NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

EXPERIMENTAL DESIGN AND ANALYSIS OF M1A1 COMMANDER/GUNNER PERFORMANCE DURING CONOPS USING THE U-COFT

by

Randy E. Geiger

September 1989

Thesis Advisor: Samuel H. Parry

Unclassified

security classification of this page

REPORT DOCUMENTATION PAGE

1a Report Security Classification Unclassified	1b Restrictive Markings
2a Security Classification Authority	3 Distribution Availability of Report
2b Declassification Downgrading Schedule	Approved for public release; distribution is unlimited.
4 Performing Organization Report Number(s)	5 Monitoring Organization Report Number(s)
6a Name of Performing Organization Naval Postgraduate School; 6b Office Symbol *(if applicable)* 55	7a Name of Monitoring Organization Naval Postgraduate School
6c Address *(city, state, and ZIP code)* Monterey, CA 93943-5000	7b Address *(city, state, and ZIP code)* Monterey, CA 93943-5000
8a Name of Funding Sponsoring Organization; 8b Office Symbol *(if applicable)*	9 Procurement Instrument Identification Number
8c Address *(city, state, and ZIP code)*	10 Source of Funding Numbers: Program Element No; Project No; Task No; Work Unit Accession No

11 Title *(include security classification)* EXPERIMENTAL DESIGN AND ANALYSIS OF M1A1 COMMANDER/GUNNER PERFORMANCE DURING CONOPS USING THE U-COFT.

12 Personal Author(s) Randy E. Geiger

13a Type of Report	13b Time Covered	14 Date of Report *(year, month, day)*	15 Page Count
Master's Thesis	From To	September 1989	81

16 Supplementary Notation The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 Cosati Codes			18 Subject Terms *(continue on reverse if necessary and identify by block number)*
Field	Group	Subgroup	Human factors, CONOPS, U-COFT, combat models, experimental design, tank crew performance, combat simulations, CCAB

19 Abstract *(continue on reverse if necessary and identify by block number)*

This paper presents an experimental design which demonstrates the potential of high fidelity simulators as performance data collection tools. The experiment employs the Unit Conduct of Fire Trainer (U-COFT), an M1A1 Tank simulator, to measure the effects of sleep loss on the performance of the commander gunner team. The Complex Cognitive Assessment Battery (CCAB) will also be used to measure sleep loss degradation of cognitive skills. The crews will be subjected to a structured environment for 72 hours with the control crews receiving eight hours of sleep each day, and the experimental crews receiving four hours of sleep each day. Furthermore, half of the experimental groups will sleep during a peak of the circadian cycle and half will sleep during a trough. The results of these experiments will provide commander gunner team performance distributions for target acquisition, identification, classification, time to fire, accuracy, and system management capabilities during continuous operations (CONOPS). The results of these experiments could be applied to land combat models, like JANUS, as a first step toward incorporating human factors into the models. The capabilities of high fidelity simulators demonstrated by this experiment should cause future simulators to be designed not only for training, but also for data collection and processing.

20 Distribution Availability of Abstract ☒ unclassified unlimited ☐ same as report ☐ DTIC users	21 Abstract Security Classification Unclassified
22a Name of Responsible Individual Samuel H. Parry	22b Telephone *(include Area code)* (408) 646-2283; 22c Office Symbol 55Lw

DD FORM 1473,84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete — security classification of this page

Unclassified

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Experimental Design and Analysis of M1A1 Commander/Gunner Performance During CONOPS Using the U-COFT.

by

Randy E. Geiger
Captain, United States Army
B.S., United States Military Academy

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1989

Author: ______________________
Randy E. Geiger

Approved by: ______________________
Samuel H. Parry, Thesis Advisor

____
Laura Johnson, Second Reader

____
Peter Purdue, Chairman,
Department of Operations Research

ABSTRACT

This paper presents an experimental design which demonstrates the potential of high fidelity simulators as performance data collection tools. The experiment employs the Unit Conduct of Fire Trainer (U-COFT), an M1A1 Tank simulator, to measure the effects of sleep loss on the performance of the commander/gunner team. The Complex Cognitive Assessment Battery (CCAB) will also be used to measure sleep loss degradation of cognitive skills. The crews will be subjected to a structured environment for 72 hours with the control crews receiving eight hours of sleep each day, and the experimental crews receiving four hours of sleep each day. Furthermore, half of the experimental groups will sleep during a peak of the circadian cycle and half will sleep during a trough. The results of these experiments will provide commander/gunner team performance distributions for target acquisition, identification, classification, time to fire, accuracy, and system management capabilities during continuous operations (CONOPS). The results of these experiments could be applied to land combat models, like JANUS, as a first step toward incorporating human factors into the models. The capabilities of high fidelity simulators demonstrated by this experiment should cause future simulators to be designed not only for training, but also for data collection and processing.

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ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the following people for their invaluable assistance in completing this thesis:

1. My wonderful family, Gwen, Rick, and Leighann, for their love and support throughout this project.
2. Professor Samuel H. Parry for his guidance, professional expertise, editorial comments, and encouragement.
3. Professor Laura Johnson for her professional assistance and recommendations.
4. MAJ Bell, Mr. Evans, Mr. Davis, SFC Schlemner, and others at the Fort Knox Armor Simulator Division for the instruction, and document and data support they provided on the Conduct of Fire Trainer.
5. The DCSPER MANPRINT office for support and sponsorship of this project through the continued funding of Human Factors modeling research at TRADOC Analysis Command - Monterey.

I. INTRODUCTION

A. THE ARMY AND COMPUTERS

Computer technology has progressed rapidly in the past few years and the Army has taken advantage of it in many areas. One key area is modeling land combat. The combat models used today range from high resolution one-on-one engagements to low resolution theater level wars. Generally, results from high resolution models are used to develop inputs to the low resolution models, and the results of all of the models are used to develop force structure, tactics, and doctrine. Since the future of the Army is decided, in part, on the outputs of these combat models, it is important that they be as accurate as possible in representing the key factors that will influence future battlefields. Since the low resolution models are somewhat dependent on the results of high resolution models, it could be argued that emphasis should initially be placed on refining the high resolution models.

What are the key factors that influence the battlefield? Tanks, planes, artillery, missiles, air defense, etc., are generally accepted as significant battlefield variables that should be and are currently included in the high resolution combat models. However, another important factor on the battlefield, which is not being adequately modeled, is the soldier [Ref. 1: p. 2]. Leadership, morale, motivation, individual, crew or unit performance above or below the norm are some examples of human factors that can significantly influence the results of the battle. Including these factors in the combat models should improve the resolution and the accuracy of their output. Unfortunately, the quantitative data necessary to apply these factors to combat models are not available. And, once the human factors are quantified, they must still be incorporated into the model. Some factors, like morale, will be extremely difficult to meaningfully introduce into the combat models. Other factors, such as individual or crew performances, may be varied relatively easily by changing the weapon system input parameters.

In the combat model, the performance of each system represented is determined by input parameters. Usually, every system of a specific type has the same input parameters. For example, an M1A1 tank is given a probability of .5 for hitting a target at 2500 meters. Every M1A1 tank is given that capability even though we know two different crews in the same tank may have significantly different probabilities of hitting the target. If the actual differences between tank crews were known, input parameters could be added or changed to reflect those differences. As mentioned earlier, the performance data required to establish the distributions of the different individual or crew performances are not available for any of the systems modeled.

Many attempts have been made to quantify individual and crew performance levels, but none have provided results that can be applied to the models. Until the performance data can be collected and analyzed, the quantitative differences between two crews in a given situation will not be known. Furthermore, combat models will continue to unrealistically represent each type of system with identical input parameters.

B. HUMAN FACTORS IN COMBAT MODELS

The reason that past attempts to collect performance data have failed is the methodology employed to collect the data. The three most common methodologies have been to use data from physiology studies, field experiments, and historical records and or surveys to establish the required performance distributions. Although each methodology provides estimates of the performance distributions, those estimates are inadequate for combat modeling purposes.

Physiological studies measure variables that change when people react to stimuli from a controlled environment and attempt to transfer these results to military tasks in a military environment. Past studies have measured variables such as blood pressure, body temperature, or pupil dilatation and attempted to correlate them to model input parameters like target acquisition or probability of hit. The report *Human Performance in Continuous Operations* produced summarized effectiveness prediction curves by using studies that measured performance levels of a general population doing common tasks and applying them to military tasks [Ref. 2]. The PERFECT computer program, based on these curves, requires the user to input situational variables and it computes the percentage of unit effectiveness degradation [Ref. 3]. However, before the output can be applied to combat models, two key questions must be answered. First, are the results valid for military tasks in a military environment? Second, how can percent degradation for a unit be interpreted for model input? What does a ten percent reduction in unit effectiveness mean in terms of target acquisition time or probability of hit?

For the first question to be answered yes, we must assume the soldier is accurately represented by the general population. But, the standards that must be met before enlisting, and the subsequent training a soldier must endure, set him or her apart from the general population. Additionally, the performances for the tasks measured in the studies probably do not reflect the impact of stress from fear, fatigue, confusion, etc. that is present in combat.

There is no absolute answer to the second question. What does a ten percent reduction in unit effectiveness mean in terms of model input parameters? Are all parameters reduced by ten percent, or are cognitive tasks degraded differently than physical tasks. Are acquisition times increased by fifteen percent and loading times increased by ten percent? Until these questions are addressed, the results of physiological studies will not provide acceptable performance data for combat models.

Field experiments also fail to provide the necessary data. These experiments measure the performance levels of soldiers conducting military tasks in a military environment. *The Effects of a 48-hour Period of Sustained Field Activity on Tank Crew Performance* [Ref. 4] is an example of this type of study.

> A 48-hour field experiment was conducted to determine the effects of sustained activity on the performance of tank crews in communication, driving, surveillance, gunnery and maintenance activities [Ref. 5: p. 2].

One shortcoming of this methodology is that the precision of the measurements was not adequate to apply to combat models. Also, since it was conducted in the early 1970s, the tanks used in the study are now relatively obsolete. The article "Are Smart Tankers Better? AFQT and Military Productivity" illustrates how significant the difference can be between a generation of tanks. According to the report, soldiers who scored in the lowest tenth thru thirtieth percentiles on the Armed Forces Qualification Test (AFQT) achieved almost twice as many "kills" on a gunnery range in an M1 tank as in the older M60 tank [Ref. 6: p. 203]. Another drawback to this methodology is cost. To conduct field experiments today with enough repetitions to provide input to a combat model would be extremely expensive. Also, some environments that occur in combat models, like sustained nighttime operations in a chemically contaminated environment, introduce safety risks that might not be acceptable in peacetime. For these reasons, field experiments are not a viable source for performance data.

Finally, surveys of veterans or historical wartime documents have been used to estimate performance parameters. It is often argued that a wartime environment can never be experimentally created and that basic human nature does not change. Therefore, looking at historical conflicts and the experiences of those veterans that participated in them is the best way to estimate the desired performance parameters. Even if these premises are accepted as valid the conclusion does not necessarily follow. As mentioned above, the impact of new equipment can significantly influence performance and it would be difficult to convincingly apply survey results or historical data to combat models with not only new equipment, but new force structure, tactics and doctrine. Furthermore, in the case of surveys, the time between the events and the survey may make reliability an issue. With historical documents, all of the required parameters may not have been measured with precision adequate to apply to combat models. These deficiencies must be addressed before historical data or survey results can be used in land combat models.

Although human performance has been measured in a variety of ways, the results were not suitable for combat models. Nor do future studies using these methodologies hold much promise for the reasons mentioned above. A new methodology must be pursued to collect the necessary data.

C. DATA COLLECTION USING SIMULATORS

In addition to applying computer technology to combat models, the Army has made tremendous progress in computerized weapon system simulators. High fidelity simulators are now available to train soldiers at a fraction of the cost of using the actual weapon system equipment in the field. Since the simulations employ software to collect and process the data to provide individual or crew performance outputs, large numbers of individual, crew, or unit performances could be aggregated on magnetic tape. The simulators train soldiers in "realistic" situations, so they should be representative of the environments occuring in the combat models. This is the most cost effective way to create a simulated warlike environment. As the number of trials for each situation increase, the performance distributions could be estimated and applied to combat models.

D. WHY EXPERIMENTS ARE NECESSARY.

Why has this approach not been implemented already? Why not just take existing training outputs, analyze them, and apply them to the combat models? There are several reasons this approach would be unsatisfactory in the long run. First, some situations may not normally be trained on the simulator. An example is CONOPS, which is defined in U.S. Army Field Manual 22-9 as "continuous land combat with some opportunity for sleep, although this sleep may be brief or fragmented." And, even if field units were scheduled to train for each situation during their normal training cycle, some situations may be trained too infrequently to provide satisfactory sample sizes in a reasonable period of time. As General Thurman pointed out, the analysis cycle must be shorter than the change cycle [Ref. 7: p. 8]. Finally, experimental results are reproducable, so when unexpected results occur, the potential for isolating the cause is greatly enhanced. Therefore, experiments using simulators are the most timely, cost effective method for collecting and processing data on human performance that will be applied to land combat models.

