Technical Report 866

Simulation-Based Command, Control, and Communication Exercise for Armor Small Unit Commanders

Robert S. Du Bois
Universal Energy Systems, Inc.

November 1989

United States Army Research Institute for the Behavioral and Social Sciences

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --
2a. SECURITY CLASSIFICATION AUTHORITY --	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE --	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) UES 788-030	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Technical Report 866
6a. NAME OF PERFORMING ORGANIZATION Universal Energy Systems, Inc. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute Fort Knox Field Unit
6c. ADDRESS (City, State, and ZIP Code) Human Factors Division 4401 Dayton-Xenia Road Dayton, OH 45432-1894	7b. ADDRESS (City, State, and ZIP Code) ATTN: PERI-IK Fort Knox, KY 40121-5620
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences 8b. OFFICE SYMBOL (If applicable) PERI-I	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F41689-86-D-0052
8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63007A PROJECT NO. 795 TASK NO. (351)3101 WORK UNIT ACCESSION NO. C2

11. TITLE (Include Security Classification)
Simulation-Based Command, Control, and Communication Exercise for Armor Small Unit Commanders

12. PERSONAL AUTHOR(S)
DuBois, Robert S. (Universal Energy Systems, Inc.)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 88/05 TO 89/08	1989, November	

16. SUPPLEMENTARY NOTATION
Barbara A. Black, Contracting Officer's Representative

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Simulation-based testing
Armor
Simulation Network-Developmental (SIMNET-D)
M1 tank
Command, control, and communication (C^3)

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

This report documents the development of a simulation-based Armor small unit commander command, control, and communication (C^3) performance assessment method. Unique to this effort is C^3 assessment based on task-loaded, full crew interactive operations conducted in the Army's interactive simulation test bed, Simulation Network-Developmental (SIMNET-D). Nine small unit C^3 tasks were selected for measurement in SIMNET-D. Multiple objective performance measures were identified and supported the development of criterion-oriented composite measures for each task. Task requirements were embedded in a 30-kilometer tactical exercise. Twenty-four tank-crew and platoon commanders and their crews completed the prototype exercise. Overall, the performance data obtained demonstrate the potential of simulation-based C^3 assessment. Six of the C^3 composite measures possessed split-half and Cronbach's alpha reliability coefficients above .50. Future small unit C^3 exercise development and evaluation research requirements are outlined, including the need for investigations of (a) the relationship between soldier background and C^3 exercise (Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Barbara A. Black	22b. TELEPHONE (Include Area Code) (502) 624-2613 22c. OFFICE SYMBOL PERI-IK

DD Form 1473, JUN 86 Previous editions are obsolete.

ARI Technical Report 866

19. ABSTRACT (Continued)

performance; (b) the test-retest reliability and validity of the C^3 measures; and (c) an examination of additional C^3 measurement approaches.

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Simulation-Based Command, Control, and Communication Exercise for Armor Small Unit Commanders

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

November 1989

Army Project Number
2Q263007A795

Training and Simulation

FOREWORD

To assist the United States Army in achieving maximum effectiveness on the battlefield, the Army Research Institute for the Behavioral and Social Sciences (ARI) conducts research on critical soldier performance issues. Within the ARI Field Unit at Fort Knox, the Future Battlefield Conditions Team works to enhance soldier preparedness by conducting both simulation and field-based evaluations of Armor soldier performance and training issues. These issues include future soldier command, control, and communication (C^3) requirements and system concepts.

This report was prepared under Science and Technology Task 3.5.1, "Training Requirements for the Future Integrated Battlefield." ARI's involvement in research on future battlefield conditions supports the memorandum of understanding between ARI and the United States Army Armor Center and School on Research in Future Battlefield Conditions signed 12 April 1989.

This report outlines the development and evaluation of a prototype Armor small unit C^3 performance assessment method for use in the Army's interactive simulation test bed, Simulation Network-Developmental (SIMNET-D). This research provides a prototype exercise and data pool to assess and train small unit C^3 skills. In addition, the C^3 assessment technique described can be used to further (a) the use of SIMNET as an exemplary C^3 training and assessment device; (b) the Army's commitment to more automated C^3 systems; and (c) ARI's involvement in the 5-year Combat Vehicle Command and Control (CVC^2) research program.

The C^3 performance scoring strategies used in this research were reviewed and refined in August 1989 by a subject matter expert panel from the Command, Control, Communication, Computers, and Intelligence (C^4I) Cell and Operations Research Systems Analysis (ORSA) Branch of the Fort Knox Directorate of Combat Developments (DCD). The results of this effort were briefed to the Chief of the DCD ORSA branch on 4 October 1989. Results were also presented at the Military Testing Association Annual Conference, November 1989.

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ACKNOWLEDGMENTS

The author wishes to acknowledge the support of research assistants and technical staff of Universal Energy Systems, Inc. (UES), who contributed to this report. Mr. Paul Smith, a former UES research scientist, assisted in the development and administration of the C^3 test, as well as in data verification efforts. Lt. Col. (Ret) Daniel Motola provided necessary Armor subject matter expert support throughout this effort. Several research assistants, including Mr. Glenn Exum, Ms. Alicia Sawyer, Ms. Cordette Herrington-Swain, and Ms. Rhonda Thomason, provided valuable and professional assistance with soldier training, test administration, and data collection, entry, and verification. Drs. Joseph Birt and Robert Howells provided writing and editing support, while Ms. Terry Kerr provided typing and graphics support.

SIMULATION-BASED COMMAND, CONTROL, AND COMMUNICATION EXERCISE FOR ARMOR SMALL UNIT COMMANDERS

EXECUTIVE SUMMARY

Requirement:

Preparing Armor tank crew and platoon commanders for the command, control, and communication (C^3) requirements of the future battlefield necessitates providing them sufficient opportunities for practice, evaluation, and feedback under realistic task conditions. There is also a need for the development of small unit C^3 measures to support the evaluation of new Armor equipment. The present research outlines the development and evaluation of a prototype C^3 assessment method for training and evaluating small unit C^3 skills in the Army's interactive simulation test bed, Simulation Network-Developmental (SIMNET-D).

Procedure:

Nine small unit C^3 tasks were selected for measurement in SIMNET-D. Multiple objective performance measures were identified and supported the development of criterion-oriented composite measures for each task. Task requirements were embedded in a 30-kilometer tactical exercise. Following SIMNET-D training, 24 tank-crew and platoon commanders, with their crews, completed the prototype exercise.

Findings:

Overall, the performance data obtained demonstrated the potential for simulation-based C^3 assessment. Six of the nine composite C^3 measures evaluated possessed split-half and Cronbach's alpha reliability coefficients above .50. Analyses suggest that doubling the length of the prototype C^3 exercise could result in reliability coefficients above .70 for all measures.

Utilization of Findings:

The results of this research demonstrate that the content of the small unit C^3 domain can be selectively sampled and assessed in SIMNET-D. Selected C^3 task requirements can yield simulation-based work samples for such diverse uses as (a) the generation of C^3 measures for multivariate simulation-based evaluations of

advanced C^3 concepts; (b) the assessment and diagnosis of C^3 training needs; and (c) the measurement of job performance. This report also outlines future small unit C^3 assessment research requirements.

SIMULATION-BASED COMMAND, CONTROL, AND COMMUNICATION EXERCISE FOR ARMOR SMALL UNIT COMMANDERS

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SIMULATION-BASED COMMAND, CONTROL, AND COMMUNICATION EXERCISE FOR ARMOR SMALL UNIT COMMANDERS

Effective small unit, tank crew and platoon, command, control, and communication (C^3) is central to the success of the Armor force on the future battlefield. Current Armor doctrine stresses speed, aggressiveness, deception, penetration, and synchronization (Department of the Army, 1986). Tank crew and platoon commanders dispersed along the forward edge of the battle area must see the whole battlefield and operate in a rapid, precise, and coordinated manner to deceive and destroy a numerically superior force. Small unit commanders must quickly and accurately recognize and report battlefield changes, rapidly receive, interpret, and execute higher level orders, as well as effectively coordinate with adjacent friendly operations.

Preparing small unit Armor commanders for the C^3 requirements of the future battlefield necessitates providing them with sufficient opportunities for practice and feedback under realistic task conditions. Reliably assessing C^3 skills in the context of combat mission field training exercises, like those conducted at the Army's National Training Center (NTC), however, is difficult. While field exercises offer the advantage of realism, C^3 performance and assessment are frequently affected by aspects of the exercise not directly related to C^3, such as doctrine, mission success, and gunnery (Crumley, 1988; Thomas, Barber, & Kaplan, 1984; Wheaton & Boycan, 1982). The complexity of coordinating multi-combat vehicle exercises and the time, cost, and resources required for field C^3 evaluations often force evaluators to assess an inadequate number of C^3 tasks with less than optimal measurement methods, such as the "Go/No Go" ratings of observers stationed off-tank along the battlefield.

