moving Own Tank, Moving Targets, Long Range

Special I/O Notes: Direct TC to use 50 Cal Sight for making the initial lay. About 10 to 15 seconds before the target appears, help the TC to orient the 50 cal. in degrees as shown below. After a few seconds more the landmark will appear, at which point you will guide the crew to the specific landmark location

Target #	Type	Degree	Landmark Location
32511(O)			
1	TANK	R4	Left side of trees
2	TANK	L5	Left side of back barn
3	APC	R4	Right side of barn
4	CHOPPER	R5	On pine tree (right of woodline)
5	CHOPPER	R2	Left side of left woods
*Press PRINT, PERF ANAL, & PRINT *			
32511(1)			
1	TANK	L5	Left side of tree
2	TANK	R5	Right side of barn
3	CHOPPER	L6	Left corner of clump of trees (right of barn)
4	APC	R5	Far back pine tree
5	TANK	L3	Far back pine tree
*Press PRINT, PERF ANAL, & PRINT *			

1) Place the MODE Switch in EMERGENCY, the RANGE Switch in SAFE, the THERMAL MODE Switch in OFF, and the FLTR/CLR/SHTR Switch in SHTR.

2) Computer and GPS are out; Apply Manual Lead.

3) Moving own tank, single moving targets. STAB OUT, TC must command DEGRADED DRIVER STOP before issuing fire command.

4) After each engagement, gunner should release the palm switches until the TC issues the fire command.

5) LRF and GPS are out. Use the appropriate range lines on the 105D sight (GAS).

6) Fire only one round per target. After firing TC must tell DRIVER TO MOVE OUT.

APPENDIX B

FIRE COMMANDS FOR WARM-UP AND TEST EXERCISES

The surrogate TCs received a listing of the fire commands for each UCOFT target scenario for the warm-up and test exercises. The list describes each target by type (e.g., tank, truck) and range, and provides the exact wording of the correct fire command. The direction (R = right, L = left) that the gunner must traverse from his initial reference point (i.e., the predetermined landmark) to engage the target was designated with a red pencil on the list. This provided an easily identifiable cue for the commander to use to guide the gunner toward the target if he failed to quickly locate the target.

All warm-up and test exercises are identified by exercise type (e.g., stationary-stationary: long range) and by engagement mode (e.g., LRF out). Exercises labeled "CONTROL" refer to exercises performed under fully operational conditions. Labels such as "LRF OUT" or "STAB OUT" indicate inoperative rangefinders and stabilization systems, respectively. The "COMP OUT" label is an abbreviation for the condition in which the ballistic computer, GPS, LRF, and stabilization systems are inoperative. The dots between part of the fire command announcing the target and the command for the gunner to fire indicate the passage of time during which the gunner must identify the target, lay on the target, and track it if it is moving.

Warm-Up Exercise 31211(O): Control Stationary-Stationary: Short Range

Target #	Target	Range	Fire Command
1	tank	1260	GUNNER, SABOT, TANK. . . . . FIRE!
2	tank	1100	GUNNER, SABOT, TANK. . . . . FIRE!
3	APC	1100	GUNNER, SABOT, PC. . . . . FIRE!

Warm-Up Exercise 31251(O): LRF OUT STATIONARY-STATIONARY: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	910	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
2	tank	1190	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
3	APC	950	GUNNER, BATTLESIGHT, PC. . . . . FIRE!

Warm-Up Exercise 32211(O): CONTROL STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1710	GUNNER, SABOT, TANK. . . . . FIRE!
2	tank	1870	GUNNER, SABOT, TANK. . . . . FIRE!
3	APC	1860	GUNNER, SABOT, PC. . . . . FIRE!

Warm-Up Exercise 32211(O): LRF OUT STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1710	GUNNER, SABOT, TANK, INDEX ONE SEVEN ONE ZERO. . . . . FIRE!
2	tank	1870	GUNNER, SABOT, TANK, INDEX ONE EIGHT SEVEN ZERO. . . . . FIRE!
3	APC	1860	GUNNER, SABOT, TANK, INDEX ONE EIGHT SIX ZERO. . . . . FIRE!

Warm-Up Exercise 32331(1): CONTROL STATIONARY-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	truck	2010	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
2	truck	2020	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
3	helicopter	1810	GUNNER, SABOT, CHOPPER . . . . . FIRE!

Warm-Up Exercise 32331(1): STAB OUT STATIONARY-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
4	tank	1970	DEGRADED, GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	2110	DEGRADED, GUNNER, SABOT, CHOPPER . . . . . FIRE!
6	tank	2100	DEGRADED, GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Warm-Up Exercise 31331(1): CONTROL STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	truck	1220	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
2	truck	1460	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
3	helicopter	1210	GUNNER, SABOT, CHOPPER . . . . . FIRE!