E. THE PURPOSE OF THIS PAPER

The purpose of this paper is to present an experimental design which demonstrates the potential training simulators have for gathering performance data. Additionally, an example of data reduction and analysis on sample output from a training simulator provides evidence of the capabilities current simulators have as performance measuring tools.

II. DESIGN OF THE EXPERIMENT

A. METHODOLOGY

Obviously, there are many ways to demonstrate the potential of high fidelity simulators for performance data collection. The approach presented in this paper is one example of an experimental design using a simulator as the primary performance data collection tool. Lindsay defines an experiment as:

> A series of controlled observations undertaken in an artificial situation with deliberate manipulation of some variables, in order to answer one or more specific questions [Ref. 8].

This definition identifies a number of issues that must be considered in any experiment, and provides a good foundation for approaching the experimental design. The following methodology will be used:

1. Identify the specific questions to be answered.
2. Define the "artificial situation".
3. Determine the variables to be manipulated.
4. Determine when and how the "controlled observations" will be measured.

The first three items will be developed as background for the key fourth issue of measuring observations.

B. DEFINING THE PROBLEM.

In today's high resolution combat models, every crew in an M1A1 tank performs equally well. Training, individual skills, fatigue, or other factors that contribute to variances in tank crew performance are ignored. This has long been one of the criticisms of combat models. One way to attack this problem is to fix as many factors as possible and vary one of the factors expected to impact on the performance. For this pilot experiment, the effects of sleep loss on performance will be measured.

Van Nostrand estimates that, "From sleep loss only, combat units will probably lose 6.25 percent of their effectiveness each day they are in contact with the enemy." [Ref. 9: p. 25] This estimate is based on the results of soldier surveys. Although the exact percentage of degradation might be questioned, the ordinal interpretation does make sense. As people get more tired, they become less effective. Furthermore, studies have shown sleep loss affects physical and cognitive tasks differently. "Tasks that require primarily physical performance are relatively immune to the effects of sleep loss." [Ref 10: p.1-1] And, "...the relationship between sleep loss and performance decrements on various cognitive tasks is well established." [Ref. 10: p. 1-2] Therefore, evaluating performances for tasks involving cognitive processes will provide a better measure of the effects of sleep loss.

Another consideration in defining the problem is the application to land combat models. The tasks being evaluated need to reflect tasks soldiers must perform in combat that influence the battlefield. The degradations due to sleep loss must be put into the model and the differences should impact on the results of the battle. M1A1 tank crew performance in target acquisition, gunnery, and weapons system management are examples of tasks that can be modeled and should have an impact on the battlefield.

Given the information above, the specific question to be answered is: How does sleep loss effect the target acquisition, gunnery, and system management performance of an M1A1 tank commander and gunner?

C. DEFINE THE "ARTIFICIAL SITUATION"

The setting of the experiment must be as realistic as possible to keep the participants motivated and add to the validity of the results. A European scenario with Blue forces initially defending is widely accepted and will provide the opportunity for high intensity conflict. Since the soldiers will not actually be sent to Europe for the experiment, the orientation briefing must motivate the soldiers and set the stage for a challenging ordeal. All support personnel and participants will be dressed for combat and the environment should be appropriately intense throughout the experiment.

The tasks the crew must perform should realistically represent those tasks they would expect to perform in a wartime environment. The scenario outlined in Appendix A starts with alert activities at home station, moves to the local dispersal area, and then to the general defensive positions. The general cycle of activities will be to load or resupply, deploy, establish the fighting position, maintain the equipment, sleep, and take care of personal hygiene, prepare for battle, fight one or more battles, and move to resupply.

The duration was set at three days for the initial study because it should be long enough to affect performance levels, while not creating a hazardous situation for the subjects. Since the experiment requires human subjects, it must meet the standards established in Army Regulation 70-25, which are briefly described in Appendix B. In summary, this scenario provides a realistic setting that can be replicated at any military installation assigned an M1A1 tank battalion.

D. DETERMINE THE VARIABLES TO BE MANIPULATED

Obviously, the amount of sleep the crew receives will be the manipulated variable, and there are many ways to control this variable. For this experiment, the control group will receive eight hours of sleep each night. The experimental groups will sleep four hours each, one group during circadian troughs and the other during circadian peaks.

Eight hours of sleep each night will permit the control group to perform without any significant sleep loss. They will provide the base against which the experimental groups will be measured. Experimental Group A will be able to sleep four hours, from 0200hrs to 0600hrs, during a low part of the circadian cycle. Experimental Group B will sleep during a high segment of the circadian cycle from 1500hrs to 1900hrs. The sleep permitted to Group A should provide more recuperative value than that of Group B resulting in better performances by Group A crews [Ref. 10: p. 1-13]. Four hours of sleep was selected for the experimental groups because that is the minimum sleep required for CONOPS [Ref 10: p. 1-10] and the surveys administered by Van Nostrand indicated soldiers do receive a minimum of four hours of sleep during CONOPS [Ref. 9: p. 16]. The experiment is designed to keep all other factors that may influence the performance of the tank crews relatively constant.

E. DETERMINE HOW TO MEASURE THE CONTROLLED OBSERVATIONS

A high fidelity simulator will be employed to collect the target acquisition, gunnery, and weapon system management performance data. Selecting the appropriate simulator to measure the performances is an important step in designing the experiment.

1. What to look for in the simulator

The questions that are to be answered by the experiment will usually determine which simulator is most appropriate. For this experiment, a high fidelity M1A1 tank simulator is required. Only a high fidelity simulator could measure the performance objectives to the desired accuracy. Also, since most simulators have not been validated, the high fidelity representation provides face validity for the simulator until a more formal validation process can be completed. And finally, if the simulator is high fidelity, there are fewer differences from the actual equipment for which the soldier has already been trained. Consequently, the training time on the simulator is minimized.

Another consideration in selecting a simulator is its availability. If the simulator is already deployed and in use as a training device, soldiers will already be familiar with it and results from experiments are more likely to reflect the effects of the variables than the soldier's ability to adapt to the simulator. Development and production costs can be avoided if the simulator is already fielded. And, if the simulator is fielded in a number of locations, flexibility and additional cost savings may be considered when selecting the experiment location.

Finally, since the results of the model will be applied to combat models, the simulator should be able to measure performance variables that can either be directly or indirectly, through statistical analysis or transformations, put into the model.

2. Introduction/Description of the U-COFT

One simulator that meets these criteria is the Unit Conduct of Fire Trainer (U-COFT) [Ref. 11]. It simulates the commander and gunner positions on the M1A1 Abrams Main Battle Tank, which certainly should have a major influence on the next battlefield. The U-COFT is a high fidelity trainer that accurately measures some key elements of the tank commander's and or gunner's performance. Target acquisition, reticle aim, and system management are the three general categories of output, but the details of target classification, identification, and selection, time to fire, miss distance (elevation and deflection), and other errors can be captured. Although the driver and loader in the tank crew may contribute to accomplishing these tasks, an assumption will be made that the performances of the tank commander and gunner determine the performance level of the tank for these tasks. Appendix C outlines some specific capabilities of the U-COFT that will apply to this experiment.

The U-COFT is already located at all armor units equipped with M1A1 tanks. This allows flexibility when selecting COFT experiment location(s) and opportunities for replication. Also, since the commanders and gunners are already familiar with the U-COFT, the experiment orientation time can be reduced and the output will be less influenced by the soldier's ability to adapt to the simulator. Over 600 exercises are available on the COFT which will allow enough variation in presentation to keep the crews from anticipating events, while still meeting the experimental requirement of replication.

3. U-COFT Exercise Selection.

Given the European scenario with Blue forces in the defense, specific exercises must be selected that provide representative engagements. The Training-Modeling Integration study entitled *Development of M1A1 Tank Section and Platoon European Training Scenarios* is one source for determining which exercises should be selected for the experiment. The study used the CARMONETTE/TRASANA combat model to

"...develop training scenarios that portray realistic threats to the M1A1 section and platoon..." by running 40 replications each of a European defense and a European offense scenario [Ref. 12: p. i].

"The history of events from each scenario was analyzed to identify threat characteristics (target type, range, aspect angle, and speed) and distributions of the RED units arrayed against the M1A1 in the scenarios." [Ref 12: p. iii] Although the results were aggregated to provide target arrays for M1A1 section and platoon engagements, the study results could be used to select appropriate exercises for this experiment.

4. The Purpose of the CCAB

The Complex Cognitive Assessment Battery (CCAB) is a "...micro-computer based system designed to provide a means for measuring the complex cognitive abilities required to perform critical Army command and control and operational tasks." [Ref. 13] It is included in the pilot experiment for several reasons. It will provide an additional measure of changes in the commander's and gunner's performance on cognitive tasks as sleep loss occurs. It will also provide data on CONOPS to researchers conducting CCAB studies. The CCAB will place the participants in a mentally stressful environment that can be controlled. And, finally, since the loader and driver can not be evaluated in the U-COFT, the CCAB will be used to measure their performance degradation.

F. CRITICISMS OF THE EXPERIMENT.

Experiments rarely go exactly as planned on the first iteration and no doubt lessons will be learned during the initial study. But, the criticisms listed below address design shortcomings that have been considered.

1. *It is only simulated war and does not reflect the true stresses that would affect performances on a battlefield.* Agreed, but we can not start a war for the purpose of collecting data and it is as good as any other peacetime methodology until proven otherwise.

2. *The video image resolution is not good.* An unpublished study conducted for the Infantry School at Fort Benning indicates the resolution of the U-COFT display provides acquisition capabilities consistent with real world acquisition capabilities [Ref 14]. If further research does prove the resolution in the U-COFT to be inadequate, it can be upgraded through modifications.

3. *The U-COFT does not simulate the driver or loader positions.* Studies indicate that physical tasks are influenced less by sleep depravation than cognitive tasks [Ref. 10]. The loader and driver positions are represented by the instructor/evaluator. The loader's performance could be measured by having him do the required tasks and recording times and error rates. A driver's simulator is available at Fort Knox to measure the performance of driver tasks. If the entire crew performance as a

team is required, the U-COFT would have to be redesigned or another simulator might be considered.

4. *Instructor input is required and may influence the results.* The instructor is required to monitor, control, and provide inputs necessary to keep the exercise going. He acts as the loader and driver and marks the time some actions of the crew occur, such as target acquisition. The criticism is valid, but there is currently no better or more accurate method for taking these measurements. The problem will remain until new technologies, like voice recognition systems, are incorporated into simulators.

5. *The activities of the crew during the exercise are not adequately controlled. Instead, have them do tasks requiring similar physical motions at a gym, track, swimming pool, or other facility where the environment is more controlled and easily replicated.* Unfortunately, realism is lost in the more controlled approach. Scheduling the facilities may be a problem and determining which activities and how many to schedule are also open for discussion. How many pushups, if any, equate to loading ten tank rounds? Using the actual equipment to perform the actual tasks the soldiers would have to perform in combat adds realism. Loading equipment, digging foxholes, camouflaging, and laying wire are examples of these activities. The weather is recognized as an uncontrollable variable in this approach. Although soldiers will have to fight in inclement weather during war, bad weather during the experiment may affect performances and skew results. Measuring the effects of different weather conditions on performance may be an embellishment worthy of future studies, but it should be a relatively constant factor for this experiment.

Again, ways to improve the design will become apparent during the initial experiment. It is important to get feedback from the crews and evaluators. It is also important during the first iterations to record shortcomings in the simulator's capabilities, especially since the simulator was designed for training and not for research. Finally, the "keep it simple" approach is necessary until the methodology is demonstrated. The primary objectives may be lost in the confusion if a lot of "whistles and bells" are incorporated into the design at this point.

III. DATA ANALYSIS

A. PURPOSE OF ANALYSIS

The data analysis presented here is not intended to provide a solution to the problem. Experiments must be conducted to determine how performance is degraded by sleep loss. Rather, it is included to show examples of simulator output and how the data might be organized for analysis. Additionally, it demonstrates analytical methods applied to data with accuracy similar to that of the U-COFT, but with values randomly generated from normal distributions. Finally, it identifies data collection and processing requirements for the experiment.

B. DESCRIPTION OF THE DATA

The data currently available from U-COFT facilities is not acceptable for demonstrating the analysis required to be conducted on the anticipated experimental data for several reasons. The most significant problem is that a crew does not repeat an exercise unless they had difficulty meeting the minimum requirements established for that exercise. Therefore, the data are biased and would not be useful for this experiment, which repeats exercises to determine performance changes over time. Once the crew is advanced, the conditions of engagement change and the exercise results are confounded by the differences in target arrays. Additionally, the sequence of the exercises administered varies between crews which further complicates the process of comparing the performance of the crews.

Another difference between the data available and the experimental data expected is the environment in which the data were collected. Since the data were taken from a training environment, the crews received feedback and instruction to improve their performances. Also, no attempts were made to control the environment of the crews before or after they were evaluated. And, only very basic information on the crews' background is available. Finally, the U-COFT performance data are only produced in printed form. Manually entering the data would be extremely inefficient. The data collection process must be automated to effectively analyze the magnitude of data that will result from this and other studies. In summary, the data currently available from the U-COFT are not adequate because they are not automated and not comparable to the data that would be collected during a sleep depravation experiment.