A promising approach for at least partially overcoming many of these C^3 assessment problems is to use interactive combat simulation. Simulation systems, used frequently for C^3 assessments at the Armor battalion-level and higher, have rarely been used for small unit assessments (Crumley, 1988). The Army's soldier-in-the-loop simulation test bed, Simulation Network-Developmental (SIMNET-D), may allow researchers to create task-loaded and target rich collective combat environments where C^3 skills can be rapidly, repeatedly, and meaningfully assessed (Gound & Schwab, 1988).

A goal of this research was to initiate the development of a simulation-based method for reliable and valid Armor small unit C^3 performance assessment. This report describes the initial development and evaluation of a prototype tank crew and platoon commander C^3 assessment method for use in SIMNET-D. By capitalizing on SIMNET-D's unique capabilities for supporting objective, standardized, automated command and control performance measurement, this prototype method is intended to (a) provide a tool for SIMNET-D evaluations of the potential impact of new C^3 equipment on small unit C^3 performance, and (b) demonstrate the capability of SIMNET-D to support Armor trainers and evaluators by providing a prototype exercise and data bank for assessing C^3 skills and diagnosing C^3 training deficiencies. While SIMNET-D-based C^3 assessment will not replace current field training assessments and new equipment evaluations, SIMNET may provide a medium for complementary and cost-effective small unit C^3 training and evaluation.

Review of the Literature

Army C^3 literature is sparse and scattered (Crumley, 1988), and reflects the need for more standardized, objective C^3 assessment techniques. In the sections that follow, literature pertaining to both Army C^3 and SIMNET-D are reviewed.

Command, Control, and Communication

Definition

Several definitions of command, control, and communication exist within the Armor community. The Army's Directorate of Training and Doctrine (DOTD, 1987) defines C^3 as

> ...the process of monitoring the enemy and friendly situations through effective use of communications; planning or implementing operations security measures; analyzing information, assessing situations and ensuring accurate information distribution in order that the activities of military forces may be coordinated to accomplish all battlefield tasks of the mission (p.1).

Obviously, C^3 is a complex and critical phenomenon, requiring goal setting, decisionmaking, planning, problem solving, feedback, commanding, controlling, and evaluating. In fact, C^3 is the backbone of Army effectiveness in all AirLand Battle operations (U.S. Army Science Board, 1986). Nevertheless, few truly appreciate all it encompasses (Levis & Athans, 1987).

General Conclusions

One reason C^3 is so often misunderstood is that the Army C^3 literature is dispersed and of varying quality. Recognizing this problem, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) recently completed several literature reviews and identified conclusions regarding Army C^3 (e.g., Cooper, Shiflett, Korotkin, & Fleishman, 1984; Crumley, 1988; Garlinger & Fallesen, 1988; Kaplan, 1987; Solick & Lussier, 1988; Sulzen, 1986; Taylor, 1983). Ten conclusions important for the present research are summarized below.

1. The Army C^3 performance research area is relatively new. The earliest C^3 reports were published in the early 1960s.

2. Reports must be carefully examined before findings are accepted. Inadequate designs, small sample sizes, and naive analyses have resulted in improper conclusions (Crumley, 1988). Applied constrains such as limited participants, time, and resources often impact C^3 research.

The current research effort, for example, includes data collection on only 24 tank crews. Although test psychometric characteristics and measurement strategies are outlined, this research does not provide a completely reliable and valid C^3 exercise and measurement strategy. Instead, this effort outlines a prototype assessment method to evaluate the unique C^3 assessment and new equipment research applications of SIMNET-D.

3. Most C^3 literature has focused on battalion or above Army Training and Evaluation Program (ARTEP) and simulation issues.

4. Concisely defining C^3 is difficult, especially with the rapid changes in Army C^3 ARTEPs and the addition of computerized C^3 systems (Crumley, 1988). Early research considered the problem of what constitutes Armor C^3 performance criteria (e.g., Olmstead, Christensen, & Lackey, 1973). Olmstead et al. identified three critical C^3 criterion constructs: adaptability, integration, and reality testing. Many Army acronyms are used and show the complexities, perspectives, and inclusiveness of C^3 (Berry, 1978). Witus, Patton, and Cherry (1985) offer a generic C^3 task matrix. This matrix classifies C^3 tasks into three primary activities: creating, processing, and communicating information. Researchers suggest the need for C^3 theory (e.g., Levis & Athans, 1987).

5. Numerous Armor small unit C^3 task analyses can support the development of C^3 exercises and measures (e.g., ARTEPs 71-2 & 17-237-10; Gound & Schwab, 1988; Lewman, 1987; O'Brien & Drucker, 1981; U.S. Army Armor School, 1987; Wheaton, Allen, Johnson, Drucker, Ford, & Campbell, 1980). C^3 task ambiguity and subjectivity, the differences in task analysis formats and results, the task conditions possible, and the imprecise nature of many standards, however, complicates the generation of realistic, standardized, and content valid C^3 exercises.

6. C^3 performance is not a direct predictor of mission success (Crumley, 1988). Unfortunately, mission success measures are often the only objective data collected in field and simulation exercises (Crumley, 1988). Too often factors beyond commander control affect battle outcomes (Taylor, 1983). C^3 is best understood by examining specific C^3 activities and products.

Olmstead et al.'s (1973) C^3 competence model, supported by applied research (e.g., Olmstead, Christensen, Salter, & Lackey, 1975; Olmstead, Baranick, & Elder, 1978a, 1978b, 1978c) and refined by Crumley (1988), best illustrates this C^3 measurement principle. Olmstead et al.'s model supports the concept that C^3 competence should be described by related specific C^3 processes (e.g., communicating, decision making, feedback) and their products (e.g., plans, decisions, information flow).

The current C^3 exercise development effort incorporated this principle by focusing on specific C^3 activities and products rather than global mission success measures. The current crew and platoon commander C^3 assessment strategies required discrete small unit C^3 behaviors and provided specific, objective, and relevant performance feedback.

7. Objective, standardized C^3 assessments can be resource intensive and difficult. C^3 measures based on objective, discrete C^3 task performance have resulted in more reliable findings than measures based on subjective data (Garlinger & Fallesen, 1987).

8. Sophisticated methods and tools have resulted in fundamental objective C^3 measures, but primarily at the battalion-level and higher. For example, methods exist for measuring the effectiveness of Operations Orders (OPORDs) (e.g., Archer, Fineberg, & Carter, 1984), plans (e.g., Defense Systems, Inc., 1984; Metlay, Liebling, Silverstein, Halatyn, Zimberg, & Richter, 1985), information flow (e.g., Kaplan, 1980; Thomas et al., 1984), and decisions (e.g., Robins, Buffardi & Ryan, 1974).

Yet these methods are resource intensive and difficult. For example, decision and plan quality methods demonstrated for battalions require generating combat scenarios and collecting effectiveness ratings for possible unit responses (Crumley, 1988). Research is needed to develop more objective, but less resource demanding, C^3 measures--exploiting advances in simulation and automated measurement, including voice recording technology. This research outlines an assessment strategy which exploits the capabilities of SIMNET-D.

While most C^3 measurement methods and tools support higher level C^3 assessments, some methods and tools have been developed for small unit assessments. For example, early research resulted in valid tank crew and platoon commander C^3 terrain board exercises to complement field assessments (e.g., Baker & Cook, 1962a, 1962b, 1963). ARI has also developed and evaluated microcomputer-based battle simulations for training and assessing Armor small unit commander C^3 skills, like the Platoon Level Battlefield Simulation (Graham, 1987; Kristiansen, 1987; Lampton, in press).

9. Simulation-based C^3 evaluations are effective if simulation capabilities are used to their full potential. The Army's C^3 simulation family tree spans two decades and includes over 17 C^3 simulations (Crumley, 1988). While commanders frequently indicate their simulator experiences were less stressful and limited in the combat conditions present (e.g., lack of communications jamming), these assertions are also directed at field experiences (e.g., Kaplan & Barber, 1979).

SIMNET-D technology, however, represents the first time that full crew, multiple combat vehicle and associated command staff functions are interactively networked to support individual and collective performance on a simulated battlefield. SIMNET may support the repeated, standardized, and objective assessment of a number of C^3 tasks too difficult or dangerous to reliably and accurately collect in the field.

10. ARTEP field evaluations of C^3 performance have fared poorly. Too often evaluators are influenced by a mission's outcome, suggesting that 'it's not how you play the game, but whether you win or lose that counts!' (Crumley, 1988). Factor analyses of unit ARTEP ratings often indicate one factor, general mission success, despite the independence of objectively measured ARTEP constructs (e.g., Thomas et al., 1984). Safety concerns and cost and resource requirements also limit the number of field assessable C^3 tasks.

