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Devices and Aids for Training M1 Tank Gunnery in the Army National Guard: A Review of Military Documents and the Research Literature

John E. Morrison, Eugene H. Drucker,
and David A. Campshure
Human Resources Research Organization

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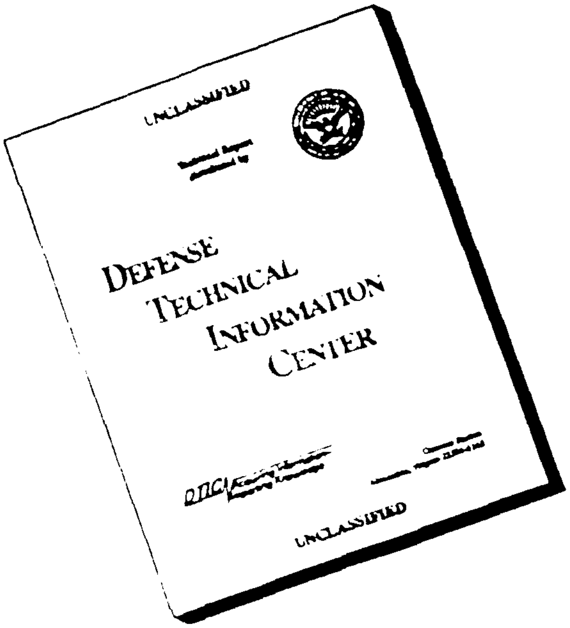
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The research described in this report represents a preliminary step in the development of a device-based, tank gunnery training strategy for use at the company level by the Army National Guard (ARNG). Six devices and aids relevant to gunnery training in an armory environment were selected for detailed review: (a) M1 TopGun; (b) M1 Videodisc Interactive Gunnery Simulator (VIGS); (c) M1 Mobile Conduct-of-Fire Trainer (M-COFT); (d) Guard Unit Armory Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I); (e) Simulation Networking (SIMNET) battlefield simulation system; and (f) Hand-Held Tutor (HHT). Military documents and technical literature were examined to identify the training functions that the devices and aids are intended or conjectured to serve. The research literature was analyzed to discuss the training effectiveness of the six devices and aids with respect to (a) skill acquisition, (b) skill retention, (c) prediction of performance, and (d) transfer of training.

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FOREWORD

The Army National Guard (ARNG) is emphasizing training devices/aids to enhance the home-station training of M1 tank gunnery. To this end, a four-phased research project is underway to identify (a) devices/aids available for use, (b) tasks to be trained on each device/aid, (c) environmental constraints affecting device-aid usage, and based on this information, to (d) develop a practicable ARNG device/aid-based M1 tank gunnery training strategy for use at home station. This report describes the results of the first phase of the project, wherein candidate gunnery training devices/aids are identified and research findings are reviewed to determine the training effectiveness of each device/aid.

The research was conducted by the Training Technology Field Activity, Gowen Field (TTFA-GF), whose mission is to improve the effectiveness and efficiency of Reserve Component (RC) training by using the latest in training technology. The research task supporting this mission, "Application of Technology to Meet RC Training Needs," is organized under the "Training for Combat Effectiveness" program area.

The National Guard Bureau (NGB) sponsored this research under a Memorandum of Understanding, signed 12 June 1985, establishing the TTFA-GF. Results have been presented to Chief, Organization and Training Division, Training Support and Management Branch, NGB; Chief, Training Division, Office of the Chief, Army Reserve (OCAR); Director, Training Development and Analysis Directorate (TDAD), Training and Doctrine Command (TRADOC); and Deputy Director, Training and Doctrine, U.S. Army Armor School (USAARMS).

EDGAR M. JOHNSON
Technical Director

DEVICES AND AIDS FOR TRAINING M1 TANK GUNNERY IN THE ARMY NATIONAL GUARD: A REVIEW OF MILITARY DOCUMENTS AND THE RESEARCH LITERATURE

EXECUTIVE SUMMARY

Research Requirements:

Reductions in the allocations of training ammunition and in operating tempo (OPTEMPO) have forced armor units to rely increasingly on various devices and aids to train and sustain tank gunnery skills. These reductions are particularly acute for the Army National Guard (ARNG), where training resources (e.g., time, equipment, devices/aids, and access to live-fire range/maneuver areas) are especially scarce. Further, trainers in the ARNG have little time to plan how such devices and aids should be used to train gunnery skills. The purpose of this research project is to design a practicable, device/aid-based training strategy tailored to the constraints of the ARNG. As a preliminary step in developing such a training strategy, this report presents a review of military documents and the research literature on the devices and aids that could be used to train and sustain gunnery skills and knowledges.

Procedure:

A comprehensive survey of gunnery training devices and aids revealed six devices/aids that are relevant to gunnery training in an armory environment: (a) the M1 TopGun arcade game; (b) the M1 Videodisc Interactive Gunnery Simulator (VIGS); (c) the M1 Mobile Conduct-of-Fire Trainer (M-COFT); (d) the Guard Unit Armory Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I); (e) the Simulation Networking (SIMNET) battlefield simulation system; and (f) the Hand-Held Tutor (HHT) computerized training aid. Military documents and the research literature were examined to determine the training functions they are intended or conjectured to serve. This statement of function defines the domain of performance addressed by the device, including the types of tasks/knowledges and particular crew positions trained by the device. This statement of function also describes how the training device/aid is or can be used for training gunnery. A review of the research literature was organized to discuss the training effectiveness of the six devices and aids with respect to four topics: (a) skill acquisition, (b) skill retention, (c) prediction of performance, and (d) transfer of training. An appendix provides a detailed description of the fidelity and instructional features of each device.

Findings:

A review of military technical documents and the research literature indicated that the training technical devices overlap somewhat in their training functions. Rather than being wasteful, this overlap was considered beneficial from both a skill retention/transfer standpoint as well as from a practical standpoint. The empirical literature indicated, for the cases where there were data, that the devices were generally effective in terms of their intended functions. However, there was very little research that addressed (directly or indirectly) the effects of training devices and aids on the retention of gunnery knowledges or skills. The skill retention issue is one that is particularly problematic for the ARNG.

Utilization of Findings:

This research was conducted as the first phase in a four-phase research project. The second phase (Campshure, 1990) presented a detailed assessment of the capabilities of selected devices and aids to train gunnery skills and knowledges. The third phase will examine current ARNG gunnery training practices. This examination will identify the training devices and aids currently available and the conditions that constrain their use in training. Information gathered during the first three phases will then be used to design a detailed, device/aid-based strategy for training and sustaining M1 gunnery skills in ARNG units.

DEVICES AND AIDS FOR TRAINING M1 TANK GUNNERY IN THE ARMY NATIONAL GUARD: A REVIEW OF MILITARY DOCUMENTS AND THE RESEARCH LITERATURE

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DEVICES AND AIDS FOR TRAINING M1 TANK GUNNERY IN THE ARMY NATIONAL GUARD:
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Overview

Reductions in the allocations of training ammunition and in operating tempo (OPTEMPO) have forced armor units to rely increasingly on various devices and aids to train and sustain tank gunnery skills. Specific guidance is needed to specify how these training devices/aids should be used to promote effective acquisition, retention, and transfer of gunnery skills. Such "how to" guidance for integrating training across different media is commonly referred to as a training strategy. The need for a device/aid-based training strategy is particularly critical for the Army National Guard (ARNG) where training resources (e.g., time, equipment, devices/aids, and access to live-fire range/maneuver areas) are especially scarce. Furthermore, trainers in the Reserve Component have little time to plan how such devices and aids should be used for training (Eisley & Viner, 1989). A useful training strategy for the ARNG would provide their trainers and training managers with practicable recommendations for using the devices/aids at their disposal.

Two device-based strategies for training gunnery have been previously published. The first strategy, which was developed for the Army Research Institute by Hoffman and Morrison (1988), focused on four computer-based devices for training M1 gunnery skills: the Videodisc Interactive Gunnery Simulator (VIGS), the arcade-type TopGun device, the Unit Conduct-of-Fire Trainer (U-COFT), and the Simulation Networking (SIMNET) battle simulation system. Using heuristic guidelines derived from instructional theory and from the practical constraints of tank gunnery training, Hoffman and Morrison derived a hierarchy of instructional units that prescribed the appropriate sequence of instruction. Because their strategy was designed to serve as a model for any gunnery training program, it was not tied to any particular course of instruction or any particular evaluation event such as Table VIII. In contrast, the second device-based training strategy, which was developed by the U.S. Army Armor School (1990), prescribed a program that was designed specifically for institutional and unit training. This document contained guidelines for the implementation of the strategy specifying how both computer-based and tank-appended devices should be used to support the combat table training program. The explicit purpose of the document was "...to provide unit commanders, training officers, and master gunners a single-source document that integrates the various individual devices into the overall Armor device-based training strategy" (p. iii). It prescribed the frequency with which devices should be used and the suggested length of individual device training sessions. This strategy was laid out for the initial year (FY 1990) and then modified for subsequent years as new devices were expected to be fielded.

The preceding descriptions of the two extant device-based training strategies stress the differences between the two approaches. However, the two strategies are similar in that they both provide general advice about how devices should be used. Thus, the Armor School document characterizes its own guidance as a "macrostrategy," implying that more detailed information (a "microstrategy") will be forthcoming. This microstrategy would include information such as specific exercises to practice on individual devices/aids; appropriate performance criteria to ensure sufficient learning, retention, and transfer; and alternate "paths" when access to certain devices/aids is blocked. This level of detail would be necessary for describing a practicable gunnery training strategy for the ARNG.

As a first step in the process of designing such a microstrategy, the capabilities of the devices and aids that are available for ARNG training must be described. The purpose of this report is to examine these capabilities by reviewing the published military documents and research literature. The second report in this series (Campshure, 1990) also examined the capabilities of gunnery training devices and aids, but in terms of the specific conditions and actions that they simulate. A third report will describe the present training program in the ARNG with particular emphasis on devices used and conditions that constrain gunnery training. The information from all three reports will be used to develop a device/aid-based training microstrategy that will provide appropriate guidance for training gunnery at the local armory (company) level. The strategy will be documented in a fourth and final report in this series.

Types of Gunnery Training Devices and Aids

The devices and aids that are available for ARNG gunnery training can be sorted into three categories. The first category includes stand-alone, computer-based devices. Improvements in computer technology (particularly in the realm of computer-generated and videodisc-based imagery) have led to the development of a variety of computer-based devices for training gunnery skills. Examples of technologies in this category include the Mobile Conduct-of-Fire Trainer (M-COFT), VIGS, the SIMNET battle simulation, and TopGun. These devices are "stand-alone" in the sense that they are self-contained and do not require the use of either the actual equipment (i.e., the tank) or a maneuver area. Thus, these devices allow soldiers to practice gunnery tasks in a realistic context without consuming OPTEMPO or ammunition resources. In addition, these stand-alone devices have built-in hardware and software capabilities called instructional features (e.g., scenario control, record/replay, and automated performance measurement) that are designed to facilitate the instructional process. As reviewed in Hoffman and Morrison (1988), these devices vary considerably in fidelity and instructional features and in their costs. Furthermore, there is a tradeoff between device features and device costs: The high-fidelity devices that provide realistic visual cues and operational controls are also the most expensive and therefore least available technologies. For the more expensive technologies (M-COFT and SIMNET), personnel must be specially trained to operate the devices and use them to their best advantage, thereby increasing the operational costs.

The next category of gunnery training technologies is devices that are appended to actual tanks. Included in this category are (a) traditional subcaliber devices mounted coaxial to the main gun (Telfare and Brewster devices), (b) subcaliber devices mounted in the bore of the main gun (the Phoenix device and the Tank Precision Gunnery Inbore Device [TPGID]), (c) thru-sight video (TSV), and (d) laser-based devices (the Tank Weapon Gunnery Simulation System [TWGSS] and Multiple Integrated Laser Engagement Simulation [MILES]). These devices are added to actual tanks to enable crews to practice gunnery without incurring the high costs, the maneuver area requirements, and/or the safety restrictions associated with full-caliber, live-fire ammunition. The advantage of tank-appended devices is that crews operate actual equipment (i.e., tanks) to hit targets viewed through the tank optics. Thus, the correspondence between the training medium and the operational context, and therefore the skill transfer potential, is quite high. A disadvantage is that most tank-appended devices incur OPTEMPO costs related to maneuvering actual tanks on appropriate ranges.

Although the distinction between stand-alone, computer-based devices and tank-appended devices appears obvious at first glance, the Guard Unit Armory Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I) provides a problem for this categorization schema. Characterized in most Army documents as a tank-appended device, GUARD FIST I is actually a computer-based device that presents computer-generated imagery through the optical systems of an actual tank. The crewmen use the actual tank controls, which are connected to the computer-based training system. Like tank-appended devices, then, GUARD FIST I offers high levels of response fidelity because the crews use actual tank controls. On the other hand, the visual scene is more like that displayed on stand-alone, computer-based training devices. Furthermore, GUARD FIST I is designed to be operated in a National Guard armory with all tank power systems off, thereby incurring no OPTEMPO expenses. For these reasons, GUARD FIST I is considered a computer-based device for the present report.

The third category consists of training aids, which can be differentiated from the other two categories of training devices as follows: Whereas training devices are designed to train gunnery skills, training aids are designed to impart knowledges that are prerequisite to or otherwise support gunnery task performance. Training aids include computer-based technologies, such as the Hand-Held Tutor (HHT) or the Electronic Information Delivery System (EIDS). The hardware for computer-based aids is designed to train a variety of topics rather than one narrowly defined topic. In other words, the content of a computer-based training aid is determined by its instructional software (i.e., its courseware). Also, because computer-based aids are designed to train knowledges, fidelity is not an issue as it is for training devices. The training aids category also includes traditional paper-based materials, such as rapid train-up and home-study packages. Probably the most salient features of such non-computer-based materials are their low cost, ease of use, and portability.

Selection of Devices/Aids for Study

The first step in the process of developing a gunnery training strategy is to select appropriate training aids/devices. In that regard, Hagman (personal communication, July 7, 1990) developed a comprehensive list of 27 gunnery training technologies (including stand-alone training devices, tank-appended training devices, and training aids) that are potentially applicable to training gunnery in the ARNG. This list was developed from official training documents including Tank Combat Training Devices, FM 17-12-7 (Department of the Army [DA], 1988b); TRADOC Training Devices for Armywide Use, TRADOC PAM 71-9 (DA, 1987); Five-Year Training Devices Plan, FY88-92, FORSCOM Pam 350-15 (DA, 1988a); and Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990). This list provided the initial starting point for selecting devices for the present research.

Upon consideration of the criteria for selecting training devices/aids from this list, it became apparent that the tank-appended training devices (excluding GUARD FIST I) are used in a distinctly different context and serve a different purpose than either stand-alone training devices or training aids. First, consider tank-appended training devices. In general, these devices are for ARNG use only at local and/or major training areas and are therefore available only at particular times during the training year. Along with full-caliber training ammunition, the function of tank-appended devices relates primarily to the evaluation of gunnery skills in the context of the Tank Tables IV-VIII.[1] The Tables provide, in essence, the intermediate and terminal performance objectives for gunnery training. Finally, the strategy for using tank-appended devices is dictated to a large extent by doctrine. For instance, Tank Combat Tables M1, FM 17-12-1 (DA, 1986) prescribes that Table VIII, the intermediate crew qualification table, be fired with live-fire training ammunition. Test media choice is also dictated by device availability and safety constraints. For instance, FM 17-12-1 prescribes that Table IV, the basic crew qualification table, be executed on a full-scale range using the Telfare subcaliber device. However, if the range cannot support live-fire, alternate media such as MILES can be used to execute Table IV. If MILES technology is not available, other alternatives such as thru-sight video (TSV) can be used in a dry-fire context.

The training context and purposes of tank-appended training devices can be sharply contrasted with those of stand-alone training devices and training aids. In general, the stand-alone training devices (including GUARD FIST I) and training aids can be used in an armory context. Because of their increased availability and lower operating costs, trainees can use these stand-alone training devices and training aids more frequently than they can use tank-appended devices. Some of the stand-alone devices are capable of training gunnery objectives that are not represented in Tables, such as the M-COFT's capability to simulate the full range of degraded modes. Despite these extra capabilities, the stand-alone training devices and training aids are used primarily to prepare crews for the Tables. The strategy for accomplishing this objective, however, is much less standardized than the strategy for using the tank-appended devices.

With this distinction in mind, it can be seen that the training strategy should focus on how stand-alone training devices and training aids should be used to train for the Tables. Consequently, the present report focuses on these two types of training media. From the list provided by Hagman, six stand-alone, computer-based training devices and aids were selected as potential media for training M1 gunnery in the ARNG:

1. M1 TopGun,

2. M1/M1A1 VIGS,

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[1] In contrast to the later tables, Tables I-III are preliminary training events that can be performed in an armory context. In the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990), Tables I and II are to be replaced by training on M-COFT, and Table III is to be replaced by training on GUARD FIST I.

3. M1 M-COFT,
4. GUARD FIST I,
5. SIMNET, and
6. The HHT modules for training fire commands, multiple returns, and degraded mode gunnery.

Purpose and Organization of Report

Given the training devices and aids that will be used in the microstrategy, the next step is to examine the capabilities of each technology in detail. A detailed description of the capabilities to simulate the conditions, actions, and knowledges related to tank gunnery is provided by Campshure (1990). The present report provides a review of military and technical documents and a review of the research literature with regard to each of the six devices and aids identified in the previous section.

The review of military and technical documents focuses on three types of information. The first is related to the training function that each device or aid is intended to or conjectured to serve. The training function includes the types of skills or knowledges trained and the crew positions addressed by the device. The second type of information gleaned from this review summarizes any published advice on how the device or aid should be used--in other words, its training strategy. The third type of information includes detailed descriptions of the devices in terms of their fidelity and instructional features. This detailed information about device/aid features is presented in an appendix to this report.

The review of the research literature examines the empirical evidence concerning the training effectiveness of the selected devices/aids. The empirical results are organized into findings relating to acquisition, retention, performance prediction, and transfer. These categories of results can be seen to address different and increasingly convincing evidence for the training effectiveness of a device or aid. First, the *acquisition* findings refer to the empirical evidence describing the extent to which performance on the device improves with repeated practice. Thus, acquisition findings address the question of whether or not the device/aid trains some skill or knowledge. The *retention* findings extend the acquisition findings by examining the extent to which the skill or knowledge learned on the device/aid is retained over periods of no practice. The *performance prediction* findings refer to the relationship between performance on the device and performance on the operational equipment. Positive correlations provide evidence for the commonality of skills between two performance contexts, and thus would be a necessary (but not sufficient) condition for transfer. Finally, the *transfer* findings are directly concerned with the results bearing on the transfer of gunnery skills and knowledges learned on the device/aid to actual gunnery performance.

The training and research issues reviewed in the present report vary considerably among the different training devices and aids. Therefore, the literature is organized by the individual training technologies. Also, the amount of available research literature differs from device to device. Where the research literature on a particular device or aid is especially extensive, the separate subsections are devoted to the findings per se and the conclusions that may be reached from those findings. In some cases, these conclusions discuss proposed research to answer questions suggested by the findings. The final section summarizes the results across the various devices and aids in an attempt to integrate the findings from the review.

TopGun

Developed jointly by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and the Defense Advanced Research Projects Agency (DARPA), TopGun is a prototype training device designed to investigate the utility of an inexpensive, arcade-type video game for training and sustaining tank gunnery skills. The prototype game, Battlesight, was designed to train gunnery for the M60A1 tank. TopGun represents an update of Battlesight and is available in both M60A3 and M1 versions.

Military/Technical Literature

Training Functions

TopGun has been described as a "part-task" trainer in that it trains only selected gunnery skills. In particular, TopGun is designed primarily to train the basic psychomotor skills that underlie gunner behaviors. Kraemer and Smith (1990) maintained that the skills learned on TopGun include "... (a) acquiring targets, (b) laying the sight reticle on target, (c) tracking moving targets, (d) using the laser rangefinder to determine target range, and (e) firing on targets in response to a fire commands" (p. 12). These skills are acquired through practice on engaging single and multiple main gun sabot targets (i.e., tanks) from a stationary position.

Strategy for Training

Various training strategies have been proposed for TopGun and its predecessor, Battlesight. The original Battlesight device was conceived as a medium for providing informal "recreational" training for Armor crewmen in barracks, dayrooms, and leisure areas. In Hoffman and Morrison's (1988) strategy, TopGun was selected as a medium for providing initial instruction on basic gunner skills. More recently, TopGun was suggested as a training medium for use by Reserve Component armor units in home-station armories and reserve centers (Hart, Hagman, & Bowne, 1990). One hundred of these devices (50 M1 and 50 M60A3 versions) were built by the contractor (NKH) and distributed by the ARI Field Unit at Fort Knox to Armor Reserve Component units. However, because TopGun remains a research technology as opposed to an officially fielded training device, it does not figure into the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990).

Research Literature

The evidence regarding the training effectiveness of TopGun is reviewed below. To provide a more comprehensive review, data related to the M60A3 version of TopGun as well as TopGun's predecessor, Battlesight, are included.

Acquisition

Research findings. The earliest research that addressed the skill acquisition issue was a series of three experiments conducted on the Battlesight device (Abel, 1986). In the first two experiments, an experienced group of gunners (defined as qualified tank commanders or gunners) was compared to an inexperienced group (drivers or loaders). A learning trial was defined by the expenditure of 50 rounds of armor-piercing discarding sabot (APDS) main gun ammunition. In the first experiment, 12 soldiers (6 experienced and 6 inexperienced) were given 10 trials distributed over two days to acquire and destroy targets using the primary sight option. No between-group differences were obtained, but performance accuracy improved steadily and significantly across trials. Similar trends were obtained for two measures of gunnery accuracy: mean number of hits per trial, and mean number of first round hits. In the second experiment, 12 different soldiers (again, 6 experienced and 6 inexperienced) were given four trials to acquire and destroy targets using the auxiliary sight option. As in the previous experiment, no between-group differences were obtained, but performance significantly improved across trials. Despite the fewer number of trials, data from the second experiment showed approximately the same degree of improvement from the first to the last (i.e., fourth) trial.

In her third experiment, Abel (1986) investigated the effects of two independent variables over three repeated trials of the Battlesight game using the primary sight. The first variable was defined by the differences between the standard Battlesight game format and a revised format. The standard format provided the game player 60 rounds and three "lives" for each session; the player continuously engaged targets until either the ammunition or the lives were expended. The revised format distributed rounds and lives over three blocks--that is, each block consisted of 20 rounds and a single life. The timeout between blocks presumably reduced fatigue; however, the length of timeout periods was not specified. The second independent variable was defined by the difference between the kill zone being set at 100% (default condition) and at 50% requiring a more precise lay. (The kill zone is the area within a target that must be hit to achieve a kill. This feature of TopGun is described in detail in the Appendix.) The two levels of both independent variables were combined to form a 2 X 2 factorial. Fifteen entry level soldiers were assigned to each of the four conditions of the experiment and were tested for three trials. In addition to the two accuracy measures obtained in the previous two experiments, a speed measure (average time to fire) was also computed by dividing the elapsed game time by the number of rounds fired.

With regard to accuracy measures, the results of Abel (1986, Experiment 3) showed a moderate but significant increase over the three trials in percentage of targets hit for the standard (100%) kill zone groups only. No other trial difference was significant for either accuracy measure. As expected, a large effect was obtained for the kill zone manipulation with the 100% groups performing significantly better than the 50% groups. No significant effects were obtained for the game format nor did the game format interact with trials. However, there was an indication in the data that, whereas the soldiers in the distributed format game improved steadily over the three trials, there was a slight downturn in performance on the third trial for the soldiers in the standard format. Abel interpreted this acquisition trend as indicating a possible negative effect of massing ammunition and lives. With regard to the speed measure (average time to fire), a large and significant decrease in average time to fire was obtained over trials for all four groups. Neither group differences nor interactions of trials by groups were obtained for the speed measure. Abel argued that the failure of the reduced kill zone group to improve in accuracy over trials was due to its tendency to respond as quickly as the standard kill zone group. In other words, the soldiers in her experiment were not able to tradeoff speed of responding for increased accuracy. Abel attributed this effect to the soldiers' use of a "fast shooting" strategy that emphasizes speed over accuracy of responding. She speculated that the "fast shooting" strategy had been acquired from soldiers' experience with similar arcade video games.

Bliss (1989) reported detailed findings on the acquisition of M1 TopGun skills. His findings were a subset of an overall transfer experiment from a combination of VIGS and TopGun to M-COFT (Turnage & Bliss, 1989). (The design and results from this transfer experiment are reported in the section on VIGS.) Of the 40 college students receiving training on TopGun and VIGS, 20 received TopGun training first. The TopGun acquisition findings focused on this subgroup because their performance was uncontaminated by previous experience with VIGS. Six gunnery measures were obtained over the four trials: elevation and azimuth errors, times to fire and kill, hit percentage, and a TopGun performance score. Significant improvements in performance were obtained on all performance measures except azimuth error. Analyses of intertrial correlations indicated that performance on most of these measures stabilized by the second trial. Post hoc analyses of between-trial differences corroborated this finding, showing significant differences between the first trial and later trials, but no differences between trials two, three, and four. Representative results are shown in Figure 1 for the TopGun performance score, which represents a composite of both speed and accuracy of performance. Breakdowns of trials by sight used (gunner's primary sight [GPS], gunner's alternate sight [GAS], and thermal imaging system [TIS]) and by target movement (stationary or moving) showed sensible differences for most measures; that is, most measures indicated poorer performance on the GAS compared to either the GPS or TIS, and poorer performance on moving than on stationary targets. Furthermore, Bliss detected a significant sight by movement interaction caused by especially poor performance on moving targets using the GAS reticle. Evidently, the requirement to manually apply range and lead required by the GAS was compounded when tracking a moving target.