C. DATA PRESENTATION AND STORAGE

Although the data currently available are not useful for demonstrating methods that could be used to analyze the experimental data, the U-COFT does have the capability to collect the required data in a controlled setting. The U-COFT uses the three basic output forms to present the data: the "Situation Monitor" (Figure 1 on page 14), the "Performance Analysis" (Figure 2 on page 15), and the "Shot Pattern" (Figure 3 on page 16) [Ref. 11: pp. D14-D16]. These forms present information for a training environment and they can be reduced to a more precise, efficient format for analytical purposes (Figure 4 on page 17).

The proposed format eliminates redundancy and graphics, and includes additional exercise details that would be useful when sorting the data. As mentioned above, the U-COFT does not currently have the capability to store the performance data beyond the exercise period so hardcopy printouts are the only way to capture the data. Obviously, a first step for the analyst desiring to use the U-COFT as a data source is to get the performance data saved on magnetic tapes. The proposed format is one way to organize the stored data.

Given the fidelity of the U-COFT simulator data collection capability, a set of data was *randomly* generated from normal distributions to represent data from a sleep loss experiment. The error values in the data are not representative of actual U-COFT data, but the data were efficiently generated using the STATGRAPHICS Random Number Generator and will serve to demonstrate some data analysis techniques [Ref. 15]. The data consist of 540 range errors and 540 azimuth errors paired to represent gunnery scores from a sleep loss experiment (Appendix F). The data are broken down into groups of ten pairs, since each exercise presents ten targets, and identified by the exercise alphanumeric introduced in the experimental design in Appendix A. The errors are all generated from normal distributions and are measured in mils. The means (MU) and standard deviations (SIGMA) for the first exercise in the experiment are loosely based on actual U-COFT results (Table 1 on page 18).

SITUATION MONITOR

	Mode	Cmptr	True
Range	MANU	1200	0
Lead	AUTO	0.0	0.0
Crosswind	AUTO	-5.0	-5.0
Cant	AUTO	3.0	3.0

Control			
		Ex No	323532
Mode	NORMAL		
Laser	SAFE	Time	9:05
Weapon	SAFE		
Load	HEAT	Sit No.	9

Sec Act	Bearing/ Weapon	Tgt Type	Numb Rnds	Reticle Lay Az		El		Results/ Errors	
	SABOT	BMP	1	R	0.86	U	0.77	KILL -	1
	SABOT	T72 WHOLE	1	L	0.09	D	0.19	KILL -	1
	SABOT	T72 WHOLE	1	R	0.49	D	0.40	KILL -	1
		M2							
	SABOT	TRUCK	1	L	0.89	D	0.33	KILL -	1
	COAX	TRUCK	68	...	....	...	....	MISS -	0
	SABOT	HIND-D	1	L	3.10	D	0.67	KILL -	1
	SABOT	T72 WHOLE	1	L	0.03	D	0.34	KILL -	1
	SABOT	BMP	1	L	1.37	D	0.50	KILL -	1
5	L 4	HIND-D	...	...	....	...	....	....	

Grade: Tgt Acq: A Ret Aim: B Sys Man: B

Ownvehicle: Defilade

Figure 1. Situation Monitor

PERFORMANCE ANALYSIS

Date: 10/20/83 Instructor: ALLEN H Training Program: SUSTAINMENT
Vehicle: 1/32 All Commander: LOVETT A Gunner: HICKS J
Exercise No: 3323532

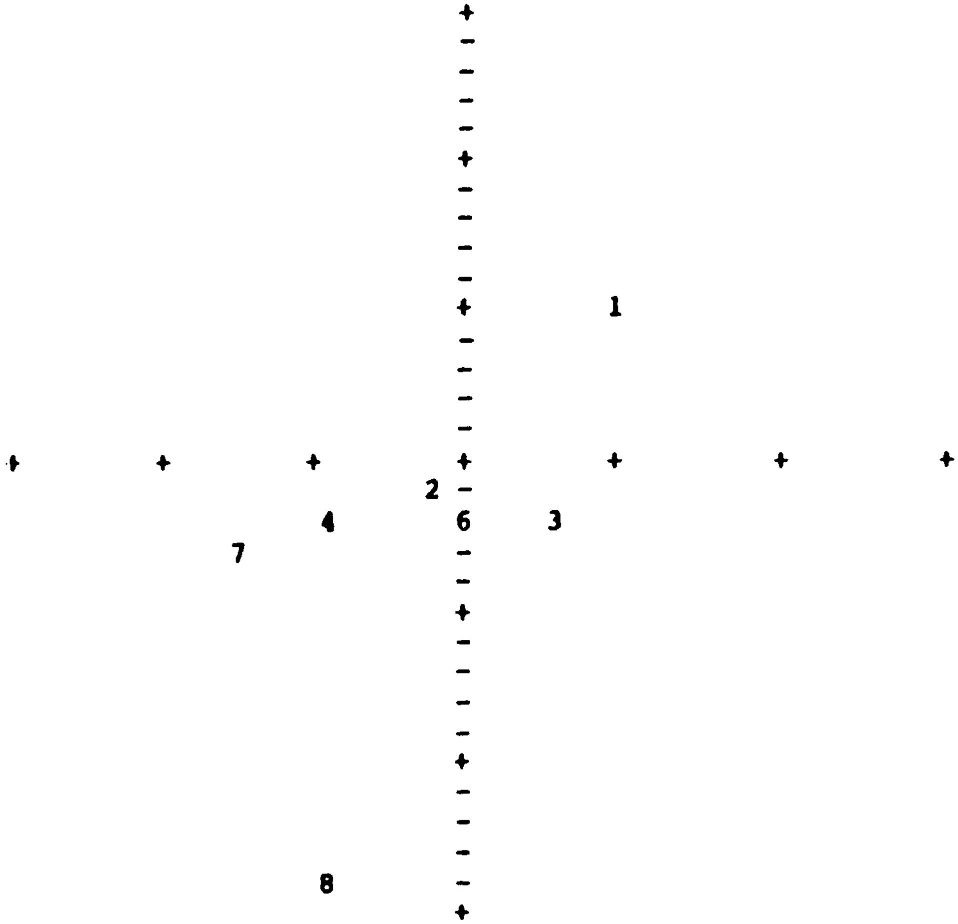
	Target	ID	Time Fire	Hit	Kill	Ammo	Rnds	Hits/ % Cov	Errors Acq	Errors Sys Man	Scores TA	Scores RA	Scores SM
1	BMP	4.0	11.4	12.0	12.0	APDS	1	1	0	0	A	B	B
2	T72-W	4.4	20.3	21.2	21.2	APDS	1	1	0	0	A	C	B
3	T72-W	4.8	12.5	13.3	13.3	APDS	1	1	0	0	A	A	B
4	M2	1.1					0	0	0	0	A	B	B
5	TRUCK	4.3	16.6	17.3	17.3	APDS	1	1	0	0	A	B	B
6	TRUCK	4.4	14.0			COAX	68	0	0	1D	A	F	C
7	HIND-D	4.5	9.0	12.9	12.9	APDS	1	1	0	0	A	B	B
8	T72-W	4.6	14.7	15.6	15.6	APDS	1	1	0	0	A	B	B
9	BMP	4.6	12.6	13.5	13.5	APDS	1	1	0	0	A	B	B
10	HIND-D	3.5	12.8			APDS	1	0	0	2D-L	A	F	F
	Totals:						76	7	0	3			
	Averages:	4.0	13.7	15.1	15.1								

TA: Rapid Adv. RA: Normal Adv. SM: Normal Adv.

Figure 2. Performance Analysis

SHOT PATTERN

Date: 10/20/83 Instructor: ALLEN H Training Program: SUSTAIN
Vehicle: 1/32 All Commander: LOVETT A Gunner: HICKS J



No.	Target	Ammo	Symbol	Round	Azm	Elv
1	BMP	APDS	1	1	+0.86	+0.77
2	T72 WHOLE	APDS	2	1	-0.09	-0.19
3	T72 WHOLE	APDS	3	1	+0.49	-0.40
5	TRUCK	APDS	4	1	-0.89	-0.33
7	HIND-D	APDS	5	1	-3.10	-0.67
8	T72 WHOLE	APDS	6	1	-0.03	-0.34
9	BMP	APDS	7	1	-1.37	-0.50
10	HIND-D	APDS	8	1	-0.83	-2.55

Figure 3. Shot Pattern

Exercise: 3323532 Instructor's Name: ALLEN H Vehicle: 1/32 A11
Training Program: SUSTAINMENT
Date: 10/20/83 Commander's Name: LOVETT A Commander's Rank: E-6
Time: 0905 Gunner's Name: HICKS J Gunner's Rank: E-5
Unit: 11 ACR/V CORPS Training Program: SUSTAINMENT

	Mode	Cmptr	True	Control		
						Sit No.: 9
Range:	MANU	1200	0	Mode	NORMAL	Own Veh: Defilade
Lead:	AUTO	0.0	0.0	Laser	SAFE	
Crosswind:	AUTO	-5.0	-5.0	Weapon	SAFE	
Cant:	AUTO	3.0	3.0	Load	HEAT	

	AMMO/ BEARING	TGT TYPE	RANGE	ID	TIME FIRE	HIT	KILL	NUM RDS	HITS/ % COV	RETICLE LAY AZ	RETICLE LAY EL	SCORES ACQ	SCORES SM	SCORES TA	SCORES RA	SCORES SM
1	APDS	BMP	700	4.0	11.4	12.0	12.0	1	1	R 0.86	U 0.77	0	0	A	B	B
2	APDS	T72-W	1020	4.4	20.3	21.2	21.2	1	1	L 0.09	D 0.19	0	0	A	C	B
3	APDS	T72-W	980	4.8	12.5	13.3	13.3	1	1	R 0.49	D 0.40	0	0	A	A	B
4		M2	600	1.1				0	0			0	0	A	B	B
5	APDS	TRUCK	790	4.3	16.6	17.3	17.3	1	1	L 0.89	D 0.33	0	0	A	B	B
6	COAX	TRUCK	1100	4.4	14.0			68	0	....		0	1D	A	F	C
7	APDS	HIND-D	1500	4.5	9.0	12.9	12.9	1	1	L 3.10	D 0.67	0	0	A	B	B
8	APDS	T72-W	1040	4.6	14.7	15.6	15.6	1	1	L 0.03	D 0.03	0	0	A	B	B
9	APDS	BMP	1010	4.6	12.6	13.5	13.5	1	1	L 1.37	D 0.50	0	0	A	B	B
10	APDS	HIND-D	1850	3.5	12.8	....	....	1	0	....		0	2D-L	A	F	F
Totals:								76	7			0	3			
Averages:				4.0	13.7	15.1	15.1									

Final Score: Target Acquisition: RAPID ADVANCE
Reticle Aim: NORMAL ADVANCE
System Management: NORMAL ADVANCE

Exercise Description:
3323532 - Evaluation -Stationary Tank - Long Range Multiple Stationary and Moving Targets
Gunner - Precision - GPS - Normal - Commander - Caliber .50 - Power - Day - Malf: LRF - NBC

Figure 4. Proposed U-COFT Data Collection Format

Table 1. **PARAMETERS USED TO GENERATE DATA**

		DAY 1 Mu	DAY 1 Sigma	DAY 2 Mu	DAY 2 Sigma	DAY 3 Mu	DAY 3 Sigma
Experimental Group A	X	0.0	0.5	0.2	0.7	0.4	0.9
	Y	0.1	0.7	0.3	0.9	0.5	1.1
Experimental Group B	X	0.0	0.5	0.3	0.8	0.5	1.0
	Y	0.1	0.7	0.4	1.0	0.6	1.2
Control Group C	X	0.0	0.5	0.0	0.5	0.0	0.5
	Y	0.1	0.7	0.1	0.7	0.1	0.7

Note how the errors along the X-axis are generally greater in magnitude than the Y-axis errors. The means and standard deviations were then increased by arbitrary amounts depending on the difficulty of the exercise and the amount of sleep loss. The analysis of variance (ANOVA) and linear regression techniques demonstrated below using the gunnery data may also be applied to the acquisition and system management information provided by the U-COFT.

D. ANALYSIS

The normal randomly generated gunnery data could be studied in the form they are collected to determine how range and azimuth errors change over time, but the measure of performance (MOP) analyzed here are the miss distances. A miss distance is first computed for each (X,Y) pair by the formula

$$miss\ distance = \sqrt{x^2 + y^2} \tag{1}$$

where X is the azimuth error in mils, and Y is the range error in mils. Next, an analysis of variance (ANOVA) is used to determine if the gunnery performances of the groups (Experimental A, Experimental B, and Control) do change as a result of sleep loss over time. In this case, the time units are days. The data is organized into a 3 X 3 matrix similar to Table 1 with the groups as rows, days as columns, and 60 data points per cell. Each data point represents the miss distance for one engagement. The model for this Two-Way ANOVA is

$$x_{ijk} = \mu + \tau_i + \theta_j + \psi_{ij} + \varepsilon_{ijk} \tag{2}$$

where

1. μ is the overall mean
2. τ_i is the row effect (group) with $i = 1, 2, 3$
3. θ_j is the column effect (day) with $j = 1, 2, 3$
4. ψ_{ij} is the interaction effect (group*day)
5. ε_{ijk} is the experimental error (residual) assumed to be $N(\varepsilon_{ijk}:0, \sigma^2)$
6. the subscript k identifies the replications (engagements) per cell ($k = 1,2,3,...,60$).