The SIMNET-D Experimental Test Bed

One of the Army's most advanced simulation test beds, Simulation Network-Developmental (SIMNET-D), interactively links a variety of combined arms simulators (Bolt, Beranek, & Newman (BBN) Laboratories, 1986; Miller & Chung, 1987; Perceptronics, 1986). The simulator network houses various soldier-in-the-loop weapon system simulators, including M1 tanks, Bradley Fighting Vehicles, and A-10 fixed wing and Apache rotary wing aircraft, along with tactical, administrative, and logistical combat service support elements. Planned SIMNET enhancements include JETNET and AIRNET, which add Air Force and Army aircraft and their tactical, logistical, and administrative resources to the SIMNET battlefield. Other enhancements may extend SIMNET to include Navy and Marine vehicles and support stations.

SIMNET Combat Vehicle Simulators

SIMNET combat vehicle simulators were developed to model the behavior of the real system to the minimum degree necessary for soldiers to perceive the system as realistic and acceptable (Chung, Dickens, O'Toole, & Chiang, 1988). Individual simulators are supported by a terrain and operations database and audio and visual systems for modeling battlefield conditions, equipment status, and weapon system performance. All simulator battlefield appearance, status, activities, and weapon system effects are linked and updated across an Ethernet.

The M1 tank simulators, for example, continuously update their operational database and audio and visual system status with respect to battlefield conditions, such as ammunition loads, vehicle speed, equipment status and grades being climbed. The tank module simulates critical tank gauges and switches. The module simulates the 105-mm main gun which is boresighted and zeroed, armed with HEAT and SABOT rounds, and linked to a stabilized laser range finder, gunner's primary sight, and commander's primary sight extension (Chung et al., 1988).

The SIMNET M1's visual system produces images across eight independent channels divided among the four man tank crew. The vehicle commander, for example, is allotted three channels for three one-power vision blocks mounted in a rotatable cupola, and shares with the gunner a repeater channel (three-power and 10-power) in the commander's main gun extension sight. The M1 driver and loader are also each provided with one vision block. The battlefield images generated provide crew members real-time updates of the terrain features, other vehicles and weapon effects within a 3,500 meter radius while moving, scanning, or shooting on a 50 by 75 kilometer battlefield (Cyrus, 1987).

In addition, the SIMNET M1's audio system simulates battlefield acoustics, such as weapons firing and track movement appropriate to tank speeds, terrain surface, steering, and gear changes.

Consistent with a selective fidelity design, however, the SIMNET M1 simulators do not include all weapon system components. For example, the SIMNET M1's lacks the real M1's machine guns, auxiliary sight, and open-hatch. Likewise, the simulator's visual system only presents a daylight environment. Efforts are in progress to improve the fidelity of SIMNET-D simulators. Recently, a thermal imaging capability was added to the SIMNET-D M1 modules to support an ARI evaluation of the Commander's Independent Thermal Viewer (Quinkert, in prep). Hence, each researcher or trainer must evaluate the simulated modules' fidelity to ensure the SIMNET environment suits their needs. The C^3 exercise developed in this effort includes only tasks compatible with evaluation on the SIMNET battlefield.

SIMNET-D Research Capabilities

Several research capabilities directly support the SIMNET-D test bed. These capabilities are outlined below and include: (a) reconfigurable simulators; (b) Semi-Automated Forces (SAF); (c) Plan View Displays (PVDs); (d) shadow view monitors; (e) the Management, Command and Control System (MCC); and, (f) the Data Collection and Analysis System (DCA).

Reconfigurable simulators. To support the evaluation of new weapon systems and subsystems, the SIMNET-D simulator hardware and software are reconfigurable. With SIMNET-D the Army can simulate, evaluate, and redesign a combat capability before having to build and field it. This capability has been demonstrated in SIMNET-D evaluations of proposed M1 Abrams Block II components (e.g., Du Bois, in prep; Du Bois & Smith, 1989; Quinkert, in prep).

Semi-Automated Forces. The SIMNET SAF is a multi-vehicle simulation program for creating and controlling automated, unmanned, opposing and friendly forces' aircraft and vehicles. The SAF can save personnel and experimental resources that would be required to operate manned simulation modules.

Soviet doctrine, for example, dictates massive superiority of five-to-one or higher in any offensive operation. Without the SAF capabilities, numerous enemy vehicle simulators and the soldiers to occupy them would be required to support SIMNET-D based tests. The SAF capabilities also allow users to create standardized unit placements and activities to require soldiers to perform specific tasks for testing and training--a critical feature for this C^3 exercise development effort.

Plan View Display. The PVD monitor provides a "bird's eye view," in real time or playback, of a SIMNET exercise. The PVD depicts a terrain base and provides map manipulation and analysis functions. In addition, an event-flagging function allows exercise controllers to time-stamp selected exercise events for later analyses. For example, as battlefield reports are transmitted, controllers can send flags to support evaluations of each report's accuracy and timeliness.

Shadow View Monitors. Shadow view monitors allow experimenters to view, in real time or playback, SIMNET-D scenario events from selected vehicle sights or vision blocks. These in-tank battlefield views can be placed at test administrator stations to support exercise control, performance measurement, and feedback.

Management, Command and Control System. The MCC provides service support stations and functions for battle management, simulator and target placement, fire supply, close air support, and combat service support.

Data Collection and Analysis System. The SIMNET-D DCA supports automated soldier performance measurement and includes the Data Logger (DL), RS/Probe, and RS/1[1].

The DL is a data collection system which captures and records all simulator network data traffic, including all PVD event flags. The data which SIMNET produces are contained in "data packets." These packets are broadcast by each simulator and by the MCC at an estimated rate of about 0.42 Kbytes per simulator per second (BBN Laboratories, 1986; Pope, Langevin, Lovero, & Tosswill, 1988). Currently, SIMNET-D automatically provides data packets containing information related to vehicle appearance, status, firing events, indirect fire impacts, service requests and receipts, and vehicle collisions (Pope, 1988)). Additional packets can be transmitted based on specific SIMNET-D research requirements.

RS/Probe and RS/1 are data management and analysis software packages linked to the DL. Both systems access a Data Dictionary which defines and labels the various SIMNET-D data packets, and hence, facilitates the accurate isolation of DL stored data. Both systems allow users to compose numerous mission, soldier, and interface effectiveness measures using data packet information. While RS/Probe supports less sophisticated data analyses, including descriptive statistics and color graphics, RS/1 supports advanced statistics, including linear and non-linear regression and parametric and non-parametric tests. SIMNET-D data can also be recorded and stored on magnetic tape for later analysis.

Evaluating Command and Control on SIMNET

Limitations of SIMNET. Users should be cognizant of at least three ways in which the SIMNET environment differs from the field setting. These differences may have implications for the validity of selected SIMNET research and training applications, including the current C^3 exercise development effort. These SIMNET limitations include the closed-hatch nature of vehicle simulators, the limited visual cues presented, and the lack of realistic, terrain bound and sensitive, communication systems.

Closed-Hatch Vehicles. First, commanders frequently perform with the tank's hatch open during field operations, allowing them to move their heads out of the tank to directly

[1]"RS/Probe" and "RS/1" are registered trademarks of BBN Software Products Corporation.

view battlefield events and communicate with other units using arm and hand signals. SIMNET vehicles, however, are permanently closed-hatched and include only three of the real M1's six commander's vision ports. The inability for an out-of-hatch view of the battlefield places constraints on the SIMNET commander's C^3, navigation, and target acquisition capabilities. The limited vision blocks make determining one's own tank orientation, a critical navigational requirement, frustrating and difficult for some users. Researchers have demonstrated performance degradation in closed-hatch field operations (Barron, Lutz, Degelo, Havens, Talley, Smith, & Walter (1976).

Nevertheless, one might think of SIMNET's battlefield conditions, however, as those of a closed-hatch nuclear, biological, or chemical (NBC) weapons environment--a setting expected in a future AirLand Battle (Department of the Army, 1986). Moreover, under artillery and small arms fire, tank commanders are required to operate with the hatches closed.

Limited Visual Cues. Visual cues presented in SIMNET graphics do not simulate some important navigational and command and control cues. Traditionally, field-based tank crews rely strongly on the sun, shadows, and object features for depth perception, orientation, and navigation. Currently, the SIMNET vehicle visual systems do not simulate these features. Distinguishing between SIMNET's natural terrain features is also difficult. The lack of battle markings or identification plates on SIMNET vehicles and a relatively immutable, non-differentiated terrain surface may also constrain C^3 performance.

One way the SIMNET visual quality may affect C^3 task performance, such as reporting battlefield information and controlling platoon fires, is in the limited ability of tank crews to acquire and engage targets, especially stationary targets, at long ranges (e.g., beyond 1,000 meters) (Du Bois & Smith, 1989; Gound & Schwab, 1988).