Warm-Up Exercise 31331(1): STAB OUT STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
4	tank	1430	DEGRADED, GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	1490	DEGRADED, GUNNER, SABOT, CHOPPER . . . . . FIRE!
6	tank	1340	DEGRADED, GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Warm-Up Exercise 31531(0): CONTROL MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	1230	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1280	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1120	GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Warm-Up Exercise 31531(0): COMP OUT MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
4	helicopter	1320	DEGRADED, DRIVER STOP, GUNNER, BATTLESIGHT, CHOPPER. . . . . FIRE!
6	tank	1320	DEGRADED, DRIVER STOP, GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!
7	truck	1210	DEGRADED, DRIVER STOP, GUNNER, BATTLESIGHT, MOVING TRUCK . . . . . FIRE!

Warm-Up Exercise 32531(0): CONTROL MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	helicopter	1610	GUNNER, SABOT, CHOPPER . . . . . FIRE!
2	tank	1660	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1570	GUNNER, SABOT, MOVING PC . . . . . FIRE!

Warm-Up Exercise 32531(1): COMP OUT MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command[a]
1	helicopter	1530	DEGRADED, DRIVER STOP, GUNNER, BATTLESIGHT, CHOPPER. . . . . FIRE!
2	tank	1720	DEGRADED, DRIVER STOP, GUNNER, SABOT, MOVING TANK, ONE FOUR HUNDRED. . . FIRE!
3	helicopter	1730	DEGRADED, DRIVER STOP, GUNNER, SABOT, CHOPPER, ONE, FOUR HUNDRED . . . . FIRE!

[a] A glitch in the UCOFT software for GAS engagements necessitated adjusting the range announced in the fire command downward 300 to 400 meters from the actual target range.

Test Exercise 311110: CONTROL STATIONARY-STATIONARY: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	960	GUNNER, SABOT, TANK. . . . . FIRE!
2	tank	1410	GUNNER, SABOT, TANK. . . . . FIRE!
3	tank	1370	GUNNER, SABOT, TANK. . . . . FIRE!
4	tank	1230	GUNNER, SABOT, TANK. . . . . FIRE!
5	tank	1460	GUNNER, SABOT, TANK. . . . . FIRE!
6	tank	1390	GUNNER, SABOT, TANK. . . . . FIRE!
7	tank	1090	GUNNER, SABOT, TANK. . . . . FIRE!
8	tank	1190	GUNNER, SABOT, TANK. . . . . FIRE!
9	tank	1400	GUNNER, SABOT, TANK. . . . . FIRE!
10	tank	1360	GUNNER, SABOT, TANK. . . . . FIRE!

Test Exercise 313110: CONTROL STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	980	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1270	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1030	GUNNER, SABOT, MOVING PC . . . . . FIRE!
4	tank	1330	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	1460	GUNNER, SABOT, CHOPPER . . . . . FIRE!
6	tank	1370	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
7	truck	1220	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
8	truck	900	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
9	helicopter	1400	GUNNER, SABOT, CHOPPER . . . . . FIRE!
10	tank	1490	GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Test Exercise 315110: CONTROL MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	1200	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1140	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1140	GUNNER, SABOT, MOVING PC . . . . . FIRE!
4	tank	1230	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	1330	GUNNER, SABOT, CHOPPER . . . . . FIRE!
6	tank	1400	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
7	truck	430	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
8	truck	1110	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
9	helicopter	1450	GUNNER, SABOT, CHOPPER . . . . . FIRE!
10	tank	1220	GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Test Exercise 321110: CONTROL STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1700	GUNNER, SABOT, TANK. . . . . FIRE!
2	tank	1980	GUNNER, SABOT, TANK. . . . . FIRE!
3	tank	1650	GUNNER, SABOT, TANK. . . . . FIRE!
4	tank	1700	GUNNER, SABOT, TANK. . . . . FIRE!
5	tank	2190	GUNNER, SABOT, TANK. . . . . FIRE!
6	tank	2320	GUNNER, SABOT, TANK. . . . . FIRE!
7	tank	1940	GUNNER, SABOT, TANK. . . . . FIRE!
8	tank	2190	GUNNER, SABOT, TANK. . . . . FIRE!
9	tank	1960	GUNNER, SABOT, TANK. . . . . FIRE!
10	tank	2340	GUNNER, SABOT, TANK. . . . . FIRE!