Hart et al. (1990) tested acquisition effects on the M60A3 version of TopGun. The experimental participants were 16 Army National Guardsmen who were either tank loaders or drivers, or were not tank crewmen; as a consequence, they had little or no experience as tank gunners. After a 15-min familiarization period (5 mins of verbal instruction and 10 mins of TopGun warm-up), soldiers were given three 20-min training sessions with a 5-min intersession rest interval. During each training session, soldiers acquired stationary and moving targets at short and long distances using the auxiliary sight. Dependent variables were number of first round hits in each block of 10 targets (accuracy), and the time from target appearance to first-round hit (speed). Overall performance in both speed and accuracy improved across the three sessions. There was more improvement for moving than for stationary targets; however, this interaction was probably caused by performance being near the speed floor and accuracy ceiling for stationary targets.

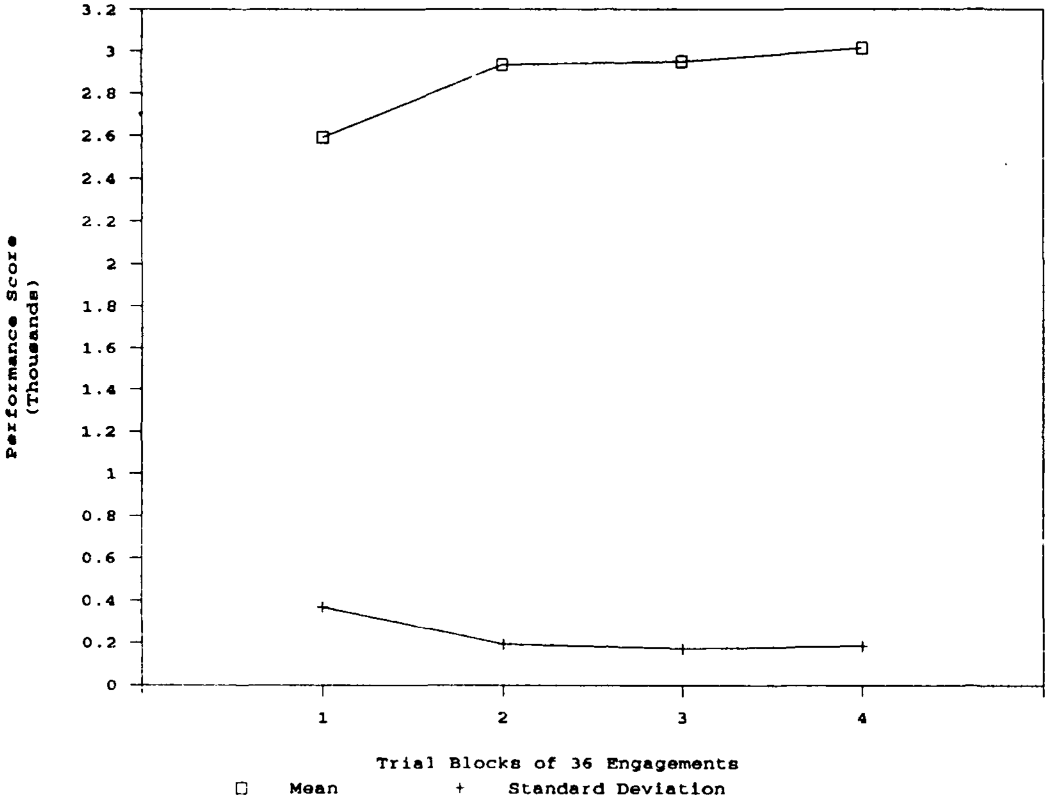

Figure 1. Performance of the TopGun first group over four trials of TopGun training. Data taken from Bliss (1989).

Kraemer and Smith (1990) conducted three experiments to examine acquisition effects on the M1 version of TopGun. Three groups of soldiers were used in each of their experiments: a formal training, a recreational training, and a no-training group. Soldiers in the no-training group received 15 mins of instruction on TopGun and M1 gunnery techniques followed by 10 mins of hands-on familiarization with TopGun under the supervision of a researcher. Soldiers in the formal training group received additional training under standardized conditions that were determined in advance. Soldiers in the recreational training group received additional training under non-standardized conditions that were determined on a probabilistic basis. The first two experiments differed only with respect to the soldiers used: In Experiment 1, the soldiers were senior Noncommissioned Officers (NCOs) who held the Cavalry Scout (19D) Military Occupational Specialty (MOS) and who were waiting to attend the Advanced Noncommissioned Officer Course; whereas in Experiment 2, the soldiers were newly commissioned second lieutenants waiting to attend the Armor Officer Basic Course. Neither group had any previous experience with M1 tank gunnery. All participants in both experiments started the experiment by receiving 15 mins of instruction and 10 mins of familiarization training on TopGun. After these pretraining events, all soldiers were administered a pretest on TopGun presented in the formal training mode. The pretest consisted of a variety of 30 engagements and took about 15 mins to complete. After the pretest, the "no-training" group of soldiers was released to their units for three hrs and asked to return for the posttest. The remaining two groups of soldiers were given a 10-min break before receiving two hrs of training on TopGun. One of the two training groups received TopGun training in the recreational mode while the other received TopGun training in the formal mode. For their last event, participants in all three groups received a posttest on TopGun, which consisted of an alternate form of the pretest. Preliminary analyses showed no differences in performance between the NCOs and officers; consequently, the data from the two experiments were combined. Statistical analyses of the data showed that there was an overall significant improvement in performance from pretest to posttest. Despite a trend for larger improvements in the groups receiving training, the group by pretest/posttest interaction was not significant. In other words, there were no differences between groups in their pretest/posttest gains.

Kraemer and Smith (1990) suggested that one possible reason for the lack of differences between experimental and control groups in Experiments 1 and 2 was the relatively short TopGun training period (2 hrs). Experiment 3 retained the same three groups (no training, formal training, and recreational training) but increased the amount of TopGun training in the latter two groups to nine hrs distributed over four days. Another important difference was that the participants in Experiment 3 were 36 experienced M1 Armor Crewmen (MOS 19E). Planned comparisons of pretest/posttest differences showed larger performance gains for the two TopGun training groups compared to the no training group for all measures except for firing rate (number of rounds fired per min). However, there were no differences between the formal and recreational training groups.

Conclusions. In general, the research findings reviewed in this section demonstrated reliable increases in both speed and accuracy as a function of repeated practice on Battlesight or TopGun. The exception to this trend were the results from the first two experiments by Kraemer and Smith (1990) which failed to show differential pretest/posttest gains as a function of TopGun practice. These researchers suggested that one possible explanation for the lack of gains was that all the performance differences were realized during the 15-min pretest and that the subsequent 2-hr TopGun performance had little, if any, additional effect on learning. In fact, Bliss's (1989) results suggested that TopGun skills are acquired quickly with no further increases in performance. Kraemer and Smith's third experiment, however, showed that a 9-hr training session on TopGun did have a measurable effect on pretest/posttest gains. Thus, it appeared that gains are possible after the initial 15-min pretest. The ambiguity of these findings point to the need to examine the skill acquisition function for TopGun. This function can only be derived through repeated training trials on the device rather than a two-point pretest/posttest determination.

Two specific findings are interesting in that they suggest future research opportunities. One is Abel's (1986) finding that manipulation of the kill zone feature of TopGun did not affect the speed of responding. This finding contradicts classic speed-accuracy tradeoff findings that speed of responding decreases as a function of aiming difficulty (e.g., Fitts, 1954).

responding decreases as a function of aiming difficulty (e.g., Fitts, 1954). Although the exact form of the function is debatable, the basic relationship between speed and accuracy has been demonstrated for a variety of tasks and conditions (e.g., Glencross & Barrett, 1989). One possible reason for not finding slower responding under the more difficult condition was that the instructions did not specify whether the subject should stress speed or accuracy in responding. This ambiguity may have resulted in individual differences in response strategies that "washed out" any tradeoff effect. Pew (1969) suggested that perhaps the best approach to instructing subjects is to systematically manipulate the payoff for speed and accuracy and examine the resulting tradeoff. Abel (1986) speculated that the failure of her soldiers to slow their responses to more difficult targets was due to a self-imposed "fast responding" strategy. If her explanation were true, the typical tradeoff would be observed only under the instructions to perform accurately as possible. The TopGun device with its ability to vary the size of target kill zone provides a interesting research medium for examining such speed-accuracy tradeoffs in tank gunnery. Note, however, that to generate a speed-accuracy operating characteristic function such as that described by Pew, more than two values of kill zone should be used.

Another interesting finding was Kraemer and Smith's (1990) lack of performance differences between formal and recreational training modes. The key difference between the two modes is that the engagements in formal training exercises were programmed to occur in an easy-to-difficult sequence, whereas engagements in recreational exercises occurred in random order. Morrison and Holding (1990) pointed out that the easy-to-difficult sequence is usually prescribed in instruction, and can be justified by the principle of *performance standards*. This principle, defined by Holding (1962), states that the easier tasks should be learned first because they allow the learner to acquire appropriate methods of performance, or smaller error tolerances, that would be impossible to acquire by learning the more complex tasks first. Morrison and Holding suggested that the easy-to-difficult sequence be followed in armor gunnery except in those cases where the principle of *inclusion* may apply. This principle applies where the more difficult task includes all parts of the easier task and the easier task omits important parts of the more difficult task. Under conditions of inclusion, better transfer of training will be obtained in the difficult-to-easy sequence. A superficial analysis of Kraemer and Smith's engagements suggests that, indeed, the more difficult engagements included most of the behavioral elements of the easier engagements. Perhaps, the principle of inclusion counteracted the benefits of the easy-to-difficult sequencing in formal training, resulting in no net advantage for either the recreational or formal training mode. These two opposing tendencies have not been confirmed in the context of gunnery. Research should be performed where gunnery engagements are selected to allow independent manipulation of both complexity and inclusion to determine whether appropriate instructional sequences can be prescribed among gunnery engagements on the basis of those two principles.

Retention

No empirical research has been performed with regard to retention of TopGun performance. However, Hart et al. (1990) speculated on two effects that TopGun might have on skill retention. First, soldiers should require fewer trials to sustain skills than to initially train them. However, this prediction is not unique to TopGun. Second, they speculated on the effects of blocked presentations of similar engagements (e.g., single, stationary targets; moving, multiple targets) versus a random presentation of different types of engagements. They noted that research suggests that random presentations would be more effective in promoting retention than blocked presentation; however, random presentation slows the skill acquisition process. They suggested that soldiers first learn TopGun under blocked conditions, then switch to random after they attain an unspecified level of skill acquisition. These predictions are clearly testable in the context of TopGun.

Prediction of Performance

Hart et al. (1990) combined data from the group receiving repeated blocks of TopGun trials (described above) with another equivalent group of 16 National Guardsmen receiving only one block of TopGun trials (i.e., $n = 32$) to determine the correlation between performance on TopGun and performance on the M-COFT. The M-COFT, although a gunnery training device itself, was assumed to be a reliable and valid measure of gunnery performance. The results showed the correlations between devices were significant for both the speed and accuracy measures, although the correlation for speed ($r = .66$) was somewhat higher than that for accuracy ($r = .30$). These results suggest that performance on TopGun can more reliably predict speed than accuracy of performance on M-COFT. However, Hart et al. proposed that differences between the two types of measures may have been caused by higher within-device reliability estimates for speed than for accuracy measures.

Transfer of Training

Research findings. The experiments reviewed in this section assessed the transfer potential of TopGun by using a quasi-transfer design. The term "quasi-transfer" denotes that transfer is assessed from one device to another rather than from a device to the actual equipment. For these two experiments, transfer or criterion performance was measured on the Conduct-of-Fire Trainer (COFT). The rationale is that the COFT is a higher fidelity and more comprehensive training device than is TopGun. Performance measures obtained from the COFT therefore provide face valid measures of gunnery performance. For a review of actual empirical relationship between COFT and live-fire gunnery performance, see the subsequent section on M-COFT. Also, for discussion of the combined effects of TopGun and VIGS on COFT, see the review of Turnage and Bliss (1989) in the section on VIGS.

Hart et al. (1990) addressed the transfer issue by comparing performance of the group receiving three TopGun training sessions (described above) on M-COFT to two other groups of 16 National Guardsmen: another experimental group that received only one TopGun session and a control group that received no TopGun training. An outline of this research design is shown in Table 1. Two military M-COFT instructor/operators (I/Os) played the role of tank commander during testing. Four M-COFT exercises (40 engagements) were selected from the M-COFT training matrix that closely paralleled the TopGun formal training exercises. Similar speed and accuracy measures were obtained on M-COFT as were obtained on TopGun. Comparisons between the two experimental groups combined versus the control group indicated significant differences for accuracy but not for speed of performance on M-COFT.

Table 1

Outline of Research Design Used by Hart, Hagman, and Bowne (1990)

Groups	Blocks of Acquisition Trials 1	 2	 3	Transfer Test
Experimental-3	TopGun	TopGun	TopGun	M-COFT
Experimental-1	--	--	TopGun	M-COFT
Control	--	--	--	M-COFT

Note. Each block of TopGun trials consisted of 40 engagements and took about 20 mins to complete. The M-COFT testing session consisted of 40 engagements and took about 50 mins to finish.

Furthermore, analysis of the accuracy of M-COFT performance showed an interaction of group by target movement. Simple effects analyses indicated that the two experimental groups were significantly different from the control group in accuracy of performance for stationary targets. However, there were no such differences between experimental and control groups for moving targets. Further analyses of stationary targets indicated larger differences between control and experimental groups for distant than for close targets. This effect was probably due to the soldiers' performance being closer to the ceiling of performance on close targets than on distant targets. None of the comparisons between the two experimental groups was significant. The latter result led the authors to conclude that transfer from TopGun to M-COFT (at least in terms of accuracy of performance) is rapid and virtually complete after only one 20-min TopGun session.

Experiment 3 of Kraemer and Smith (1990) assessed the transfer of skills learned on TopGun to the M1 Institutional Conduct-of-Fire Trainer (I-COFT). The transfer issue was addressed by inserting an I-COFT pretest prior to TopGun familiarization and an I-COFT posttest after TopGun training but prior to the TopGun posttest. The I-COFT is virtually identical to the U-COFT and M-COFT except that the I-COFT has the added capability to train gunners individually by simulating the role of the tank commander. This particular option was used in the present research to standardize Tank Commander (TC)/gunner interactions. As in the Hart et al. (1990) experiment, four I-COFT exercises (40 engagements) were chosen to closely parallel TopGun training. The results showed significant increases in I-COFT performance from pretest to posttest. However, none of the group by pretest/posttest interactions were significant. In other words, the gains in I-COFT performance did not differ among the three groups: TopGun training in recreational mode, TopGun training in formal mode, and no TopGun training.

Conclusions. In summary, whereas Hart et al. (1990) showed significant transfer from TopGun to M-COFT, Kraemer and Smith (1990) failed to show such a transfer effect from TopGun to I-COFT. One obvious difference between the experiments was their use of different versions of the COFT. By their use of the automated tank commander, Kraemer and Smith were better able to standardize the engagement presentations. Without the variability introduced by human tank commanders, the experiment by Kraemer and Smith would have been more sensitive to detecting differences among groups. Therefore, the difference between COFT versions does not explain the different results in transfer of training. A more likely explanation for the failure of Kraemer and Smith to obtain transfer effects was that there was a 2-2.5 day period between the end of TopGun training and the beginning of the I-COFT posttest (R. E. Kraemer, personal communication, July 26, 1990). In contrast, Hart et al. held this interval to only 15 mins to minimize the effects of forgetting. Another possible explanation is that Kraemer and Smith did not examine TopGun transfer effects as a function of target characteristics. TopGun's effects may have been limited to certain types of target engagements. For instance, Hart et al. showed that transfer from TopGun was greatest for stationary targets presented at a distance. Because of the problems with the experiment by Kraemer and Smith, their lack of positive findings should not be regarded as a clear failure to transfer skills.

M1/M1A1 VIGS

The M1/M1A1 VIGS is a table-top, part-task gunnery trainer for training gunners assigned to the M1 and M1A1 tanks. It is intended for use in training and sustaining basic gunnery skills. Three prototypes of VIGS were built by Perceptronics: one for the M60A1 tank, one for the M60A3 tank, and one for the M1 tank Battlefield scenes were videotaped for the prototypes and stored on videodisc along with stationary and moving targets. These target scenes are presented to the gunner, along with appropriate fire commands, during a training exercise with the gunner being required to acquire, track, and engage the simulated targets. The current version of the M1 VIGS is manufactured by ECC International Corporation. Like the prototype, scenes of stationary and moving targets are stored on videodisc; unlike the prototypes, however, the scenes were originally generated by computer. Other changes have also been incorporated into the new version of VIGS and are described in detail by Turnage and Bliss (1989).

Military/Technical Literature

Types of Skills Trained

VIGS is intended to train only the basic gunnery skills required by the gunner in the M1 and M1A1 tanks. Among these are (a) adjusting switches such as the thermal mode switch, the gun select switch, and the ammunition select switch, (b) laying the GPS or GAS sight reticle on the target, (c) using the daylight channel or thermal mode, (d) tracking moving targets, (e) using the laser rangefinder to determine target range, (f) firing on targets in response to fire commands, and (g) adjusting fire.

Strategy for Training

According to the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990), VIGS is the first gunnery device to be used during the gunnery cycle. This macrostrategy specifies that VIGS is to be used 1 hr during each weekend drill and 1 hr before each training session on M-COFT during each of six additional training assemblies.

Research Literature

Research on the training effectiveness of VIGS is summarized below. Both the prototypes and the final version of VIGS have been used for this research, and the summary includes research outcomes based on prototypes for the M60-series of tanks as well as for the M1 tank. None of the reviewed literature dealt with the issue of skill retention; consequently, that section is omitted for this device.

Acquisition

Research findings. Three experiments have dealt with the acquisition of gunnery skills on VIGS. Hoffman and Melching (1984) performed two experiments using the M60A1 prototype. The first experiment was conducted using three groups of officers enrolled in the Armor Officer Basic (AOB) course at Fort Knox. One group of AOB students received almost 2 hrs of training on the M60A1 prototype in addition to their normal gunnery training; the second group received 1 hr of additional training on the prototype; and the third group (a control group) received no additional training on the prototype. Students in all three groups showed an improvement in performance from a pretest on the M60A1 prototype to a posttest on the device. Analysis of covariance was used to correct for differences in pretest scores. Significant group effects were obtained for three of the seven performance measures: announcing "identified," announcing "on the way," and overall posttest score on the device. In all cases, the groups that were trained on the M60A1 prototype of VIGS scored higher on the posttest than the control group. Thus, Hoffman and Melching found some evidence that performance on the prototype improves as a result of practice.

Hoffman and Melching (1984) used students in Basic Armor Training in their second experiment. The second experiment was similar to their first one except that three different sets of engagements were used for testing performance on the M60A1 prototype of VIGS: (a) engagements that were included in both the pretest and posttest as well as in training; (b) engagements that were included in both the pretest and posttest, but not in training; and (c) engagements that were included only in the posttest. Significant pretest-posttest improvements were obtained on all seven performance measures for the engagements that were used for training. The improvements on two of seven performance measures (engagement score and secs to complete the engagement), however, were significantly greater for the students trained on the VIGS prototype than for students in the control group. When analysis of covariance was used to control for group differences in pretest scores, significant group differences were also obtained for a third performance measure (announcing "on the way"). On engagements that were included on both the pretest and posttest but not in training, there were significant improvements from pretest to posttest on five of six criterion measures (announcing "identified," announcing "on the way," engagement score, secs to complete the engagement, and rounds fired, but not target hits). Hoffman and Melching again used analysis of covariance to control for pretest differences. Significant group differences on the posttest were obtained on four of the six performance measures (announcing "on the way," engagement score, secs to complete engagement, and hits). Finally, on engagements that were administered only during the posttest, significant differences between groups were found on two of the six performance measures (score and secs to complete the engagement) with performance being better for the groups trained on the VIGS prototype than for the control group. Thus, Hoffman and Melching found evidence in both of their experiments that training on the VIGS prototype leads to acquisition of gunnery skills (as measured by VIGS). They note, however, that these improvements appear to be the result of improvements in speed rather than accuracy. Students who practiced on the M60A1 prototype were faster at hitting the targets and therefore had higher engagement scores. They did not appear to be more accurate, however, as indicated by the failure to find differences between groups in number of rounds used or average miss scores.

Witmer (1988) conducted research on VIGS using the M1 prototype. The primary purpose of the research was to determine if skills learned on the VIGS prototype transferred to U-COFT and vice versa. Experimental participants were soldiers assigned to M60A3 tanks. Half of the soldiers first conducted two sets of 27 engagements (a total of 54 engagements) on the VIGS prototype and then conducted two similar sets of 27 engagements on U-COFT. The other half of the soldiers conducted the engagements first on U-COFT and then on the VIGS prototype. Analyses of performance data revealed that performance improved significantly from the first set of 27 engagements to the second set. The amount of improvement was smaller on the VIGS prototype than on U-COFT, however. Witmer surmised that performance improved less on the VIGS prototype because the engagements were less difficult on VIGS and therefore initial performance levels were higher. Witmer also compared performance on the first set of 27 engagements to performance on the second set of 27 engagements on VIGS for soldiers who had not yet trained on U-COFT. He found a significant improvement in performance, but only when he increased the degrees of freedom in the error term by decreasing the number of performance measures.

Turnage and Bliss (1989) conducted a transfer experiment in which college students were first trained on both TopGun and the ECC version of VIGS and then tested on I-COFT. The design of this experiment is outlined in Table 2. As shown in this table, half of the students receiving training on the two devices were trained first on VIGS; the other half were trained first on TopGun. A control group was tested on I-COFT without any prior training on either VIGS or TopGun. The students trained on VIGS and TopGun received four trials of training on each device. Each trial of training on VIGS consisted of 41 target engagements. A significant main effect for trials was obtained for five of the six performance measures obtained on VIGS (time to fire, time to kill, elevation error, hit percentage, and performance score). Azimuth error was the only performance score whose analysis failed to result in a significant main effect for trials.

Conclusions. The results of all three experiments support the conclusion that training on VIGS leads to improvement in gunnery skills. Although Turnage and Bliss (1989) and Witmer (1988) found improvements in both speed and accuracy of performance, Hoffman and Melching (1984) found an improvement only in speed. The discrepancy in the results may have been due to the additional gunnery training received by the soldiers in the research by Hoffman and Melching. The experimental participants used by Hoffman and Melching were enlisted men undergoing Basic Armor Training and officers attending Armor Officer Basic training. In contrast, the participants used by

Table 2

Outline of Research Design Used by Turnage and Bliss (1989)

Groups	Training Sessions 1	 2	Transfer Test
TopGun First	TopGun	VIGS	I-COFT
VIGS First	VIGS	TopGun	I-COFT
Control	--	--	I-COFT

Note. TopGun training sessions comprised four blocks of 36 engagements each, whereas VIGS sessions comprised four blocks of 41 engagements each. The transfer test consisted of six different I-COFT exercises consisting of 10 engagements each.

Turnage and Bliss were college students and those used by Witmer were soldiers assigned to M60A3 armor units. It is possible that the additional gunnery training received by the soldiers who participated in Hoffman and Melching's research may have masked any effects of VIGS training on accuracy of gunnery performance but not on speed.

Prediction of Performance

Research findings. Witmer (1988) correlated eight different performance measures obtained on the M1 prototype of VIGS with the same performance measures obtained on U-COFT. Three of the four correlations involving accuracy measures--hit percentage (r = .50), first round hit percentage (r = .58), and elevation aiming error (r = .52)--were significant, but none of the correlations involving speed were significant. Witmer concluded that gunners who shoot accurately on the VIGS prototype also shoot accurately on U-COFT.

Turnage and Bliss (1989) correlated six measures of performance obtained from college students being trained on the ECC version of VIGS with the same performance measures obtained from the same students on TopGun. None of the correlations were significant indicating the performance on VIGS cannot predict performance on TopGun and vice versa. This finding is unexpected because both devices are designed to train basic gunnery performance. Turnage and Bliss hypothesized that their failure to find a significant relationship between the two sets of measures could be explained by the lack of reliable performance measures. The reliabilities of the performance measures obtained on the VIGS were particularly low, ranging from .18 to.42. Turnage and Bliss also correlated five performance measures obtained from students being trained on VIGS with the same performance measures obtained from the same students on I-COFT. Correlations on three of the five performance measures (azimuth error, target acquisition error, and reticle aim score) were significant and ranged from .38 to .56, suggesting that performance on I-COFT can be predicted from performance on VIGS.