Actually, the error terms are distributed as the square root of a Chi-Squared distribution with two degrees of freedom. This can be assumed normal for large sample sizes. Univariate tests such as Kolmogorov-Smirnov may be used to test the validity of this assumption. A transformation of miss distances may be analyzed using the techniques described below in the case of invalid assumption. We will assume the untransformed miss distances meet the assumptions for the purposes of demonstrating the analytical techniques. Summarized results of the ANOVA using SAS [Ref. 16] are presented below. Detailed results of all SAS results are in Appendix F. Results are considered significant throughout this Chapter if the probability of occurence is less than five percent ($\alpha = .05$).

SOURCE	DF	ANOVA SS	F VALUE	PR > F
GROUPS	2	23.71816850	39.20	0.0001
DAYS	2	20.58374033	34.02	0.0001
GROUPS*DAYS	4	6.86934373	5.68	0.0002
ERROR	531	160.66165789		

The interaction between the groups and the days is significant, indicating the other results from this ANOVA are suspect and separate One-Way ANOVAs for groups and days would be more appropriate. The ANOVA model with only one main effect and no interaction effects is

$$x_{jk} = \mu + \tau_j + \varepsilon_{jk}. \tag{3}$$

The One-Way ANOVA comparing the groups shows there is indeed a significant difference between the performances of the groups.

SOURCE	DF	ANOVA SS	F VALUE	PR > F

GROUPS	2	23.71816850	33.85	0.0001
ERROR	537	188.11474195		

Likewise, the One-Way ANOVA to determine the impact of time is significant.

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAYS	2	20.58374033	28.90	0.0001
ERROR	537	191.24917012		

Since there is a difference between the days and groups, the analyst may consider doing a Two-Way ANOVA to investigate the effects within either or both of them. The following ANOVA looks at the first day to determine if there are any significant relationships between the gunnery scores and the groups, or exercises, or both. The ANOVA shows the relationships between gunnery scores and groups or exercises are not statistically significant on the first day.

SOURCE	DF	ANOVA SS	F VALUE	PR > F
GROUP	2	0.43313162	1.51	0.2248
EXERCISE	5	1.01976406	1.42	0.2201
GROUP*EXERCISE	10	1.18317354	0.82	0.6069
ERROR	162	23.28687391		

By further dividing the data, a researcher could find out if there a difference between the morning and evening gunnery scores for an experimental group. An ANOVA of the scores of Experimental Group A on the first day indicates there is not a significant difference between the two exercise periods.

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AM_PM	1	0.10600917	0.67	0.4169
ERROR	58	9.19475136		

However, a check of the variances of the first, second, and third exercises in the exercise periods of Experimental Group A on the first day revealed there is a significant relationship, however slight, between the exercise number and the gunnery score.

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BLOCK	2	1.03954663	3.59	0.0341
ERROR	57	8.26121390		

Even individual exercises could be compared using ANOVA. Differences between Exercises A1 and and A4 were small and statistically insignificant.

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EX_A1_A4	1	0.00000007	0.00	0.9839
ERROR	18	2.58519791		

Although these examples used data from a given distribution with known parameters, they demonstrate the usefulness of ANOVA for comparing factors between or within blocks. Further work could be done to find out if there are relationships between scores for certain types of targets, if the range to a target is significant, or whether the order in which the target appears influences the score. The time since the last sleep period, and its duration, may also have a bearing on the gunnery scores. All of these relationships could be statistically analyzed by ANOVA by blocking the data properly. The analyst can learn much about the relationships between factors by properly employing the ANOVA test method.

If relationships are found between factors that can be quantified, regression can be used to further describe how much the factors change with respect to each other. For these data, time, measured in days, is the dependent variable and the miss distance for an engagement is the independent variable. By assuming a linear relationship, the variables are fitted to the model

$$y = \alpha + \beta x + e \tag{4}$$

where y is the dependent variable time, α is the y-intercept, β is the slope of the regression line, x is the independent variable, miss distance, and e is the error term. The method of least squares is used to find the line that best estimates the relationship between x and y, represented by the equation $y = a + bx$. Several assumptions must be made to use linear regression.

1. For each value of the predictor variable x there is a probability distribution of independent values of the criterion variable y. From each of these y distributions, one or more values is sampled at random.
2. The variances of the y distributions are all equal to one another, a condition refered to as *homoscedasticity*.
3. The means of the y distributions fall on the regression line $\mu_y = \alpha + \beta x$; where μ_y is the mean of a y distribution for a given value of the predictor variable x, β is the slope of the line, and α is the y-axis intercept of the line. [Ref. 17: p. 248]

These assumptions should be validated before using linear regression on actual data generated by the experiment. If the second assumption is not met initially, using weighted regression to weight the variances may be necessary to achieve homoscedasticity. Using SAS, the linear regression equation that best describes the randomly generated data is

$$\textit{miss distance} = .57296290 + (.21380425 \times \textit{day}). \qquad (5)$$

The correlation between the miss distances and days is not high, as evidenced by the R-squared value of 0.077. This indicates less than 10% of the variation in miss distances is explained by the days.

The regression equation is also useful for predicting the dependent variable for any independent variable value within the range of the data. Again, the regression equation can be used to further describe the relationships between factors only if they can be quantitatively represented.

The ANOVA and regression techniques demonstrated above are two basic analytical tools which, when applied to the accurate, detailed performance data yielded by the U-COFT, should provide an answer to the specific question identified when the experiment was designed: "How does sleep loss effect the target acquisition, gunnery, and system management performance of an M1A1 tank commander and gunner?" Target acquisition performance can be analyzed using the times provided in the identification time (ID), and time to fire (Fire) columns in the Performance Analysis form. It should be noted that the ID times are input by the instructor when he or she hears the verbal commands given to alert the crew a target has been identified. If the instructor fails to enter the time, a default time of half of the fire time is recorded. Because the acquisition process is cognitive and the measurements are biased by the instructor's input, this is the weakest part of the data collection effort. However, the firing times do record the time from when the target appeared to when it was engaged, which includes the acquisition time, so there is an accurate measure for the combined acquisition and lay load time.

The time required to engage the same target on the first day of the exercise can be compared to the time on the second and third day for the Control Group and the Experimental Groups using ANOVA and regression. An additional measure of the impact of sleep loss on target acquisition is the target identification error rate. The U-COFT also has the capability of recording these errors with its built-in tape recorder and instructor inputs. Indeed, the U-COFT does collect enough data to investigate the effects of sleep loss on target acquisition.

The methodology for analyzing the gunnery data has already been demonstrated. It should be noted that since the simulator was designed to train gunnery, the gunnery performance data collected by the U-COFT are very precise. Errors in reticle lay are recorded to the nearest hundreth mil.

The U-COFT also has the capability of collecting the data required to determine how sleep loss affects some areas of system management. The simulator is designed to ensure the crew uses the proper procedures and operates the equipment correctly. Mistakes made by the crew are recorded and can be analyzed to find out if the numbers increase as the crew becomes tired. Many of the system management tasks involve cognitive skills, which are expected to be affected more by sleep loss than physical skills, so the evaluation of these tasks is important.

In addition to the U-COFT collecting the data required to investigate the effects of sleep loss on tank commander and gunner performances, the Complex Cognitive Assessment Battery (CCAB) may prove to be a valuable tool for measuring changes in the crew's cognitive skills. The CCAB will be administered to the participating crew members at different times throughout the experiment. Analysis could be conducted to investigate the relationship between sleep loss and the CCAB scores. The results could also be compared to the performance data. If correlations are established between the crews' CCAB scores and their U-COFT performance, and we assume or prove good U-COFT performances are strongly correlated to good tank crews, the CCAB may be a useful recruiting tool. Even if the CCAB results are not studied in conjuction with this experiment, the data collected will be valuable to researchers attempting to validate the assessment battery. The CCAB is described further in Appendix E.

Certainly, between the U-COFT and the CCAB, sufficient data can be collected to study the relationship between sleep loss and M1A1 tank crew performance. The high fidelity simulator is the key data collection tool in the sleep loss experiment. Conducting the sleep loss experiment will demonstrate the value of high fidelity simulators as performance data collection tools.

IV. EMBELLISHMENTS FOR FUTURE EXPERIMENTS

The purpose of this chapter is to begin exploring other uses of the U-COFT simulator as a performance data collection tool, recommend modifications to the simulator to enhance its capabilities, and present some ideas about the future of high fidelity simulators in general. Modifying the U-COFT experiment presented in this paper could lead to answers for many human factors questions being asked today. As the U-COFT is used, new requirements will continue to surface which need to be incorporated in the current system as modifications or in the designs of future tank simulators. As other high resolution models are fielded, they must be developed and employed for training and research using the knowledge gained from today's simulators.

A. VARIATIONS USING CURRENTLY AVAILABLE EQUIPMENT.

The experimental design presented in Chapter 2 is very basic and may be embellished in many ways. The following examples are possible modifications to the experiment using the current hardware and software.

First, the schedule of activities could be revised. The experiment duration may not be long enough to adequately test the effects of sleep depravation. The next war involving conventional forces will certainly last more than 72 hours, and subsequent experiments could test the effects of sleep loss over longer periods. Additionally, changes to the the U-COFT and CCAB evaluation times relative to the sleep cycles or other activities may impact on the performance measurements. Also, changing the lengths or timing of the sleep cycles may be important. Varying the sleep for different crew members is another area to investigate. Obviously, there are many ways to modify the experiment just by changing the schedule.

Another area of investigation could be the exercise selection process. The exercises were selected based on output from the CARMONETTE combat model. The output of the model may not be representative of situations that will occur on the next battlefield. Checking the variations of crew performance for different exercises may merit further investigation.

In addition to reviewing the exercises, evaluating variations of the scenario is essential. Before the performance data can be applied to a combat model, it must be collected and anaylzed for each of the general situations occuring in the model. The experiment should be modified to run with different force structures, different mixes of offense and defense, and different environmental conditions. Obviously, there are many potential scenarios, but using experimental design techniques, like latin squares, can greatly reduce the number of samples required to get statistically significant results [Ref. 18: pp. 245-281]. A masterplan for collecting the data should be developed to take advantage of experimental design shortcuts.

Further investigations could be centered around the effects that degradation to key components of the M1A1 Tank system have on crew performances. For example, determining the impact of an inoperative gunner's primary sight (GPS) on the probability of hitting a target may help designers build even better tanks in the future. The experiment could be modified and used to answer many of the designer's questions which would otherwise go unanswered. The informaticn could be applied equally well to combat models to determine the effects of inoperative equipment on the overall performance of a unit.

Another possible area for study is "between crew" comparisions. If crew background information is collected at the time of the experiment, analysis could be conducted to determine which, if any, background factors are related to performance. Training, experience, age, and rank are examples of soldier characteristics that may be related to performance. The list in Appendix D solicits information on the subjects' background characteristics that is required to conduct the experiment or is potentially performance related. Identifying the traits common to the best performing crews could lead to standards for selection, training, and retention of soldiers in the armor branch. New recruits displaying traits common to good tankers would be encouraged to join the armor field. Training could further develop the traits, and minimum standards could be established for purposes of accelerated advancement or retention. Also, if there is a strong predictive relationship between these characteristics and performance, it may be possible to put crews Army-wide into performance categories. The distribution of the performance categories could be applied to combat models by enabling crews to be drawn randomly from the distribution representing the total Army population, or possibly representing the distribution of a theatre's crews would be more accurate. Collecting the background information at the time of the experiment opens many opportunities for future research into the relationships between the crews' characteristics and performance.

However, the distribution of crews in different performance categories may already be available through the U-COFT. The U-COFT scores the crew after each exercise and schedules the next exercise based on the their performance. The location of the crew in the U-COFT exercise matrix indicates the minimum level of performance that crew has achieved. The progress of every M1A1 crew in the Army could be tracked and the distribution of crews at different performance levels determined. This is another method for finding the distribution of tank crews at different performance levels. Again, it could be used to improve land combat model accuracy.

The embellishments presented above suggest only a few research topics the high fidelity simulators currently fielded could support. Hopefully, it will inspire the reader to find new applications for simulators in research and training.

B. IDEAS FOR PRODUCT IMPROVEMENT PROGRAMS.

High fidelity simulators are already valuable research tools, but they are designed primarily for training. Minor modifications to the simulators for research purposes could increase storage and processing capabilities, thereby enhancing the data analysis process. As new research topics are pursued, recommendations can be made for future modifications that will improve the simulator for both training and research. Some of the recommendations for modifications to the U-COFT that surfaced during the design research for the sleep loss experiment are presented below.