Test Exercise 323110: *CONTROL STATIONARY-MOVING: LONG RANGE*

Target #	Target	Range	Fire Command
1	tank	1920	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1900	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1900	GUNNER, SABOT, MOVING PC . . . . . FIRE!
4	tank	2470	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	2300	GUNNER, SABOT, CHOPPER . . . . . FIRE!
6	tank	2030	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
7	truck	1830	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
8	truck	740	GUNNER, SABOT, MOVING TRUCK. . . . . FIRE!
9	helicopter	2190	GUNNER, SABOT, CHOPPER . . . . . FIRE!
10	tank	1960	GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Test Exercise 325110: CONTROL MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1790	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1650	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	APC	1720	GUNNER, SABOT, MOVING PC . . . . . FIRE!
4	tank	1700	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
5	helicopter	1750	GUNNER, SABOT, CHOPPER . . . . . FIRE!

Test Exercise 325111: CONTROL MOVING-MOVING: LONG RANGE

1	tank	1670	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
2	tank	1780	GUNNER, SABOT, MOVING TANK . . . . . FIRE!
3	helicopter	1800	GUNNER, SABOT, CHOPPER . . . . . FIRE!
4	APC	1790	GUNNER, SABOT, MOVING PC . . . . . FIRE!
5	tank	2050	GUNNER, SABOT, MOVING TANK . . . . . FIRE!

Test Exercise 311110: STAB OUT STATIONARY-STATIONARY: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	960	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
2	tank	1410	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
3	tank	1370	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
4	tank	1230	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
5	tank	1460	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
6	tank	1390	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
7	tank	1090	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
8	tank	1190	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
9	tank	1400	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
10	tank	1360	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!

Test Exercise 313110: STAB OUT STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	980	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
2	tank	1270	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
3	APC	1030	DEGRADED-GUNNER, SABOT, MOVING PC. . . . . FIRE!
4	tank	1330	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
5	helicopter	1460	DEGRADED-GUNNER, SABOT, CHOPPER. . . . . FIRE!
6	tank	1370	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
7	truck	1220	DEGRADED-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
8	truck	900	DEGRADED-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
9	helicopter	1400	DEGRADED-GUNNER, SABOT, CHOPPER. . . . . FIRE!
10	tank	1490	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!

Test Exercise 315110: STAB OUT MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	1200	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
2	tank	1140	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
3	APC	1140	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING PC. . . . . FIRE!
4	tank	1230	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
5	helicopter	1330	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER. . . . . FIRE!
6	tank	1400	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
7	truck	430	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
8	truck	1110	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
9	helicopter	1450	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER. . . . . FIRE!
10	tank	1220	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!

Test Exercise 321110: STAB OUT STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1700	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
2	tank	1980	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
3	tank	1650	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
4	tank	1700	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
5	tank	2190	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
6	tank	2320	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
7	tank	1940	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
8	tank	2190	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
9	tank	1960	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!
10	tank	2340	DEGRADED-GUNNER, SABOT, TANK . . . . . FIRE!

Test Exercise 323110: STAB OUT STATIONARY-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1920	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
2	tank	1900	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
3	APC	1900	DEGRADED-GUNNER, SABOT, MOVING PC. . . . . FIRE!
4	tank	2470	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
5	helicopter	2300	DEGRADED-GUNNER, SABOT, CHOPPER. . . . . FIRE!
6	tank	2030	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
7	truck	1830	DEGRADED-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
8	truck	740	DEGRADED-GUNNER, SABOT, MOVING TRUCK . . . . . FIRE!
9	helicopter	2190	DEGRADED-GUNNER, SABOT, CHOPPER. . . . . FIRE!
10	tank	1960	DEGRADED-GUNNER, SABOT, MOVING TANK. . . . . FIRE!

Test Exercise 325110: STAB OUT MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1790	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
2	tank	1650	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
3	APC	1720	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING PC. . . . . FIRE!
4	tank	1700	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
5	helicopter	1750	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER. . . . . FIRE!

Test Exercise 325111: STAB OUT MOVING-MOVING: LONG RANGE

1	tank	1670	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
2	tank	1780	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!
3	helicopter	1800	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER. . . . . FIRE!
4	APC	1790	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING PC. . . . . FIRE!
5	tank	2050	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK. . . . . FIRE!

Test Exercise 311110: LRF OUT STATIONARY-STATIONARY: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	960	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
2	tank	1410	GUNNER, SABOT, TANK, INDEX ONE FOUR ONE ZERO . . . . . FIRE!
3	tank	1370	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
4	tank	1230	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
5	tank	1460	GUNNER, SABOT, TANK, INDEX ONE FOUR SIX ZERO . . . . . FIRE!
6	tank	1390	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
7	tank	1090	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
8	tank	1190	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
9	tank	1400	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
10	tank	1360	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!