Radio System Capabilities. The citizen's band (CB) radios currently used in SIMNET do not allow researchers to effectively simulate radio traffic conditions experienced in the field. These conditions include jamming and a limited radio message transmission range based on distance between units and terrain feature locations. Whether commanders are separated by 15 meters or 15 kilometers, their radio communications will show no degradation in transmission quality. Hence, some of the communications which occur freely in SIMNET may not be transmittable in the field. Intuitively, these radio limitations could significantly effect C^3 performance; however, no research has addressed this issue.

Moreover, under the Combat Vehicle Command and Control (CVC^2) program, efforts are in progress to provide enhancements to the fidelity of SIMNET-D radio communications. These efforts include degraded communications as a function of range and terrain geometry and modeling of the Army's new Single Channel Ground and Airborne Radio Sub-system-VHF (SINCGARS) radios.

SIMNET-D does offer some compensatory features for reducing the effects of some of these limitations, including an Azimuth Indicator, Turret Reference System, and special paper maps. In summary, however, SIMNET is not a panacea for C^3 performance measurement. The potential for differences between simulator and real tank conditions to affect SIMNET research findings must be analyzed carefully, just as the limitations of any training medium, including field exercises, must be evaluated.

This research was aimed at demonstrating the usefulness of SIMNET for training and evaluating selected C^3 tasks. Where Armor experts suggested that SIMNET limitations may affect task outcomes, steps were taken during exercise development to significantly reduce their repercussions. For example, the current C^3 exercise avoids intensive soldier terrain analysis requirements by using primarily road-bound routes and easily identifiable checkpoints. Nevertheless, until research is conducted to assess the validity of SIMNET-D based research and training, evaluators must be careful in assuming that their effects generalize to field, and, ultimately, to actual combat performance.

Advantages of SIMNET. SIMNET offers many unique advantages over other simulations and field exercises. For example, the fidelity of C^3 assessments in SIMNET, relative to other simulation mediums, may be greater with respect to (a) the realism of task-loaded environments; (b) the realism of combat stress levels and communications; and, (c) the capability for automated and objective performance measurement.

Task-Loaded Environments. In SIMNET, soldiers can be readily placed in task-loaded environments where combat mission tasks can be repeatedly assessed. In other simulations, including miniature and computerized battlefield combat gaming exercises, tank crews do not face the high levels of operational workload, stress, and complexity achieved in SIMNET.

Moreover, board games and microcomputer simulations do not allow crews to practice many of the tactical behaviors, across varying conditions, that can be executed in SIMNET. Soldiers can repeatedly execute tasks in combat situations that are unsafe or too costly for field exercises, such as requesting indirect fires, reacting to air assaults, or bypassing minefields.

Furthermore, in SIMNET crews can fight against other soldiers in a variety of simulators, including helicopters, tanks, jets, and infantry vehicles. Unlike crews using combat games or microcomputer simulations, tank crews in SIMNET do not use touch pads, remote control boxes, or flashlights to simulate mounted land navigation, C3, and gunnery. SIMNET combatants can directly observe the effects of direct and indirect fire and must perform critical mission tasks from within their tanks.

Combat Stress Levels and Communications. Jones, Wylie, Henriksen, Shriver, and Hannaman (1980) reviewed tactical board games and battle simulations. They noted that soldier communications during these simulations and games tend to be informal and conversational and not representative of the radio communications required between commanders in combat. In SIMNET, however, crews occupy their own vehicle and are physically prevented from directly observing or hearing other crews. They use an intercom for within tank communications and use a CB radio to select preset frequencies from platoon, company and other radio networks.

Automated, Objective Performance Measurement. SIMNET-D includes the capability to record and analyze large quantities of diverse data including mission, soldier, and human factors measures. SIMNET-D provides an opportunity to evaluate some tasks using measures which cannot be easily or effectively collected in field combat mission settings, such as the accuracy of spot reports, shell reports, and calls for fire. Researchers and trainers may also record intercom and other radio communications using a SIMNET time-synchronization voice recorder for later analysis. Shadow view monitors allows researchers to see the battlefield from selected combat vehicles and aircraft during an exercise or in playback.

Numerous research efforts have been conducted using SIMNET-D test bed resources (e.g., Directorate of Combat Developments (DCD), 1988; Du Bois, in prep; Du Bois & Smith, 1989; Gound & Schwab, 1987; Schwab, 1987; Pate, Lewis, & Wolf, 1988). This earlier research provides useful examples of exercises, measures, and administration techniques for this C^3 exercise development effort. For example, Gound and Schwab (1988) present a series of tables which outline tank platoon tasks which may be fully, partially, or not trained and evaluated in SIMNET. These tables were guides for defining the domain of tasks included in the current SIMNET-D evaluation.

Statement of the Research Problem

In response to a need for small unit C^3 training and assessment techniques, this research developed and evaluated a prototype Armor small unit commander C^3 assessment method for use on SIMNET-D. Based on a review of past literature, Armor subject matter expert (SME) guidance, and experience, this research identified and reviewed Armor small unit C^3 performance objectives. A sample of C^3 objectives were selected for measurement in SIMNET-D.

The primary purpose of this research was to demonstrate SIMNET-D's potential to complement current field C^3 evaluations by prototyping an approach for rigorously assessing and training tank commander and platoon leader C^3 performance. The prototype Armor small unit C^3 exercise also provides combat developers with strategies for generating C^3 measures to support SIMNET-D based evaluations of new equipment.

Method

Research Participants

Soldier Participants. One-hundred and eight solders stationed at Fort Knox, Kentucky, served as tank crew and platoon members for this research. The soldiers were assigned in groups of three (one commander--either a platoon leader, platoon sergeant, or tank commander--and a driver and a gunner) to form 36 tank crews. Twelve crews participated in exercise pretesting and 24 crews participated in the formal exercise evaluation. To promote effective ARI troop utilization, soldiers for the current research were selected from the baseline group tank platoon participants of an ongoing ARI SIMNET-D evaluation of the Intervehicular Information System (IVIS). IVIS is an automated C^3 system proposed for inclusion in the upgraded Block II M1 tank. While other tank crews (n=24) in the IVIS condition also completed the C^3 exercise, those data are summarized in a separate ARI technical report (Du Bois, in prep). The data collection for the prototype assessment exercise evaluation reported in this experiment ran concurrent with the IVIS experiment, beginning in November 1988 and ending in March 1989.

Ultimately, Army unit commanders decided on the particular soldiers who participated in this research. However, soldiers were required to be qualified for the tank position they served. Tank crews were formed through a process of random assignment of the gunners and drivers to the platoon leader, platoon sergeant, or wingman tank. Tank crews were not intact, or formally established, Armor crews and platoons. They were collections of individual crew members assigned to ad hoc crews.

Loaders/Research Assistants. Four research assistants served as ammunition loaders and data collectors in this research. The primary reasons for using loader assistants were:

(a) to minimize the number of soldiers required; (b) to allow an in-tank observer to collect various behavioral and process measures; and (c) to provide a training instructor for each crew. The loader position was especially suited for research assistant occupancy because the loader has relatively little influence over tank crew performance of C^3 and land navigation tasks. In fact, the loader position is currently being evaluated by the Army for automation.

To take full advantage of the standardization possible with SIMNET, loader assistant behavior must be identical for all tank crews during the exercise. To achieve this uniformity, the four loader assistants received extensive training on SIMNET-D. Each loader assistant received about 100 hours of training. Forty hours of this training was formal and included: (a) an overview of the M1 tank, including a briefing on an actual M1A1 tank; (b) formal instruction on the C^3 tasks and procedures currently used by soldiers; (c) practice, with SME guidance, of the M1 tasks supported by SIMNET tank modules; (d) a description of the crew training program and test exercise used in this research; (e) use (and revision) of training scripts; (f) instructions for collecting behavioral observation data; and, (g) use (and revision) of data collection logs.

The loader assistants received an additional 60 hours of informal on-the-job training during the pilot stages of C^3 exercise development. There were repeated opportunities during training for loader assistants to operate the SIMNET-D vehicles, to use the training scripts, and to use the data collection logs.

Exercise Development

Development of the prototype Armor small unit C^3 exercise was accomplished in five steps. These steps included: define performance objectives; review performance objectives; generate the draft prototype exercise; try out or shakedown the draft prototype exercise; and, finalize the prototype exercise. As part of the test development/evaluation process, criterion measures were selected and developed.

Define Performance Objectives

The first step in developing the C^3 assessment exercise was to define the performance objectives--tasks, conditions, and standards--that comprise the Armor small unit C^3 domain. While the USAARMS Master Task List (U.S. Army Armor School, 1987) provided a useful skeleton for a final task tabulation, a review of Armor C^3 tasks analyses and research was conducted to identify additional task characteristics. Current military standards, as well as additional objective measures identified from past research efforts, were also linked to each task. This effort identified the domain of potential commander C^3 tasks, independent of their importance or SIMNET compatibility.