Conclusions. The results obtained from these two experiments suggest that performance on the COFT, but not TopGun, can be predicted from performance on VIGS. From his results, Witmer (1988) concluded that the predictive relation between VIGS and U-COFT held for accuracy but not for speed measures. He argued that the lack of correlation between speed measures was due to the additional error variance associated with the TC's contribution to speed of performance on U-COFT. (Implicit in this argument is that the TC has little or no effect on the gunner's accuracy on U-COFT.) On the other hand, Turnage and Bliss (1989) found that I-COFT reticle aim score correlated with VIGS performance. Because reticle aim score is a composite of both time (time to fire the first round and time to kill) and accuracy (magnitude of aiming error), this finding suggests that speed measures derived from VIGS and I-COFT may be correlated. If so, this would not contradict Witmer's interpretation, because the I-COFT uses a "synthetic" TC, thereby reducing error variance due to TC/gunner interactions. On the other hand, Hart et al. (1990) found the opposite relationship between TopGun and M-COFT with speed measures displaying larger correlations than accuracy measures. Witmer's interpretation runs counter to the findings of Hart et al., because, like the U-COFT, the M-COFT has no provision for a "synthetic" TC; consequently, Hart et al. used humans (two instructor/ operators) to play the role of TC. Clearly, research is needed to clarify the nature of the relationship between performance on the COFT and performance on the two gunnery part-task trainers, VIGS and TopGun.

Transfer of Training

Research findings. Hoffman and Melching (1984) examined the effects of training on the M60A1 version of VIGS on dry-fire performance using actual tanks. Students in the Advanced Officer Basic class received, in addition to their normal gunnery training, either 1 hr of training on the VIGS prototype, almost 2 hrs of training on the prototype, or no training at all on the prototype. Multivariate analyses of variance failed to yield a significant group effect on data obtained from these students. Univariate analyses of variance revealed a significant group difference on one of nine dry-fire performance measures--first round optimum lead. However, mean differences on this measure were not as predicted. The students who received 1 hr of training on the M60A1 prototype of VIGS had more accurate leads than students with 2 hrs of training or students receiving no training on the device at all. Using entry-level soldiers enrolled in Basic Armor Training, Hoffman and Melching (Experiment 2) failed to find an effect due to training on the M60A1 prototype for either dry-fire performance or live-fire performance on Table VI. In sum, they found no evidence that training on the M60A1 prototype transferred to performance on actual tanks.

Boldovici (1986) conducted an experiment in which soldiers were given 2 hrs of gunnery training on the M60A3 prototype of VIGS or 1 hr on the Wiley Burst-on-Target Trainer in addition to their conventional gunnery training. Soldiers in a control group received only conventional gunnery training. All soldiers were tested on actual tanks using both dry and live fire. The research design for this experiment is shown in Table 3. Hoffman (1988) analyzed Boldovici's data and found that soldiers who trained on the

Table 3

Outline of Research Design Used by Boldovici (1986)

Groups	Training Events 1	Training Events 2	Transfer Test
VIGS	CONV	VIGS	Tank
WILEY	CONV + 1 hr	WILEY	Tank
CONV	CONV	--	Tank

Note. All groups received the conventional (CONV) gunnery training as part of Basic Armor Training. VIGS training comprised a 2-hr block wherein soldiers fired 90-120 engagements each. Wiley training was only a 1-hr session plus an additional hr of CONV. The transfer test comprised 15 live-fire and 15 dry-fire engagements using the actual tank.

M60A3 prototype of VIGS had faster opening times on the dry-fire exercises than soldiers trained on the Wiley Burst-on-Target Device or those in the control group. Hoffman also found that there were no differences between the groups on accuracy measures from dry firing or on any of the live-fire measures. Boldovici observed that soldiers trained on the VIGS prototype made far fewer procedural errors (failure to turn on main gun, failure to lase, and failure to index correct ammunition) on the dry-fire engagements than soldiers trained on the Wiley Burst-on-Target Trainer or the control group. Boldovici also observed that soldiers trained on the VIGS prototype engaged targets faster and were more efficient, that is, they hit the targets faster.

Witmer (1988, described earlier) found no evidence of transfer of training from the M1 prototype of VIGS to U-COFT. Inspection of mean differences showed a slight advantage in all U-COFT performance measures for the group that was pretrained on VIGS. Nevertheless, statistical tests of the data failed to reveal any reliable differences.

Turnage and Bliss (1989) studied transfer of training from both M1 VIGS and TopGun to I-COFT. As shown in Table 2 (in previous section on acquisition), half of the students in their experimental groups were trained first on the ECC version of the M1 VIGS, and the other half were trained first on TopGun. After being trained on both VIGS and TopGun, the students were trained and tested on I-COFT. A control group was trained and tested on I-COFT without prior training on either VIGS or TopGun. Performance scores obtained on TopGun were analyzed to determine if training on VIGS transferred to TopGun. Significant group effects were obtained for five of the six performance scores (time to fire, time to kill, azimuth error, hit percentage, and performance score). The group that received prior training on VIGS performed better than the group that had not received this prior training. Combined training on VIGS and TopGun was found to result in improved performance on three I-COFT criterion measures (target acquisition error, reticle aim grade, and hit percentage), but not on two others (time to fire and time to kill). No differences in I-COFT performance were found due to the order in which VIGS and TopGun training was conducted.

It should be noted that training on VIGS led to an improvement on TopGun despite the lack of significant correlations between performance on the two devices. Although these findings appear to be contradictory, the discrepancy may be due to differences in the importance of test reliability in transfer versus correlational research. Turnage and Bliss (1989) hypothesized that the failure to obtain significant correlations between the devices was due to the low reliability of performance measures, particularly those obtained on VIGS. Although reliable performance measures are generally assumed to be necessary to demonstrate transfer, Hoffman, Fotouhi, Meade, and Blacksten (1990) have shown that experimental power is more strongly influenced by sample size than by test reliability. Thus, despite low reliabilities, the sample size in the experiment by Turnage and Bliss (n = 20 per group) provided sufficient power to detect a significant transfer effect from VIGS to TopGun. On the other hand, low reliability will have a greater impact on detecting correlations. The sample used by Turnage and Bliss, which was adequate for detecting transfer, may have been too small for detecting relationships between performance on the two devices.

The experiments dealing with the transfer of skills from VIGS to other devices or to actual tanks yielded results that were contradictory. The discrepancy between the results obtained by Boldovici (1986) and those obtained by Hoffman and Melching (1984) may have been due to differences in targets that were employed (R. G. Hoffman, personal communication, August 23, 1990). Hoffman and Melching, who found no evidence of transfer, used jeeps and armored personnel carriers as targets, whereas Boldovici, who did find evidence of transfer, used target panels. The jeeps and armored personnel carriers were harder to detect than the panels, and they were harder to hit because they moved at a much higher rate of speed. Hoffman and Melching may not have found any evidence of transfer during their dry-fire test because target acquisition time was a major component of their time measures and because the gunnery task may have been too difficult. When examined together, the results of the two experiments suggest that VIGS may not be an effective device for training target acquisition or for attaining the advanced skill levels required for hitting rapidly moving targets. It may be adequate, however, for attaining the more elementary skill levels required for hitting slowly moving targets.

The two experiments that examined transfer to other devices were inconclusive. Witmer (1988) found no evidence that training on the M1 prototype of VIGS improved performance on U-COFT. Turnage and Bliss (1989), on the other hand, found that training on the M1 VIGS resulted in improved performance on TopGun. The results of these experiments may simply indicate that the skills trained on VIGS transfer to TopGun but not to U-COFT. On the other hand, the discrepancy in the results may have been due to differences in the experimental participants used in the research. Turnage and Bliss used college students, whereas Witmer used soldiers who were assigned to M60A3 tanks. It is possible that the soldiers used by Witmer were sufficiently experienced in tank gunnery that they may not have benefitted from additional practice on VIGS. On the other hand, the college students used by Turnage and

Bliss may have benefitted from their training on VIGS because they had no previous experience with tank gunnery.

Turnage and Bliss (1989) also found that combined training on VIGS and TopGun resulted in improved performance on I-COFT. Because Turnage and Bliss did not use a VIGS-only training condition, the effects of training on VIGS cannot be separated from the effects of training on TopGun.

Conclusions. In summary, the literature suggests that training on VIGS, under certain circumstances, transfers to other devices and to the tank itself. VIGS appears to train procedural aspects of gunnery and to train speed rather than accuracy during gunnery engagements. Its effectiveness appears to be greatest among trainees with little or no previous gunnery experience. If so, VIGS may be an effective device for use during skill acquisition, but not during sustainment. Although these conclusions are highly speculative, they are clearly testable.

M1 M-COFT

The M1 M-COFT is a high fidelity, computer-based armor gunnery simulator that presents a full range of target engagement situations to a TC and gunner placed in simulated crew stations. During the course of training exercises on M-COFT, TC/gunner teams are instructed to follow the actual engagement procedures necessary to produce "kills" of computer-generated target images. M-COFT, a direct offspring of the Unit Conduct-of-Fire Trainer (U-COFT), was developed to accommodate the distinctive training needs of Reserve Component armor units, primarily the National Guard. Training demands for the National Guard are unique due to the geographical dispersion of company-sized elements from the rest of the battalion. Consequently, the M-COFT is mounted on a special flatbed truck so that it can be moved from site to site.

Military/Technical Literature

Types of Skills Trained

M-COFT was designed to train and sustain critical skills required of TCs and gunners during tank gunnery engagements. The specific gunnery skills trained on M-COFT, as outlined in the M1 Unit Conduct-of-Fire Trainer (U-COFT) Training Device Support Package, FC 17-12-7-1 (U.S. Army Armor Center, 1985) are listed in Table 4. A unique function of M-COFT is that it provides training in gunnery skills under a number of degraded conditions. M-COFT has four types of built-in programs for training tank gunnery skills, each of which supports a different training purpose. These purposes are, in descending order of importance, (a) to sustain year-round gunnery performance of experienced TCs and gunners, (b) to cross train loaders and drivers in gunner duties and gunners in TC duties, (c) to transition train armor personnel to the M1 or M1A1 tank, and (d) to provide nonarmor personnel (cooks, mechanics, etc.) with basic gunnery training in order that they may serve as battlefield replacements (U.S. Army Armor Center, 1985).

Table 4

Gunner and Tank Commander Skills Trained on the M1 M-COFT

Gunner Skills	Tank Commander Skills
Target acquisition [a]	Target acquisition [a]
Target identification [a]	Target identification [a]
Range estimation [a]	Range estimation [a]
Reticle lay	Initial fire commands
Tracking	Directions to driver [b]
Lasing	Lay of gun for direction
Firing	Target hand over
Target effect assessment [a]	Target effect assessment [a]
Adjustment of fire	Subsequent fire commands
Announcements	Announcements
Switch positioning and equipment adjustments	Engage from the commander's position (coax, main gun, cal .50)
Use of computer for manual input of data	Boresighting and zeroing of the caliber .50 machine gun

[a] The practice of these skills on M-COFT is different than the practice of these skills in the real world due to the computer-generated imagery used in the visual scenes. [b] The TC can only give basic driver commands (e.g., "DRIVER--MOVE OUT," "DRIVER--STOP"); he cannot affect the path of the tank.

Strategy for Training

The current issue plan calls for the fielding of one M-COFT per Reserve Component battalion. As of December 1989, seven M1 and 22 M60A3 M-COFTs had been fielded by the manufacturer, Elbit Computers, Ltd., with additional devices scheduled for distribution starting in November 1990. In the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990), the use of M-COFT replaces Tables I and II.

The macrostrategy calls for ARNG tank crews conducting sustainment training on M-COFT to spend two hrs during every other weekend drill, 2 hrs during six bimonthly additional training assemblies, and 2 hrs during annual training on M-COFT. This amounts to 13 sessions, or 26 hrs, of sustainment training per year. The exact schedule of training on M-COFT depends upon the crews progress in the training matrix. Their progress, in turn, can be described generally in terms of the crew's advancement through six groups (Reticle Aim Groups 1-6) of increasingly difficult exercises. The progression goals for TC/gunner pairs training on M-COFT are summarized in Table 5. The M-COFT training matrix is described in more detail in the Appendix.

Table 5

M-COFT Progression Goals

Time on M-COFT	Expected Proficiency Level
New equipment training or annual training	Complete reticle aim group 2
8 to 12 months	Complete reticle aim group 3
10 to 14 months	Complete reticle aim group 4
12 to 18 months	Complete reticle aim group 5
16 to 24 months	Certification

The four general principles for scheduling M-COFT may be summarized as follows:

1. The proficiency level of new TC/gunner pairs as established in accordance with M1 Unit Conduct-of-Fire Trainer (U-COFT) Training Device Support Package, FC 17-12-7-1, (U.S. Army Armor Center, 1985), is determined partly by a consideration of the TC/gunner in other media and how they perform on standard U-COFT exercises.

2. New and beginning level TC/gunner pairs receive 10 to 15 hrs of intense training, preferably during annual training, until they have completed Reticle Aim Group 2 of the M-COFT TC/gunner matrix. Thereafter, the pairs receive 4 to 6 hrs on the device every other month until certification is achieved. Certified TC/gunner crews are then scheduled for 2 hrs every other month to sustain their certification.

3. Priority in scheduling training on M-COFT goes to TC/gunner pairs that have not yet completed Reticle Aim Group 3 of the TC/gunner matrix.

4. TCs and gunners transitioning to the M1 tank receive 10 hrs on M-COFT during the new equipment training (NET) period. At the conclusion of the NET period, the crew should have completed Reticle Aim Group 2 of the TC/gunner matrix.

The U-COFT was selected as the primary device for training M1 gunnery skills in Hoffman and Morrison's (1988) strategy and as the preferred device/medium of instruction for eight of the 19 instructional units. The topics for which U-COFT was selected as the preferred device were (a) practice on basic TC skills related to precision gunnery, (b) TC/gunner practice in coordinating skills related to precision gunnery, (c) practice on skills related to coaxial machine gun engagements, (d) practice on degraded modes of gunnery involving battlesight, GAS, emergency mode, and manual mode engagements, (e) practice on techniques for adjusting fire, (f) practice in recognizing and reacting to multiple returns from the LRF, (g) practice on skills related to simultaneous engagements, and (h) practice on skills related to multiple engagements.

Research Literature

Little research has been performed on the M-COFT device per se. As noted above, the M-COFT is not functionally different from U-COFT. Thus, the substantial literature regarding the training effectiveness of U-COFT is directly applicable to M-COFT and is reviewed in the present section. This section also includes results from research on another related device: the Institutional Conduct-of-Fire Trainer (I-COFT). The I-COFT has all the features of the other two versions of COFT plus an additional capability: a "synthetic" TC feature that simulates the responses of the commander in a gunnery engagement. This feature has implications for the standardization of TC/gunner interaction for evaluating gunner skills on the COFT.

Acquisition

Research findings. Most of the research on within-device changes on the U-COFT has not focused on acquisition effects per se. For instance, the purpose of the research by Graham (1986) was to determine the reliability of U-COFT performance measures. (His correlational findings are discussed below again in the section on Prediction.) To test individual gunner skills, Graham used three different TCs: a senior NCO, a junior NCO, and a civilian who had extensive experience with the U-COFT. Despite attempts to standardize the actions of the TCs, significant differences were obtained between gunners who were tested with the three TCs: Gunner performance was best when paired with the U-COFT experienced civilian and worst when paired with the junior NCO; gunner performance with the senior NCO fell between those two points. Furthermore, the differences changed over the 12 sessions (42 hrs) required to test all the gunners. Performance of the gunners paired with the civilian TC systematically increased across the first twenty hrs of training and showed stability thereafter. In contrast, gunner performance with the junior NCO increased across all test sessions with no evidence of stabilization. These data clearly showed that TC skill acquisition can be manifested in the gunner's performance on U-COFT.

Black and Abel (1987) were primarily interested in determining the relationship between performance on U-COFT and performance in the Canadian Army Trophy (CAT) live-fire gunnery competition. (These correlational results are described again in section on Prediction.) With respect to within-device acquisition effects, Black and Abel tested 14 crews (i.e., TC/gunner combinations) who were specially selected for the CAT competition and who remained intact throughout the training and the CAT competition. These crews were tested four times on a standardized U-COFT exercise. These tests occurred immediately before and after each of two different periods of U-COFT training sessions. During the first period, TC/gunners received seven training sessions consisting of "standard" U-COFT training exercises, whereas during the second period the participants received seven sessions of specially prepared exercises wherein the U-COFT visual scene was designed to replicate that of the CAT range. Pretest/posttest comparisons showed significant gains in both the speed and accuracy of gunnery performance for both the first and the second training periods.

As reviewed earlier, Witmer (1988) looked at U-COFT acquisition in the context of measuring transfer to and from VIGS. With regard to acquisition effects, he compared performance on the U-COFT (as well as the VIGS) between two blocks of 27 engagements finding that gains in both speed and accuracy of performance were greater with U-COFT than with VIGS. Witmer speculated that these differences were due to the fact that gunnery on the U-COFT was much more difficult than on the VIGS. Consequently, performance on the U-COFT starts low and improves greatly with practice, whereas performance on the VIGS starts at a high level leaving much less room for improvement.

More recently, Morrison and Walker (1990) were interested in assessing the effects of mental practice on initial gunnery performance. Whereas Black and Abel (1987) examined the within-U-COFT performance gains for a group of highly selected, experienced TC/gunner combinations, Morrison and Walker examined the effects of practice on I-COFT for entry level trainees firing as individual gunners. Eighty-eight basic trainees were pretested and posttested on a standardized I-COFT exercise (E-1). Between the pretest and posttest, a control group of trainees received approximately 7 hrs of training on the I-COFT. The experimental group received the same standard I-COFT training in addition to instructions to mentally practice gunnery engagements before each I-COFT session and during breaks in training. Whereas the experiment failed to reveal an effect for mental practice, it did indicate marked improvements in the speed and accuracy of performance between the two performance tests.

In contrast to the previous experiments in which skill acquisition was a side issue, Graham and Smith's (1990) recent research focused on the phenomenon of skill acquisition on the I-COFT. Two types of soldiers differing in gunnery skill levels were tested: 18 participants in the Excellence in Armor (EIA) program, who were high ability entry-level soldiers selected to receive additional training after completing initial entry training in armor, and 10 senior non-commissioned officers (NCOs), who served as gunnery instructors in the Armor School. The EIA soldiers initially received 20 hrs of gunnery instruction on the I-COFT as part of initial entry training. At the start of EIA training, these soldiers were pretested using a standardized I-COFT test consisting of three scored exercises made up of either (a) single stationary targets at long ranges, (b) multiple stationary targets at short ranges, or (c) single moving targets at long range. They then received 14 additional hrs of I-COFT training, and were subsequently posttested using the same I-COFT test as on the pretest. In contrast, the Gunnery Instructors were simply tested twice: Half were tested first on the same I-COFT test that EIA soldiers received followed by a parallel form of the test but administered on U-COFT,[2] whereas the other half were tested in the reverse order.

Graham and Smith's (1990) research is notable for the level of detailed gunnery performance data that they obtained and their unique analyses of those data. In addition to performance data automatically collected by I/U-COFT

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[2] A secondary issue addressed by Graham and Smith (1990) concerned differences between performance on the I-COFT and the U-COFT. This issue arose from the concern that the I-COFT's synthetic TC responded too slowly, thereby adversely affecting the performance of experienced gunners. However, the results failed to show any important differences due to the performance test media.

systems, they also obtained video recordings of the gunner's sight picture taken from the instructor/operator's station and audio recordings of all verbal commands. The development of skill was examined by two types of comparisons. The first type of comparison examined two contrasts of overall differences: (a) pretest vs. posttest performance within the EIA group, and (b) posttest performance of the EIA group vs. performance of the NCO group on the I-COFT test. The second type of comparison concerned contrasts of skill levels within groups. These skill levels were defined by hit rate (probability of hit divided by opening time) with EIA soldiers divided into low, middle, and high skills groups and NCOs divided into low and high groups. Error analyses were also performed to examine the incidence of different types of aiming errors, tracking errors, and procedural errors. In addition, a global measure of tracking goodness was obtained.

The overall performance results are summarized in Table 6. As can be seen, all measures showed significant improvements in performance in the EIA group from pretest to posttest. The results also revealed some important differences between measures of performance accuracy and measures of performance speed. With respect to measures of performance accuracy, Graham and Smith (1990) found no differences between EIA group and instructors for short-range stationary targets. The researchers interpreted this finding as indicating that skills related to accuracy in these engagements develop quickly. Analysis of target misses indicated that they were accounted for by soldier's aiming either too high or too low. For moving targets, the NCOs were more accurate than EIA soldiers, suggesting that these skills grow more slowly. The principle error committed by EIAs was that of tracking too slowly. With respect to measures of performance speed, Graham and Smith found differences between EIAs and NCOs and across skill levels. Thus, the researchers concluded that skills related to speed grow more slowly than those related to accuracy. Detailed analyses of the components of the overall speed measure (opening time) indicated EIA/NCO differences were accounted for by the interval from the gunner's first getting the reticle on target to the point where he lases to the target for range. The authors interpreted this interval as measuring controlled tracking skills. Finally, the researchers showed that the global measure of tracking was successful in predicting speed and accuracy of gunnery performance. Graham and Smith concluded that "...taken together, the various analyses showed that tracking skills largely accounted for speed and accuracy on both stationary and moving targets" (p. 34).

Conclusions. The evidence from these experiments clearly suggests that performance of both experienced and inexperienced tankers (both gunners and TCs) improves dramatically with practice. Graham and Smith's (1990) research deserves special attention in that it specifically addressed the phenomenon of skill acquisition. Their detailed examination of acquisition effects on the I-COFT stands as an example of how research can provide information about the learning on the device itself. Furthermore, given the high fidelity of U/I/M-COFT trainers, such device-based research can provide valuable information about gunnery skill acquisition effects in general. National Guardsmen, who have had little previous experience with U/I/M-COFTs, provide ideal participants for this sort of research.

Table 6

Summary of Findings from Graham and Smith (1990)

Type of Engagement Performance Measure	Statistical Comparisons Pretest/Posttest[a]	 Posttest/NCO[b]
Single Long-Range Stationary Targets		
Percentage of Total Hits	Yes	No
Percentage of First-Round Hits	Yes	No
Opening Time	Yes	Yes
Azimuth Error	Yes	No
Elevation Error	Yes	No
Multiple Short-Range Stationary Targets		
Percentage of Total Hits	Yes	No
Percentage of First-Round Hits	Yes	No
Opening Time (First Target)	Yes	Yes
Opening Time (Second Target)	Yes	Yes
Azimuth Error	Yes	No
Elevation Error	Yes	No
Single Long-Range Moving Targets		
Percentage of Total Hits	Yes	Yes
Percentage of First-Round Hits	Yes	Yes
Opening Time	Yes	Yes
Azimuth Error	Yes	Yes
Elevation Error	Yes	No

Note. An entry of "yes" indicates that the cross-referenced comparison was in the expected direction and significant at the conventional .05 level; "no" indicates that the comparison was not significant. The table is adapted from Graham and Smith (1990).

[a] Pretest/posttest compared mean performance of EIA soldiers before and after receiving 14 hrs of additional instruction. [b] Posttest/NCO compared gunnery performance of the EIA soldiers to that of the NCOs as tested on the I-COFT.

Retention

Research findings. A report prepared in 1984 by the General Electric Company, Training Matrix Validation and Verification Test for the M1 Unit-Conduct of Fire Trainers (U-COFT) (reported in Boldovici, Bessemer, & Haggard, 1985), provided some of the earliest empirical data on skill retention on the U-COFT. In the validation and verification report, two major issues were examined: (a) the effects of sustaining gunnery performance of five M1-qualified, TC/gunner pairs, and (b) the effects of transition training of five TC/gunner pairs who were qualified on tanks other than the M1. Both groups were trained on the device for about three weeks, and then posttested using a U-COFT-based performance test. Two of the five pairs who received sustainment training were retested after 10 weeks. The results showed a "definite proficiency loss." Another two TC/gunner pairs who had been transition trained using the U-COFT were retested after 3 weeks showing no loss in proficiency. The data were used to make an argument for retraining crews on U-COFT between every 3-10 weeks. Boldovici et al. objected to the conclusions on two grounds: (a) the results were based on extremely small sample sizes, and (b) the transition group practiced 33% longer (40 vs. 30 hrs) and performed approximately 20% more exercises (174 vs. 143) than the sustainment group. As a result, the reader cannot determine whether the transition group's superiority is due to shorter retention interval or greater practice.

One of the many issues addressed by Hughes, Butler, Sterling, and Berglund (1987) in their Post Fielding Training Effectiveness Analysis (PFTEA) was the effect of U-COFT on the retention of live-fire gunnery skills. Six battalions participated in the experiment: Five battalions had received the M1 U-COFT nine months prior to the experiment, while the sixth comparison battalion received theirs after the experiment. One month after the initiation of the research, all six battalions were tested on Table VIII. Three months later, a stratified sample of 15 crews from each battalion fired a special Table VIII without firing either of the two usual prequalification tables (Tables VI and VII). With respect to the retention findings, the results indicated that, for the non-U-COFT trained group, about half of the crews increased in their Table VIII scores from test to retest while the other half decreased in score. For the U-COFT trained group, there was a sharp division between those who (at retest) were still in Reticle Aim Groups 1-2 and those in Groups 3-6. The majority of those who were still in the earlier matrix exercises showed a drop in Table VIII score, whereas the majority of those who had progressed to Reticle Aim Group 3 and beyond showed gains in Table VIII scores. Hughes et al. used these results to argue that simple exposure to U-COFT does not ensure skill retention; the crews must use the device and make progress in the matrix. Another interpretation of these findings is that crews who complete more U-COFT exercises and progress farther in the matrix are highly motivated personnel who are apt to gain more from training, or are those who are simply more proficient in gunnery. Thus, their superior gains in performance may be due as much to personal characteristics of the crews as to the effectiveness of U-COFT per se.