Test Exercise 313110: LRF OUT STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	980	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
2	tank	1270	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
3	APC	1030	GUNNER, BATTLESIGHT, MOVING PC . . . . . FIRE!
4	tank	1330	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
5	helicopter	1460	GUNNER, SABOT, CHOPPER, INDEX ONE FOUR SIX ZERO. . . . . FIRE!
6	tank	1370	GUNNER, BATTLESIGHT, CHOPPER . . . . . FIRE!
7	truck	1220	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
8	truck	900	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
9	helicopter	1400	GUNNER, BATTLESIGHT, CHOPPER . . . . . FIRE!
10	tank	1490	GUNNER, SABOT, MOVING TANK, INDEX ONE FOUR NINE ZERO . . . . . FIRE!

Test Exercise 315110: LRF OUT MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	1200	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
2	tank	1140	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
3	APC	1140	GUNNER, BATTLESIGHT, MOVING PC . . . . . FIRE!
4	tank	1230	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
5	helicopter	1330	GUNNER, BATTLESIGHT, CHOPPER . . . . . FIRE!
6	tank	1400	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
7	truck	430	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
8	truck	1110	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
9	helicopter	1450	GUNNER, SABOT, CHOPPER, INDEX ONE FOUR FIVE ZERO . . . . . FIRE!
10	tank	1220	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!

Test Exercise 321110: LRF OUT STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1700	GUNNER, SABOT, TANK INDEX ONE SEVEN HUNDRED. . . . . FIRE!
2	tank	1980	GUNNER, SABOT, TANK INDEX ONE NINE EIGHT ZERO. . . . . FIRE!
3	tank	1650	GUNNER, SABOT, TANK INDEX ONE SIX FIVE ZERO. . . . . FIRE!
4	tank	1700	GUNNER, SABOT, TANK INDEX ONE SEVEN HUNDRED. . . . . FIRE!
5	tank	2190	GUNNER, SABOT, TANK INDEX TWO ONE NINE ZERO. . . . . FIRE!
6	tank	2320	GUNNER, SABOT, TANK INDEX TWO THREE TWO ZERO . . . . . FIRE!
7	tank	1940	GUNNER, SABOT, TANK INDEX ONE NINE FOUR ZERO . . . . . FIRE!
8	tank	2190	GUNNER, SABOT, TANK INDEX TWO ONE NINE ZERO. . . . . FIRE!
9	tank	1960	GUNNER, SABOT, TANK INDEX ONE NINE SIX ZERO. . . . . FIRE!
10	tank	2340	GUNNER, SABOT, TANK INDEX TWO THREE FOUR ZERO. . . . . FIRE!

Test Exercise 323110: LRF OUT STATIONARY-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1920	GUNNER, SABOT, MOVING TANK INDEX ONE NINE TWO ZERO . . . . . FIRE!
2	tank	1900	GUNNER, SABOT, MOVING TANK INDEX ONE NINE HUNDRED. . . . . FIRE!
3	APC	1900	GUNNER, SABOT, MOVING PC INDEX ONE NINE HUNDRED . . . . . FIRE!
4	tank	2470	GUNNER, SABOT, MOVING TANK INDEX TWO FOUR SEVEN ZERO . . . . . FIRE!
5	helicopter	2300	GUNNER, SABOT, CHOPPER INDEX TWO THREE HUNDRED . . . . . FIRE!
6	tank	2030	GUNNER, SABOT, MOVING TANK INDEX TWO ZERO THREE ZERO . . . . . FIRE!
7	truck	1830	GUNNER, SABOT, MOVING TRUCK INDEX ONE EIGHT THREE ZERO . . . . . FIRE!
8	truck	740	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
9	helicopter	2190	GUNNER, SABOT, CHOPPER INDEX TWO ONE NINE ZERO . . . . . FIRE!
10	tank	1960	GUNNER, SABOT, MOVING TANK INDEX ONE NINE SIX ZERO . . . . . FIRE!

Test Exercise 325110: LRF OUT MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1790	GUNNER, SABOT, MOVING TANK INDEX ONE SEVEN NINE ZERO . . . . . FIRE!
2	tank	1650	GUNNER, SABOT, MOVING TANK INDEX ONE SIX FIVE ZERO . . . . . FIRE!
3	APC	1720	GUNNER, SABOT, MOVING PC INDEX ONE SEVEN TWO ZERO. . . . . FIRE!
4	tank	1700	GUNNER, SABOT, MOVING TANK INDEX ONE SEVEN HUNDRED . . . . . FIRE!
5	helicopter	1750	GUNNER, SABOT, CHOPPER INDEX ONE SEVEN FIVE ZERO . . . . . FIRE!