Review Performance Objectives

After small unit C^3 tasks were tabulated, a sample of C^3 tasks was selected that was deemed: (a) capable of assessment in SIMNET-D; (b) critical to effective small unit combat performance; and, (c) capable of standardized, rapid, objective measurement without requiring unacceptable support requirements (e.g., administrators, exercise participants).

Initially, the researchers removed tasks known to be incompatible with measurement in SIMNET-D, including tasks like "Direct a demolition guard mission," "Install a hot loop", or "Establish an observation post." A cooperative enterprise between the researchers and five Armor SMEs resulted in the final list of tasks. These Armor SMEs included an instructor for the Armor Officer's Basic Course, a test officer, a retired officer, and two tank platoon leaders from active units. Previous SIMNET task-compatibility estimates (e.g., Gound & Schwab, 1988) were referenced frequently during this review. The researchers and SMEs also identified common task scenarios and measures.

Overall, nine C^3 tasks were identified for assessment in SIMNET-D. These tasks, which are among the most frequently required of small unit commanders, are listed in Table 1. The small unit tasks that were not included in the current C^3 exercise were primarily those tasks requiring interactive commander performance (e.g., "Coordinate with adjacent platoons" and "Maintain platoon formations") or those tasks requiring off-tank, on-the-ground, performance (e.g., "Establish an observation post" and "Process enemy personnel and equipment"). While many of the tasks not evaluated may be at least partially assessable in SIMNET-D, the tasks included in this effort were those deemed by SMEs as most readily amenable to SIMNET-D performance.

Generate Draft Exercise

Once a sample of C^3 tasks was selected, an initial draft C^3 exercise was developed based on the judgments of the SMEs who identified and reviewed the C^3 tasks. The development of the draft exercise required: (a) a map and vehicle-based analysis of the SIMNET terrain to select appropriate locations for C^3 task performance; (b) the development of the initial unit situation, mission task sequences, and external events required to initiate desired platoon responses; and, (c) a series of exercise tryouts and revisions by the SMEs and researchers. Whenever significant

Table 1

Armor Small Unit C^3 Tasks Selected for SIMNET-D Based Assessment

C^3 Task
1. React to a change of mission (FRAGO).
2. Bypass obstacles.
3. Issue calls for fire (CFFs).
4. Report own location.
5. Report control measures.
6. Report enemy contact (CONTACT reports).
7. Report battlefield activity (SPOT reports).
8. Report indirect fire activity (SHELL reports).
9. Select and occupy a battle position (BP).

graphical or structural changes to the C^3 exercise were made, they were evaluated and refined in simulation by the SMEs to maximize task realism.

Try Out Draft Exercises

The draft exercise was pre-tested on SIMNET. During this pre-testing, twelve tank crews completed and evaluated the draft small unit C^3 exercise. Four tank crews participated each week during three weeks of shakedown testing. As in the actual formal exercise evaluation, soldiers were selected from an ongoing SIMNET-D IVIS evaluation. All of these soldiers participated in the current shakedown evaluation immediately following their completion of an one-and-a-half day, crew and platoon, SIMNET-D training program designed for the IVIS experiment.

For eight of the twelve crews, this shakedown evaluation was informal and provided an opportunity to evaluate the routes, task requirements, administration procedures, data collection routines, and measures used for the exercise. Independently, each tank crew completed the C^3 exercise at least twice. Upon completing each exercise run, crews were given an after action review to describe their performance of each task. Then crews were urged to give extensive feedback on the quality of the C^3 exercise and to offer suggestions for improving it. For the third group of four crews, this shakedown evaluation was more formal and served as a pilot test for administering the prototype C^3 exercise.

Finalize the Prototype Exercise. Feedback from the draft exercise pretesting was examined to revise and finalize the C^3 exercise, including task requirements, overlays, measures, and administration procedures. Time constraints required the exercise to be shortened. Therefore, the number of C^3 task requirements (i.e., the number of reports, FRAGOs, calls for fire (CFFs), and bypass tasks required during the exercise) were reduced. The C^3 exercise was structured to be executed in about four hours by most commanders. Table 2 presents the final task requirements included in the small unit C^3 exercise.

Table 2

Task Requirements Included in the Armor Small Unit C^3 Exercise

C^3 Task	Number of Times Task Required
1. React to a change of mission (FRAGO).	2
2. Bypass obstacles.	2
3. Issue calls for fire (CFFs)	3
4. Report own location.	4
5. Report control measures.	7
6. Report enemy contact (CONTACT reports).	6
7. Report battlefield activity (SPOT reports).	6
8. Report indirect fire activity (SHELL reports).	8
9. Select and occupy a battle position (BP).	1

The C^3 exercise was designed specifically to require and assess C^3 task performance. Hence, the exercise was primarily road bound to minimize land navigation, map reading, and terrain analysis requirements. Test controllers, stationed at PVD, SAF, and MCC stations, administered the exercise and served as each crew's higher-level commander. Figure 1 depicts the small unit C^3 exercise evaluated in this research. Appendix A includes additional exercise materials, including the exercise controller log and specific target and shelling placement information. Below is a description of how each of the nine tasks were required for evaluation.

Throughout exercise administration, if SIMNET-D module or support capabilities broke down, the equipment was fixed, simulators were reconstituted (if necessary), and the crews continued their mission. Breakdown times were also removed from all time-based criterion measures.

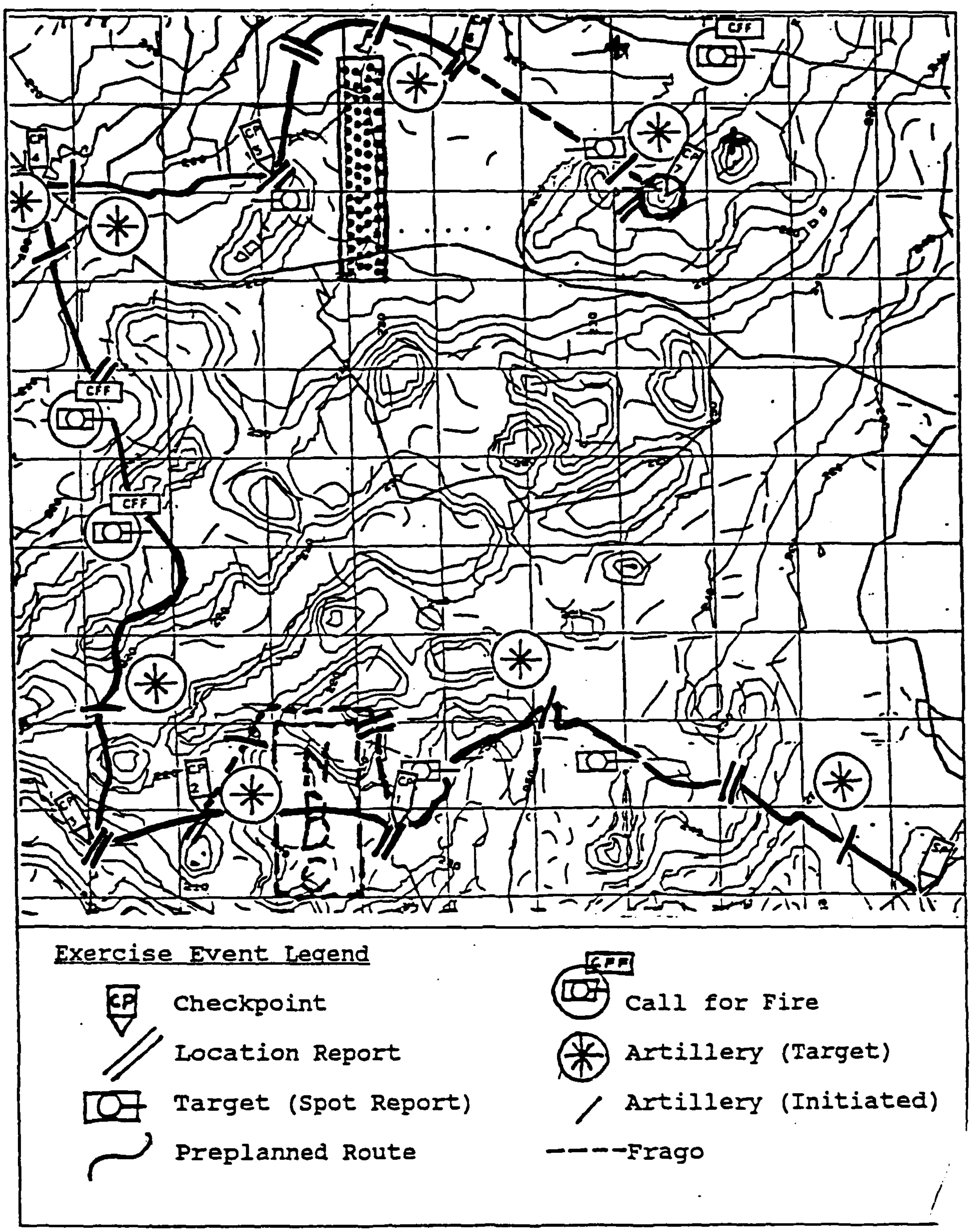

Figure 1. The Armor small unit C^3 exercise map overlay and task structure.