Conclusions. The PFTEA (Hughes et al., 1987) provided some evidence that U-COFT sustains live-fire gunnery performance. This generalization is somewhat weakened by their allowing crews to determine the amounts of sustainment training that occurs during the retention interval. Research should be designed to experimentally control not only the length of the retention interval but the amount of retraining that occurs between initial training and retention testing. If live-fire testing were prohibitively expensive, data on U-COFT performance alone would be useful. These performance data could be used to plan a sustainment training strategy that is based on actual retention performance rather than the subjective estimates of skill losses that were reported in the U-COFT validation and verification report.

Prediction

Two types of experiments have been performed to examine the relationship between performance on U-COFT and performance on live-fire gunnery. The first type examines the correlation between live-fire gunnery performance and performance on some special test of the U-COFT proficiency, whereas the second type examines the correlation between live-fire performance and the progress that crews have made in the U-COFT training matrix. The latter sort of U-COFT variable is sometimes referred to as U-COFT "achievement." These two types of experiments are reviewed separately below.

Proficiency on special U-COFT tests. Black and Graham (1987) offered strong a priori arguments based essentially on fidelity that U-COFT performance should predict live-fire combat performance. However, the findings have been unimpressive. For instance, results from the Training Developments Study (TDS) conducted during Operational Test (OT) III of the M1 U-COFT (Butler, Reynolds, Kroh, & Thorne, 1982; Kuma & McConville, 1982) indicated no correlation between performance on a standardized U-COFT exercise administered after training and performance on a live-fire gunnery exercise. In their review of U.S. training for the Canadian Army Trophy (CAT), Black and Abel (1987) found a few significant correlations between performance on a standardized U-COFT test delivered after U-COFT training and subsequent CAT performance. However, the significant correlations were confined to only speed measures of performance; that is, none of the accuracy measures correlated between U-COFT and live-fire performance were significant. Hughes, et al. (1987) also attempted to relate performance on a 10-15 min U-COFT test consisting of 11 engagements selected to mirror Table VIII and live-fire gunnery performance on Table VIII administered approximately one month after the special U-COFT test. Despite relatively large samples (235 crews), these researchers were not able to demonstrate a single significant correlation and concluded that the relationships were "practically zero" (p. 15).

One reason for the lack of correlations in this first type of research is the unreliability of U-COFT performance measures. Graham (1986) developed a standardized M1 U-COFT test that consisted of 8 engagements designed to mirror Table VIII requirements and that required approximately 15-20 mins to administer. As discussed previously, this test was designed to assess gunner skills only and therefore required a well-practiced confederate to play the role of the TC. Graham measured test/retest reliability for nine measures of performance by administering the test twice to 32 M60A3 tankers with a 10-min rest period in between the two test administrations. Graham concluded that U-COFT test/retest reliability was adequate based on the findings that "...the reliability for six of the U-COFT measures was greater than .70, and for three of those measures, at least .80" (p. 6). DuBois (1987) sought to replicate Graham's design while improving it in several respects. For instance, he tested more soldiers than did Graham (165), all of whom were M1 entry-level tankers with no U-COFT experience. DuBois's data indicated significant test/retest correlations, but they were lower in magnitude than those found in Graham's experiment: Only two of the nine measures exceeded .70 and most were in the .20 to .50 range. DuBois speculated that one reason for his lower correlations was that his soldiers started at a lower level on the first test and showed much larger gains in performance from test to retest than did Graham's soldiers. These findings again emphasize the importance of studying the acquisition characteristics of U-COFT in detail. Although Graham and Smith's (1990) research provided a step in that direction, future research should provide measures of the stability of performance such as within-crew variances and trial-to-trial correlations. Such data can then be used to estimate the number of repeated exercises required to obtain stable estimates of performance.

Another reason for the lack of correlations between such special tests and live-fire gunnery is the unreliability of live-fire gunnery. The fact that live-fire gunnery is unreliable is almost an accepted truism in gunnery research. (For a recent discussion of this topic, see Hoffman, Fotouhi, Meade, & Blacksten, 1990.) In contrast to the findings reviewed above, however, the findings discussed below indicate that a correlation between U-COFT achievement and live-fire gunnery can be detected. This suggests that there is some measurement reliability in live-fire gunnery measures, albeit minimal, that permits its prediction from another independent estimate of gunnery proficiency. Thus, unreliability of live-fire gunnery measures, although a likely contributing factor, cannot be the sole explanation for the lack of correlation between special tests and live-fire performance.

U-COFT matrix achievement. Two investigations have examined the relationship between U-COFT achievement (i.e., progress in the matrix) and live-fire gunnery. In the PFTEA (Hughes et al., 1987), five USAREUR battalions received their U-COFTs nine months prior to the evaluation. All crews were tested on live-fire gunnery using the standard Table VIII conditions. Three months after their normal Table VIII, a stratified sample of the crews fired a special Table VIII without firing the usual preceding tables (Tables VI and VII). With regard to both the initial Table VIII and the special Table VIII, the results indicated that those who had advanced farther than Reticle Aim Group 3 in the matrix at the time of the live-fire test had faster opening times in live-fire performance than those who had not; however, neither the accuracy measures nor the total score on Table VIII were significantly different between those classifications. The most striking results were those that focused on changes between the first and second Table VIII administrations: The majority of those progressing beyond Group 3 (by the time of the retest) improved in their total score on retest, whereas the ones still in Groups 1-2 worsened as indicated by the total score.

The second investigation examined U-COFT data and first run, live-fire performance data on Table VIII as provided by two groups of CONUS units who had trained with U-COFT for years (Campshure & Drucker, 1990). For the first group of units who provided data from 77 crews in two M1 armor battalions, they found significant bivariate relationships between Table VIII total score and U-COFT achievement defined either by crew Reticle Aim Level or by TC Reticle Aim Level. They found even better prediction of Table VIII total score when Reticle Aim Level was combined with time in crew or total number of exercises in a multiple regression equation. Figure 2 provides a scatterplot of these data showing the relationship between actual and predicted scores on Table VIII for regressing Reticle Aim Level and time in crew on Table VIII total score. Time in crew and total number of exercises were both weighted negatively in the regression equations, but were not significantly related to total Table VIII score in the bivariate correlations. Thus, time in crew and total number of exercises partialed out (or suppressed) that part of the reticle aim variable that was unrelated to the total score, thereby improving the predictions. The authors then used these relationships to construct

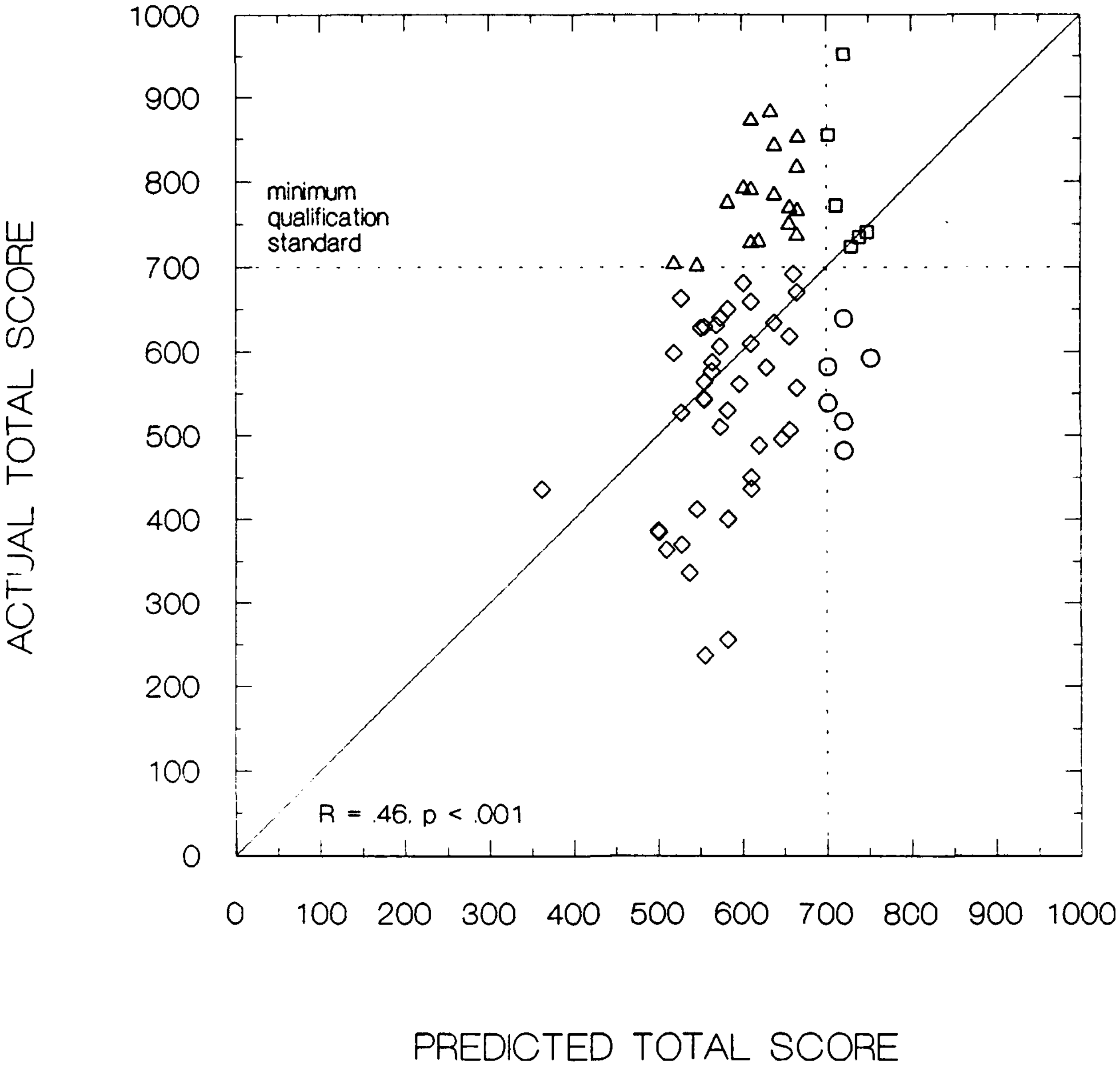

Figure 2. Actual total score plotted against a predicted total score based on crew Reticle Aim Level and time in crew. (Actual total score = average total score x 10. Predicted total score = 419.16 + [9.14 x crew reticle aim level] + [-.921 x time in crew]. Geometric shapes were used as plotting points to assist the reader in identifying the quadrant of the plot in which a point occurred.) From Campshure and Drucker (1990). Reprinted by permission.

tables for aiding the trainer to predict which crews would qualify on their first run of Table VIII based on reticle aim level and either time in crew or total number of exercises.

In an attempt to replicate these findings, Campshure and Drucker (1990) examined similar data from four additional battalions (136 crews). None of the relationships discovered in the first data set were detected in the second set, nor was the regression equation derived in the first data set successful in predicting live-fire performance in the second data set. However, these researchers noted that the units in the first data set were under severe mileage constraints limiting the amount of on-tank time that crews had to prepare for Table VIII. The units in the second data set were under no such constraints and participated in virtually unlimited on-tank preparatory exercises, particularly Table IV. Thus, U-COFT accounted for a larger proportion of gunnery training for units in the first data set than for units in the second set. In other words, the on-tank experiences of the units in the second data set may have reduced the observed relationship between U-COFT achievement and Table VIII performance.

Why is U-COFT achievement better able to predict live-fire gunnery performance than are special tests of U-COFT proficiency? One obvious reason is that matrix position is an aggregate score reflecting performance over many hrs of training on U-COFT. Thus, one would expect that an aggregated score would be more reliable than a single assessment of U-COFT performance gathered from a limited number of exercises. Another explanation of the differences in the predictive power of two types of U-COFT performance measures is that they measure distinguishably different but overlapping constructs. Performance on a U-COFT test, if sufficiently comprehensive, should provide a relatively pure measure of U-COFT proficiency. Achievement in the U-COFT matrix should also be related to U-COFT proficiency; however, it may also be related to other concepts such as perseverance of the crew to use U-COFT regularly, or even command emphasis on the use of U-COFT. It would be useful to perform research examining the intercorrelations of these two measures to estimate the degree to which they are related to each other and to other factors that potentially affect U-COFT proficiency.

Transfer

Research findings. The first research to address transfer of U-COFT to live-fire performance was the TDS for the M1 U-COFT (Butler, et al., 1982). The essential findings of this study were also reported by Kuma and McConville (1982). Experimental participants were four companies who had previously undergone M1 training in conjunction with OT III of the M1 tank. Two companies comprising 22 TC/gunner combinations were trained on a contractor-developed, proponent-reviewed U-COFT training program (the U-COFT group), whereas a third company comprising 8 TC/gunner pairs was trained on an M1-based training program developed by the proponent (the baseline group). The study was executed in three phases: pretest, training, and posttest. In both the pretest and posttest phases, crews were tested on a live-fire gunnery test, a tracking test requiring crews to use the M1 fire control system to track a moving target, a vehicle identification test, and a knowledge test on specific information about the M1. The groups also took a performance exercise that was specific to their condition: The U-COFT group took a U-COFT-based test, whereas the baseline group was tested on a gunnery test similar to the live-fire test but administered with the subcaliber Telfare device. Between pretest and posttest, the groups received training in their assigned media over a five-day period. Comparing pretest and posttest performance indicated improvements on most performance measures. Comparing differences between the two groups showed no differences in most measures. The exception was performance on the live-fire test: The baseline group improved in target acquisition, target identification, and first round times compared to the U-COFT group that did not improve. However, the two groups did not differ in their overall pass/fail rates for the live-fire test. Butler et al. attributed differences in acquisition performance to the fact that U-COFT provides practice only in closed-hatch mode whereas acquisition in the live-fire test was open-hatch. In short, except for the difference in acquisition times, results from the TDS failed to provide evidence of differential transfer between a U-COFT-based and a tank-based training program.

As M1 U-COFTs were beginning to be fielded in USAREUR, Martellaro, Thorne, Bryant, and Pierce (1985) performed a Training Effectiveness Analysis (TEA) of the system. More specifically, they examined the effects of U-COFT training and prequalification ammo use on Table VIII performance. Four companies were assigned to the research. Two of the companies were assigned to a non-U-COFT trained condition wherein crews were trained using "normal" procedures. The other two companies were assigned to a U-COFT trained group wherein crews received normal training plus 18.5 hrs of U-COFT instruction per crew scheduled over 9 days. U-COFT training occurred at the Combined Arms Training Center (CATC) in Vilseck, and live-fire performance was evaluated at Grafenwoehr with a 1-3 week gap between training and testing. Crews within the companies were further differentiated into groups having high and low allocations of ammunition on the basis of the number of live rounds fired in the prequalification exercises (Tables V and VI). The dividing point was set between 20 and 21 rounds per crew. The cutoff was calculated by subtracting 12 rounds (the proposed ammunition reductions resulting from the fielding of U-COFT) from 32 rounds (the maximum number of rounds allowed prior to Table VIII).

Results from the U-COFT TEA (Martello et al., 1985) showed that the crews firing more prequalification rounds were more accurate in scoring first-round hits and more hits per rounds fired than those firing fewer prequalification rounds. U-COFT and non-U-COFT trained groups were compared using the number of prequalification rounds as a covariate. These comparisons indicated that the U-COFT trained group showed higher percentage of first-round hits and a higher percentage of hits per round fired than the non-U-COFT trained group. To examine the interaction of these two factors, the researchers compared the U-COFT trained, low ammunition allocation condition with the non-U-COFT trained, high ammunition allocation condition. The differences were minimal leading Martellaro et al. to conclude that training on U-COFT successfully offset the reduction in ammunition. The authors were also careful to caution the reader that the results were based on unsatisfactorily small samples, and that their study should be regarded as pilot work for suggesting lines of future research.

The PFTEA (Hughes et al., 1987) followed up Martello et al.'s (1985) findings. Hughes et al. designed their study with two deficiencies of the previous two studies in mind: short training periods and small sample sizes. As described earlier, a total of six battalions (367 crews) participated in the research and five of these units were allowed nine months to use the U-COFT prior to their pregunnery evaluation on the U-COFT, and another month prior to their initial live-fire gunnery evaluation on Table VIII. As shown by the design outlined in Table 7, the five battalions were also differentiated between the two that fired a Table VI and VII prior to Table VIII (Normal ammo) and the three that fired only Table VII prior to VIII (Reduced ammo). The battalion not trained on U-COFT fired both Tables VI and VII prior to VIII. Comparisons of the five battalions who trained with U-COFT

Table 7

Outline of Research Design Used by Hughes, Butler, Sterling, and Berglund (1987)

Group	Number of Battalions	U-COFT Training	Live-Fire Training Table VI	Live-Fire Training Table VII	Test Table VIII
U-COFT trained					
Normal Ammo	2	Yes	Yes	Yes	Yes
Reduced Ammo	3	Yes	No	Yes	Yes
Non-U-COFT trained	1	No	Yes	Yes	Yes

Note. The two groups receiving live-fire training on Table VI (U-COFT trained, normal ammo and Non-U-COFT) fired an average of 12.5 more main gun rounds per crew prior to Table VIII.

versus the one who did not showed a significant difference in opening times in favor of the U-COFT trained group. The results also indicated that, as expected, the U-COFT battalions firing both prequalification tables performed best. Furthermore, the U-COFT trained battalion who fired only Table VII in the prequalification period performed better than the non-U-COFT trained battalion firing both prequalification tables. The latter finding suggested that, in accordance with the findings of Martellaro et al. (1985), U-COFT training offset the negative effects of the reduction in live-fire rounds. These performance trends were noted in the Table VIII scores and in opening times but were significant only for the latter measure.

As described earlier, Hughes et al. (1987) retested a sample of 15 crews from each of the original six battalions three months after their initial live-fire evaluation on a special Table VIII that was not preceded by prequalification Tables VI and VII. The results indicated that those in the U-COFT group who had completed 10 or fewer exercises or who had not progressed beyond Reticle Aim Group 2 performed at about the same level or a little worse than those who did not have access to U-COFT. In contrast, those crews in the U-COFT group who completed 11 or more exercises or who had progressed beyond Reticle Group 2 performed better than either of the previous groups in terms of the Table VIII score, the probability of first round hits, and opening times. However, as in the initial live-fire test, the differences were significant only for the opening time measures. The authors interpreted this finding as support of the notion that training on U-COFT sustains performance. As argued earlier, however, the process of dividing the experimental group on amount of retraining, which is defined as a correlational variable, complicates this interpretation somewhat.

Conclusions. The weight of the evidence suggests that U-COFT training positively transfers to live-fire gunnery performance. One notable difference between the latter two TEAs is that Martellaro et al. (1985) found differences in accuracy measures of performance, whereas Hughes et al. (1987) found significant differences in speed of responding only. It should be noted that Martellaro et al. only measured accuracy and total Table VIII scores and did not measure speed as a separate measure. There are certainly no a priori reasons to suspect that U-COFT is differentially effective on the speed and accuracy of live-fire.

One applied research question that is particularly important to Army training managers is the degree to which U-COFT gunnery training can substitute for live-fire gunnery training. To answer this question, more sophisticated, multi-condition transfer designs must be used instead of the simple designs used thus far. An example of a sophisticated transfer design is that used by Bickley (1980) to assess the transfer effectiveness of the AH-1 (Cobra) flight simulator to actual performance on the Cobra helicopter itself. Analogous research has not been performed in the context of U-COFT training for a number of reasons; however, three difficult technical problems are preeminent: (a) the costs and safety considerations of live-fire gunnery tests are usually prohibitive; (b) as discussed earlier, the measures obtained from live-fire gunnery performance are often unreliable; and (c) the traditional live-fire test (Table VIII) does not evaluate the full range of gunnery conditions simulated and actions trained in U-COFT. (For a detailed discussion of the development of a comprehensive gunnery test, see Hoffman et al., 1990.) Until these technical problems can be solved, this important research question cannot be addressed.

GUARD FIST I

GUARD FIST I is a computer-based training technology that presents computer-generated imagery through the sights of a static tank (i.e., dead turret, power-off mode). The device also enables the tank's controls to be used to engage the computer-generated targets much as they would be used in a live-fire engagement. As argued in the beginning of the report, although GUARD FIST I is technically a tank-appended device, it is functionally more like a computer-based device in its use of computer-generated imagery and its appropriateness to armory training. It should be noted that GUARD FIST I is a developing technology; that is, it has not yet been fielded. At the time of this report's writing (July-August 1990), a prototype of GUARD FIST I was undergoing initial user testing by the TEXCOM Armor and Engineer Board. The competitively bid contract for production of GUARD FIST I was scheduled to be awarded by December 1990.

Military/Technical Literature

Types of Skills Trained

GUARD FIST I provides crew gunnery training on a variety of main gun and coax target engagements fired from a stationary or moving platform under a variety of conditions. These conditions include selected degraded modes embodying (a) LRF failure, (b) GPS/TIS failure, (c) loss of symbology in the GPS, and (d) loss of stabilization. An important aspect of GUARD FIST I is its capability to provide training on the interactions among all four members of an armor crew.

Strategy for Training

The proposed basis of issue plan is to distribute one GUARD FIST I per National Guard company. In the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990), GUARD FIST will replace Table III and should be used in preparation for Tables IV, VI, and VII. Once fielded, armor crews from the ARNG are supposed to use GUARD FIST I for 1 hr during each of the 12 monthly Inactive Duty Training (IDT) periods and once during AT, for a total of 13 hrs per year. This macrostrategy does not specify any formal prerequisites for using GUARD FIST I.

Research Literature

There was no empirical evidence regarding the training effectiveness of GUARD FIST I at the time of the present writing (July-August 1990). Data were being collected with regard to initial user tests in the North Carolina and South Carolina National Guards, but these data were not yet available.

SIMNET

The SIMNET battle simulation is a multifaceted training technology and research testbed having several interrelated purposes. SIMNET was originally conceived as a research and development project for DARPA. Specifically, SIMNET was designed as a testbed or technology demonstration for large-scale networking of low-cost interactive combat simulators. The networking is designed to link large numbers of simulators within a single site (local area networking) and across geographically separated sites (long haul networking). The overall objective of SIMNET is to use these technologies to simulate the battlefield thereby providing practice on collective and combined arms tasks.

There are two types of SIMNET facilities serving qualitatively different functions or purposes. SIMNET-D (Developmental) facilities are designed to serve a continuing research function. SIMNET-D facilities have a limited number of simulators that can be reconfigured to test the effects of new doctrine and/or equipment. Another important function of SIMNET-D has been to specify the technical requirements of new simulators such as the Close Combat Tactical Trainer (CCTT) currently being developed for the Armor Branch. In contrast to SIMNET-D, SIMNET-T (Training) facilities have an operational training function. SIMNET-T sites are currently in transition from DARPA to Army control. SIMNET-T provides an important resource for armor collective training at the armor platoon, company, and battalion level until the CCTT can be fielded. With regard to National Guard training, one platoon-sized SIMNET is currently in place at Camp McCain, MS at a fixed site. An additional platoon-sized SIMNET system that can be moved from site to site (Mobile SIMNET) is planned for the South Carolina National Guard.

Military/Technical Literature

Types of Skills Trained

Like GUARD FIST I, SIMNET provides a full-crew interactive simulated training environment. In contrast to GUARD FIST's focus on gunnery, however, the SIMNET User's Guide (U.S. Army Armor Center, 1989) describes SIMNET's primary function as training command, control, and tactical movement skills. SIMNET is sometimes referred to as a "part-task" trainer because it does not fully support all training requirements, particularly with regard to tank gunnery. For instance, SIMNET does not simulate firing of either the coaxial machine gun or the commander's machine gun. However, SIMNET is generally acknowledged as an appropriate medium for training section- and platoon-level gunnery skills related to fire distribution and control (U.S. Army Armor Center, 1989, p. 2-4).

The issue of what SIMNET trains, which has become a research topic in itself, is thoroughly reviewed by Burnside (1990). He pointed out that SIMNET is a unique training technology in that it was developed as a research project without a precise specification of the training requirements (i.e., to-be-trained tasks). Without these specifications, various lists of tasks that SIMNET can train have been developed after the fact. In the main, these lists agree that SIMNET trains tasks related to command/control and tactical maneuver. However, there is some disagreement on individual tasks that can be trained within that domain. To help quell this debate, Burnside developed some explicit criteria for rating the "...degree to which each task element...can be performed or met in the simulation" (p. 11). Decision rules were also constructed for combining the individual ratings at the subtask and task levels. The technique was then applied to SIMNET's capabilities (as of late 1989) to support armor collective training (as defined by the ARTEP Mission Training Plan) at the platoon, company, and battalion levels. Overall, SIMNET supported training on 35% of the tasks, most of them being in the areas related to maneuver and command/control/communications.

Strategy for Training

Because SIMNET does not simulate some of the basic aspects of gunnery, Hoffman and Morrison (1988) recommended that it not be used for initial gunnery training. However, they argued that it could be used for more advanced crew-level training because (prior to the development of GUARD FIST I) it was the only stand-alone, computer-based device that simulates important tactical conditions and supports full-crew interaction. SIMNET was developed as a demonstration of technology; it was not incorporated into the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990). However, there are plans for fielding the CCTT, which will be designed as a direct follow-on to SIMNET and should therefore have similar capabilities. According to the Armor Training Strategy, the CCTT may be used by the ARNG to prepare for section and platoon level tactical tables. The macrostrategy also prescribes that CCTT be used once per quarter in a 4-hr, platoon training session for a total of 16 hrs per year.