Test Exercise 325111: LRF OUT MOVING-MOVING: LONG RANGE

1	tank	1670	GUNNER, SABOT, MOVING TANK INDEX ONE SIX SEVEN ZERO. . . . . FIRE!
2	tank	1780	GUNNER, SABOT, MOVING TANK INDEX ONE SEVEN EIGHT ZERO. . . . . FIRE!
3	helicopter	1800	GUNNER, SABOT, CHOPPER INDEX ONE EIGHT HUNDRED . . . . . FIRE!
4	APC	1790	GUNNER, SABOT, MOVING PC INDEX ONE SEVEN NINE ZERO . . . . . FIRE!
5	tank	2050	GUNNER, SABOT, MOVING TANK INDEX TWO ZERO FIVE ZERO. . . . . FIRE!

Test Exercise 311110: COMP OUT STATIONARY-STATIONARY: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	960	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
2	tank	1410	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
3	tank	1370	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
4	tank	1230	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
5	tank	1460	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
6	tank	1390	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
7	tank	1090	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
8	tank	1190	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
9	tank	1400	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!
10	tank	1360	GUNNER, BATTLESIGHT, TANK. . . . . FIRE!

Test Exercise 313110: COMP OUT STATIONARY-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	980	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
2	tank	1270	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
3	APC	1030	GUNNER, BATTLESIGHT, MOVING PC . . . . . FIRE!
4	tank	1330	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
5	helicopter	1460	GUNNER, BATTLESIGHT, CHOPPER . . . . . FIRE!
6	tank	1370	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!
7	truck	1220	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
8	truck	900	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
9	helicopter	1400	GUNNER, BATTLESIGHT, CHOPPER . . . . . FIRE!
10	tank	1490	GUNNER, BATTLESIGHT, MOVING TANK . . . . . FIRE!

Test Exercise 315110: COMP OUT MOVING-MOVING: SHORT RANGE

Target #	Target	Range	Fire Command
1	tank	1200	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!
2	tank	1140	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!
3	APC	1140	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING PC. . . . . FIRE!
4	tank	1230	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!
5	helicopter	1330	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, CHOPPER. . . . . FIRE!
6	tank	1400	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!
7	truck	430	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TRUCK . . . . . FIRE!
8	truck	1110	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TRUCK . . . . . FIRE!
9	helicopter	1450	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, CHOPPER. . . . . FIRE!
10	tank	1220	DEGRADED-DRIVER STOP-GUNNER, BATTLESIGHT, MOVING TANK. . . . . FIRE!

Test Exercise 323110: COMP OUT STATIONARY-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1920	GUNNER, SABOT, MOVING TANK, ONE FIVE HUNDRED . . . . . FIRE!
2	tank	1900	GUNNER, SABOT, MOVING TANK, ONE FIVE HUNDRED . . . . . FIRE!
3	APC	1900	GUNNER, SABOT, MOVING PC, ONE FIVE HUNDRED. . . . . FIRE!
4	tank	2470	GUNNER, SABOT, MOVING TANK, TWO ONE HUNDRED. . . . . FIRE!
5	helicopter	2300	GUNNER, SABOT, CHOPPER, ONE NINE HUNDRED . . . . . FIRE!
6	tank	2030	GUNNER, SABOT, MOVING TANK, ONE SIX HUNDRED. . . . . FIRE!
7	truck	1830	GUNNER, SABOT, MOVING TRUCK, ONE FOUR HUNDRED. . . . . FIRE!
8	truck	740	GUNNER, BATTLESIGHT, MOVING TRUCK. . . . . FIRE!
9	helicopter	2190	GUNNER, SABOT, CHOPPER, ONE EIGHT HUNDRED. . . . . FIRE!
10	tank	1960	GUNNER, SABOT, MOVING TANK, ONE SIX HUNDRED. . . . . FIRE!

NOTE: A glitch in the UCOFT software for GAS engagements necessitated adjusting the range announced in the fire command downward 400 meters from the actual target range.