React to a change of mission (FRAGOs). Twice during the C^3 exercise, crew and platoon commanders were stopped and given an impromptu change of mission order. This order included a description of necessary route changes (e.g., new route checkpoints) and mission purposes. For example, one FRAGO required a change of course to bypass a suspected contaminated area. Immediately following the FRAGO radio transmission, commanders planned their new mission, reported ready status, and began FRAGO execution. The FRAGO routes are identified in Figure 1 with dashed lines. Solid lines indicate the original mission graphics given to each commander. FRAGOs were transmitted at checkpoints one and six.

Bypass obstacles. Twice during the C^3 exercise, crews were required to bypass an obstacle, either an NBC area or minefield. A minefield bypass task was included on their original overlay. An NBC bypass, however, was impromptu and triggered through a change of mission order. Both obstacles were notional (unmarked) areas that covered at least a one by two kilometer battlefield area. Bypass routes were specified for both tasks.

Issue calls for fire (CFFs). Three times during the exercise, crews were presented with situations where fire missions, CFFs, were required to effectively engage and destroy enemy units. In all cases, commanders acquired four enemy vehicles. In one case, these vehicles were moving. Commanders were required to issue a CFF and up to five CFF adjustments to reach target effect (i.e., direct artillery within 200 meters of the target vehicles). The SIMNET-D MCC fire support functions were used to deliver fire missions immediately upon CFF receipt. Time delays common in field exercises or combat between CFF transmissions and shell impacts were not included in the current exercise. If no target effect was reached or a CFF mission resulted in the friendly crew's own destruction, the CFF task was ended, crews were reconstituted (if necessary), and crews were ordered to continue the mission.

Report own location. Four times during the exercise, commanders were ordered to stop and report their own grid location. In each case, these reports were impromptu and requested after a heated engagement, enemy indirect fire attack, or during a FRAGO. This task evaluated the commander's ability to maintain situation awareness in a task-loaded setting.

Report control measures. Seven checkpoints were located along the mission course. Two of these checkpoints (checkpoints two and seven) were defined in change of mission orders. Commanders were required to report their arrival at each checkpoint. Again, to minimize land navigation and map reading requirements, all but two of these checkpoints were located at discrete or easily identifiable battlefield points, such as road junctions or intersections, bridges, and hilltops.

Report enemy contact (CONTACT reports). Six distinct groups of enemy vehicles, both stationary and moving, were placed along the exercise route. In some cases, these vehicles appeared near the front of the commander's vehicle upon cresting a hill. In other instances, these vehicles were hidden among trees or other terrain features at both short and long ranges. Enemy vehicles included personnel carriers (PCs) and tanks, in groups of one to three vehicles. In each case, commanders were required to send a complete contact report, which included the keyword "CONTACT," what was contacted (e.g., tanks, PCs), and the cardinal direction of the enemy (e.g., east, west).

Report battlefield activity. Immediately after each of the six exercise battlefield engagements, commanders were required to send a spot report. This SPOT report should include what type and how many enemy were engaged, and where the enemy were located (i.e., a six-digit grid coordinate).

Report indirect fire activity (SHELL reports). Eight times during the exercise, artillery or mortar fire was directed at specific grid coordinates along the crew's route. Each barrage of indirect fire was triggered as each crew reached selected route points. For each task, ten repeated barrages of four shells each were dropped. Immediately upon sensing indirect fire, commanders were required to report the location (i.e., six-digit grid coordinate) of this activity.

Select and occupy battle position (BPs). Once during the Armor small unit C^3 exercise, commanders were given a change of mission requiring them to select and occupy a battle position on a specific hilltop, checkpoint seven, and to orient their main gun to cover a 60 degree sector between two target reference points. Commanders were advised that the SIMNET terrain included no hull or turret positions at the BP location. Commanders could, however, seek cover among numerous trees located at the battle position. After planning their new mission and reporting ready status, commanders executed this task. Once commanders secured their battle position, this task was completed.

Criterion Measures

SIMNET-D provides capabilities for collecting C^3 measures that are too costly or too dangerous to accurately gather in the field. With SIMNET-D, researchers must choose between the numerous objective criterion measures that can be constructed.

The Armor small unit C^3 performance measures selected for collection in SIMNET-D were identified by the SMEs and researchers. The individual C^3 task performance measures selected for each C^3 task are listed in Table 3.

Table 3

Armor Small Unit C^3 Exercise Performance Measures

C^3 Task	Performance Measures
React to a change of mission (FRAGO)	FRAGO success (# successful) Time to plan FRAGO in minutes Time to execute FRAGO in minutes
Bypass obstacles	Bypass success (# successful) Time to execute bypass in minutes
Issue calls for fire (CFFs)	Accuracy of initial CFF in meters Time to reach target effect* or use six CFFs in minutes Number of CFFs used to reach target effect or use six CFFs CFF success (# times effect reached)
Report own location	Accuracy of grid reported in meters Time to report location in seconds
Report control measures (i.e., route checkpoints)	Accuracy of grid reported in meters
Report enemy contact (CONTACT reports)	Accuracy of report "what" component Accuracy of report "where" component Percent of reports sent
Report battlefield activity (SPOT reports)	Accuracy of report grid in meters Accuracy of report "what" component Accuracy of report "where" component Time to report activity in seconds Percent of reports sent
Report indirect fire activity (SHELL reports)	Accuracy of report grid in meters Time to report activity in seconds Percent of reports sent
Select and occupy a battle position	Time to plan in minutes Time to execute in minutes BP Successful (yes or no)

*Target eff.ct is reached when a CFF grid is within 200 meters of the actual target location.

Measurement Concerns. Evaluating the multiple performance measures associated with each task raises a number of challenging issues, including task contingencies, criticality, and standards. First, evaluating each measure in isolation can result in some faulty interpretations, especially when "successful" performance on one task measure is contingent on "successful" performance on an ancillary task measure. For instance, once a tank commander directs his crew through an NBC or minefield area (a mistake that would likely cost lives on a real battlefield), the "time to execute bypass" measure becomes meaningless. Regardless of how fast a commander executed the bypass, he made a costly, if not fatal, mistake. His score should indicate that.

Similarly, a spot report which, although sent rapidly with a correct "what" and "count" component, includes a grid over 1,000 meters away from the actual target location, provides potentially misleading information to a higher level commander.

Evaluating each task measure alone also does not consider the importance of each measure. For example, the most important role of a contact report is to inform a higher level commander that one's unit has acquired enemy aircraft or vehicles. Although the report should, according to standards, include "what" is acquired (e.g., tanks, helicopters, etc) and "where" the enemy is located relative to one's own location (e.g., north, south), modest misinformation is not as important as remembering to inform the commander that "CONTACT" has been made.

Finally, task assessment techniques must account for current military standards. For example, current standards require commanders to report graphic control points and battlefield activity to within 200 meters and within 30 seconds. Hence, final measures selected should indicate commander performance with respect to these standards.

Composite Measures. To resolve these concerns, criterion-oriented composite performance measures were created for each C^3 task. These composite measures are created for each task through a point assignment scheme. Performance on each task measure can contribute points toward one's final overall task score.

For example, the overall composite score for contact reports, CONREP, results from performance on three task measures: whether the report was sent (i.e., at least the keyword "CONTACT" was reported), and the accuracy of the report's "what" and "where" components. Each of six contact reports prompted throughout the small unit C^3 exercise were worth up to five points each. Three points were awarded for each report sent, and one point each was awarded for correct report "what" and "where" components. The overall CONREP score was the sum of the three component scores across all six reports.

For some measures, this composite scoring strategy was more complicated. Performance of a FRAGO, for example, is a function of the time commanders required to plan and execute the mission change and whether the commander reacted to the change of mission as directed. The most critical component, by far, is success. If a crew did not successfully execute the FRAGO, the mission was a failure. Hence, the crew's FRAGO score was 0 of 12 points possible, regardless of plan or execution time. Successful execution was awarded half of the 12 points possible per FRAGO.

Although Army task analyses and field manuals were used to support most scoring assignments, some task standards were not specified in these documents. In these instances, SMEs were necessary for determining appropriate strategies. In addition, a panel of Armor SMEs from the Operations Research Systems Analysis (ORSA) and command, control, communication, computers, and intelligence (C^4I) branches of DCD reviewed and refined these scoring strategies. The criterion-oriented scoring strategies used for each of the nine C^3 tasks evaluated in this research are included in Appendix B. The total points achievable for each task were arbitrarily determined and do not represent the relative importance of each task. For example, CFFs are not four times as important as BP tasks. For comparison, both the individual C^3 task measure values and the composite measure values were included in this report.