Research Literature

Although there is a growing body of empirical data on the training effectiveness of SIMNET, most of the research has addressed the effectiveness of the system to train tactical, as opposed to gunnery, objectives. In the interests of comprehensiveness, the following section reviews the evidence concerning both types of training objectives.

Acquisition and Retention

There have been no published empirical findings concerning the capability of SIMNET to train and sustain skills learned in the simulation. One reason for the dearth of basic information about SIMNET is that on-device performance information is difficult to obtain. The data logger, which can record all the data that pass through the SIMNET network, provides extremely detailed information that is not easily attributed in individual crew performance. The alternative is to use human testers to gather performance data from observation. Given the collective nature of SIMNET performance, this sort of labor-intensive research is difficult to support. Development of the Unit Performance Assessment (UPAS), which will enable the unobtrusive collection of performance data, may be helpful in obtaining information on the acquisition and retention of skills learned on SIMNET. (For a description of UPAS, see the Appendix.)

Performance Prediction

Graham, Leet, Elliott, Hamill, and Smith (1989) collected performance data from field exercises and from SIMNET tactical exercises to examine the effects of mental ability on collective performance. They obtained a modest but significant overall correlation ($r = .28$) between SIMNET and field performance. They attributed the low relationship to the fact that the two tests were designed to be complementary: one-third of the field test included precombat tasks not examined on the SIMNET test, and the SIMNET test included call for fire and encoding/decoding tasks not examined on the field test. For these reasons, Graham et al. used a combination of the field and SIMNET tests as the ultimate criterion of collective performance for their research.

No research has examined the correlation between corresponding forms of field and SIMNET tests. One possible avenue for future research is to examine the relationship between performance on SIMNET and performance at the National Training Center (NTC). The UPAS should facilitate this research as it is designed to collect performance data in a format that is compatible with NTC data bases.

Transfer of Training

Research findings. There are some findings that directly or indirectly address the issue of the degree to which SIMNET training affects field performance. The first experiment (Kraemer & Bessemer, 1987) examined these transfer issues by using a correlational design and by obtaining anecdotal reports on the transfer potential of SIMNET. Kraemer and Bessemer focused on the use of SIMNET by the U.S. Canadian Army Trophy (CAT) team to prepare for competition. SIMNET terrain and exercises were constructed to closely parallel CAT battleruns. Their results were based on the performance of the nine M1 platoons who participated in the CAT competition and showed a moderate relationship ($r = .53$) between the number of SIMNET battleruns completed and the score obtained on the CAT competition. This relationship was mostly accounted for by one platoon that completed more SIMNET exercises than the other eight and also scored highest on CAT. With only seven degrees of freedom, the correlation was not significant. Nevertheless, their data suggested that there may be a relation between amount of SIMNET training and live-fire performance.

In addition to the quantitative data, Kraemer and Bessemer (1987) documented anecdotal reports on two problems with SIMNET training. The first problem is caused by the fact that the lead system is not faithfully duplicated in SIMNET. The result of this deficiency is that gunners could short circuit procedures that are required in live-fire gunnery such as relaying after lasing, dumping lead, or steady tracking for 2-3 secs. At least one unit leader recognized that this problem could have been a source of negative training, and scheduled dry-fire training prior to CAT to ensure that gunners were using proper procedures for automatically inputting lead to the fire control system. The second problem related to driving behaviors. Drivers recognized clear differences in acceleration, braking, and steering responsiveness between SIMNET and the M1. Perhaps more serious were problems in maintaining position in formation caused by the driver's limited field of view. This caused the driver to change his behavior by (reportedly) relying more on TC driving commands and guidance. The researchers speculated that these problems could have been the root cause for the lack of more impressive relationships between SIMNET and CAT performance.

Gound and Schwab (1988) conducted a Concept Evaluation Program (CEP) of SIMNET whose express purpose was "...to evaluate the capability of the Simulation Networking (SIMNET) system to support platoon level command and control exercises and to assess the potential of the SIMNET system to train selected individual and collective platoon-level tasks" (p. 1-1). As shown in Table 8, the design of the CEP called for measuring the collective performance of eight platoons that were pre- and posttested on a tactical exercise at Fort Hood. The tactical test, which combined Situational Training Exercises (STXs) E (movement to contact), F (hasty attack), and B (hasty defense), used actual tanks equipped with the Multiple Integrated Laser Engagement Simulation (MILES) system. Performance was evaluated by independent evaluators from the Armor School. During the six-day training period, all eight platoons were trained on tactical missions similar to those on the pre- and posttests. The platoons were differentiated on the media used in this period: Four platoons were shipped to Fort Knox to be trained using SIMNET, while the other four platoons were trained "using standard field training methods at Fort Hood." The results from the CEP indicated that, on average, both groups improved from pretest to posttest. Between-group comparisons showed that, for the objectives that were fully or partially trainable in SIMNET, the SIMNET-trained group improved more than the baseline, but they also started at a higher level. Statistical analyses showed significant group differences at both pretest and posttest. Similar results were obtained when the researchers analyzed performance on all tasks, regardless of their being trainable on SIMNET. Because of the preexisting differences between groups, the authors cautioned that the performance improvements from pre- to posttest cannot be attributed to SIMNET training. Based on other data, however, Gound and Schwab argued that "... the perception by the unit chain of command and the test directorate is that the SIMNET training did in fact have an overall benefit on the groups' performance" (p. 1-12).

Brown, Pishel, and Southard (1988) conducted a Preliminary Training Developments Study (PTDS) using the performance data from the same eight platoons that participated in the CEP. They reexamined the pretest/posttest differences reported by Gound and Schwab (1988) but focused on 10 tasks that were common to SIMNET and each of the eight STXs. In contrast to the data reported by Gound and Schwab, performance on the 10 "common" tasks showed only slight pretest differences between the two groups. Pretest/posttest comparisons indicated substantial improvement in the SIMNET group (52% GOs on pretest vs. 82% GOs on the posttest) compared to a slight decline in the baseline group (45% GOs on pretest vs. 42% GOs on the posttest). Brown et al. reported that the differences between groups on the pretest were not significant, whereas the posttest difference were statistically reliable at

Table 8

Outline of Research Design Used by Gound and Schwab (1988) and by Brown, Pishel, and Southard (1988)

Group	Pretest	Tactical Training	First Posttest	Second Posttest[a]
SIMNET	STX	SIMNET	STX	ARTEP
Baseline	STX	Field	STX	ARTEP

Note. Duration of SIMNET training was 50-52 hrs; duration of field training was 52-56 hrs.

[a] Results from the second posttest were reported in Brown, Pishel, and Southard (1988) only.

the .05 level.[3] On the basis of their analyses, Brown et al. were willing to make a stronger conclusion from their analyses of the data than were Gound and Schwab: "SIMNET training improves platoon level performance" (p. 50).

Brown et al. (1988) also reported on performance on a subsequent company/team ARTEP evaluation that was administered about two days after the STX posttest. The SIMNET group improved only slightly on the 10 common tasks from posttest to the ARTEP (82% vs. 92% GOs), whereas the baseline group improved dramatically (42% vs. 82% GOs). The larger improvements in the baseline group were likely due to the fact that the SIMNET-trained group were already close to the performance ceiling (i.e., 100% GOs) at the posttest and had less room for improvement. Brown et al. reported that the differences between groups were not significant.[4] Thus, these data failed to show that SIMNET transferred to the ARTEP exercises. Nevertheless, on the basis of evaluators' observations, they concluded that the SIMNET-trained group moved better and communicated more than the field-trained group although no empirical data were presented to substantiate this claim.

More recently, the TEXCOM Combined Arms Test Center (1990) performed a Force Development Testing and Experimentation (FDTE) study of SIMNET-T to determine whether to proceed with full-scale development of the CCTT, the follow-on system. One of the explicit reasons for conducting the FDTE was that the findings from the CEP were characterized as "inconclusive" (p. 1-1).

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[3] Bessemer (1990) questioned Brown, Pishel, and Southard's (1988) analyses of the data. Specifically, he criticized their use of X^2 (chi-square) and binomial tests of inference on nonindependent tasks as sampling units.

[4] Bessemer's (1990) criticism of Brown, Pishel, and Southard's inappropriate use of X^2 (chi-square) applies to this analysis as well.

Two groups of nine platoons (armor and mechanized infantry) participated in the FDTE; both groups were treated similarly. As shown in Table 9, the study began with a field exercise (a movement to contact STX) conducted at Fort Hood, TX under daylight conditions. This STX exercise required approximately one day with an additional make-up day scheduled to execute remaining tasks and subtasks that were not executed during the first day. Performance on the STX was scored at the level of the collective task, the collective subtask, and the individual task/subtask standard (i.e., performance element). Following pretraining, platoons were sent to Fort Knox, KY to practice similar collective scenarios on SIMNET-T. SIMNET training consisted of two days of orientation and three days of training on the tactical scenarios. After SIMNET training, platoons were returned to Fort Hood, TX for a posttest that was identical to the pretest except that it was conducted on different terrain. Because only nine platoons of each type could be evaluated within the resource constraints of the study, the FDTE was limited to a single-group design--that is, there was no control group receiving the pretest and posttest but no SIMNET training.

Table 9

Outline of Research Design Used by TEXCOM (1990)

Group	Pretest	Train	Posttest
Armor Platoons	STX	SIMNET	STX
Infantry Platoons	STX	SIMNET	STX

The results from the collective task data showed that, for a large proportion of tasks (41.2%), performance was initially low and did not improve from pre- to posttest. Analysis of the collective subtasks and individual task standards indicated a different trend--that is, that platoons generally improved in performance from pre- to posttest. The TEXCOM researchers interpreted this finding as indicating that training on SIMNET transferred to the field. They acknowledged, however, the limitations inherent in their use of a single-group research design. Campbell and Stanley (1966) classified such single-group designs as "preexperimental" and did not recommend them for evaluating the effectiveness of an educational or training program. With regard to the present study, the increases in performance could not be unequivocally attributed to SIMNET without comparison to an appropriate control group. Without comparison to a control group, the increase in posttest performance could be attributed to other likely factors such as the training received during the pretest. In sum, the results from the FDTE did not provide any additional evidence in favor of SIMNET's effectiveness.

The emphasis in these first four investigations (i.e., Kraemer & Bessemer, 1987; Gound & Schwab, 1988; Brown et al., 1988; TEXCOM, 1990) was on platoon collective performance rather than on individual performance. Because each sampling unit (i.e., the platoon) requires four tanks with each tank crew consisting of four personnel, the sample sizes have been necessarily small thereby limiting the statistical confidence that one can place on their results. Bessemer (1990) addressed both of these limitations by taking advantage of his knowledge that SIMNET was to be implemented in the AOB course at Fort Knox prior to the Mounted Tactical Training (MTT) exercise. AOB is the course that trains newly commissioned second lieutenants how to be armor platoon leaders, and the MTT is an intensive ten-day field exercise at the end of AOB wherein students are trained and evaluated on planning and executing platoon combat missions. Records of MTT performance were obtained from 24 classes prior to the introduction of SIMNET and 12 classes subsequent to that change. The total sample consisted of 110 platoons and 1705 individual students. The (1990) data were analyzed as an interrupted time series design to assess the effects of two and one-half days of SIMNET training on MTT performance.

Bessemer's (1990) results indicated that SIMNET facilitated the MTT exercise by decreasing the number of elementary contact exercises and increasing the number of more advanced defensive and offensive missions. On average, the advanced exercises began about 0.7 days sooner after SIMNET was implemented in AOB. Furthermore, as shown in Figure 3, individual soldiers showed better performance on the MTT during the SIMNET phase than during the baseline phase; however, these differences only appeared gradually after the improvements to MTT efficiency were obtained. Bessemer argued that the gradual increments in performance were due to the fact that trainers had to "learn to train" effectively with SIMNET. Although Bessemer's data seemed to support the effectiveness of SIMNET, the interrupted time series design complicated the interpretation of the results. This sort of design is termed quasi-experimental by Campbell and Stanley (1966) because the training conditions (SIMNET vs. no SIMNET) were not randomly assigned to experimental groups. As a consequence, any time-associated changes that occurred during the research are confounded with the treatment effect and pose a threat to the "internal validity" of the experiment. One such internal threat to validity was the introduction of additional field training that was confounded with the introduction of SIMNET. In this additional field training, which occurred prior to the MTT, AOB students used High Mobility, Multi-Purpose Wheeled Vehicles (HMMWVs) to practice tactical techniques learned in class. These and other threats to validity were systematically considered (and largely discounted) by Bessemer.

Conclusions. Although the findings from any one of these investigations may be questioned to one extent or another, the thrust of the data suggests that SIMNET training transfers to field performance. Furthermore, given that skills learned on SIMNET transfer to the field, these findings imply that SIMNET skills can be acquired and retained and that SIMNET performance is predictive of field performance. Despite this generally positive conclusion, two limitations of the empirical research to date should be noted.

The first problem with the research is that the research designs used to investigate SIMNET's effectiveness have had some serious flaws. The first three investigations (Kraemer & Bessemer, 1987; Gound & Schwab, 1988; Brown, Pishel, & Southard, 1988) were based on extremely small sample sizes, precluding formal statistical treatment of the data. The FDTE (TEXCOM, 1990) used a somewhat larger sample size and demonstrated significant performance gains; but without an appropriate control group one could not rule out the likely alternative hypothesis that the gains were due to simple test-retest

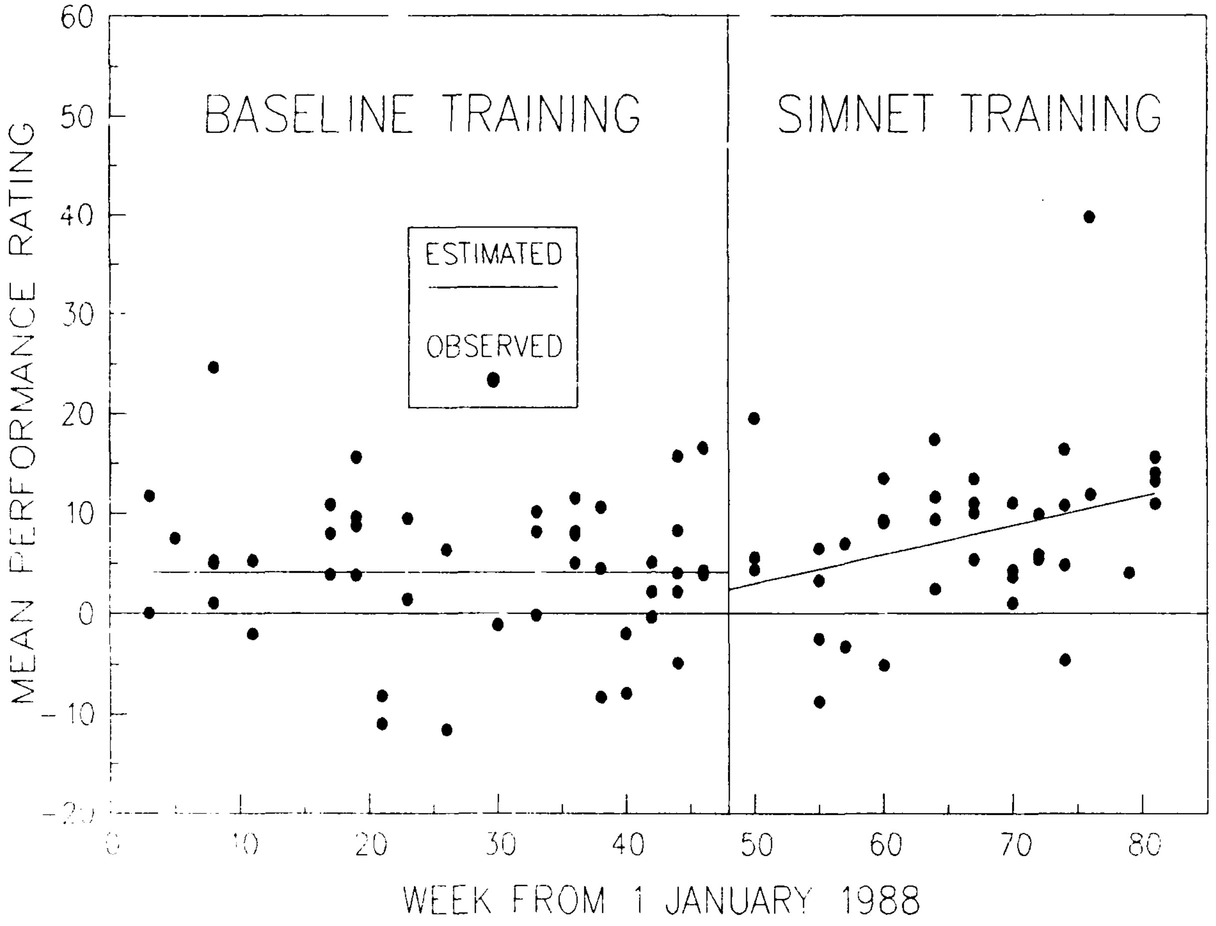

Figure 3. Adjusted mean performance rating by platoon for AOB students in their first rated exercise during MTT. Rating values can range from 100 to -100. From Bessemer (1990). Reprinted by permission.

effects. Bessemer's (1990) use of archival data represented a conceptual advancement in that it used much larger samples and allowed comparisons of SIMNET training to baseline conventions. However, the quasi-experimental nature of the research did not permit the performance differences to be attributed to SIMNET training alone.

The second problem with the SIMNET research concerns the specific purposes of the present project: Except for Kraemer and Bessemer (1987), the research to this point has not directly addressed gunnery skills per se. Furthermore, the Kraemer and Bessemer report only examined gunnery performance at the platoon level. Future research on SIMNET should examine its transfer potential for individual- and crew-level gunnery tasks. One approach is to develop single-tank exercises such as those described in Drucker and Morrison (1987). In contrast to previous SIMNET research, a single-tank exercise focuses on individual and crew tasks performed in a combat context. This shift from platoon to individual/crew tasks addresses two research shortcomings. First, the focus on individual and crew tasks allows the research to focus on gunnery type activities. Second, shifting from platoon collective tasks to individual and crew tasks means that more data points can be obtained from the same number of personnel.

HHT

The Hand-Held Tutor (HHT) is an inexpensive, portable, microprocessor-controlled training aid for presenting and controlling programmed learning exercises. ARI developed the HHT to provide the Army with a flexible and innovative training technology for reducing the disparity between the requirements of highly technical Army jobs and the skills of entry-level soldiers (Harman, Bell, & Laughy, 1989).

Military/Technical Literature

Types of Knowledges Trained

The HHT is designed to provide instruction on knowledges related to certain military tasks. With regard to M1 tank gunnery, HHT courseware and other materials have been developed for the knowledges required by the tank commander (a) to execute appropriate fire commands for single and multiple targets, (b) to direct engagements under degraded modes of operations, and (c) to conceive strategies for obtaining multiple returns from the laser rangefinder. Shlechter (1990) has argued that the low cost and portability of the HHT make it an especially appropriate medium for training armor crewmen in the Reserve Component.

Strategy for Training

In Hoffman and Morrison's (1988) strategy, the HHT fire command was prescribed for use in an introductory unit that preceded all instruction in their hierarchy. The HHT was also prescribed for more advanced instruction on multiple returns and degraded modes. Bridgeman and Fertner (1986) suggested that the optimal strategy for using the HHT is to have soldiers work 30-60 mins/day for one to two weeks. In other words, soldiers should devote from 2.5 - 10 hrs to the HHT distributed over at least one week. Like TopGun, the HHT is a research technology rather than a officially fielded training aid; consequently, HHT does not have a role in the Armor Training Strategy, ST 17-12-7 (U.S. Army Armor School, 1990). Only 20 copies of the armor version of the HHT were ever fabricated, and none were distributed to active or reserve armor units.

Research Literature

The following review presents research on the gunnery version of the HHT as well as the version that was designed to train job-related mathematics. Again, in the interests of thoroughness, all the data on the HHT are reviewed below.

Acquisition

Research findings. There have been three demonstrations that soldiers can learn from the HHT. In the first experiment, Harman et al. (1989) examined the effectiveness of the HHT to train job-related mathematics to 27 combat engineers. The engineers were instructed to use the tutor for 1 hr per day for six days or until mastery of the subject matter was achieved. They were given equivalent forms of a mathematics exam prior to HHT training (pretest) and after finishing HHT (posttest). Two separate groups of engineers were evaluated several months apart. The only reported difference between the groups was the amount of self-reported time they spent on the HHT. The first group ($\underline{N}$ = 19) reported using the HHT for an average of 1.4 hrs, whereas the second group ($\underline{N}$ = 8) reported an average of 4.5 hrs study time. Both groups showed gains from pre- to posttest with the first (short study time) group exhibiting 14.7% average gain in performance over the two tests and the second (long study time) group showing 30.4% average gain. The data were not subjected to formal test of statistical inference. Furthermore, this demonstration did not provide a group that received the pre/posttests but not the HHT training to control for the effects of repeated testing. However, because of the apparent relation between amount of training and performance gain, this experiment suggests that the performance gains cannot be entirely attributed to repeated testing effects.

Two other experiments have attempted to evaluate the HHT courseware on M1 tank gunnery, and are therefore especially relevant to the present review. This version of the HHT was based on a set of paper-based guides, concerning the following topics in M1 gunnery: fire commands, multiple returns, and degraded modes (Kraemer, 1984a, 1984b, 1984c). The first evaluation was conducted on 13 students in the Armor Basic Noncommissioned Officer Course (Bridgeman & Fertner, 1986). The content of this course is mostly devoted to training TC skills. These researchers developed a written test consisting of multiple-choice and short, fill-in items corresponding to information presented in the tank gunnery HHT units. The same test was administered both before and after HHT training. In the first session, five soldiers were allowed approximately 5.5 hrs to interact with the HHT between pre- and posttest; in the second session, eight soldiers were given less than 3 hrs to study with the HHT. The results showed gains from both sessions but with larger gains in the first session (28.0%) compared to the second session (6.8%). Again, the data were not subjected to statistical analysis.[5] As in Harman et al. (1989), this experiment suggests that the performance gains were correlated with amount of training time.

A second evaluation of the tank gunnery version of the HHT was performed by Shlechter (1990). This experiment is particularly relevant for its use of National Guard soldiers to test the HHT. Eighty-five guardsmen completed all 13 HHT units on degraded mode gunnery and multiple return strategies in one day. (For a description of the 13 units of instruction, see the Appendix.) As shown in the first two columns of Table 10, the soldiers were assigned to one of four training conditions designed to address issues related to small group use of the technology. In the Individual condition, a single soldier was assigned to an HHT; whereas in the Group condition, three soldiers were assigned to a single HHT with explicit instructions to discuss the instructional materials as they were being completed. The two remaining groups, in which two soldiers were assigned to a single HHT, were designed to address the effects of discussion in small group learning: In the Discussion

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[5] Bridgeman and Fertner (1986) reported individual gain scores, which provided the necessary data for t-tests for dependent samples. Analyses by the present authors showed that gains were statistically significant for the large gains in the first session and for the smaller gains in the second session; $\underline{t}(4) = 19.31$, $\underline{p} < .0001$; and $\underline{t}(7) = 3.24$, $\underline{p} < .01$; respectively.

Table 10

Outline of Research Design Used by Shlechter (1990) and Summary of Results

	Experimental Conditions		Performance	
Group	Soldiers per HHT	Discuss Content?	Gain in Test Score[a]	Time to Complete[b]
Individual	1	No	5.9	127.9
Non-Discussion	2	No	5.2	124.5
Discussion	2	Yes	6.6	133.4
Group	3	Yes	6.9	112.8

[a] Number correct items on posttest minus number correct on the pretest.
[b] Mins to complete the posttest.

group, soldiers were allowed to discuss the HHT materials; whereas in the Non-discussion group, soldiers were explicitly prohibited from discussing the materials. All soldiers were tested before and after HHT training using 30 test items taken from Bridgeman and Fertner (1986). Different forms of the test were administered at pre- and posttest but with eight items included on both versions.

The results of Shlechter (1990), summarized in the second two columns of Table 10, indicated a significant improvement between pretest and posttest performance as shown by a 20% increase in test scores. Furthermore, the effect did not seem to be due to repeated testing as performance on repeated items showed less overall gain (about 16%). With regard to the effect of group instruction, the results did not show differences in these gains as a function of group assignment; that is, the group X trials interaction was not significant. However, there were group differences in the time to complete the HHT units and in scores on the embedded pretests. These differences were accounted for by the superiority (faster unit completion times and higher pretest scores) of the Group condition; the other groups were not different on those measures. Shlechter concluded that group presentation was an "instructionally efficient" strategy in that soldiers in the Group condition completed HHT training more quickly with pre/posttest gains that were (apparently) equivalent to the other conditions. However, the results failed to clarify the role of discussion in group learning.

Conclusions. Taken as a whole, the results from these experiments clearly demonstrate that learners acquire knowledge from the HHT. An unresolved issue related to skill acquisition is to determine the appropriate amount of time to complete the gunnery HHT. As mentioned earlier, Bridgeman and Fertner (1986) suggested that the optimal strategy is to use a distributed training strategy where the soldiers work 30-60 mins per day for one to two weeks. In contrast to this prescription, the two experiments that have evaluated the HHT have used a massed training strategy: In the Bridgeman and

Fertner experiment, soldiers completed all 27 units in less than 6 hrs of a single day; and in the Shlechter (1990) experiment, soldiers required an average of just over two hrs of massed instruction to complete 13 of the 27 units. Two specific questions are suggested by these findings: (a) whether or not Bridgeman and Fertner's suggestion to distribute training over multiple training sessions is more effective than massing training into single sessions; and (b) given more training time, whether or not repeating the units results in cost-effective gains in performance.