Test Exercise 321110: COMP OUT STATIONARY-STATIONARY: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1700	GUNNER, SABOT, TANK, ONE FOUR HUNDRED. . . . . FIRE!
2	tank	1980	GUNNER, SABOT, TANK, ONE SIX HUNDRED . . . . . FIRE!
3	tank	1650	GUNNER, SABOT, TANK, ONE FOUR HUNDRED. . . . . FIRE!
4	tank	1700	GUNNER, SABOT, TANK, ONE FOUR HUNDRED. . . . . FIRE!
5	tank	2190	GUNNER, SABOT, TANK, ONE EIGHT HUNDRED . . . . . FIRE!
6	tank	2320	GUNNER, SABOT, TANK, ONE NINE HUNDRED. . . . . FIRE!
7	tank	1940	GUNNER, SABOT, TANK, ONE FIVE HUNDRED. . . . . FIRE!
8	tank	2190	GUNNER, SABOT, TANK, ONE EIGHT HUNDRED . . . . . FIRE!
9	tank	1960	GUNNER, SABOT, TANK, ONE SIX HUNDRED . . . . . FIRE!
10	tank	2340	GUNNER, SABOT, TANK, ONE NINE HUNDRED. . . . . FIRE!

NOTE: A glitch in the UCOFT software for GAS engagements necessitated adjusting the range announced in the fire command downward 300 to 400 meters from the actual target range.

Test Exercise 325110: COMP OUT MOVING-MOVING: LONG RANGE

Target #	Target	Range	Fire Command
1	tank	1790	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK, ONE FOUR HUNDRED. . . . FIRE!
2	tank	1650	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK, ONE FOUR HUNDRED. . . . FIRE!
3	APC	1720	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING PC, ONE FOUR HUNDRED. . . . . FIRE!
4	helicopter	1770	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER, ONE FOUR HUNDRED. . . . . FIRE!
5	helicopter	1750	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER, ONE FOUR HUNDRED. . . . . FIRE!

Test Exercise 325111: COMP OUT MOVING-MOVING: LONG RANGE

1	tank	1670	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK, ONE FOUR HUNDRED. . . . FIRE!
2	tank	1780	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK, ONE FOUR HUNDRED. . . . FIRE!
3	helicopter	1800	DEGRADED-DRIVER STOP-GUNNER, SABOT, CHOPPER, ONE FOUR HUNDRED. . . . . FIRE!
4	APC	1790	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING PC, ONE FOUR HUNDRED. . . . . FIRE!
5	tank	2050	DEGRADED-DRIVER STOP-GUNNER, SABOT, MOVING TANK, ONE SEVEN HUNDRED . . . FIRE!

NOTE: A glitch in the UCOFT software for GAS engagements necessitated adjusting the range announced in the fire command downward 300 to 400 meters from the actual target range.

APPENDIX C

INSTRUCTIONS TO SUBJECTS

The purpose of this research project is to determine how gunnery performance is affected by degraded engagement conditions. You will be required to engage a series of computer-generated targets on the U-COFT under normal or degraded conditions. Prior to engaging these targets you will perform warm-up exercises to introduce you to the U-COFT and degraded gunnery techniques. Questions about the U-COFT or about experimental procedures should be asked during the warm-up exercises. After the warm-up you will be given a 10-minute break and then return to the U-COFT to perform the test exercises. For the test, you will perform two sets of three exercises each, separated by a 10-minute break. No assistance will be provided by the U-COFT Instructor/Operator or by the TC on the test.

The U-COFT presents both offensive and defensive scenarios. In the offensive scenarios you will usually shoot with your tank on the move. In the defensive engagements, your tank moves up from behind a berm, stops, and then fires while stationary. Your instructor/operator will inform you prior to an exercise whether you are in an offensive or defensive posture.

The U-COFT is capable of simulating both normal and degraded conditions. The instructor/operator will inform you of the system degradation that exists for each exercise prior to the start of the exercise. The instructor operator will also instruct you on the switch settings for the exercise and indicate the procedures to be used in that exercise.

As each target is presented, your TC will lay the gun on a landmark near the target and issue a fire command. Because fire commands will vary from one engagement to the next, you must listen very carefully to each fire command. When you hear the TC command, you should search for the target with your GPS or GAS, and announce IDENTIFIED upon acquiring the target. When you detect a target with the GPS, you should switch the GPS to 10X, lay on the target, track it if it is moving, and fire upon the TC's command announcing ON THE WAY when you fire. Your speed and accuracy of engaging targets is important and will be measured for each engagement. When you hit a target, a white flash occurs at the target, its normal motion ceases, and it assumes a killed posture. If you miss a target dirt will be kicked up. If you fail to kill the target in the allotted time (18 to 24 seconds), all sights will go black and controls will be inoperative for five seconds to indicate that you were killed. The gun select switch will return to the TRIGGER SAFE position when you are killed and must be reset to the MAIN GUN position prior to firing the next engagement.