Training and Assessment Procedures

As only four M1 tank simulators were available for use in this research, four tank crews were trained and evaluated during each week of this research. The training and evaluation process for each group of four tank crews required two-and-a-half days, and is outlined on an hour-by-hour basis in Table 4. The crew and platoon training program, a day-and-a-half program, was designed specifically for the SIMNET-D IVIS evaluation. Since only IVIS baseline group (NO IVIS) soldiers were included in this C^3 effort, only the activities relevant to the baseline training program are outlined and described.

The Familiarization Training Program. Overall, the training occurred in four phases across Day One and the morning of Day Two for each testing session. During the first or orientation phase of training, the tank crews were given an overview of the SIMNET program and the research objectives for both the current and IVIS efforts. This overview included a description of the current experiment, the presentation of a SIMNET-D videotape, and a seat-specific orientation on the M1 simulator. The seat-specific orientation session was conducted by the research assistants and designed to familiarize crew members with the differences in SIMNET crew positions and the actual M1 or M60A3 tank positions.

Table 4

Training and Assessment Procedures

Day	Time	Description	Location
1	0800-1000	SIMNET-D/Test Overview	SIMNET-D Classroom
	1000-1020	Break	
	1020-1100	Seat Specific Orientation	SIMNET-D M1s
	1100-1200	Classroom Training	SIMNET-D Classroom
	1200-1300	Lunch	
	1300-1520	Structured Practice	SIMNET-D M1s
	1520-1540	Break	
	1540-1700	Small Unit Commander C^3 Practice Exercise	SIMNET-D M1s
2	0800-1000	Platoon Combat Mission Practice	SIMNET-D M1s
	1000-1100	After Action Review	SIMNET-D Classroom
	1100-1300	Lunch	
	1300-1700	Small Unit Commander C^3 Exercise (Session #1: Two Crews)	SIMNET-D M1s
3	0800-1200	Small Unit Commander C^3 Exercise (Session #2: Two Crews)	SIMNET-D M1s

In the second or <u>classroom phase</u> of training, crews received classroom instruction on adapting to the C^3 and navigational procedures and techniques unique to SIMNET (e.g., how to use SIMNET's version of a magnetic compass, the azimith indicator, and the turret reference system). This training was supported by numerous lecture aids, including hand out materials (e.g., SIMNET M1 operator manuals, user guides, SIMNET maps, and copies of the lecture outline), and overhead transparencies. The Armor small unit C^3 exercise (and other exercises developed for the IVIS experiment), especially administration procedures, task requirements, and measures, were also described to each crew.

During the third or <u>hands-on phase</u> of training, crews received an opportunity to practice operating the SIMNET M1 tank and using the C^3 and navigational resources available. For example, crews practiced preparing and transmitting battlefield reports and calls for fire, as well as executing FRAGO, battle position, and bypass tasks. The research assistants, using structured scripts and task lists, conducted this training. A test controller, located at a PVD and SAF station, controlled battlefield events, coordinated crew training, and transmitted specific performance feedback, such as actual vehicle grid coordinates to each commander. Assistants were trained to have each crew complete each training task three times or until the soldiers indicated that they understood and were comfortable with the task requirements and standards.

The fourth or formal practice phase of training provided each tank crew an opportunity to complete a practice C^3 exercise and, as a platoon, a practice combat mission. The combat mission was specifically designed for the IVIS evaluation, but did provide the crews evaluated in this research with an opportunity for continued practice of selected C^3 and navigation tasks.

The practice small unit C^3 exercise was similar to, but about half as long as, the actual small unit C^3 exercise evaluated in this research. The practice exercise required performance of each Armor small unit C^3 task included in the actual exercise, except the battle position task, at least once. During this phase, the research assistants and exercise controllers monitored and stressed that each crew used the C^3 and navigational capabilities available to them.

The assistants and controllers also provided performance feedback to the crewmen to promote retention and transfer of the material taught during the earlier training phases. For example, all battlefield reports transmitted by each commander were promptly followed by the test controller telling the commander the actual grid location, and how far off, in meters, their reported grid deviated from the actual grid.

Following the practice exercises, the crew members met for a group discussion and feedback session with the test controllers and research assistants. This session focused on providing the crew members with specific feedback on their exercise performance and final instructions on actual exercise requirements. Crew members were also urged to express their reactions to the training.

Armor Small Unit C^3 Exercise Administration. Immediately after training, the four crews were assigned a time to complete the C^3 exercise (either PM Day Two or AM Day Three). SIMNET-D resources provided, including two PVDs, an SAF station, MCC, and three radios, allowed up to two crews to complete the exercise in a time-lagged fashion. That is, after one crew had completed about one third of the exercise (i.e., reached checkpoint one), the second crew was given their orders and began planning their mission. Two crews completed the exercise in the afternoon of Day Two. The remaining two crews completed the exercise in the morning of Day Three. Unless soldier commitments dictated otherwise, crews were randomly assigned to exercise sessions.

Immediately before each tank crew executed the C^3 exercise, each commander was given an order for the exercise, including a paper map with exercise overlay (essentially a road march course), protractor, and a grease pencil. Commanders, with their crews, were then allowed to begin their exercise planning. No time limits were placed on this planning time, but the criticality and danger of their upcoming mission was stressed. Before actually beginning their mission, however, commanders were required to report when they had completed their planning and were ready to move out on the road march course. Although a few crews took longer than the four hours allotted for exercise completion, all crews were able to complete the C^3 exercise. Each crew was given at least one 15 minute break during the exercise.

Privacy Procedures

Throughout the conduct of this research, including both the pilot and actual exercise administrations, the confidentiality of all participant responses was maintained. Whenever possible, participants were identified by number. Soldiers were assured of the confidentiality of their responses and performance before completing any questionnaires and SIMNET-D exercises.

Data Analysis

Analyses were performed to examine the background of the soldier participants and the psychometric characteristics of the Armor small unit C^3 exercise. These analyses examined: (a) the soldier aptitude and experience data means and standard deviations; (b) the criterion-oriented composite score means, standard deviations, and coefficients of variation; (c) the individual performance measure means, standard deviations, and coefficients of variation; and, (d) the criterion-oriented composite measure reliability (split-half and Cronbach's alpha).

Results

Soldier Background Data Analyses

Table 5 presents the means and standard deviations for eight soldier background measures collected for each of the 72 soldiers

Table 5

Soldier Background Data: Means (M) and Standard Deviations (SD) by Tank Position

Soldier Measure		ALL	PL	PS	TC	DVR	GNR
			----------Tank Position----------				
ASVAB_CO	M	108	*	103	108	108	108
	SD	12		7	13	12	12
	N	61		5	11	21	24
ASVAB_GT	M	104	*	100	103	105	104
	SD	14		13	14	15	13
	N	63		6	12	21	24
JOB_EXPER (Months)	M	26	5	33	40	22	25
	SD	30	7	35	20	19	42
	N	72	6	6	12	24	24
TANKTIME (Months)	M	71	6	177	113	46	66
	SD	59	6	73	23	35	48
	N	72	6	6	12	24	24
LAST_EXERCISE (Weeks)	M	86	52	123	154	54	83
	SD	89	61	113	127	66	68
	N	72	6	6	12	24	24
NTCCOUNT (# Rotations)	M	.5	0	1	.3	.4	.7
	SD	1.2	0	1	.5	1.2	1.6
	N	68	6	5	10	24	23
SIMNET_EXPER (Hours)	M	19	27	20	17	19	19
	SD	28	39	32	25	29	27
	N	72	6	6	12	24	24
COFT_EXPER (Hours)	M	44	4	35	180	13	20
	SD	178	4	67	420	17	23
	N	72	6	6	12	24	24

* The Army does not collect ASVAB_CO and ASVAB_GT scores for Armor officers.

Note: M is mean. SD is standard deviation. N is sample size. ASVAB_CO and ASVAB_GT are Armed Services Vocational Aptitude Battery Combat Orientation and General Technical scores, respectively. JOB_EXPER is experience in months in current test tank position. TANKTIME is experience in months in Armor. LAST_EXERCISE is time in weeks since last field training exercise. NTCCOUNT is number of rotations at the Army's National Training Center (NTC). SIMNET_EXPER is experience in hours on SIMNET. COFT_EXPER is experience in hours on Conduct of Fire Trainer.

who participated in the formal C^3 exercise evaluation. The soldier measures collected included each soldier's Armed Services Vocational Aptitude Battery Combat Orientation, (ASVAB_CO) and General Technical (ASVAB_GT) scores, experience in their current exercise tank position in months (job_exper), experience in Armor in months (tanktime), time since last field training exercise in weeks (last_exercise), previous number of rotations at NTC (ntccount), previous SIMNET experience in hours (SIMNET_exper), and previous Conduct of Fire Trainer (COFT) experience in hours (COFT_exper). Univariate analyses of variance (ANOVAs) detected tank position differences in job_exper (F=4.747, p=.020), tanktime (F=29.445, p=.000), and ntccount (F=1.426, p=.032). No position differences were detected in ASVAB_CO (F=.510, p=.487), ASVAB_GT (F=.973, p=.341), last_exercise (F=1.682, p=.210), SIMNET_exper (F=.286, p=.755), and COFT_exper (F=1.638, p=.222).