First, include more variation in the performance of the driver. Currently, the driver's route is fixed for each exercise. This eliminates a variable the crew would normally have to consider. Permitting more flexibility in the driver's performance would make the training more realistic for the commander and gunner. The data required to establish a typical driver's performance could be provided by an M1A1 driver's training simulator scheduled to be fielded at Fort Knox this year. Adding variance in the driver's performance will improve both the quality of the training and the research data obtained from the simulator.

Another area requiring modification is the data collection and processing capabilities of the U-COFT. Once the value of the simulator as a data collection tool has been demonstrated, the demands on the simulator for research are sure to increase. Currently, the simulator is not designed to support research, and training sponsors are sure to resist any attempts to release the simulators from their training missions. Researchers must recommend modifications to make the data collection and processing transparent to trainers. In the U-COFT, the performance of the crew for a specific exercise is printed out, but not stored. Minor software modifications and additional memory space would permit the data to be saved for analysis. Then, trainers would not need to print an extra copy of the data for a study and the investigator could avoid the manual transfer of the data to another computer for analysis. Further modifications to the software would enable some basic statistical analysis to be completed within the the U-COFT. Researchers should seek out and recommend modifications to improve the research capabilities of the simulator.

Other software modifications could improve the the performance of the U-COFT simulator in the area of target selection scoring. The current scoring system provides an error message if the "best" target was not engaged first. The "best" target is determined by the doctrine established in Field Manual 17-12-1. The drawback of this scoring procedure is that it does not provide a quantitative assessment of the crew's error. Normally, the differences between threats represented by the potential targets are significant, and the error message is appropriate. But, if the crew selected the "wrong" target, and the differences are insignificant, the error message still appears and the crew is penalized incorrectly. A modification to the software could introduce a threat index to the scoring procedure [Ref 19]. The threat index would assign a numerical threat value to each potential target based on range, aspect angle, orientation of tube, moving or stationary, etc. The U-COFT could then provide a quantitative target selection score.

A final recommendation for a modification to enhance the capabilities of the U-COFT eliminates the influence of the instructor in recording the target identification times. The system relies on the instructor to press a key when he or she hears the crew identify a target. The impact of this on the scoring is not known at this time. It may be negligable since the times are recorded to the nearest tenth of a second. However, if a voice recognition system were installed in the simulator, the target identification time could be recorded directly from the crew's commands. The instructor would have one less task to perform and the measurements should be more accurate.

These are but a few ideas for improving the performance of the U-COFT and, when applicable, other high fidelity simulators. As the simulators are improved, the quality of the data will increase and they will be better able to support training and research requirements.

C. LOOKING TOWARD FUTURE GENERATIONS OF SIMULATORS

The future of simulators is almost unlimited. Advances in computer and simulation technologies are occuring faster than imaginative applications are being devised to take take advantage of them. We must look to the future and boldly organize now to profit from the progress. The programs presented below are intended to exploit that progress.

As mentioned earlier, an expanded data collection capability is essential for future research, but modifications to allow basic statistical computations at each U-COFT site may not be cost effective. An alternative solution would be to establish a central data analysis facility to receive, store, and study data from high fidelity simulators in use throughout the Army. Establishing this facility while high fidelity training simulators are relatively new has several advantages. First, the data currently being generated could be captured and consolidated to provide the most extensive, up-to-date data base possible for research. It could establish data collection requirements and format standards for new simulators being developed. And, it would be the Army's central clearing station for all research involving simulators. Simulators are already being used to answer questions about system designs, tactics, doctrine, force structure, and combat modeling. Potential consequences of not having a centralized review include redundancy, analysis using limited data bases, and mismanagement of limited resources. Considering the enormous costs involved in developing, building, fielding, and operating simulators, we can not afford to use them inefficiently. The possible long term savings and benefits make a centralized data collection, storage, and analysis facility an alternative worthy of consideration.

Also, a center for simulators needs to be established to take advantage of the lessons designers and operators are learning now. Millions of dollars have been spent to develop algorithms and hardware designs for the weapons systems simulators in use today. If no attempts are made to collect the information we have gained, we will pay for it every time we build a new simulator. This problem is not only one for the Army, but the entire Department of Defense will sacrifice time and money by not establishing a simulator design data base operated by knowledgeable technicians. This is another program that requires commitment and funding "up front" to realize cost and time savings later.

Finally, improvements can be made in future generations of simulators. The number of different weapons systems represented by the simulators should increase. Cost savings by using the technology base already developed, coupled with the savings inherent in using simulators, will allow combat soldiers to train frequently on their weapon system simulator. The fidelity of the simulators must also improve to the point that all of the training requirements possible are satisfied by training on the simulator. The Army must decide what those requirements are and devise a plan to meet those requirements. For instance, the U-COFT is capable of training the commander and gunner, but can not be netted to provide unit training. The SIMNET simulator is capable of netting, but the fidelity of the crew functions is not nearly as high as in the

U-COFT. A high fidelity simulator is being developed separately to train drivers. Much can be said about the advantages of independent development to find different methods for attacking the problem, and it might be argued that the simulators are designed for different purposes: command and control or gunnery or driving. But, is anyone planning to put all of the components together in the future so the crew is required to train on all of their combat tasks at one time? Of course many decision makers have considered the idea, but no comprehensive plan for Army-wide simulator development is available. This plan would also provide direction to the facility proposed above to collect the simulator design information. Knowing the future of simulators envisioned by decisionmakers would provide the facility priorities for collecting and joining the technology already developed. Consolidating efforts Army-wide would save time and money otherwise wasted by duplicated efforts.

Again, the future of simulators is almost unlimited. The major limiting factor is funding. Simulators provide relatively inexpensive training compared to the costs associated with deploying actual equipment to the field. Their role in the training arena will continue to expand as technology advances and their fidelity improves. The Army must commitment itself now to programs which will exploit the potential of training simulators. And, the research community must also look for ways to take advantage of the capabilities of simulators to collect data otherwise unavailable. The ideas presented above barely touch the surface of the potential uses of simulators in research. Other uses are left to the imagination of the reader.

V. CONCLUSIONS

The results of the sleep loss experiment will provide data required to determine the effects of sleep loss on the performance of an M1A1 tank commander and gunner. Many other areas of tank crew performance could also be investigated using the U-COFT by changing the experimental design.

More importantly, conducting the sleep loss experiment, or one similar to it, will demonstrate the potential high fidelity simulators have as performance data collection tools. The embellishments listed in Chapter Four are only the "tip of the iceberg" of possible research topics simulators could investigate. As the Army continues to improve current simulators and build new simulators, it needs to design them with data collection and processing in mind. Modifications to systems and software already fielded may be too costly and, if the systems are nearing the end of their life cycle, unproductive. The focus should be on new systems that will serve the Army into the next century.

Also, researchers must be sensitive to the main purpose of the simulators, which is to train soldiers. This means the research requirements must be met with minimal disruption to the training mission. Designing the systems to accomplish both goals early in the development phase will save money by avoiding modification costs later.

In addition to measuring physical performance parameters, high fidelity simulators, such as SIMNET, are currently being used to train command, control, communications, and intelligence tactics and doctrine [Ref. 20]. The SIMNET system can tie simulators of different systems together to train unit tactics in a combined arms environment. The systems can be manually operated by crews or can be operated in a semi-automated mode. Again, the potential research areas using this simuator are unlimit.

Soon data from many different high fidelity simulators will be available and care must be exercised when integrating the performance data from the various simulators into combat models. Differences in resolution may lead to unrealistic or incompatable performance levels for the systems played in the model. The long term goal should be for all systems represented in the model to have at least the same performance resolution the M1A1 can potentially have by applying the U-COFT results.

With the improved resolution on the BLUE side, one might wonder what is to be done about the RED systems. Steps must be taken to maintain comparable resolution on the RED side. One possible solution is to estimate the best and worst case performance parameters to estimate the range of possible outcomes. Using the National Training Center force may be a good worst case estimate since they have the advantages of long term cohesiveness and training intimate knowledge of the terrain, and experience gained from repetition. Regardless of how the RED is played, the addition of human performance will make the combat models more accurate.

In addition to making the combat models more accurate, the information gained from the high fidelity simulators will further support analysis of modifications and follow-on developments of the systems simulated. Much can be learned from the simulators currently fielded to improve the simulators of the future in terms of both training and research.

Certainly, the demonstrated worth of high fidelity simulators in training and their potential as research tools should prompt the Army to establish policies and plans to exploit these important resources.

VI. RECOMMENDATIONS

The following recommendations apply, in order, to the sleep loss experiment, the use of simulator data in combat models, and the overall future of simulators in the Army.

First, resources should be committed to modify the U-COFT simulator to efficiently store all of the required performance parameters. These modifications will benefit both the training and research communities. Then, the sleep loss experiment presented in this paper should be conducted as soon as possible. The information gained from the experiment will help answer questions concerning the effects of fatigue on soldier performance, and will demonstrate the value of high fidelity simulators as data collection tools. The lessons learned from conducting experiments like this will also contribute to improving the designs of simulators in the future. Certainly, conducting the experiment will be a worthwhile endeavor.

In the area of combat models, studies need to be conducted to determine the sensitivity of high resolution land combat models to the introduction of human factors. If we find the performance levels of crews differ significantly, will the models accurately represent those differences and will the results from the models reflect those differences? If not, the models may require modifications or a new model may be necessary to accurately incorporate human factors. Comparable resolution between systems must be considered, but the human factors information gained from simulators should be introduced into combat models to make them as accurate as possible.

Finally, the Army must commit itself to exploiting the potential of high fidelity simulators not only as training tools, but as research assets, also. A steering committee should be established to look at the current status of the Army's simulator programs, and to develop strategies to maximize the potential of the simulators five, ten, or twenty years from now. The committee should assemble experts from the fields of simulators, simulation and combat modeling, research, design and engineering, human factors, training and doctrine, test and evaluation and any other areas that may provide insight into the potential uses of simulators. Ideas the group might consider include future requirements for simulators, the central data collection and analysis facility proposed in Chapter Four, and design improvements recommended by simulator users that could be standardized for all simulators built in the future. Designing simulators with training and research in mind is one example of a recommendation that should become a standard. The Army must plan and act now to maximize the benefits from these simulators in the future.

The final recommendation is simply to use the high fidelity simulators as data collection tools and they will prove themselves to be important training and research resources.

APPENDIX A. EXPERIMENTAL DESIGN

The experimental design presented in this Appendix is one way to collect the required performance data. As discussed in Chapter Four, many embellishments could be added, and the design could easily be modified to meet the needs of other research or to adapt to the test facilities available. The activities for each day are provided on separate tables. Below are brief descriptions of the exercises. The sixth digit identifies the replication of the exercise and is not included in the descriptions below.

31111-Stationary Tank - Short Range(< 1500m) Single Stationary Tank Targets - Day

31112-Stationary Tank - Short Range(< 1500m) Single Stationary Tank Targets - Dusk

32111-Stationary Tank - Long Range(> 1500m) Single Stationary Tank Targets - Day

32112-Stationary Tank - Long Range(> 1500m) Single Stationary Tank Targets - Dusk

32311-Stationary Tank - Long Range(> 1500m) Single Moving Targets - Day

32312-Stationary Tank - Long Range(> 1500m) Single Moving Targets - Dusk

In all cases, the gunner is the crew member firing using the precision gunnery method on the gunner's primary sight(GPS) in a normal operational mode.

An overview of the CCAB can be found in Appendix E. The tests scheduled for this experiment are the Tower Puzzle (TP), Following Directions (FD), and Information Purchase (IP). These tests are designed to measure cognitive skills in the areas of Attention to Detail, Planning, Situation Assessment, Decision Making, and Problem Solving. Future iterations of the sleep loss experiment should vary the tests to take advantage of the extensive capabilities of the CCAB.