Retention

No empirical research has been performed on retention effects related to the HHT. However, consideration of retention issues suggests at least two fruitful areas for research. The first issue is inspired by the previously suggested work on the effects of repeated practice. Repeated training sessions may not produce increases in immediate performance beyond the criterion level of performance; however, training past that criterion (a procedure called overtraining) may produce continued benefits in retention of HHT knowledges. Such retention benefits for overtraining have been shown for motor skill tasks (e.g., Schendel & Hagman, 1982), but these effects may not be obtained for task-related knowledges. The second retention issue is suggested by the relative low-cost and portability of the HHT. As such, the HHT may provide an appropriate medium to take home and complete when time allows. In this context, research should be performed to determine the extent to which use of the HHT can sustain performance between drill weekends.

Prediction of Performance

No research has been performed to correlate performance on the HHT to actual or simulated job performance. The problem with the HHT is that it has no inherent capability to store or download performance data from individual trainees. Because of this deficiency and because of the relative remoteness of the HHT knowledges to hands-on performance, this would not seem to be a fruitful area for future research.

Transfer

No research has been performed to assess the transfer of training from HHT to job performance. The central question here is whether the knowledges demonstrably gained from HHT practice transfer to improved gunnery performance. Because the expense of assessing transfer to live-fire gunnery would be prohibitive, transfer to a training device such as the M-COFT (i.e., quasi-transfer) would be an appropriate medium for measuring gunnery proficiency.

Summary of Findings and Final Considerations

This final section summarizes the findings of the report. It is divided into two parts corresponding to the division between the review of the military/technical literature and the review of the research literature.

Military/Technical Literature

The previous descriptions of training functions indicated that the tank gunnery training devices range from part-task trainers of individual gunner skills to full-crew interactive trainers, and that each device provides a variety of fidelity and instructional features. This section presents some overall considerations of the training devices and aids and the implications for a device/aid-based training strategy.

Overlap in Devices

The descriptions of training functions clearly demonstrated that the devices overlap somewhat in function. For instance, both TopGun and VIGS provide part-task training of gunnery skills and both GUARD FIST I and SIMNET provide practice in full-crew interaction. GUARD FIST I and M-COFT both provide practice on TC/gunner interactions under normal and degraded conditions. At first glance, this overlap would appear to be a wasteful duplication. From a learning standpoint, however, the overlap may promote retention and transfer of skills. Morrison and Holding (1990) argued that alternating between devices whose fidelity to the actual equipment is less than perfect can potentially increase transfer effects. If the departures from fidelity in the devices are somewhat complementary, the process of alternating between devices should permit the trainee to build a better cognitive model of the target skill and thus promote transfer to the actual equipment. This principle was derived from the findings that retention and transfer are enhanced by practicing tasks under a variety of conditions (e.g., Wells & Hagman, 1989) and by theoretical notions such as the mental schema (e.g., Schmidt, 1975). Furthermore, as concluded by Hoffman and Morrison (1988), the overlap in devices should be exploited to provide multiple experiences on gunnery training objectives in increasingly realistic contexts. Whether the transfer benefits of multiple devices outweigh the increased logistical costs is a potential subject for future research.

Having devices that overlap in function may be beneficial from a practical standpoint as well. ARNG units may not have access to some of the training devices described in this section. The overlap in device functions may allow the strategy to specify secondary as well as primary devices for specific training objectives. In other words, the trainer would have the choice of a secondary device for a particular objective if the primary device were not available.

Centrality of M-COFT

It is expected that, as in the two previously published macrostrategies (Hoffman & Morrison, 1988; U.S. Army Armor School, 1990), the Conduct-of-Fire Trainer (in particular, the M-COFT version) will continue to play a central role in the training strategy. The reason for the centrality of the M-COFT is that it offers the highest level of fidelity among the five training devices (Campshure, 1990). At first glance, it might appear that GUARD FIST I offers higher training fidelity because it allows crewmen to train in the actual tank. However, many of the tank systems are not powered up during a GUARD FIST I training session and consequently do not function. In contrast, the M-COFT provides a high-fidelity, functioning representation of most tank commander and gunner systems. Because of the relatively high level of correspondence between M-COFT and the actual equipment, high levels of transfer are expected. Furthermore, the high fidelity of M-COFT permits the trainer to address objectives that cannot be trained by other devices. For instance, the M-COFT is the only device that can train certain engagements (e.g., simultaneous engagements) and certain degraded modes (e.g., manual mode). For the training strategy, these findings imply that M-COFT will assume a central role in the gunnery training strategy. The other devices can then be viewed as providing training to either prepare crews for or to elaborate on M-COFT training.

Dearth of Training Aids

The initial survey of training aids revealed only one computer-based aid (the HHT) that was relevant to M1 gunnery training in the ARNG. Other aids such as the Handbook for Sight Picture Training (Drillings, 1979) and the Rapid Train-up Package (Kraemer, Anderson, Kristiansen, & Jobe, 1985) were developed for the M60-series tank and are not appropriate to M1 training. Some computer-based training was developed for M1 gunnery training; however, this courseware has also been developed for the MicroTICCIT computer-based training system, which is not available to most National Guard units. For the training strategy, the only alternative is to prescribe traditional paper-based materials (e.g., field and technical manuals) for training critical gunnery knowledges. A serious problem with prescribing such materials is that they are designed as reference sources--not for training per se. Thus, one obvious research need is to develop and test training aids that would support training knowledges that are related to M1 tank gunnery. Campshure (1990) identified key gunnery knowledges that are candidates for training aids. Research should also address how to systematically choose the appropriate media for each knowledge area. Possible media for training aids include the HHT, the Army-wide Electronic Information Delivery System (EIDS), or simply paper-based booklets, such as those described in Silbernagel, Vaughan, and Schaefer (1982). (For a description of these latter materials, see the Appendix.) With regard to paper-based training materials, the ARI Armor R&D Activity is currently updating the Rapid Train-Up Package for the M1 and M1A1.

Research Literature

Although the details concerning the research literature were quite complex, it was found that the results could be summarized briefly in the following fashion: The literature provided *strong evidence* that the device/aid affects one of the four processes (acquisition, retention, prediction, and transfer) if the majority of findings show significant effects, *some evidence* if at least one experiment or study indicated significant effects on one of the processes, or *no evidence* if no significant effects were detected. In some cases, there are *no empirical data* at all on a particular issue. Using these simple categories, Table 11 summarizes the findings previously reviewed.

Some general trends are noteworthy. One is that very little research has addressed the effects of training devices and aids on the retention of gunnery knowledges or skills. Skill retention is a particular problem for the National Guard wherein training is distributed into "discrete chunks" over a calendar year (Wells & Hagman, 1989). Furthermore, a particular task may be practiced in only certain of those chunks resulting in the potential for skill retention problems. Thus, research on the effects of device training should

Table 11

Summary of Findings from Research on Gunnery Training Devices and Aids

	Research Findings Related to			
Device	Skill Acquisition	Skill Retention	Performance Prediction	Transfer of Training
TopGun	• Strong evidence that skills are acquired on device • No evidence of acquisition differences between recreational and formal modes	• No empirical data on this issue	• Some evidence that TopGun predicts U-COFT performance	• Some evidence of transfer to U-COFT
VIGS	• Strong evidence that skills are acquired on device	• No empirical data on this issue	• Some evidence that VIGS predicts U-COFT performance but not TopGun performance	• Some evidence of transfer to dry-fire but not to live fire • Some evidence of transfer to TopGun
M-COFT	• Strong evidence that gunner skills are acquired on device • Some evidence that TC skills are acquired on device • Some evidence that accuracy skills are acquired more quickly than speed skills	• Some evidence that U-COFT sustains crew performance	• No evidence that special tests of U-COFT proficiency predict live-fire performance • Some evidence that matrix achievement predicts live-fire performance	• Some evidence of transfer to live-fire gunnery
GUARD FIST I	• No empirical data on this issue	• No empirical data on this issue	• No empirical data on this issue	• No empirical data on this issue
SIMNET	• No empirical data on this issue	• No empirical data on this issue	• Some evidence that performance on SIMNET predicts field measures of tactical performance	• Some evidence that tactical training on SIMNET transfers to field performance
HHT	• Strong evidence that gunnery knowledges are acquired with device	• No empirical data on this issue	• No empirical data on this issue	• No empirical data on this issue

directly address the capabilities of the devices to sustain performance over these periods of no practice.

Given that skill retention research is important for gunnery training in the National Guard, it should be cautioned that gunnery is a multifaceted cognitive and behavioral process. By that, it is meant that gunnery performance comprises a variety of different types of overt and covert behaviors including individual discrete responses (e.g., setting switches at the gunner's control panels), procedural responses (e.g., power-up tank systems at driver's station), perceptual responses (e.g., acquire and identify targets), psychomotor responses (e.g., track, lase, and fire and targets), and cognitive responses (e.g., determine engagement priorities). Research indicates that there are differences among these behaviors in their retention characteristics. For instance, Mengelkoch, Adams, and Gainer (1971) showed that the discrete procedural aspects of flying skills are forgotten at a more rapid rate than continuous responses involved in controlling the aircraft. These results suggested that flyers would benefit from sustainment training with low-fidelity procedures trainers. Research has shown that the retention of task components varies with respect to other key characteristics that affect retention such as difficulty, number of individual steps or elements, interstep cueing, and the "relevance" of the component to task goals (Rose et al., 1985). Empirical research should be performed to determine whether the retention performance on the various components of gunnery can be predicted from such task characteristics. Information from this research could be combined with information about the capabilities of training devices and aids (Campshure, 1990) to make valid prescriptions for sustainment training.

Another noteworthy general trend is that, for cases where there are sufficient data, skill acquisition takes place as a result of practice on gunnery devices and training aids. Although the evidence for skill acquisition is indisputable, it is important to confirm that the correct skills are being learned. That is, it is important to prove that the skills acquired during training on gunnery devices and training aids are not device or aid specific, but that they transfer to high fidelity devices and to the actual equipment. The transfer of training research, unfortunately, has not yet resolved this issue. Although there is evidence that gunnery skills do transfer, research is needed to identify (a) the types of skills that transfer from one device to another (or to the tank itself) and (b) the practice conditions that facilitate transfer of gunnery skills.

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Appendix A

Detailed Description of Features of Training Devices and Aids

Device/aid capabilities are described in this appendix in terms of their specific features. These features are organized according to some common distinctions made in the training literature. For training devices, features are commonly subdivided into fidelity and instructional features. Fidelity features are defined as those components that enable the device to mimic the operational equipment. In contrast, instructional features are those device capabilities that facilitate the instructional process. Similarly, the features of computer-based training aids are commonly subdivided into hardware and courseware features. Hardware features refer to physical characteristics of the system such as the configuration and input/output characteristics of the system. The courseware features refer to the functional aspects of the instructional software that accompanies the system.

TopGun

TopGun is an example of a computer-based, stand-alone training device. In general, TopGun appears physically similar to a single-player, video arcade game. The device is a completely self-contained unit that can be easily transported to different sites. An external view of TopGun is shown in Figure A-1. Detailed descriptions of TopGun have been provided by the manufacturer (NKH, 1986, 1988).

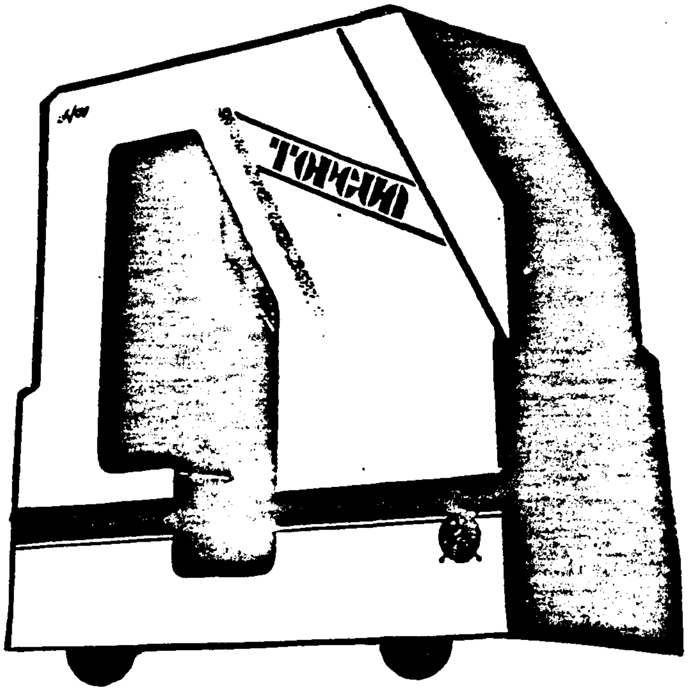

Figure A-1. External view of TopGun.

Fidelity Features

A medium-resolution (RGB) color monitor presents a computer-generated view of the battlefield under daylight conditions. The default viewing condition contains no visual obscuration, but fog conditions are available as a field modifiable initiation parameter (FMIP).[1] The playing area is approximately 1100-6000 meters in depth. The player's tank is in a stationary, non-defilade position at the center of a 360° battlefield; however, all targets are located within a 102° (2400 mil) slice of the battlefield. The player views the visual scene directly using unaided binocular vision; that is, the monocular vision blocks of the tank are not simulated. The scene depicted is that viewed from either the primary (nonballistic) sight reticle (3X or 10X) or the auxiliary (ballistic) sight reticle (8X). The player changes sights using a switch as opposed to moving his head between the different sights that are present in the actual M1. Thermal images are also available in 10X and 3X, but are relevant only under visually obscured (fog) conditions. The display presents both stationary and moving targets (Soviet T-62 tanks) at ranges between 1100 and 5000 meters in single and multiple target arrays. Targets, which have "shoot-back" capability, can appear in defilade, in partial defilade, or in full view. The targets are placed amidst appropriate cultural objects such as houses. Range and system status displays that are available in the actual sights of a tank are fully simulated in the TopGun display. When the gun is fired, the screen is "washed out" to simulate firing.

The player interacts with the scene by using realistic gunner control handles including the magnetic brake (palm) switches, the lase/lead buttons, and the trigger button. Thus, TopGun fully simulates the procedures related to lasing, tracking, and firing at targets. The other gunner controls that are functional in TopGun include the laser rangefinder (LRF) RANGE switch and the GPS MAGNIFICATION switch. The GUN SELECT switch is represented but not functional in TopGun. The AMMO SELECT switch is not represented because TopGun simulates the effects of only one type of M1 ammunition: the armor-piercing, sabot-discarding (APDS) round. Some of the controls for the thermal imagery system (TIS) are also represented including the TIS PWR switch, POLARITY switch, and the THERMAL MAGNIFICATION switch.

TopGun's sound system presents the sound of the player firing and the sound of rounds hitting or nearly missing the firing tank. The most important function of the sound system is to simulate loader and tank commander (TC) verbal announcements. For the loader, the system simulates his announcement of "up" indicating that a round has been loaded and the safety switch placed on FIRE. For the TC, the system generates single and multiple appropriate fire commands as appropriate to target arrays. In addition, the simulated TC aids the gunner in acquiring targets in one of two modes that can be set by a FMIP. The default mode is to provide verbal prompts ("traverse left/right, steady, on") as appropriate to get the target within the gunner's sight picture. The other mode simulates the TC using his own control handles to override the gunner's handles to slew the gun (and the gunner's sight) close

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[1] A FMIP is, in essence, a software switch that can be set by the trainer who controls TopGun, but not by the players.

to the target. TopGun also simulates the interaction between TC and loader corresponding to the movement of ammunition from storage to ready racks. This interaction is simulated by the TC announcing "cease fire" and the words MOVING AMMO appearing at the right bottom of the screen. During the period when this display is on the screen, the gun cannot be fired, simulating the loader's having placed the main gun in SAFE. The action ends with the loader's "up" announcement. At that point, the MOVING AMMO display disappears and the gun can be fired.

In addition to the simulated TC cues for acquiring targets, the gunner has an additional visual cue in the upper right-hand corner of the display showing a top-down representation of the relative position of threats. This additional visual display, called the Wide Field of View (WFOV), shows an area approximately 3 times larger than the 3X sights. The targets in the WFOV are color coded red, yellow, and blue. Red targets are most dangerous in that they are close and pose an immediate threat, yellow targets are dangerous in that they are farther in range but still pose a threat, and blue targets are least dangerous targets in that they are distant and effectively out of range. The WFOV display does not correspond to any sight in the M1; the intention of the WFOV is to compensate for the lack of view (via the TC) through his unity window or from his open-hatch. If desired, the WFOV feature can be disabled by changing the appropriate FMIP; otherwise, the default condition is to have the WFOV display available to the player.

As in the actual tank, the gunner's sight of choice is the gunner's primary sight (GPS). The TopGun player is forced to use the gunner's auxiliary sight (GAS) when the GPS is temporarily down due to LRF overheating, or permanently lost due to battle damage. If the LRF fails due to overheating, the player receives an appropriate "F" fault symbol in the GPS. Subsequent fire commands contain appropriate range elements to allow the player to switch to the GAS, and to manually apply elevation using the ballistic reticle. The GPS becomes functional again after an appropriate period of time has elapsed to simulate the LRF "cooling down." If the computer fails due to battle damage, the sight is automatically switched to the GAS and remains there.

Instructional Features

TopGun can be used to train soldiers in one of two modes: recreational mode or formal training mode. In recreational mode, TopGun is played like a video game wherein the soldier uses the device without direct supervision. One key feature of the recreational mode is that the construction of the battlefield scenario, including placement of cultural objects and threat targets and the placement and maneuvering of threats, is determined on a probabilistic basis. As a result, the player cannot learn to look for targets in specific places, because no two TopGun sessions are identical. In contrast, the formal training mode repeats scenarios that have been determined ahead of time by trainers or researchers. The formal training mode allows practice on specific situations and collection of performance data under standardized conditions. In the following paragraphs, the recreational mode is assumed unless otherwise indicated.

The objective of the game is for the player to destroy the threats before threats kill the player. At the beginning of the game, the player is allotted three lives and 63 rounds of APDS. The game itself is played in three stages. A stage ends when the player either kills all allotted threats, is killed himself, or runs out of ammunition or lives. If the player kills all threats, he progresses to the next higher stage. If the player is killed, he is reset to the previous stage. If the player runs out of ammunition or lives, the game is over.

The degree of difficulty (DOD) of an individual scenario is defined by a number of game characteristics such as the number of threats allocated, the number of threats that can be simultaneously active, the kinematic characteristics of the threats, and the sight used. These characteristics, in turn, are partially determined by stage of the game; that is, the DOD increases as the game progresses. The second determinant of DOD is the player experience level (PEL). The PEL has three levels defined as novice, qualified, and expert. The player sets the starting PEL at the beginning of the game to affect the initial DOD. All of the characteristics defining the DOD can be changed by FMIP.

Using actual APDS ballistic characteristics, TopGun calculates the point of impact of the player's rounds within the simulated battlefield. A kill is obtained if the simulated round falls within the predefined "kill zone" of a target. Under default conditions, the kill zone is defined as the rectangle that completely surrounds the target. Through the use of a FMIP, the kill zone can be reduced to some percentage of the default kill zone, thereby making it harder for the player to obtain a hit.

TopGun provides information on the current status of a game on the Amplifying Data Area (ADA) of the display located at the bottom right hand of the display directly below the WFOV. At the top of the screen, the display repeats, in words, the responses simulated by the TC and loader. In addition, the ADA provides a constant readout of the range to the current target being engaged and the azimuth of the player's gun tube (in mils). The ADA also provides readouts concerning the student's current performance including the game stage, lives left, ammunition available, PEL, cumulative score, and the elapsed time in the present stage.

At the end of Stages 1 and 2, the player is presented a screen with information summarizing his performance. The raw data presented include (a) the total elapsed time spent in the previous stage, (b) the total number of enemy tanks killed, and (c) the total number of rounds expended. Two composite measures of performance are calculated from these data: the average number of rounds per destroyed tank (an accuracy measure) and the average time per kill (a speed measure). Similar information is presented at the end of the game plus the total score for the game. The total score is based on the average number of rounds per kill prorated for the sight used; that is, more points are allocated for equivalent rounds/kills when the GAS is used as opposed to either the GPS or the TIS. The total score also reflects the subtraction of penalty points for the procedural infractions, such as firing the gun before the "up" announcement and firing before the "fire" command. The player is awarded 10 extra rounds each time he scores 10,000 points or multiple thereof.

In formal training mode, much more detailed performance measurement information can be downloaded on computer diskette and then uploaded to a microcomputer using special software. This detailed performance information is divided into three printouts that are analogous to U/I/M-COFT printouts. The first printout is called the "Performance Monitoring System Statistics" and simply identifies the player and summarizes the information normally provided at the end of a game played in recreation mode. The second printout, which is called the "Performance Analysis," breaks down performance on a round-by-round basis. The Performance Analysis includes detailed information such as target engaged, speed measures (e.g., time to fire and time to kill), accuracy measures (e.g., hit/miss, aim error), and system status (position of LRF RANGE switch, input range to target, and actual range to target). The third printout is the "Shot Pattern" that summarizes the distribution of simulated round impacts relative to the centers of mass of the targets. This printout can be used to reveal constant errors in the player's aiming behaviors.

Finally, an instructional feature that is common to many simulators is the ability to freeze a scenario to permit short discussions between student and instructor. TopGun has the capability to freeze scenarios through the use of an FMIP. If this FMIP is enabled, moving the GUN SELECT switch to COAX will indefinitely freeze the ongoing scenario. If the FMIP is disabled, the COAX position on the GUN SELECT switch is nonfunctional.

M1/M1A1 VIGS

The description of the Videodisc Interactive Gunnery Simulator (VIGS) that follows is based on hands-on experience with the device and from information contained in the following two documents: M1/M1A1, Tank Videodisc Gunnery Simulator (VIGS), Device 17-142: Instructor's Utilization Handbook for Simulation Equipment (ECC International Corporation, 1988), and Skill Transfer for Tank Gunnery (Turnage & Bliss, 1989). Figure A-2 shows the two components of VIGS: (a) the gunner's console and (b) the videodisc player.

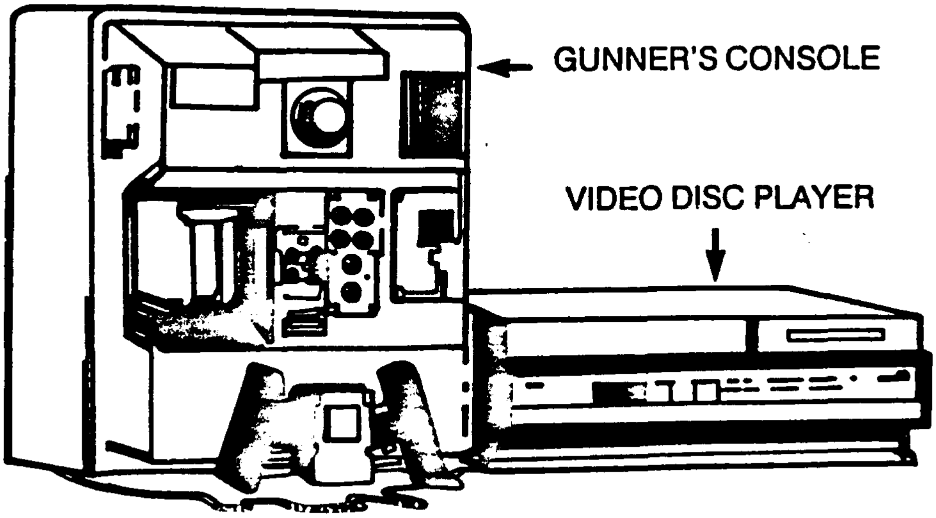

Figure A-2. Videodisc Gunnery Simulator (VIGS).

Fidelity Features

Computer-generated pictures of target scenes are stored on a videodisc. The gunner is able to see a target scene by looking through a simulated sight. Unlike an actual tank in which the gunner's station has two separate sights (the GPS and GAS), VIGS has only a single sight. When the GPS is simulated, the GPS reticle appears in the sight. When the GAS is simulated, either the HEAT reticle or the SABOT/HEP-T reticle will appear. The appearance of the GPS or GAS reticle in the sight is controlled by the computer software. When the GAS reticle is simulated, the gunner must select the appropriate reticle (HEAT or SABOT/HEP) as he would in the tank by using the reticle select lever. When the sight simulates the GPS, the gunner can select either the daylight channel or the TIS by using the thermal mode switch and the FLTR-CLEAR-SHTR switch. The GPS thermal ballistic door is not simulated. Neither the magnification lever (normally located on the gunner's primary sight panel) nor the thermal magnification lever (normally located on the TIS panel) is simulated. Magnification is preset at 10X.

VIGS simulates both the main gun and the coaxial machine gun. The gunner selects the gun using the GUN SELECT switch. If he selects the main gun, he is expected to select the appropriate ammunition using the AMMUNITION SELECT switch. The gunner can also select the first or last laser return using the LASER RANGEFINDER switch. The gunner tracks the target using the power control handles. Each control handle includes a palm switch, a laser range button, and a trigger. The palm switch must be squeezed to operate the control handle, the laser range button, or the trigger.

The tank commander's fire commands are presented by synthesized speech. The commands include a statement of the target type, the ammunition that is to be used, and five other directives including range to target (for engagements with the GAS), "up," and "fire." If the gunner destroys the target with a main gun round, an impact signature appears, and the image of the target (as seen through the sight) shows that it has been destroyed. If the gunner misses the target, an impact signature is shown.