APPENDIX D

BIOGRAPHICAL QUESTIONNAIRE - AUG 86

Subject # _____ Group _____ Date _____

1. Age _____ years

2. Grade E- ____

3. Education level. Circle one.

   a. less than 12 years b. GED c. high school graduate

   d. technical school e. some college ____ years

   f. college graduate g. other (describe) _____

4. General Technical (GT) Score _____ Social Security No. _____

5. Total time in service _____ years ____ mos.

6. How long have you been in Armor? ____ years ____ mos.

7. Present crew position _____ Time in position ____ mos.

   Present vehicle _____

8. Time spent as a gunner ____ mos. Time as M1 gunner ____ mos.

   Time as M60A3 gunner ____ mos. Other gunner time _____ Vehicle _____

9. When was your last training/sustainment gunnery practice? ____ mos. (Exclude COFT)

10. On how many separate occasions have you fired the COFT? ____ Hours on COFT _____

APPENDIX E

DEGRADED GUNNERY TRAINING STRATEGIES QUESTIONNAIRE

1. What special strategies or techniques did you use to engage targets during the preceding exercises?

2. What percentage of the time did you use these techniques? ____% N/A ___

3. Would you recommend these techniques to other gunners? Yes ____ No ____

4. How would you train gunners to use these techniques?

5. What other actions or techniques would you recommend for engaging targets under these conditions?

6. How would you train these alternatives?

APPENDIX F

M1 UCOFT GUNNERY PERFORMANCE

Table F-1

Gunnery Performance as a Function of Tank-Target Movement, Range, and UCOFT Fire Control System Degradation

Tank-Target Movement	Range	Degraded System	Gunnery Index [a]
SS	Short	NONE	63.46 (6.27)
SS	Short	STAB	64.47 (6.07)
SS	Short	LRF	62.26 (8.77)
SS	Short	COMP,STAB,LRF,GPS	57.42 (5.17)
SS	Long	NONE	60.98 (6.32
SS	Long	STAB	64.50 (6.31)
SS	Long	LRF	53.61 (12.10)
SS	Long	COMP,STAB,LRF,GPS	47.71 (11.08)
SM	Short	NONE	49.62 (6.86)
SM	Short	STAB	50.75 (6.45)
SM	Short	LRF	48.53 (6.04)
SM	Short	COMP,STAB,LRF,GPS	44.19 (4.41)
SM	Long	NONE	43.66 (6.47)
SM	Long	STAB	33.91 (5.28)
SM	Long	LRF	30.84 (9.52)
SM	Long	COMP,STAB,LRF,GPS	29.68 (5.49)
MM	Short	NONE	59.63 (6.69)
MM	Short	STAB	51.83 (9.02)
MM	Short	LRF	50.75 (6.27)
MM	Short	COMP,STAB,LRF,GPS	48.21 (5.26)
MM	Long	NONE	46.16 (8.85)
MM	Long	STAB	38.90 (8.60)
MM	Long	LRF	30.46 (4.93)
MM	Long	COMP,STAB,LRF,GPS	34.50 (8.60)

[a] Mean values of the gunnery index are shown with standard deviations in parentheses.

Table F-2

Gunnery Performances Under Fully Operational Conditions as a Function of Tank-Target Movement and Target Range

Tank-Target Movement	Range	Hit Percentage	Azimuth Error	Elevation Error	Opening Time	Gunnery Index
SS	Short	93.06 (10.58)	0.43 (0.10)	0.39 (0.14)	14.31 (2.35)	63.46 (6.27)
SS	Long	91.57 (8.37)	0.45 (0.20)	0.33 (0.08)	15.97 (2.14)	60.98 (6.32)
SM	Short	71.20 (22.68)	1.57 (0.70)	0.40 (0.14)	14.77 (1.97)	49.62 (6.86)
SM	Long	57.52 (17.17)	1.51 (0.47)	0.40 (0.22)	16.36 (2.79)	43.66 (6.47)
MM	Short	86.94 (8.99)	1.58 (0.44)	0.48 (0.10)	12.00 (1.93)	59.63 (6.69)
MM	Long	53.89 (16.57)	1.85 (0.92)	0.56 (0.32)	14.16 (2.71)	46.16 (8.85)

Note. Mean values for speed and accuracy measures are shown with standard deviations in parentheses.

Table F-3

Gunnery Performances Under Simulated Stabilization System Failure as a Function of Tank-Target Movement and Target Range

Tank-Target Movement	Range	Hit Percentage	Azimuth Error	Elevation Error	Opening Time	Gunnery Index
SS	Short	93.33 (6.51)	0.48 (0.13)	0.38 (0.13)	13.57 (2.07)	64.47 (6.07)
SS	Long	96.67 (6.51)	0.35 (0.14)	0.35 (0.13)	15.83 (2.64)	64.50 (6.31)
SM	Short	79.17 (10.84)	1.58 (0.34)	0.40 (0.12)	15.06 (2.07)	50.75 (6.45)
SM	Long	32.64 (12.76)	3.35 (0.90)	0.45 (0.22)	17.02 (2.75)	33.91 (5.28)
MM	Short	70.74 (16.43)	1.88 (0.94)	0.38 (0.13)	13.48 (2.06)	51.83 (9.02)
MM	Long	47.78 (28.83)	2.89 (2.46)	0.42 (0.17)	16.72 (1.95)	38.90 (8.60)

Note. Mean values for speed and accuracy measures are shown with standard deviations in parentheses.