Table 2. EXPERIMENTAL DESIGN - DAY 1

<table>
<tr><th>Time</th><th>Experimental Group A</th><th>Experimental Group B</th><th>Control Group C</th></tr>
<tr><td>0600
0700
0800
0900</td><td>Upload (4 hrs)
Move to LDA
Set Up
Eat</td><td>Upload (4 hrs)
Move to LDA
Set Up
Eat</td><td>Upload (4 hrs)
Move to LDA
Set Up
Eat</td></tr>
<tr><td>1000
1100
1200</td><td>Exercises (2 hrs):
311110 (A1)
323110 (A2)
321110 (A3)
CCAB (30 mins)</td><td>Exercises (2 hrs):
311110 (B1)
323110 (B2)
321110 (B3)
CCAB (30 mins)</td><td>Exercises (2 hrs):
311110 (C1)
323110 (C2)
321110 (C3)
CCAB (30 mins)</td></tr>
<tr><td>1300
1400</td><td rowspan="2">Upload
Move to GDP
Set Up
Eat
Security</td><td>Terrain Walk
Improve Position</td><td rowspan="2">Upload
Move to GDP
Set Up
Eat
Security</td></tr>
<tr><td>1500
1600
1700
1800</td><td>Sleep (4 hrs)</td></tr>
<tr><td>1900
2000
2100</td><td>CCAB (30 mins)
Exercises (2 hrs):
311120 (A4)
323120 (A5)
321120 (A6)
CCAB (30 mins)</td><td>CCAB (30 mins)
Exercises (2 hrs):
311120 (B4)
323120 (B5)
321120 (B6)
CCAB (30 mins)</td><td>CCAB (30 mins)
Exercises (2 hrs):
311120 (C4)
323120 (C5)
321120 (C6)
CCAB (30 mins)</td></tr>
<tr><td>2200
2300
2400
0100</td><td>Improve Position
Training</td><td rowspan="2">Upload
Move to GDP
Set Up
Security
Improve Position
Training</td><td rowspan="2">Sleep (8 hrs)</td></tr>
<tr><td>0200
0300
0400
0500</td><td>Sleep (4 hrs)</td></tr>
</table>

Table 3. EXPERIMENTAL DESIGN - DAY 2

Time	Experimental Group A	Experimental Group B	Control Group C
0600 0700 0800 0900	Upload (4 hrs) Move to LDA Set Up Eat	Upload (4 hrs) Move to LDA Set Up Eat	Upload (4 hrs) Move to LDA Set Up Eat
1000 1100 1200	Exercises (2 hrs): 311111 (A7) 323111 (A8) 321111 (A9) CCAB (30 mins)	Exercises (2 hrs): 311111 (B7) 323111 (B8) 321111 (B9) CCAB (30 mins)	Exercises (2 hrs): 311111 (C7) 323111 (C8) 321111 (C9) CCAB (30 mins)
1300 1400	Upload Move to GDP Set Up Eat Security	Terrain Walk Improve Position	Upload Move to GDP Set Up Eat Security
1500 1600 1700 1800		Sleep (4 hrs)	
1900 2000 2100	CCAB (30 mins) Exercises (2 hrs): 311121 (A10) 323121 (A11) 321121 (A12) CCAB (30 mins)	CCAB (30 mins) Exercises (2 hrs): 311121 (B10) 323121 (B11) 321121 (B12) CCAB (30 mins)	CCAB (30 mins) Exercises (2 hrs): 311121 (C10) 323121 (C11) 321121 (C12) CCAB (30 mins)
2200 2300 2400 0100	Improve Position Training	Upload Move to GDP Set Up Security Improve Position Training	Sleep (8 hrs)
0200 0300 0400 0500	Sleep (4 hrs)		

Table 4. EXPERIMENTAL DESIGN - DAY 3

Time	Experimental Group A	Experimental Group B	Control Group C
0600 0700 0800 0900	Upload (4 hrs) Move to LDA Set Up Eat	Upload (4 hrs) Move to LDA Set Up Eat	Upload (4 hrs) Move to LDA Set Up Eat
1000 1100 1200	Exercises (2 hrs): 311112 (A13) 323112 (A14) 321112 (A15) CCAB (30 mins)	Exercises (2 hrs): 311112 (B13) 323112 (B14) 321112 (B15) CCAB (30 mins)	Exercises (2 hrs): 311112 (C13) 323112 (C14) 321112 (C15) CCAB (30 mins)
1300 1400	Upload Move to GDP Set Up Eat Security	Terrain Walk Improve Position	Upload Move to GDP Set Up Eat Security
1500 1600 1700 1800		Sleep (4 hrs)	
1900 2000 2100	CCAB (30 mins) Exercises (2 hrs): 311122 (A16) 323122 (A17) 321122 (A18) CCAB (30 mins)	CCAB (30 mins) Exercises (2 hrs): 311122 (B16) 323122 (B17) 321122 (B18) CCAB (30 mins)	CCAB (30 mins) Exercises (2 hrs): 311122 (C16) 323122 (C17) 321122 (C18) CCAB (30 mins)
2200	ENDEX	ENDEX	ENDEX

APPENDIX B. USE OF HUMAN SUBJECTS IN RESEARCH

The Army Regulation (AR) pertaining to use of volunteers in Army funded research is AR 70-25, "Use of Volunteers as Subjects of Research." This appendix highlights some requirements that must be considered during the planning phases of the experiment. It is not a comprehensive checklist and the Regulation should be thoroughly reviewed to ensure all requirements are met by the experimental design.

The Summary in AR 70-25 states:

> This revision implements Department of Defense (DOD) Directive (DODD) 3216.2. It reflects the present legal requirements pertaining to the use of humans as research subjects funded by research, development, test, and evaluation (RDTE) appropriations. This revision provides guidance for establishing human use committees (HUCs). Excluding limited situations, authority to approve research using human subjects can be delegated within the military chain of command. [Ref. 21: p. 1]

Since this experiment will be funded by RDTE appropriations and it involves the use of human subjects, it must be reviewed by an HUC.

A protocol or test plan must be prepared and submitted to the HUC. The HUC will determine if the experiment involves more than minimal risk to the subjects and may make the following recommendations to the approving authority: Approved, approved with modification, defer review to higher authority, disapproved, or exempt from further human use review [Ref. 21: p. 6].

The specific requirements for the investigator, the person primarily responsible for the actual execution of the research, are listed in paragraph 2-9.c. of AR 70-25:

1. Prepare a protocol following the policies and procedures in this regulation.
2. Prepare adequate records on-
   a. Receipt, storage, use, and disposition of all investigational drugs, devices, controlled drug substances, and ethyl alcohol.
   b. Case histories that record all observations and other data important to the study.
   c. Volunteer informed consent documents (see app E, AR 70-25). The principal investigator will fill in the information in parts A and B of DA Form 5303-R (Volunteer Agreement Affidavit) and inform the subject of each entry on the form.
3. Prepare progress reports, including annual reports, as determined by the approving authority and regulatory agencies.

4. Promptly notify the approving authority, through the medical monitor, and the HUC of adverse effects caused by the research.
5. Report serious and/or unexpected adverse experiences involving the use of an investigational device or drug to the sponsor and the FDA in accordance with AR 40-7.
6. Ensure that the research has been approved by the proper review committee(s) before starting, changing, or extending the study.
7. Ensure that all subjects, including those used as controls, or their representatives are fully informed of the nature of the research to include potential risks to the subject.
8. Ensure that investigative drugs or devices are administered only to subjects under their personal supervision, or that of a previously approved associate investigator.
9. Ensure that a new principal investigator (PI) is appointed if the previously appointed PI cannot complete the research (for example, permanent change of station (PCS), retirement, etc.).
10. Appraise the HUC of any investigator's noncompliance with the research protocol.
11. Seek HUC approval for other investigators to participate in the research.
12. Ensure that research involving attitude or opinion surveys are approved in accordance with AR 600-46.

Although some of these requirements may not apply to the experiment proposed in this paper, they may apply to future embellishments on the experiment. Also, knowing these requirements may assist the investigator in preparing the protocol.

Requirements for volunteer recruiting teams are listed in paragraph 2-9.d., AR 70-25. It states that members will-

1. Establish volunteer requirements prior to recruitment.
2. Coordinate recruiting activities with unit commanders.
3. Undertake recruiting in a moral, ethical, and legal manner.

These requirements will become more critical as the experiments are conditioned on the backgrounds of the crew members and the crew selection process becomes more precise.

In conclusion, the principal investigator must know and comply with AR 70-25 before the experiment can be conducted. The initial experiment was designed with AR 70-25 in mind and should receive approval from a HUC. The principal investigator is responsible for ensuring AR 70-25 is followed during the execution of this design, and that any future design modifications comply with the regulation.

APPENDIX C. CAPABILITIES OF THE U-COFT

The following information is extracted from the *Instructor's Utilization Handbook for the M1A1 Unit-Conduct of Fire Trainer* (U-COFT) [Ref. 22] and the *M1/M1A1 Unit Conduct-of-Fire Trainer Training Device Support Package* [Ref. 11]. It is provided to briefly describe the U-COFT and to give an indication of the system's fidelity. Anyone desiring to learn more about the U-COFT should study the references and/or contact the COFT Training Facility at Fort Knox, Kentucky.

A. OVERVIEW OF THE U-COFT

The M1 U-COFT is a tank gunnery training device for M1 commander-gunner teams. The U-COFT places the commander and gunner in realistically simulated crew stations and presents them with a full range of target engagement situations controlled by the U-COFT instructor operator. This results in challenging, progressive training for gunnery.

B. PURPOSE AND CAPABILITIES OF THE U-COFT

The primary purpose of the M1 U-COFT is to increase and sustain critical gunnery skills required of M1 commanders and gunners. The U-COFT provides the following capabilities and features to accomplish this mission:

1. Choice of 685 training exercises in U-COFT orientation, preparation of crew stations, boresighting and zeroing weapons, acquisition and manipulation, target engagement from the commander's position, target engagement from the gunner's position, and evaluation. Training within a battalion is available daily without using the tank, fuel, or ammunition.
2. Selection of exercises by computer recommendation, content, or number.
3. Sampling of all target engagement conditions. The U-COFT permits training in a wide variety of simulated weather and visibility conditions, tactical situations, and levels of equipment operational readiness.
4. Standardization of engagement procedures, conditions, times, scoring, and record keeping.
5. Built-in training programs for four types of gunnery training:
   a. Sustainment -- Experienced M1 commanders and gunners.
   b. Transition -- Qualified tank crewmen with no M1 experience.
   c. Cross -- M1 crewmen who are inexperienced in the position to be trained.

d. Basic -- Prospective M1 crewman who have had no previous M1 or other tank experience.

6. Computer-guided progress, based on student performance.

7. Computer-selected exercises, based on student performance.

8. Instrctor/Operator (I/O) selected exercises, based on student performance.

9. Automatic evaluation of individual and commander-gunner performance.

10. Storage or printout of crew and unit training data.

11. Air-conditioned training environment.

The following list summarizes the simulation capabilities of the U-COFT in selected areas.

1. Weapons Simulation
   a. M68, 105-mm main gun
   b. 7.62-mm coax manchine gun
   c. Commander's weapon station caliber .50 machine gun
   d. M250 grenade launchers
2. Ammunition Simulation
   a. 105-mm high explosive antitank (HEAT)
   b. 105-mm armor piercing, discarding sabot (APDS)
   c. 105-mm high explosive, plastic (HEP)
   d. Caliber .50 machine gun
   e. 7.62-mm machine gun
   f. M250 smoke grenades
3. Normal Mode Simulation
   a. Stabilized coax machine gun
   b. Stabilized main gun
   c. Commander's weapon
   d. Commander's weapon sight (CWS)
   e. Gunner's primary sight (GPS)
   f. Gunner's primary sight extension (GPSE)
   g. Gunner's auxiliary sight (GAS)
   h. Thermal imaging sight (TIS)
   i. Target ranging up to 3000 meters (laser range finder)

j. Ballistic computer

k. Normal azimuth and elevation drift

l. Browpad recoil

4. Failure Simulation

a. Laser range finder failure

b. Main gun stabilization failure

c. Ballistic computer complete failure

d. Gunner's power control handle failure

e. Firing switch failure

f. Coax machine gun failure

g. TC weapon station power failure

h. Total turrent power failure

i. GPS failure

5. Visual Simulation

a. Targets

1) T-72, BMP, HIND-D, truck (GAZ-69), troops, M1, M2/M3, M60A3

2) Multiple and single targets

3) Varied ranges, speeds, and exposures

b. Own vehicle - moving and stationary

c. Firing effects

1) Initial firing

2) Round tracer

3) Scene obscuration

4) Tracer paths

5) Round impact and effect on target

6) Round impact on terrain

d. Friendly enemy fire

1) Friendly fire from flanks

2) Enemy direct fire

3) Enemy indirect fire

4) Hit on own vehicle

e. Visibility

1) Day unlimited

2) Day with haze

3) Day with fog

4) Dawn/dusk

5) Night unlimited (thermal)

6) Night with thermal clutter

6. Sound Simulation

   a. Enemy fire, including artillery

   b. Load/reload sounds

   c. Engine and transmission sounds

   d. Tank track clatter

   e. Gun jump sounds

   f. TIS cooling fan

   g. Turret blower fan

   h. Hit on own vehicle

7. Panel and Display Simulation

   a. Commander's control panel

   b. Gunner's GPS control panel

   c. TIS control panel

   d. Ballistic computer control panel

   e. GAS control panel

8. Auxiliary Equipment Simulation

   a. Gas particulate filter system

   b. Seating with adjustment controls

   c. Chestrest, leg guards, and knee guards

   d. Domelight

   e. Ballistic door actuating handles

   f. Intercom system

A component of the M1 U-COFT instructional software is the adaptive evaluation system for evaluating crew performance and controlling crew progress through the exercise library. The U-COFT scores each engagement according to the following criteria:

SKILL DIMENSION	CRITERIA
Target Acquisition	- Time to acquire target.
	- Number of identification/classification errors.
Reticle Aim	- Time of fire first round/burst.
	- Time to kill.
	- Magnitude of aiming error (main gun only).
System Management	- Number of switch setting errors before firing.
	- Number of switch setting errors at the time of firing.
	- Defilade errors.

These scores highlight the errors a crew can make. When a crew performs satisfactorily, the computer normally increases the complexity of the next engagement scenario. For the experiment described in this paper, the exercises are pre-selected as a test environment control measure.

Again, the purpose of this Appendix is to provide an introduction to the capabilities of the U-COFT and to give the reader unfamiliar with the U-COFT an overview of the simulator's fidelity.