The gunner can engage stationary or moving targets from a stationary or moving tank. However, only precision gunnery is simulated on VIGS. Battlesight cannot be used because there is no provision to enter range into the ballistic computer.

Instructional Features

The videodisc available for VIGS contains 36 missions. Twenty-eight of the missions are fired using the GPS, half of these using the daylight channel and half using TIS. Of the 8 missions fired using the GAS, six employ the SABOT/HEP reticle and two employ the HEAT reticle. Targets include tanks, personnel carriers, trucks, helicopters, and troops. Included are stationary and moving targets as well as single and multiple targets. The range to the targets varies from 500 to 2,000 meters. The missions range from 30 to 60 secs in duration. The instructor can select the missions that will be included in a lesson. As on TopGun, the instructor can alter the size of the kill zone to change the difficulty of target laying.

VIGS provides four types of feedback:

1. At the end of each mission, a replay of the mission is automatically displayed in the sight. The replay shows the location of the target whenever a round was fired and the location of each impact. If the gunner wants the replay repeated, he can initiate the replay using an option menu.

2. Automatically shown on a separate display screen at the end of each mission are the score obtained on the mission, the highest score that was possible on that mission, the duration of the mission, a percentage score across all missions in the lesson, an overall performance classification (unqualified, qualified, superior, or distinguished), the total number of main gun and coax rounds fired, the total number of main gun and coax rounds remaining, the percent of target coverage when using the coax, and the elevation and deflection errors for each round fired (up to five rounds). The score that a gunner receives is a function of hits and elapsed time. Penalties, ranging from 5 to 30 points, are subtracted for various performance errors. For example, five points are subtracted for firing at the wrong target first, and 30 points are subtracted for using the wrong GAS reticle. If the gunner changes the display after the mission, he can restore it using an option menu.

3. The gunner can retrieve a mission summary on the display screen. The summary presents the elevation and deflection errors in mils for each round fired, the elapsed time when each round was fired, and whether the round hit or missed the target.

4. The gunner can also retrieve a critique of his performance during the mission. There are 17 different messages that can be displayed (e.g., "WRONG AMMUNITION INDEXED," "YOU FIRED BEFORE THE COMMAND 'FIRE'").

After completing a mission on VIGS, a gunner can, at his option, move on to the next mission, repeat the mission just completed, or repeat an entire lesson from the beginning. In addition to the training exercises on VIGS, special exercises are available that enable the gunners to practice identifying the different target vehicles and estimating range.

M1 M-COFT

The Mobile Conduct-of-Fire Trainer (M-COFT) is composed of four components: (a) the general purpose computer (GPC), which receives, transmits, and calculates data during training and maintenance on the device; (b) the special purpose computer (SPC), which produces the visual images viewed by the TC and gunner; (c) the Instructor/ Operator (I/O) station, which the I/O operates to initiate the exercise, interact with the crew during the exercise, and monitor the crew's performance; and (d) the crew station, which simulates the TC and gunner stations of an M1 tank. Figure A-3 presents a cut-away view of an M-COFT. M-COFT is actually a transportable U-COFT. The description of the device that follows is based on documentation for the U-COFT, namely the Instructor's Utilization Handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (General Electric, 1985) and the M1 Unit Conduct-of-Fire Trainer (U-COFT) Training Device Support Package, FC 17-12-7-1 (U.S. Army Armor Center, 1985). Both of these publications contain extensive descriptions of U-COFT's components, characteristics, and capabilities.

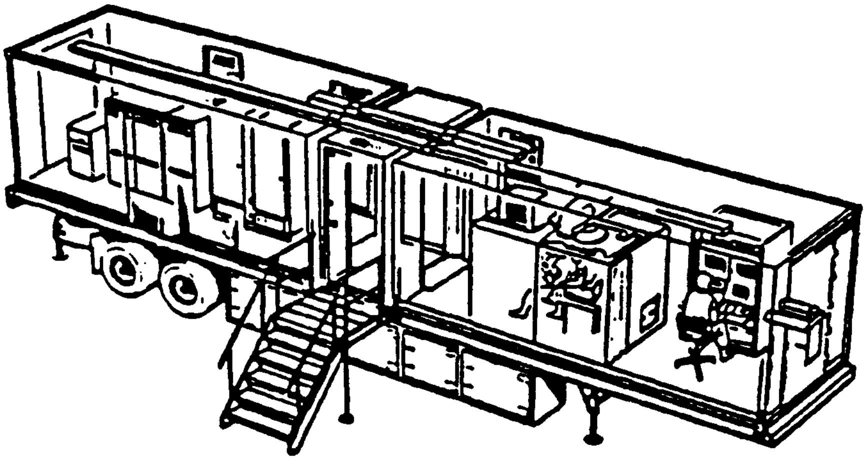

Figure A-3. The Mobile Unit Conduct-of-Fire Trainer (M-COFT).

Fidelity Features

Full-color, computer-generated visual scenes on M-COFT are created by the SPC and are viewed in the simulated TC and gunner crew stations through the (a) gunner's primary sight (GPS), (b) gunner's auxiliary sight (GAS), (c) gunner's primary sight extension (GPSE), (d) commander's weapon sight, and (e) commander's forward unity periscope (FUP). The visual scenes simulate an area three kilometers in depth and six kilometers in width. M-COFT provides two data bases, one representing European terrain and the other depicting desert terrain. Each data base contains an assortment of features that define its specific environment, such as trees, rocks, hedges, and various buildings. These features serve to enhance the realism of the terrain and to provide objects for masking targets. Targets in the visual scenes are presented as either single or multiple (two or three) and as either moving or stationary. Targets are programmed to appear at different points on the data base and appear at a variety of different angles and positions. Both threat targets (T72, BMP, HIND-D, trucks, and troops) and friendly targets (M60A3, M1, and M2/M3) are presented on the simulated terrain. M-COFT also simulates the ability to "maneuver" through the data base, allowing crews to simulate engaging targets from a moving vehicle.

M-COFT simulates six different visibility conditions including (a) day unlimited (b) day with haze (c) day with fog, (d) dawn/dusk, (e) night unlimited (thermal mode), and (f) night with thermal clutter. In addition, a number of visual special effects are produced including initial firing, scene obscuration, round tracer and tracer paths, round impact and effect on target, round impact on terrain, friendly fire from flanks, enemy direct/indirect fire, and hit on owntank.

A number of sounds associated with tank gunnery in a combat environment are produced by the M-COFT sound system. These sounds include owntank weapon fire (main gun, coax, caliber .50, and smoke grenade), friendly fire, enemy fire, tank track clatter, engine and transmission sounds (idle, turning, varying speeds), the TIS cooling fan, the turret blower fan, gun jump sounds (associated with activating the palm switches while stabilization is in effect), loading of the main gun (loader's announcement of "up", breech opening/closing, round removal, expended casings falling, ammo doors opening), and hits on owntank. Sounds are presented to the TC and gunner through CVC helmets which are connected into M-COFT's radio/intercom system. This system also allows the I/O to communicate with the TC and gunner.

The TC and gunner stations in M-COFT simulate the actual M1 vehicle controls, sights, and indicators that are required for gunnery training. In the gunner's station, all of the sights and control panels present in the M1 are represented and functional with the exception of the hydraulic pressure gage, the gunner's unity periscope, the ammunition temperature gage, and the gunner's TIS focus knob which are represented but not functional. The gunner's seat, chestrest, domelight, and ballistic doors handles are replicated. Automatic firing of the coax machine gun and operation of the charging handle used to apply immediate action for stoppages are simulated; however, manual firing of the coax is not simulated. In the TC's station, the commander's control panel is replicated and functional with the exception of the LOW BAT CHG, CKT BKR OPEN, and ENGINE FIRE lights which are represented but not functional. The TC's seat, domelight, and kneeguards are simulated, but the hatch is not. Partially simulated are the TC's periscopes (only the FUP is represented) and the caliber .50 machine gun. Closed-hatch firing of the caliber .50 is possible, but open-hatch manual firing is not. In addition, the radio/ intercom and the gas particulate filter system are simulated in both crew stations.

The degraded modes simulated by M-COFT are (a) LRF failure, (b) stabilization failure, (c) GPS/TIS failure, (d) gunner's power control handle failure, (e) electrical triggers failure, (e) ballistic computer failure, (f) commander's weapon station (CWS) power failure, (g) commander's power control handle failure, and (h) coax stoppage. Not simulated are failures associated with the crosswind, cant, and lead angle sensors.

Instructional Features

The instructional subsystem of M-COFT is quite complex and, to a certain extent, dictates how M-COFT is used. Thus, it deserves special attention. This instructional system provides for 685 exercises divided into three major categories: (a) special purpose, (b) commander, and (c) commander/gunner exercises. The 19 special purpose exercises are manually selected by the I/O and are used to orient crews to the device; to train crews to place the crew stations into operation, boresight and calibrate/zero weapons, detect targets and manipulate controls on M-COFT; and to evaluate the crew's proficiency on the device. There are 156 commander exercises (126 European and 30 desert exercises) designed to develop or sustain the gunnery skills of TCs. Each commander exercise contains from five to ten targets grouped into single target situations and is fired by the TC alone. There are also 510 commander/ gunner exercises (390 European and 120 desert exercises) designed to train crew gunnery skills. The commander/gunner exercises contain up to ten targets grouped into either single or multiple target situations.

The commander and commander/gunner exercises are organized into two separate training matrices. Each matrix is made up of three dimensions which represent critical skill areas associated with tank gunnery training. Those dimensions are: (a) target acquisition (TA), which includes target identification and acquisition skills; (b) reticle aim (RA), which includes aiming and firing skills; and (c) system management (SM), which includes skills necessary to operate the fire control system. As a TC progresses along a particular dimension of the commander matrix, or a TC/gunner pair advances along a particular dimension of the TC/gunner matrix, the difficulty of the corresponding skill area increases. The commander and commander/gunner matrices are shown in Figures A-4 and A-5, respectively.

The commander matrix comprises three levels of target acquisition. Increases in TA difficulty are attained by reducing visibility and adding distractions for the crew. TA Level One contains exercises fired under unlimited day visibility conditions. The exercises in TA Level Two are conducted under dawn/dusk visibility conditions. TA Level Three is made up of exercises conducted under day visibility conditions with haze and with friendly and enemy fire, to simulate the distraction of an actual day combat environment. The level of difficulty in the SM skill area is increased by increasing the range to the targets presented within an engagement. Overall progress in the matrix proceeds along the RA dimension. Increases in RA difficulty are attained by introducing system malfunctions into the simulation and by changing the movement of owntank and targets. The RA dimension is divided into 21 levels which are organized into five groups according to owntank and target movement situations. As shown in Figure A-4, the 21 RA levels are combined into five RA groups defined by movement of the owntank and movement of the targets.

As shown in Figure A-5, the commander/gunner matrix is similar in organization to the commander's matrix. The commander/gunner contains three levels of TA which increase in difficulty as visibility diminishes and distractions are added. TA Level One includes exercises fired under either unlimited day or unlimited night visibility conditions. The exercises in TA Level Two are conducted under the reduced visibility conditions of dawn/dusk, night with thermal clutter, or day with fog and thermal clutter. The exercises in TA Level Three are conducted under hazy day conditions with friendly and enemy fire or under night conditions with thermal clutter, and friendly and enemy fire. As in the commander matrix, RA increases in difficulty as malfunctions are introduced into the system and the movement of owntank and target changes. There are 39 levels of RA difficulty in the commander/gunner matrix, which are arranged into six RA groups. The exercises are similarly grouped according to combinations of owntank and target movement; as shown in Figure A-5, however, there are six rather than five RA groups. The certification exercises used to qualify crews on M-COFT comprise RA Group Six. Finally, there are four SM levels in the commander/gunner matrix, which increase in difficulty as the range and number of targets presented increase.

A crew's specific entry point into each matrix and the point at which it reaches certification are dependent on the amount of prior training it has received and their proficiency level on the device. That is, crews with little or no prior gunnery experience begin at, progress through, and are certified on the easier TA and SM levels. Upon achieving certification they

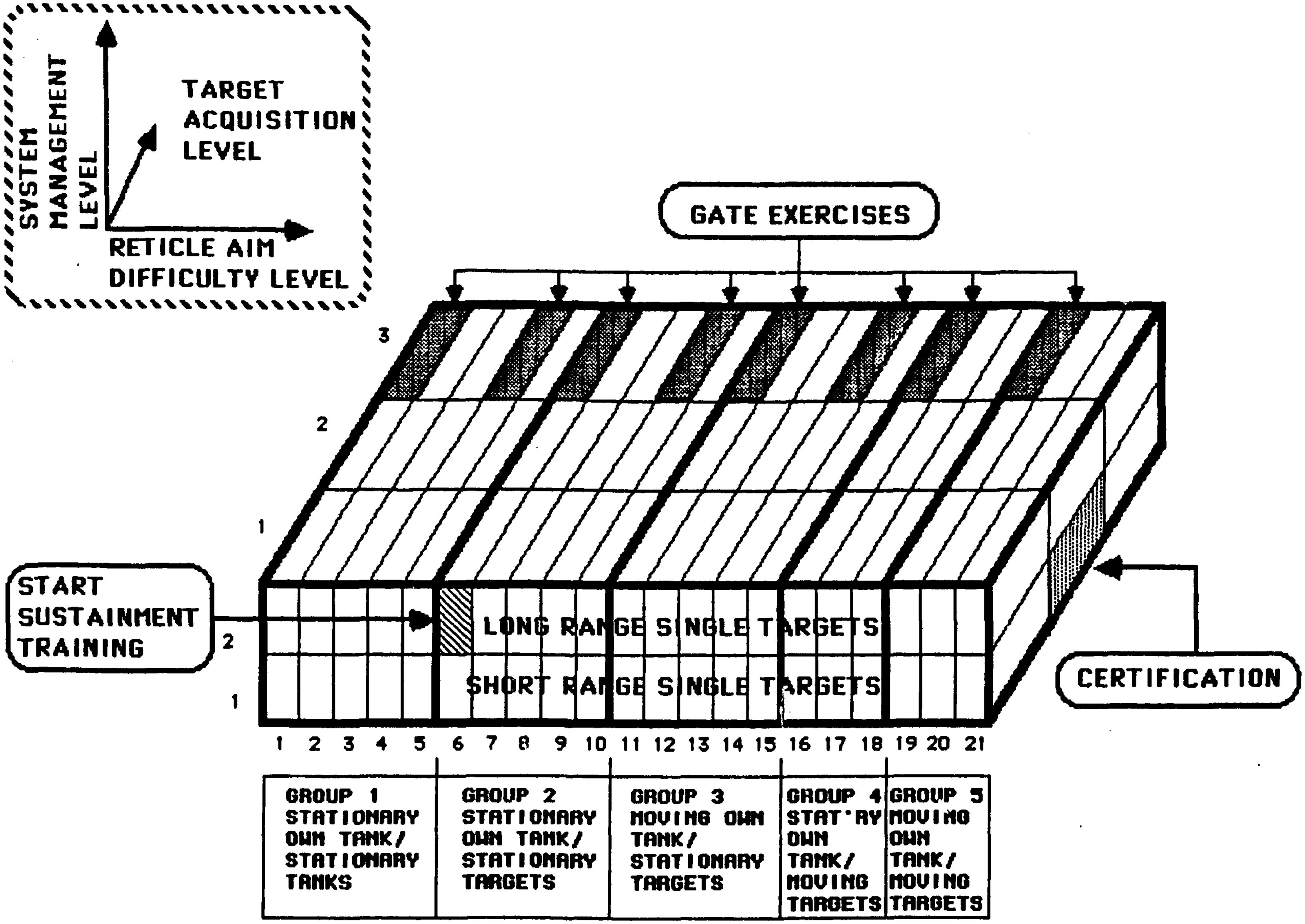

Figure A-4. M-COFT commander training matrix.

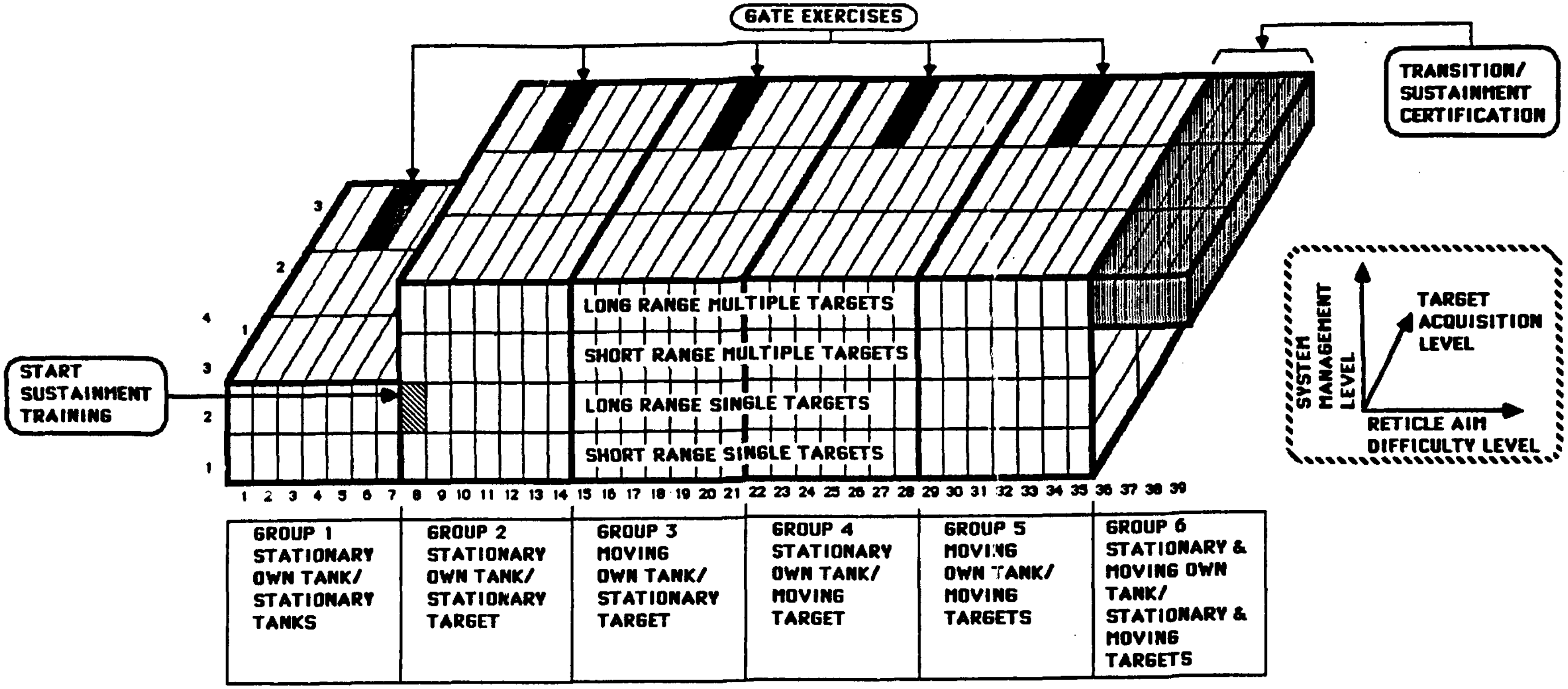

Figure A-5. M-COFT commander/gunner training matrix.

then reenter the matrix at the sustainment level. Experienced gunnery crews enter the matrix at the sustainment level and progress through and are certified on the more difficult TA and SM levels. Crews are allowed to advance through the matrices at their own pace. Progression through the matrices is controlled by matrix movement rules, which are different for each of the four levels of training on M-COFT (sustainment, transition, cross, and basic). The movement rules are designed to prohibit crews from advancing to the next higher level of difficulty until they have demonstrated an acceptable level of mastery within a dimension

After each exercise is completed, the GPC calculates a score for the crew on each of the three skill areas and develops a recommendation pertaining to the crew's movement within the matrix. The four recommendations the computer can make are: (a) reduction in level, (b) no advancement, (c) normal advancement, and (d) rapid advancement. The computer then checks this recommendation against the matrix movement rules to determine the next exercise to be fired. Briefly stated, in order to advance to the next higher difficulty level within a skill area, a crew must perform at or above a minimum acceptable proficiency level, and they must attain a normal advance computer recommendation on all three dimensions on the "gate" exercise within each RA group in the matrix. These exercises are gates in the sense that they must be successfully passed before proceeding to the next RA group. In the commander matrix, the gate exercise in each RA group is the most difficult exercise that contains no system malfunctions. In the commander/gunner matrix, the gate exercise in each RA group is the most difficult NBC exercise.

In addition to the automatic sequencing recommended by the M-COFT training program, the I/O has the option of manually selecting exercises to emphasize certain skill areas. In scoring these optional exercises, the GPC calculates a letter "grade" (A, B, C, or F) rather than recommending a level of advancement. Performance on I/O selected exercises is not taken into account by the GPC when regulating advancement through the matrices.

Currently under development is an advanced matrix for the U/M-COFT which will replace the present commander and commander/gunner matrices as the primary training software. Tentatively scheduled for release in May 1991, the advanced matrix is being designed because many crews have difficulty advancing beyond RA Group Two in the commander/gunner matrix. This situation poses a problem in that most Major Commands require crews to pass "gate" COFT exercises as a prerequisite to live-fire training; many of the exercises selected as these gates are beyond RA Group Two. Thus, at present, many crews that have not passed RA Group Two are temporarily withdrawn from the matrix to fire the gate exercises and then placed back into the matrix at their previous level. The new matrix avoids this predicament by positioning exercises commonly used as gate exercises at the end of RA Group One. In addition, the advanced matrix will allow the TC the option of deciding how to fight the tank. That is, as long as the crew's actions result in hits or kills, the TC can choose battlesight over precision, or use the GAS instead of the GPS and not be penalized. Also, unannounced malfunctions will be randomly induced into exercises, requiring the crew to make the appropriate adjustments. Finally, the hit plate on targets will be reduced, so that some targets may require two or more rounds before a kill is registered.

With regard to performance measurement capabilities, the GPC automatically keeps track of individual, crew, and unit progress through the M-COFT training matrices. This information can be accessed by the I/O in the form of printouts that can be used to provide the crews with feedback on their performance. With regard to individual crew performance, six printouts are available:

- Situation Monitor - provides information on ammunition selected, target type, reticle lay, number of rounds fired, engagement result, and letter grades for each of the three skill areas.
- Performance Analysis - provides information on target type, number of rounds fired at each target, number of main gun hits and percent of machine gun coverage, TA and SM errors, individual engagement scores, the GPC recommendation for each of the three skill areas, and individual and average times to identify, fire, hit, and kill targets.
- Shot Pattern - depicts reticle lay error in both graphic and tabular formats.
- Session Summary - provides a summary of the crew's last training session. The printout contains, by exercise, the total number of rounds fired, total number of hits, number of targets engaged, total number of TA and SM errors, the GPC recommendation or letter grade for each skill area, and the average times to identify, fire at, hit, and kill targets.
- Crew record - provides a record of the last 100 exercises fired by the crew and the GPC recommendation or letter grade for each skill area for each exercise. It also includes coordinates that indicate the crew's present and expected positions in the matrix, the number of GPC recommended exercises fired, whether the TC and/or gunner are certified, and a summary of the crew's progress in the commander/gunner training matrix.

In addition to the matrix and performance measurement features, Hoffman and Morrison (1988) identified a number of additional instructional features that are incorporated on the U-COFT. These features include the ability to (a) select exercises according to a set of parameters, (b) record and replay the visual and aural cues from an exercise, (c) freeze and unfreeze action during an exercise, (d) repeat any portion of an exercise, (e) continuously monitor the sight pictures presented to the TC and gunner from the I/O station, (f) automatically record errors relating to improper positioning of switches, and (g) provide a written briefing on upcoming exercises that the I/O can deliver to the TC and gunner.

GUARD FIST I

The Guard Unit Armor Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I), consists of three sets of components. According to the Operator's Manual for GUARD FIST I (Daedalean, Inc., 1990) those three sets of components are (a) the components that are appended to an actual M1 tank, (b) the instructor/operator (I/O) station, and (c) the cable harness that connects the tank-appended components to the instructor/operator station. The harness transmits information from crewmember's controls to the computer, and transmits information from the computer to the tank controls. The components of the device are pictured in Figure A-6. A complete description of GUARD FIST I components and functions can be obtained in the Operator's Manual.

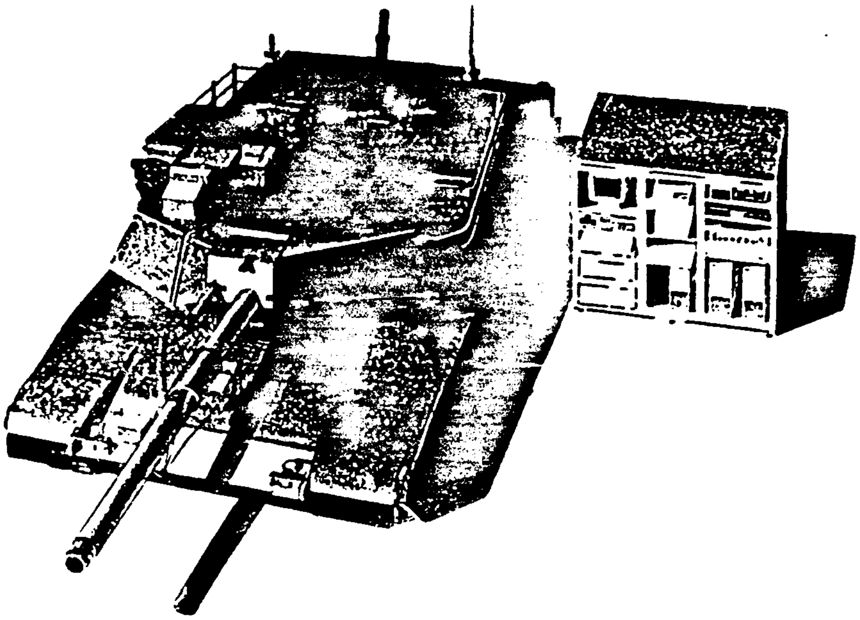

Figure A-6. The Guard Unit Armor Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I).