Table F-4

Gunnery Performances Under Simulated Laser Rangefinder (LRF) Failure as a Function of Tank-Target Movement and Target Range

Tank-Target Movement	Range	Hit Percentage	Azimuth Error	Elevation Error	Opening Time	Gunnery Index
SS	Short	90.37 (12.23)	0.43 (0.18)	0.50 (0.12)	14.22 (2.32)	62.26 (8.77)
SS	Long	85.62 (22.31)	0.62 (0.70)	0.35 (0.17)	20.88 (3.26)	53.61 (12.10)
SM	Short	75.19 (10.71)	1.29 (0.52)	0.49 (0.12)	16.65 (2.47)	48.53 (6.04)
SM	Long	36.79 (26.16)	2.03 (0.86)	0.52 (0.42)	22.59 (3.18)	30.84 (9.52)
MM	Short	71.11 (13.51)	2.80 (0.54)	0.58 (0.13)	13.32 (2.69)	50.75 (6.27)
MM	Long	31.76 (12.43)	2.74 (0.79)	0.82 (0.36)	19.88 (2.65)	30.46 (4.93)

Note. Mean values for speed and accuracy measures are shown with standard deviations in parentheses.

Table F-5

Gunnery Performances Under Simulated Failure of the Ballistic Computer, the Gunner's Primary Sight, the Laser Rangefinder, and the Stabilization System as a Function of Tank-Target Movement and Target Range

Tank-Target Movement	Range	Hit Percentage	Azimuth Error	Elevation Error	Opening Time	Gunnery Index
SS	Short	79.07 (10.25)	0.38 (0.08)	0.43 (0.10)	15.71 (1.38)	57.42 (5.17)
SS	Long	61.92 (24.33)	0.43 (0.26)	0.88 (1.12)	18.47 (1.89)	47.71 (11.08)
SM	Short	53.98 (14.77)	1.63 (0.41)	0.67 (0.14)	14.87 (1.57)	44.19 (4.41)
SM	Long	18.75 (17.37)	3.21 (1.32)	0.58 (0.26)	17.68 (1.55)	29.68 (5.49)
MM	Short	63.33 (14.97)	1.87 (0.61)	0.75 (0.07)	13.79 (1.63)	48.21 (5.26)
MM	Long	23.89 (21.31)	2.36 (0.82)	0.54 (0.27)	15.88 (2.95)	34.50 (8.60)

Note. Mean values for speed and accuracy measures are shown with standard deviations in parentheses.

APPENDIX G

GUNNERY INDEX (GI)

The Gunnery Index combines standard measures of gunner speed and accuracy into a single composite measure of gunner proficiency. GI is based on a series of observations of gunnery performance, combining stable estimates of gunnery speed and accuracy in a manner that reliably detects small changes in gunner performance. The Gunnery Index may be calculated for each gunner in the test sample by using the following formula.

$$\text{Gunnery Index (GI)} = (.5W1\ \sqrt{ABC} + .5W1D + W2E) \times 100$$

Where A = Number of First Round Hits/Number of Targets Presented

B = Number of Hits/Number of Rounds Fired

$$C = \frac{\text{(Number of Targets Presented - Number of Targets Engaged)}}{\text{Number of Targets Presented}}$$

D = J/Average Aiming Error

E = K/Average Opening Time

And J is the smallest average aiming error from the center of mass exhibited by a given population of gunners for a particular set of engagements; $0 < J \leq$ smallest average aiming error for the test sample.

K is the fastest average opening time exhibited by a given population of gunners for a particular set of engagements; $0 < K \leq$ fastest average opening time for the test sample.

W1 and W2 are weights assigned by the evaluator based on the judged relative importance of accuracy and speed. W1 + W2 = 1.0.

Equal weights were assigned to the speed and accuracy components for purposes of this research; that is, W1 = W2 = 0.5. Gunners were allowed only one round for each target presented. With only one round per target and equal weights for W1 and W2, the gunnery index assumes a simpler form.

$$\text{Gunnery Index (GI)} = (.25A + .25D + .5E) \times 100 = 25A + 25D + 50E$$