APPENDIX D. COLLECTING SUBJECT BACKGROUND INFORMATION

Crew background information must be collected to meet the requirements of Army Regulation 70-25 (see Appendix B). Also, the data collected during the experiment may pertain to future studies attempting to relate crew characteristics to performance. For example, a study may be initiated to determine if there is a relationship between the education level of the tank commander and the performance of his crew. The entries listed below are intended to collect information during the experiment that is required for the current study and may be required for future research. Recovering the information later, if it is even available, will be more costly and less accurate.

1. Subjects administrative identification number (to be provided by the investigator).
2. Name.
3. Social security number.
4. Rank grade.
5. Time in service.
6. Civilian education completed.
7. Military education completed.
8. General aptitude test scores.
9. Most recent skills qualification test (SQT) score.
10. PULHES.
11. Height weight.
12. Army physical fitness test (APFT) scores: pushups/situps/run.
13. Unit.
14. Length of time assigned to unit(months).
15. Length of time assigned to crew(months).
16. Length of time the crew has been together in current positions.
17. Crew position.
18. Length of time assigned to current crew position(months).
19. Estimated field training days in current position with current crew.
20. Most recent tank gunnery scores.
21. Current U-COFT exercise level.

22. A brief history of previous assignments.

23. Is the subject planning to make the Army a career.

Two other items should be considered before collecting the information. First, it should be collected using a computerized mark-sense form to enhance storage and analysis. Second, a Privacy Act Statement must be included at the top of the form. Again, many of the questions above do not apply to this experiment, but the performance data collected by the experiment can be used in many areas of research. Collecting the background information now will save time and money in the long run.

APPENDIX E. OVERVIEW OF THE CCAB

The following information is extracted from the *Expanded Complex Cognitive Assessment Battery (CCAB)- Final Test Administrator User Guide* [Ref. 23]. The CCAB is provided by the Army Research Institute (ARI) with the understanding that they will receive copies of any CCAB data collected during the experiment. Also, the CCAB test materials and software will not be further copied or distributed. Anyone desiring copies of the CCAB software or documentation should contact Dr. Christine Hartel or Dr. Donald Headley at ARI, 5001 Eisenhower Avenue, Alexandria, Virginia, 22333-5600.

A. WHAT IS CCAB?

The computerized Complex Cognitive Assessment Battery (CCAB) is a product of a research project sponsored by the System Research Laboratory of the U.S. Army Research Institute and funded by the U.S. Army Medical Research and Development Command through the Triservice Joint Working Group for Drug Dependent Degradation on Military Performance. The objective of this research was to develop a battery of tests to measure the complex cognitive abilities required to perform critical Army tasks.

The CCAB is a micro-computer based program designed to provide a means for evaluating performance on tasks that require high-level, complex cognitive skills. The foundation for the CCAB is a comprehensive taxonomy of 14 complex cognitive constructs including the following:

1. Attention to Detail
2. Perception of Form
3. Memory Retrieval
4. Time Sharing
5. Comprehension
6. Concept Formation
7. Verbal Reasoning
8. Quantitative Analysis
9. Planning
10. Situation Assessment
11. Decision Making

12. Communication
13. Problem Solving
14. Creativity

B. CCAB CONTENT

The CCAB consists of nine tests, and each test is designed to measure a number of these cognitive constructs. Complete descriptions of each test, including its research background and technical specifications, are available in a CCAB Test Description document.

Figure 5 on page 49 provides estimated levels of association between CCAB tests and cognitive constructs. These estimates reflect the degree to which the given test was designed to measure the respective construct. Note that the cognitive constructs are arranged in categories that correspond to four general types of cognitive processing; the cognitive demands imposed by tasks or tests in these categories are assumed to increase in complexity from Category I through Category IV.

Each test includes a set of instruction screens, practice problems, a quiz to evaluate the subject's understanding of the required tasks, and a set of test problems which can be used in repeated measures test administrations. The CCAB software allows the Test Administrator flexibility in setting up test sessions for subjects in a variety of ways, e.g. which tests are to be taken and in what order, and whether or not test Instructions and a Quiz are given. Futhermore, the randomization of test-problem stimuli can be manipulated in different ways.

Once a test session is set up and a subject begins to perform the test, the battery is self-administered and automatically computer-scored. For each test, a comprehensive set of performance scores is generated and stored on the disk for subsequent printout together with integrated performance scores across all tests taken.

LEVEL OF ASSOCIATION BETWEEN CCAB CONSTRUCTS AND TESTS

[1 = Low; 2 = Medium; 3 = High]

	Cognitive Complexity Categories	Cognitive Construct Measured	CCAB TESTS*								
			TP	FD	WA	LR	MN	NW	IP	RP	MI
I.	Responding to Data	Attention to Detail		3	1	1		2	2	1	2
		Perception of Form	1		2			3	1	2	2
		Memory Retrieval		2	3	1	1	2	1		
		Time Sharing		2			2	3	1		
II.	Going Beyond Data	Comprehension		2		3	1				
		Concept Formation	1		1	1		2	1	1	3
		Verbal Reasoning		2		3	1				
		Quantitative Reasoning	1	1		2	3		2	1	3
III.	Taking Action Based on Data	Planning	3		2				2	3	
		Situation Assessment	3				1		3	2	1
		Decision Making	2		2			2	3	1	
IV.	Creating Data Or Solutions	Communication	1	1						2	3
		Problem Solving	3		1	1			1	2	2
		Creativity	1		3						

* CCAB consists of 9 tests. Codes used in the table for tests are as follows: Tower Puzzle (TP), Following Directions (FD), Word Anagrams (WA), Logical Relations (LR), Mark Numbers (NM), Numbers and Words (NW), Information Purchase (IP), Route Planning (RP), and Missing Items (MI).

Figure 5. Level of Association Between CCAB Constructs and Tests.

APPENDIX F. DATA AND COMPUTER SOLUTIONS

This Appendix lists the data used in Chapter Three to demonstrate analysis of variance(ANOVA) and regression. The range and azimuth errors are organized in columns based on groups, days, and exercise alphanumeric used in the experimental design(Appendix A). Each column was randomly generated from normal distributions with parameters identified in Table 1, Chapter Three, which is reproduced below for reference.

Table 5. PARAMETERS USED TO GENERATE DATA

		DAY 1		DAY 2		DAY 3	
		Mu	Sigma	Mu	Sigma	Mu	Sigma
Experimental	X	0.0	0.5	0.2	0.7	0.4	0.9
Group A	Y	0.1	0.7	0.3	0.9	0.5	1.1
Experimental	X	0.0	0.5	0.3	0.8	0.5	1.0
Group B	Y	0.1	0.7	0.4	1.0	0.6	1.2
Control	X	0.0	0.5	0.0	0.5	0.0	0.5
Group C	Y	0.1	0.7	0.1	0.7	0.1	0.7

This Appendix also provides the detailed SAS ANOVA and regression outputs discussed in Chapter Three. The outputs have been edited to eliminate unnecessary material.

1. **Random Miss Distances Generated by STATGRAPHICS.**

EXPERIMENTAL GROUP A

Day 1		Day 2		Day 3	
Exercise A1		Exercise A7		Exercise A13	
X	Y	X	Y	X	Y
-0.14	0.07	-0.39	-0.43	0.05	2.18
0.72	-0.69	0.82	1.2	0.54	1.8
0.28	-0.68	-0.15	0.64	0.11	-0.19
-0.26	-0.4	0.07	0.21	0.82	-0.64
-0.55	-1.12	-0.32	0.28	-1.1	1.28
0.46	-0.09	-0.56	0.67	0.26	2.49
-0.16	0.8	1.26	1.35	0.56	-0.76
-0.51	-0.04	-0.25	0.94	0.45	-0.43
0.56	0.02	-0.24	-1.8	-0.58	0.46
0.77	0.62	-0.45	1.39	-0.41	0.12

Exercise A2		Exercise A8		Exercise A14	
X	Y	X	Y	X	Y
0.02	-1.16	-0.89	-0.66	0.3	1.07
-1.02	-1.33	-0.4	1.48	0.94	0.5
0.1	1	1.13	1.64	0.15	3.07
0.76	-1.37	-0.01	-0.34	0.78	0.92
-0.8	-0.85	-1.62	0.2	0.39	1
-0.12	0.1	0.55	0.57	0.93	0.09
0.53	0.37	0.44	1.51	0.43	1.21
-0.17	0.45	-0.13	-0.19	0.5	2.69
0.88	-0.09	-0.29	2.47	0.79	-0.41
-0.23	0.06	-0.43	-1.38	0.55	0

EXPERIMENTAL GROUP A

Day 1		Day 2		Day 3	
Exercise A3		Exercise A9		Exercise A15	
X	Y	X	Y	X	Y
0.5	0.46	-0.11	0.19	-1.91	1.49
-0.45	-0.56	-1.22	-1.12	0.97	0.54
-0.58	-0.05	0.87	-0.77	-0.97	0.57
-0.02	0.53	0.6	-0.82	-0.01	0.44
0.12	-0.99	0.66	0.64	0.11	1.18
-0.16	-0.15	0.01	0.94	-0.73	0.45
0.22	-0.24	1.72	-0.03	1.41	1.26
-0.15	0.02	0.51	-0.96	0.59	-0.45
0.11	-1.23	0.64	-1.02	0.97	1.08
0.2	0.6	1.36	0.19	1.5	-0.9

Exercise A4		Exercise A10		Exercise A16	
X	Y	X	Y	X	Y
0.48	0.57	1.29	1.49	0.45	0.69
-0.27	1.02	0.68	-0.15	1.04	0.66
0.55	-0.5	-0.21	1.13	-2.07	0.64
0.03	-0.09	0.59	0.91	0.25	3.99
-0.05	0.18	1.68	-1.87	0.85	2.04
0.42	0.34	0	0.94	1.06	0.16
0.38	0.36	0	1.7	0.63	0.67
0.75	0.32	0.58	-0.1	1.48	1.37
-0.01	1.6	0.87	2.11	0.6	0.72
0.59	-0.19	-0.06	0.94	0	0.72

EXPERIMENTAL GROUP A

Day 1		Day 2		Day 3	
Exercise A5		Exercise A11		Exercise A17	
X	Y	X	Y	X	Y
0.02	1.05	1.12	0.97	0.59	1.64
0.56	0.41	0.34	0.17	-0.61	-1.52
-0.23	0.65	0.84	1.67	-1.27	0.42
0.01	-1.44	0.23	0.45	0.67	-1.05
-1.1	0.6	1.55	0.63	-0.63	2.02
0.15	-0.41	1.37	1.79	1.51	-0.01
0.42	1.19	-0.88	2.03	0.97	-0.45
0.17	1.18	0.7	-0.28	0.71	0.74
0.53	0.37	0	0.25	0.78	-0.83
0.37	1.54	0.59	0.4	0.25	0.25

Exercise A6		Exercise A12		Exercise A18	
X	Y	X	Y	X	Y
-0.77	0.32	-1.48	-1.75	0.81	1.4
-0.95	0	0.9	-0.98	0.44	0.99
-0.27	-1	-0.09	-0.86	0	0.35
0.04	-0.47	-0.84	0.6	1.3	0.78
-0.47	-0.45	-1.32	0.6	-0.26	0.74
0.06	0.64	-0.05	2.05	0.39	-0.42
-0.88	-0.85	0.87	-0.82	-0.01	-1.03
0.79	0.19	0.25	0.67	0.96	-0.38
0.13	-0.34	0.74	0.04	2.56	0.43
0.11	0.36	-0.6	1.99	-1.05	2.12

EXPERIMENTAL GROUP B

Day 1		Day 2		Day 3	
Exercise B1		Exercise B7		Exercise B13	
X	Y	X	Y	X	Y
0.83	0.18	0.99	0.94	-0.02	2
0.23	-0.77	1.83	0.71	0.94	-0.65
-0.74	0.44	-1.05	-0.05	-0.67	0.61
0.19	0.25	0.55	-0.05	-0.07	-0.92
0.19	-0.69	-0.86	0.44	0.52	0.17
-0.02	1.02	1.24	0.42	0.92	0
0.04	0.38	0.12	-0.51	-0.2	2.84
0.3	-0.17	0.46	1.01	1.1	0.4
-0.35	0.32	-0.88	2.74	-1.35	1.49
1.1	-0.65	0.1	0.99	-0.55	-0.09

Exercise B2		Exercise B8		Exercise B14	
X	Y	X	Y	X	Y
-0.07	-0.88	1.25	1.59	-0.74	1.69
-0.28	1.28	-0.06	0.04	0.13	0.76
-0.59	-0.06	1.65	0.53	-1.14	-0.57
-0.33	0.31	0.77	1.91	0.39	-0.1
-0.21	-0.16	-0.13	0.46	0.92	-1.62
-1.21	0.62	0.52	0.99	0.34	1.28
-0.15	-1.54	1.75	-0.43	1.42	0.54
0.58	-0.76	1.77	0.17	0.73	0.42
-0.35	0.77	-0.46	0.44	-0.11	0.37
-0.42	0.33	-1.1	0.9	1.18	1.2