Fidelity Features

The device's visual images are provided to the crewmembers via four 16-inch, high resolution, color monitors. The four monitors are placed outside of the tank in front of (a) the gunner's primary sight (GPS), (b) the gunner's auxiliary sight (GAS), (c) the tank commander's weapon station (CWS) vision block, and (d) the driver's center vision block. These pictures on the monitors simulate the scenes that would be viewed from these four sights. Three types of stationary or moving threat targets are presented in the visual scenes, each requiring different weapon/ammunition combinations: (a) heavily armored vehicles (T72), which should be engaged with the main gun using APDS rounds; (b) lightly armored vehicles (BMP, ZSU 23-4, and BRDM), which should be engaged with the main gun using High Energy Anti-Tank (HEAT) rounds; and (c) "soft" targets (infantry personnel), which should be engaged with the coaxial machine gun. Also projected is background scenery appropriate to either a European or a desert scenario.

During GUARD FIST I exercises, a sound generating system synthesizes the sounds corresponding to various actual sources associated with tank gunnery including the main gun and coax machine gun, the ready ammo door, the engine, the turret blower, and the compressor on the thermal imaging system. These sounds are transmitted through the intercom system and through a pair of bass and treble speakers mounted under the breechblock. GUARD FIST I supplies power to the intercom boxes so that these tank components can be used with actual CVC helmets for intratank communications. The intercom system also allows the instructor/operator (I/O) to communicate with the crew. GUARD FIST I also supplies power to the individual domelights at all stations; these tank components function as they would if the tank were powered up. The following paragraphs describe the controls and displays that function at each crewmember's station.

At the commander's control panel, two controls related to battlesight engagements function normally: the MANUAL RANGE BATTLE SGT pushbutton and the MANUAL RANGE ADD-DROP switch. Also on the commander's control panel, the FIRE CONTROL MALF comes on at appropriate times during the training and evaluation exercises. The control handles at the CWS simulate the traversal of the CWS by changing the CWS display; that is, the cupola does not move, but the simulated scene does. The CWS does not allow the tank commander to fire his caliber .50 machine gun as that weapon system is not simulated in GUARD FIST I. The commander's power control handle functions as it normally would to override/operate the gunner's power control handles. That is, this handle allows the tank commander to elevate/traverse the turret, activate the LRF, and fire the main gun or coaxial machine gun.

At the gunner's station, a faceplate mounts directly in front of the gunner's control panel providing a simulation of some of the controls on that panel including the RANGE switch, the FIRE CONTROL MODE switch (the MANUAL setting is not functional), the GUN SELECT switch, and the AMMUNITION SELECT switch. TIS controls that are functional include the FLTR/CLEAR/SHTR switch, the THERMAL MAGNIFICATION switch, and the POLARITY switch. The remaining controls on the gunner's control panel overlay are nonfunctional two-dimensional representations of the actual equipment. The RETICLE switch on the GAS control panel enables the gunner to change between the SABOT/HEAT combination reticle and the HEAT reticle as he would in the actual tank. Finally, the gunner's control handles function as they do in the tank to elevate/traverse the turret, activate the LRF, and fire the main gun or coaxial machine gun.

At the loader's station, the loader's control panel simulates two functions of the panel controls and displays: (a) the GUN/TURRET DRIVE switch can be placed in EL UNCPL or POWERED positions as appropriate (the MANUAL position does not work), and (b) the MAIN GUN STATUS lights (ARMED and SAFE) illuminate to indicate the position of main gun spent case ejection guard. The loader's knee switch functions normally to allow the loader to choose ammunition in the ready rack. However, the ready rack door does not open as it does in the tank; rather, the loader chooses ammunition by depressing either the HEAT or SABOT button on the ammunition select panel. This latter panel is not in the operational tank. Another component not on the actual tank is the breech load select switch. After an appropriate interval, the READY light on top of the breech load select switch illuminates to indicate that the loader can simulate loading the round into the breech. This action is simulated by pushing a spring-loaded button in the center of the breech load select switch. At that point the READY light goes out and the LOADED light comes on. The loader completes the loading procedure by moving the ejection guard to the FIRE position as he would in the actual tank.

At the driver's station, sensors are attached to detect (a) changes in the steering column to determine the direction the tank is steered, (b) the position of the throttle, and (c) position of the service brake, and (d) the transmission gear selected. These sensors feed information into the computer which makes appropriate changes to the computer-generated images in each of the monitors. Except for these four controls, none of the other components at the driver's station operate.

GUARD FIST I simulates a number of degraded modes including LRF failure, GPS/TIS failure, loss of symbology in the GPS, and loss of stabilization. However, it does not simulate turret power failure and thus does not support training for operating the tank in manual mode.

Instructional Features

The trainer has access to a total of 36 training exercises arranged in six groups of six exercises. In addition to the six training exercises, each group has three evaluation exercises. Each training or evaluation exercise consists of two or more tasks (single- or multiple-target gunnery engagements). The six groups are ordered in difficulty from easiest to most difficult. The groups are distinguished on multiple dimensions of engagement conditions. For instance, in the first group, crews engage fully exposed, single stationary targets presented at moderate ranges from a stationary owntank experiencing no malfunctions. In contrast, the sixth group requires crews to engage fully and partially exposed, multiple, stationary and moving targets at short to long ranges from a moving tank experiencing a variety of unannounced malfunctions. The overall training strategy calls for crews to practice on training exercises within one group. When the I/O deems that the crews are prepared, they take one or more of the evaluation exercises. They must pass the evaluation exercise for that group in order to go to the next group in the series.

GUARD FIST I can be run in one of two modes. In the primary mode, the I/O selects and runs training and evaluation, and can perform all crew record and management functions. The crew records maintained by GUARD FIST I include such information as the crew identification number, the current exercise group, whether or not crew has qualified in the group and the date of qualification, and the number of times specific exercises were run, failed, and/or passed. In the secondary mode, the tank commander can select and run training exercises through the use of a keypad that is appended to the left of the GPSE. However, the tank commander cannot run evaluation exercises, nor does he have access to crew records.

The I/O station provides two monitors (gunner/driver and tank commander), which operate in two modes. In "realtime" mode, the gunner/driver monitor can be switched back and forth between the views from either the gunner or driver's monitors. For the view from the gunner's monitor, the default condition is to show the GPS. However, if the gunner places his head in the GAS and trips an appended infrared sensor, the gunner display at the I/O station automatically switches to the GAS. At the same time, the tank commander monitor shows the view from the CWS vision block. In "non-realtime" mode, the system displays menus through the gunner/driver monitor, and a test pattern is displayed at the tank commander monitor. In addition to the monitors, the I/O has a standard QWERTY keyboard for interacting with GUARD FIST I software. One function of this keyboard allows the I/O to freeze an engagement within an exercise by depressing a function key (F12). When an exercise is frozen, a menu is presented in the gunner/driver monitor offering the I/O the option to unfreeze the engagement, to restart the exercise, or to terminate the exercise.

GUARD FIST I has the capability to monitor errors that the crew commits during an exercise. Some errors are monitored automatically by the system itself. These errors are grouped into four levels of increasing seriousness: minor, important, major, and critical. A critical error (e.g., collision with an obstacle) results in automatic termination of exercise and a "fail" rating. Verbal responses cannot be monitored by the system, and are therefore keyed in by the I/O using the function keys on the QWERTY keyboard. For instance, the function keys F1-F9 are used to log in the elements of the fire command and other verbal announcements prescribed by gunnery doctrine.

At the end of either a training or evaluation exercise, a menu appears to allow the I/O to access and/or to print the Trigger Pull Error Report. This performance assessment provides basic hit/miss information as well as the owntank movement, target movement, target range, and type of round fired for each individual round fired. This report also provides a count of the number of errors committed for each pull of the trigger. From this screen, the I/O can access a page that identifies each error. If the exercise is for training, this screen allows the I/O to use the performance information and his own judgment to pass or fail the crew. If the exercise is for evaluation, the system automatically assigns the crew a pass/fail grade.

SIMNET

Simulation Networking (SIMNET) is a multi-faceted system that supports combined arms training at the platoon, company, and battalion level. Detailed and complete descriptions of the entire system are available in the <u>M1 SIMNET Operator's Guide</u> (U.S. Army Armor Center, 1987) and the <u>SIMNET User's Guide</u> (U.S. Army Armor Center, 1989). The following description focuses on just those components that are most relevant to armor crew- and platoon-level gunnery. A single SIMNET M1 crew simulator is shown in Figure A-7. Figure A-8 shows the basic structure of a SIMNET local area network, which is used to link the simulators and the computers that control the simulation.

Fidelity Features

The visual images in SIMNET are constructed by a microcomputer and graphics processor assigned to each vehicle. These processors use information obtained from the network on terrain, vehicle status, and weapon effects to construct a computer-generated image of the battlefield. The images are then projected into various sights of the vehicles. The effect is to provide all crew members a daytime (i.e., no thermal), closed-hatch view of a common battlefield that is appropriate to their own vantage point. In addition, some of the sights within a vehicle can be rotated to scan the battlefield. Although the visual scene is remarkably compelling, several sources (e.g.,

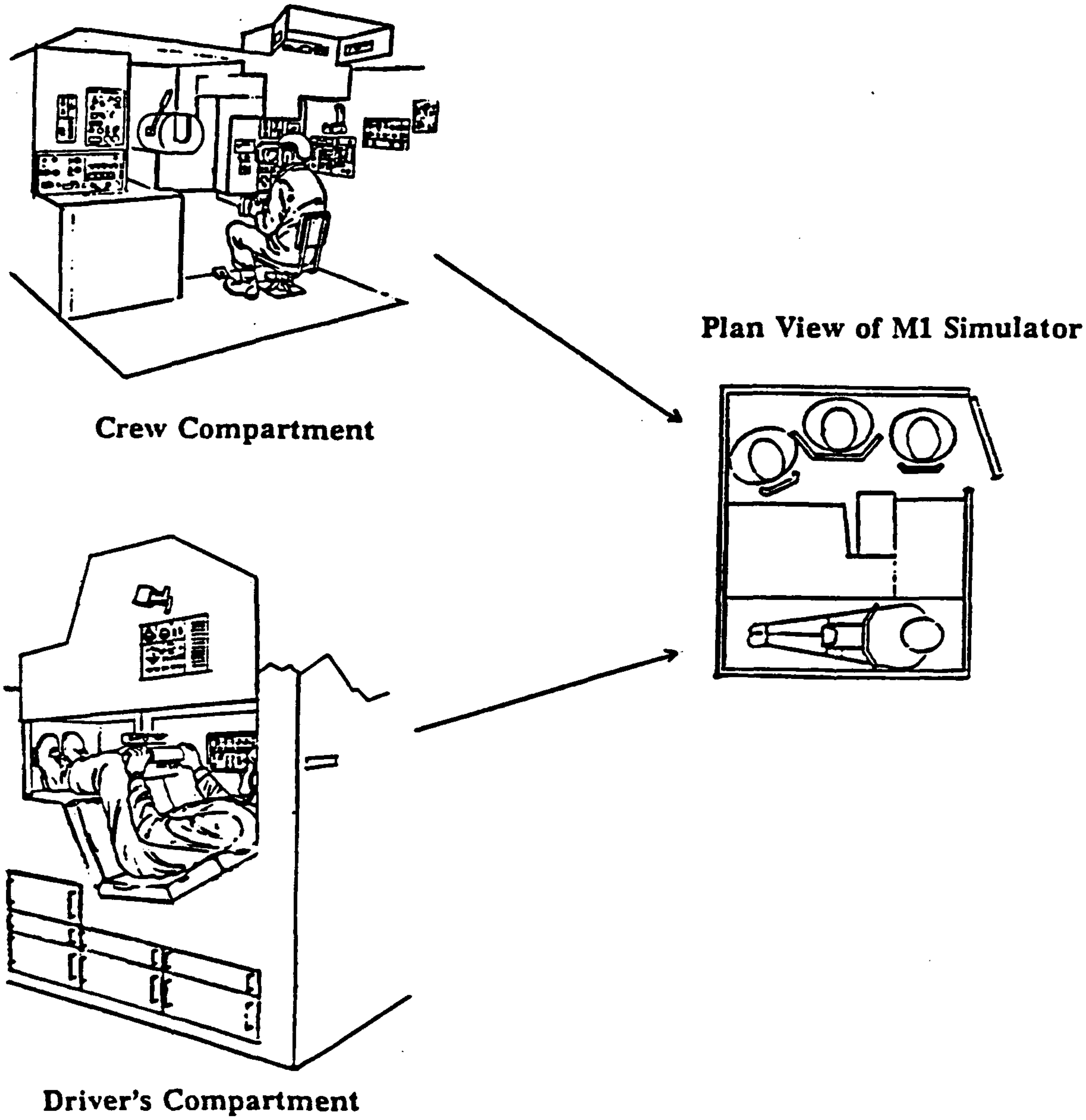

Figure A-7. A Simulator Networking (SIMNET) M1 Tank crew simulator.

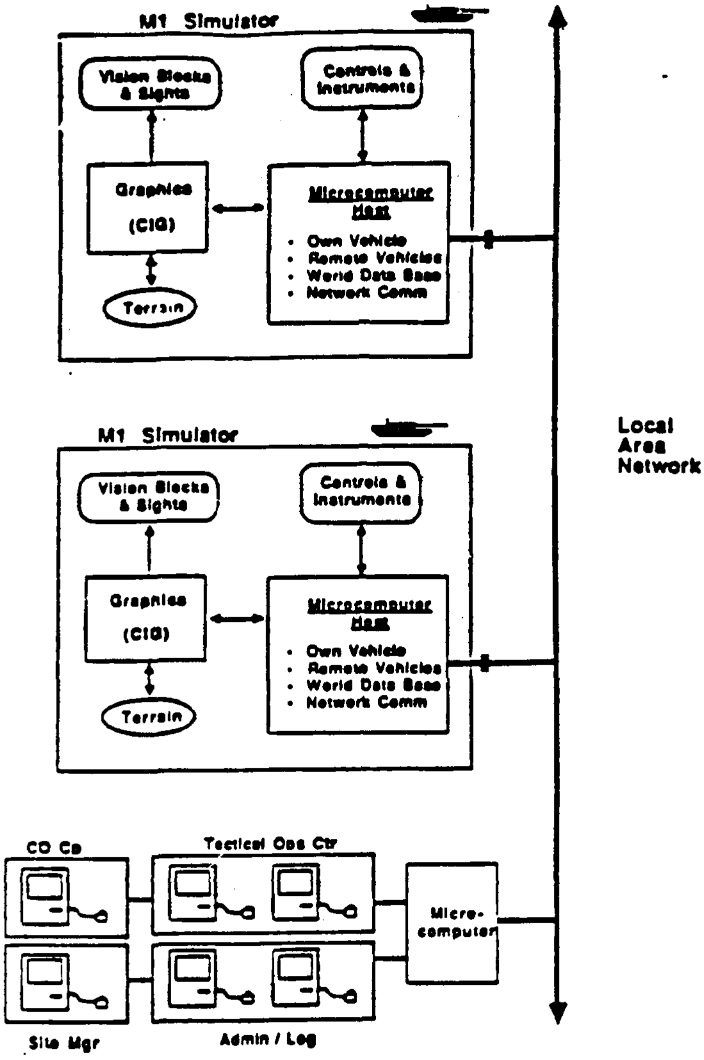

Figure A-8. Basic structure of a Simulation Networking (SIMNET) local area network.

Drucker & Campshure, 1990; U.S. Army Armor Center, 1989) have noted some important shortcomings of the visual system that conceivably have an impact on gunnery: (a) the simulated terrain is unrealistically smooth and open with very few natural or man-made features; (b) no visual feature beyond 3500 meters, regardless of size, is generated by the system; (c) the terrain is not dynamic, that is, not affected by SIMNET user's actions or the outcomes of these actions; and (d) no visual obscuration is represented by the system.

At the gunner's station, the trainee can view the simulated battlefield at either 3X or 10X through a representation of the GPS which provides appropriate reticle, range display, and fire control malfunction symbols. There is no simulation of the Gunner's Auxiliary Sight (GAS); however, if the GPS suffers damage in a simulated engagement, the GAS ballistic reticle automatically replaces the nonballistic reticle in the GPS. The gunner can fire main gun ammunition using his control handles. By using his AMMUNITION SELECT switch, the gunner can select either APDS or High Explosive Anti-Tank (HEAT) ammunition. However, SIMNET does not simulate either the 7.62mm coax or the TC's caliber .50 machinegun. In general, the simulated fire control system is always boresighted and system calibrated. The main gun is also stabilized and the stab system is adjusted to null point (no drift control knobs). Finally, the cant sensor, wind sensor, and ballistic computer are always operational.

As in the actual tank, the GPSE provides the TC the identical view that the GPS provides the gunner. Also, the TC's power control handles provide him the capability to override the gunner's controls to aim, lase, and fire at targets. In addition to the GPSE, the tank commander can also view the battlefield through three unity power windows providing a 64° horizontal field of view. By rotating his cupola with the CWS handle, the tank commander has an effective 300° horizontal field of view.

The loader views the battlefield through his unity periscope, which he can rotate 300°. Because the loader's M240 machine gun is fired from an open-hatch position, this weapon system is not simulated in SIMNET. The loader performs his loading and ammunition redistribution duties by pushing buttons to represent the required physical actions. Loading is restricted to only main gun rounds since machinegun fire is not simulated.

The driver views the battlefield through three unity periscopes affording a 170° horizontal field of view. The driver's station and controls are similar to those on the actual equipment. The SIMNET simulates appropriate acceleration and deceleration effects as a function of grade and hardstand.

For communication purposes, all crewmen are provided a combination headset and boom mike that replaces the CVC helmet that they would normally use in the tank. The intercom capabilities of SIMNET correspond closely to the actual system. The tactical FM radio is simulated by a citizen's band (CB) radio system. This difference requires some modification of frequency selection procedures that are used in the actual tank.

Two other features provide augmented visual cues in the sense that they are not real cues that are present in the actual equipment. These augmented cues are designed to compensate for crucial stimuli that are missing in the simulation. One of these augmented cues is the turret-to-hull reference display. This display, visible to the three crewmen in the turret compartment (gunner, tank commander, and loader), indicates the position of the gun tube relative to the hull. This display is intended to compensate for the lack of motion cues, the absence of visual cues from open-hatch viewing, and the missing cues provided by the relative position of the driver's compartment to the turret in the actual tank. The other augmented cue is provided by the grid azimuth indicator, a display not present in the actual tank. This indicator displays the azimuth of the main gun in mils. To use this feature, the vehicle must be stopped and the gun laid in the desired direction before the azimuth indicator button is depressed. The grid azimuth indicator is designed to compensate for the inability to dismount from the vehicle to obtain a grid azimuth.

Instructional Features

The controls at the battlemaster station comprise some of the more essential functional features of SIMNET. The battlemaster station affords the battlemaster (the system operator) the capability to set up, start, stop, and restart exercises. A unique characteristic of SIMNET is that it has no set exercises or canned scenarios. Instead, the battlemaster can create virtually an unlimited number of scenarios by presetting a set of simulation parameters such as the location, number, and type of vehicles that will be used in the exercise. The actions of the vehicles are not preset because the system is used for spontaneous "force-on-force" tactical exercises.

Another essential functional feature is the data logger that provides the capability to record and replay the stream of data that is passed over the SIMNET network. One way to play back this information is through the Plan View Display (PVD), which provides a top-down view of the battlefield. The scale or location of the PVD is under control of the user. The PVD has been shown to be especially effective for providing after action reviews (AARs). Information from the data logger can also be replayed through the Stealth Displays. This relatively new display is projected on three television monitors allowing a 120° field of view. The viewer can move around freely to view the battlefield from any height, distance, and angle.

The present configuration of SIMNET has no built-in facilities for automated performance measurement; however, two add-on systems may provide this capability. The Data Collect and Analysis (DCA) system, which is currently available only on SIMNET-D, "...collects, replays, reduces, and analyzes the data packets generated by a SIMNET exercise" (Garvey & Radgowski, 1988). Because the primary mission for SIMNET-D is research and development, the DCA collects information on only small numbers of units trained under special conditions. The Unit Performance Analysis System (UPAS), a research product being developed for the Army Research Institute (ARI), can be used in the context of SIMNET-T. UPAS is a low-cost, microcomputer-based system that collects and analyzes SIMNET-T data to support after-action reviews (White, McMeel, & Gross, 1990). The extent to which this system will prove useful to AARs and to research is presently unknown.

HHT

The Hand-Held Tutor (HHT) is the only example of a gunnery training aid. The HHT has been described as falling "...on a continuum between traditional paper-based materials and microcomputer/videodisc systems. The [HHT] lacks the flexibility and moving graphics capabilities of interactive videodiscs, but it is a fraction of the cost of such systems and is easily portable" (Bridgeman & Fertner, 1986, p. 2).

Hardware

The HHT, as shown in Figure A-9, is a self-contained unit measuring approximately 10 X 11 X 2 in. At the top of the HHT is a 32-character, liquid crystal diode (LCD), dot matrix display screen. At the bottom are input keys for the numbers 0-9; for the letters A-E; and for game functions SAY, ERASE, and GO. In the middle of the HHT is an indentation for holding a 5 X 5 in booklet. In addition to output from the display screen, the HHT presents audio output from a digitized speech system that outputs through either a built-in speaker or plug-in earphones. HHT software is programmed onto an erasable, programmable read only memory (EPROM) chip that is installed on the printed circuit board. The database for the software is contained in a plug-in module that is tailored for the M1 gunnery application. System power is provided by rechargeable nickel-cadmium batteries or transformers.

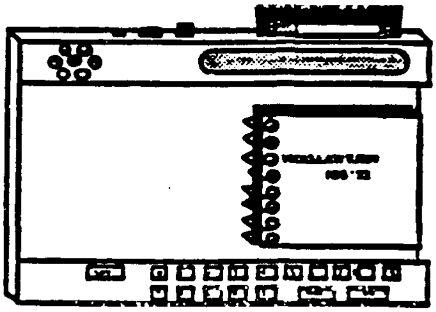

Figure A-9. The Hand-Held Tutor (HHT).

The learner interacts with the HHT via three function keys. The numbers 0-9 are for indicating what unit the learner desires to work on, whereas the letters A-E represent response alternatives. The GO function key is used to indicate when the learner is ready to go to the next question, and the ERASE function key is used to change an answer. Finally, the SAY key is used to activate the digitized speech function of the HHT.

Courseware

The content of the M1 gunnery version of the HHT was based on paper-based aids that were developed earlier for training and sustaining M1 gunnery knowledges and skills (Silbernagel, Vaughan, & Schaefer, 1982). These materials were essentially paper-based programmed learning booklets. The unique aspect of these booklets was the use of combat scenarios to present realistic combat situations to armor crewmembers. These scenarios consist of a simple line drawing depicting the battle situation together with a brief verbal description of the situation and the status of the M1 tank system. Immediately following this element are problems that the crewman must solve. Following the problems on the next page are the doctrinally correct solution to the problem plus a brief explanation of the solution. These original materials on fire commands were later updated in paper form to reflect the changing M1 armor doctrine (Kraemer, 1984a, 1984b, 1984c). These materials were revised again when they were redesigned for implementation on the HHT.

Bridgeman and Fertner (1986) described the HHT's instructional software (or courseware) as consisting of three components. The first component controls the sequence of pretest and explanatory texts corresponding to each instructional unit. If the learner makes no errors on the unit pretest, this courseware component sequences him to the next unit; if the learner makes an error, the component displays the correct answer and then sequences him to the explanatory text for the unit.

The second component of the HHT courseware is a game called "Word War" that is designed to provide drill-and-practice sessions on (a) weapon/ammunition selection, (b) identification of threat weapons, and (c) appropriate target descriptions for the fire command. A situation is presented followed by a presentation of alternative responses on the LCD screen. The soldier is supposed to press GO when the correct response is on the screen. If the soldier selects an incorrect response, the item is presented again after just one other intervening item, again after three more items have been presented, and so on. The rationale for this instructional strategy was developed in a 1980 AERA convention paper by Siegel and DiBello (cited in Fertner & Bridgeman, 1986).

The third component of the HHT courseware is a game called "Picture Battle." The picture battle component provides the vehicle for implementing the combat scenarios proposed in the original fire command booklets (Silbernagel, Vaughan, & Schaefer, 1982). This game requires the recognition of an appropriate stimulus given an appropriate aural prompt. The LCD screen is used to display the score: When the learner responds correctly, an arrow (representing a projectile) moves one step from left to right; when the soldier responds incorrectly, the arrow moves in the opposite direction. The object of the "game" is to destroy the enemy before he destroys you. Hitting the target is accompanied by the sound of an explosion.