EXPERIMENTAL GROUP B

Day 1		Day 2		Day 3	
Exercise B3		Exercise B9		Exercise B15	
X	Y	X	Y	X	Y
-0.09	-1.29	1.03	-0.32	-1.24	-0.03
-0.63	-0.24	0.54	0.7	2.95	1.74
0.24	-0.34	-0.7	-1.27	-0.56	3.34
0.13	-1.56	-0.38	-1.01	-0.47	2.58
-0.12	0.09	-0.01	-0.08	1.49	1.08
-0.38	0.89	1.22	-1.45	-0.69	-0.33
0.5	0.09	0.21	1.26	2.41	-0.14
0.3	0.32	1.7	0.51	-1.52	3.27
-0.1	0.41	0.58	0.56	2.21	-0.15
0.1	0.25	1.03	1.66	1.9	0.85

Exercise B4		Exercise B10		Exercise B16	
X	Y	X	Y	X	Y
0.33	0.77	0.18	1.49	-1.9	-0.7
0.48	0.92	0.55	-0.16	-1.02	-0.71
-0.21	0.17	-0.24	-0.4	1.92	-1.8
-0.12	0.5	0.9	0.87	0.85	0.09
-1.01	0.18	-0.25	-0.35	0	0.73
0.46	0.17	-0.26	0.98	0.02	0.15
-0.46	-0.39	1.35	-0.47	1.73	1.86
0.24	0.6	1.96	1.12	-0.83	0.6
0.06	0.4	-1.32	0.32	0.42	-0.82
0.26	-1.81	0.01	1.29	2.04	1.82

EXPERIMENTAL GROUP B

Day 1		Day 2		Day 3	
Exercise B5		Exercise B11		Exercise B17	
X	Y	X	Y	X	Y
0.43	0.21	0.12	-0.51	0.2	0.94
0.37	-1.44	0.72	0.09	-0.7	1.35
0.57	0.23	0.73	0.88	0.52	1.07
0.31	0.6	0.3	0.66	0.7	1.84
0.31	-0.4	1.58	-0.05	-0.58	-0.38
-0.49	0.77	0.46	1.77	0	-0.49
0.81	0.36	0.49	-0.05	0.5	-1.57
0.3	-0.33	0.19	0.91	1.87	1.39
0.16	0.08	-1.09	0.13	-0.99	1.18
-0.43	-0.66	0.94	0.63	0.96	1.11

Exercise B6		Exercise B12		Exercise B18	
X	Y	X	Y	X	Y
-0.85	-0.2	0.29	-0.06	0.88	0.32
0.13	-0.58	1.64	0.46	1.23	-0.18
0.03	0.01	1.66	1.73	0.31	1.06
0.54	0.96	0.75	0.03	0.45	0.23
1.12	0.67	0.44	-0.6	-1.25	0.38
-0.43	-0.56	-0.27	0.99	-0.57	-1.22
0.07	0.48	1.49	2.03	1.54	2.15
-0.26	0.37	-0.16	0.4	0.94	1.97
-0.57	0.78	-0.97	0.81	0.43	1.02
0.55	0	-0.32	1.4	0.68	-1.07

CONTROL GROUP C

Day 1		Day 2		Day 3	
Exercise C1		Exercise C7		Exercise C13	
X	Y	X	Y	X	Y
-0.46	-0.12	-0.91	-0.23	1.03	0.58
0.93	0.54	0.14	-0.57	-0.26	1.44
0.15	0.37	0.2	0.02	-0.07	-1.49
0.35	-1.25	0.77	0.15	-0.54	0.03
0.32	0.45	0.86	0.69	-0.31	-0.45
0.25	0.31	-0.3	-0.09	-0.45	-1.2
-0.18	-0.13	0.37	1.19	-0.69	-0.63
-0.61	0.42	0.19	-0.84	0.11	0
0.47	-0.2	-0.42	0.74	0.5	0.19
1.05	0.53	-0.46	-0.16	0.11	0.11

Exercise C2		Exercise C8		Exercise C14	
X	Y	X	Y	X	Y
0.29	0.02	0.88	0.52	1.22	0.12
0.71	0.55	-0.65	-0.78	-0.49	0.23
-0.26	-0.44	0.47	-0.11	-0.45	1.2
1.04	0.55	0.17	0.02	-1.23	0.51
-0.45	-0.36	-0.08	-0.18	0.31	0.35
0.64	-1.63	-0.55	0.46	0.6	0.56
0.42	0.01	0.02	0.04	-0.98	-1.11
0.79	-0.03	-0.25	0.19	-0.43	-0.09
-0.41	-0.22	0.27	-0.35	-0.06	-0.68
0.05	-0.74	-0.79	1.14	-0.37	-0.26

CONTROL GROUP C

Day 1		Day 2		Day 3	
Exercise C3		Exercise C9		Exercise C15	
X	Y	X	Y	X	Y
-0.44	-0.75	0.81	0.11	-1.06	0.21
0.47	0.14	0.46	1	-0.22	-0.1
-0.25	0.66	0.21	0.64	-0.41	-0.77
-0.63	0.28	-0.63	0.17	-1.13	0.46
-0.26	-0.35	0.4	-0.15	0.29	-0.83
-0.22	0.2	0.82	0.24	-0.67	0.02
-0.08	0.31	-0.35	-0.07	-0.74	1.13
-0.85	0.93	-1.08	-0.23	-0.32	0.43
-0.24	-0.68	-0.13	0.65	-0.84	0.74
0	0.1	0.07	0.43	-0.12	0.3

Exercise C4		Exercise C10		Exercise C16	
X	Y	X	Y	X	Y
0.39	-0.01	-0.58	0.37	-0.29	0.45
-0.35	0.11	0	-0.11	-0.53	-0.85
-0.34	0.3	1.43	-0.34	0.16	-0.36
-0.01	-0.18	-0.99	-0.79	1	-0.56
0.21	-0.12	0.02	1.3	-0.63	-0.22
0.38	-0.5	1.01	1.08	-0.02	-0.84
0.35	0.74	-0.55	0.63	0.53	-0.1
-0.39	-0.28	0.42	0.3	-0.24	0.24
0.15	0.82	-0.34	0.07	-0.1	-0.55
-0.35	0.5	0.17	-0.28	-0.71	0

CONTROL GROUP C

Day 1		Day 2		Day 3	
Exercise C5		Exercise C11		Exercise C17	
X	Y	X	Y	X	Y
-0.78	1.08	-0.46	-0.28	-1.2	1.19
-0.1	-0.18	0.11	0.61	1.27	0.38
0.33	-0.17	0.49	-1.15	0.14	0.19
0.68	0.04	0.19	0.09	-0.33	1.24
-0.89	-0.02	1.02	0.61	1.04	1.43
-0.35	0.46	-0.23	0.39	-0.7	0.18
-0.21	-0.01	0.77	-0.71	-0.47	-0.93
-0.17	-0.39	-0.02	1.07	0.51	-1.4
0.44	-0.36	0.68	0.68	0.04	1.39
-0.61	0.18	-0.51	0.1	-0.07	-0.23

Exercise C6		Exercise C12		Exercise C18	
X	Y	X	Y	X	Y
-0.53	-0.93	0.1	0.09	-0.13	-0.21
0.16	-0.72	-0.55	0.04	-0.61	-0.71
-0.46	0.2	-0.27	-0.1	-0.15	0.31
0.32	1.33	0.04	0.32	-0.34	0.14
-0.52	0.29	0.54	0.75	0.31	0.74
-0.18	-0.21	0.71	0.19	-0.42	0.07
0.22	0.84	-0.08	-0.41	-0.28	-0.45
0.53	-0.04	0.77	-0.84	-0.27	-0.22
0.98	-0.82	-0.44	-0.27	-1.01	-0.1
-0.5	-0.84	-0.35	0.07	0.08	0.99

2. SAS Two-Way Analysis of Variance

The following table is a TWO-WAY analysis of variance of gunnery scores with the factors groups (Experimental A and B, and Control) and days. The procedure was conducted using SAS.

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GROUPS	3	1 2 3
DAYS	3	1 2 3

NUMBER OF OBSERVATIONS IN DATA SET = 540

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	8	51.17125256	6.39640657	21.14
ERROR	531	160.66165789	0.30256433	PR > F
CORRECTED TOTAL	539	211.83291045		0.0001

R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN
0.241564	54.9744	0.55005848	1.00057140

SOURCE	DF	ANOVA SS	F VALUE	PR > F
GROUPS	2	23.71816850	39.20	0.0001
DAYS	2	20.58374033	34.02	0.0001
GROUPS*DAYS	4	6.86934373	5.68	0.0002

3. SAS One-Way Analysis of Variance (Groups)

The following table is a ONE-WAY analysis of variance of gunnery scores with the factor groups (Experimental A and B, and Control). The procedure was conducted using SAS.

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GROUPS	3	1 2 3

NUMBER OF OBSERVATIONS IN DATA SET = 540

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	2	23.71816850	11.85908425	33.85
ERROR	537	188.11474195	0.35030678	PR > F
CORRECTED TOTAL	539	211.83291045		0.0001

R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN
0.111966	59.1529	0.59186720	1.00057140

SOURCE	DF	ANOVA SS	F VALUE	PR > F
GROUPS	2	23.71816850	33.85	0.0001

4. SAS One-Way Analysis of Variance and Regression (Days)

The following table is a ONE-WAY analysis of variance of gunnery scores with the factor days. It also presents the regression analysis. The procedures were conducted using SAS.

DEP VARIABLE: MISSDIST

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	16.45641255	16.45641255	45.315	0.0001
ERROR	538	195.37650	0.36315334		
C TOTAL	539	211.83291			

ROOT MSE	0.6026221	R-SQUARE	0.0777
DEP MEAN	1.000571	ADJ R-SQ	0.0760
C.V.	60.22779		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	0.57296290	0.06861154	8.351	0.0001
DAYS	1	0.21380425	0.03176097	6.732	0.0001

5. SAS TWO-WAY Analysis of Variance (Day 1/Groups vs. Exercises)

The following table is a TWO-WAY analysis of variance of gunnery scores from the first day. The factors being investigated are the groups (Experimental A and B, and Control C) and the exercises (A1 thru A6, B1 thru B6, and C1 thru C6). The procedures were conducted using SAS. evening exercise periods. The procedure was conducted using SAS.

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GROUP	3	1 2 3
EXERCISE	6	1 2 3 4 5 6

NUMBER OF OBSERVATIONS IN DATA SET = 180

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	17	2.63606922	0.15506290	1.08
ERROR	162	23.28687391	0.14374614	PR > F
CORRECTED TOTAL	179	25.92294313		0.3787

R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN
0.101689	52.4153	0.37913868	0.72333586

SOURCE	DF	ANOVA SS	F VALUE	PR > F
GROUP	2	0.43313162	1.51	0.2248
EXERCISE	5	1.01976406	1.42	0.2201
GROUP*EXERCISE	10	1.18317354	0.82	0.6069

6. SAS ONE-WAY Analysis of Variance (Morning vs. Evening)

The following table is a ONE-WAY analysis of variance of gunnery scores for Experimental Group A on the first day. The factor being investigated is the performance difference between the morning and evening exercise periods. The procedure was conducted using SAS.

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
AM_PM	2	1 2

NUMBER OF OBSERVATIONS IN DATA SET = 60

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	0.10600917	0.10600917	0.67
ERROR	58	9.19475136	0.15853020	PR > F
CORRECTED TOTAL	59	9.30076053		0.4169

R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN
0.011398	51.3259	0.39815851	0.77574523

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AM_PM	1	0.10600917	0.67	0.4169

7. SAS ONE-WAY Analysis of Variance (By Exercises)

The following table is a ONE-WAY analysis of variance of gunnery scores for Experimental Group A on the first day. The factor being investigated is the performance difference between the first, second, and third exercises in both morning and evening exercise periods. The procedure was conducted using SAS

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
BLOCK	3	1 2 3

NUMBER OF OBSERVATIONS IN DATA SET = 60

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	2	1.03954663	0.51977331	3.59
ERROR	57	8.26121390	0.14493358	PR > F
CORRECTED TOTAL	59	9.30076053		0.0341

R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN
0.111770	49.0756	0.38070143	0.77574523

SOURCE	DF	ANOVA SS	F VALUE	PR > F
BLOCK	2	1.03954663	3.59	0.0341

8. SAS ONE-WAY Analysis of Variance (Exercises A1 vs. A4)

The following table is a ONE-WAY analysis of variance of gunnery scores for Experimental Group A on the first day. The factor being investigated is the performance difference between the Exercises A1 and A4. The procedure was conducted using SAS.

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EX_A1_A4	2	1 2

NUMBER OF OBSERVATIONS IN DATA SET = 20

DEPENDENT VARIABLE: MISSDIST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	1	0.00006007	0.00006007	0.00
ERROR	18	2.58519791	0.14362211	PR > F
CORRECTED TOTAL	19	2.58525798		0.9839
R-SQUARE	C.V.	ROOT MSE	MISSDIST MEAN	
0.000023	54.5937	0.37897507	0.69417368	

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EX_A1_A4	1	0.00006007	0.00	0.9839

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