Overall, the soldiers evaluated in this research possessed an average of 26 months of experience in their exercise tank position (job_exper). Platoon leaders, however, possessed significantly less job experience--an average of only five months--than platoon sergeants, tank commanders, drivers, and gunners. Similarly, platoon leaders, on the average, possessed significantly less Armor experience (tanktime). No significant differences, however, were detected in the recency of each soldier's last formal field training experience. On the average, the soldiers' had about 86 weeks (about one-and-a-half years) without field training exposure.

There was considerable variance, however, within the experience measures (job_exper, tanktime, last_exercise, SIMNET_exper, and COFT_exper), with measure standard deviations often larger than their associated mean values. Although SIMNET is a relatively new simulation technology at Fort Knox, the soldiers possessed, on the average, about two-and-a-half days (19 hours) of SIMNET experience prior to this evaluation.

Armor Small Unit C^3 Assessment Exercise Analyses

Descriptive Analyses

Exercise plan and execution time. Table 6 presents the means and standard deviations for the exercise execution and plan time measures. On the average, soldiers took nearly three-and-one-half hours (209 minutes) to plan and execute the prototype small unit C^3 exercise. There was considerable variance in exercise completion times, however, with exercise plan times ranging from five to 50 minutes, and exercise execution times ranging from 125 to 257 minutes.

Table 6

Armor Small Unit C^3 Exercise Plan and Execution Time: Means (M), Standard Deviations (SD), and Range

Measure	M	SD	Min/Max
Exercise Plan Time in minutes	26min	12min	5min/50min
Exercise Execution Time	183min	41min	125min/257min

Individual task performance measures. Table 7 presents the means, standard deviations, and coefficients of variation for each of the raw individual task performance measures collected (see Table 3). The coefficient of variation is a measure which describes the degree of variability in a measure relative to its mean (i.e., the standard deviation divided by the mean).

Overall, the small unit commanders evaluated demonstrated room for improvement in performance across most of the individual C^3 task performance measures collected. For example, commanders, on the average, successfully executed only one of the two change of mission orders and obstacle bypasses required in the prototype C^3 exercise. Moreover, only 42 percent of the commanders successfully executed the battle position task. Nevertheless, the impact that SIMNET-D limitations, described earlier, have on soldier performance still needs to be determined.

Reported locations were also quite inaccurate, especially for calls for fire, where initial report grids deviated, on the average, 832 meters from the actual target location. The mean deviation for other battlefield reports ranged from 433 meters (control measures) to 608 meters (shell reports). These report grid deviations are especially surprising, considering that the C^3 test was primarily road bound, with discrete checkpoints, to limit navigation and map reading requirements.

Report times were also slow. Commanders took, on the average, about one-and-a-half minutes to report their own location, battlefield activity (spot reports), and indirect fire activity (shell reports). Moreover, commanders took, on the average, nearly eight-and-a-half minutes to fully execute each call for fire task. Still, the commanders, on the average, only achieved target effect for two of the three CFF tasks.

Table 7

Armor Small Unit C^3 Exercise Task Performance Measures: Means (M), Standard Deviations (SD), and Coefficients of Variation (COV)

C^3 Task/Performance Measures	M	SD	COV
React to a change of mission (FRAGOs)			
Frago success (# FRAGOs successfully executed of 2)	.96	.75	.78
Time to plan FRAGO in minutes	7.05min	1.70min	.24
Time to execute FRAGO in minutes	21.06min	8.85min	4.30
Bypass obstacles			
Bypass success (number of bypasses successfully executed of 2)	1.12	.74	.66
Time to execute bypass in minutes	22.20min	9.62min	.43
Issue calls for fire (CFFs)			
Accuracy of initial CFF (deviation in meters between actual and reported grid)	832m	621m	.75
Time to reach effect (time in minutes from target acquisition to reach target effect or send six CFFs without effect)	8.28min	4.57min	.55
Number of CFF adjustments used (number of CFF missions sent before reaching target effect, maximum of six)	3.72	1.30	.35
CFF Success (number of CFF tasks of 3 for which target effect was reached)	2.13	.95	.45
Report own location			
Accuracy of grid reported (deviation in meters between actual and reported grid)	502m	371m	.74
Time to report location (time in seconds from controller prompt to report transmission)	69sec	32sec	.46

Table 7 (Continued)

Armor Small Unit C^3 Exercise Task Performance Measures: Means (M), Standard Deviations (SD), and Coefficients of Variation (COV)

C^3 Task/Performance Measures	M	SD	COV
Report control measures			
Accuracy of grid reported (deviation in meters between actual and reported grid)	433m	325m	.75
Report enemy contact (CONTACT reports)			
Number of reports sent of 6	3.17	2.04	.64
Accuracy of report "what" (percent of reports sent with correct "what")	24%	32%	1.33
Accuracy of report "where" (percent of reports sent with correct "where")	41%	43%	1.05
Report battlefield activity (*SPOT reports*)			
Number of reports sent of 6	5.25	.90	.17
Accuracy of report "what" (percent of reports sent with correct "what")	54%	12%	.22
Accuracy of report "count" (percent of reports sent with correct "count")	94%	12%	.13
Time to report activity (time in seconds from engagement end to report sent)	92sec	42sec	.46
Accuracy of report grid (deviation in meters between actual and reported grid)	529m	285m	.54
Report indirect fire activity (SHELL reports)			
Accuracy of report grid (deviation in meters between actual and reported grid)	608m	262m	.43
Time to report activity (time in seconds from shell impact to report sent)	87sec	68sec	.78

Table 7 (Continued)

Armor Small Unit C^3 Exercise Task Performance Measures: Means (M), Standard Deviations (SD), and Coefficients of Variation (COV)

C^3 Task/Performance Measures	M	SD	COV
Select and occupy a battle position (BP)			
Time to plan BP task in minutes	6.32min	1.87min	.30
Time to execute BP task in minutes	11.83min	5.40min	.46
Accuracy of BP task execution (correct BP location, within 500 meters, and main gun orientation, within assigned sectors--1=succeeded, 0=failed)	.42	.50	1.19

Note: N is 24 small unit commanders for all measures.

On the average, 50 percent of the contact reports were sent, with only about half of these containing accurate "what" and "where" information. Nearly all (5.25) of the six spot reports required, however, were sent. While 94 percent of these reports contained correct "count" information, the "what" information was incorrect for 54 percent of the spot reports sent.

While, on the average, individual C^3 task measures indicated far less than maximum performance, commander performance did vary considerably for many of the measures. The individual measure standard deviations for 22 of 26 measures collected were at least one-third the measure's mean. Only the SPOT report "what" and "where" component accuracy measures, the SPOT report sent measure, and the battle position plan time measure showed limited variability (i.e., COVs equal .22, .13, .17, and .30, respectively). C^3 performance was especially variable for the FRAGO execution time, contact report "what" and "where" component accuracy, and battle position execution accuracy measures (i.e., COVs equal 4.30, 1.33, 1.05, and 1.19, respectively).

Criterion-Oriented Composite Measures. Table 8 presents the mean, standard deviation, range (minimum and maximum values), coefficient of variation, and percent of task points achieved values for each of the nine C^3 composite scores.

Table 8

Armor Small Unit C^3 Exercise: Criterion-Oriented Composite Measure Means (M), Percent of Total Points Achieved (%TOT), Standard Deviations (SD), Range, and Coefficients of Variation (COV)

C^3 Composite Measure	M	%TOT	SD	Min/Max	COV
FRAGO React to a change of mission (24 points possible)	9.33	39%	7.07	0/20	.76
BYPASS Bypass Obstacles (20 points possible)	11.46	57%	5.98	0/20	.52
CFF Issue Calls For Fire (60 points possible)	32.04	53%	14.68	3/58	.46
LOCREP Report Own Location (32 points possible)	21.46	67%	5.13	12/29	.24
CPREP Report Control Points (28 points possible)	20.58	74%	5.02	10/28	.24
CONREP Report Enemy Contacts (30 points possible)	11.96	40%	8.18	0/26	.62
SPOTREP Report Battlefield Activity (72 points possible)	42.54	59%	10.44	27/57	.25
SHELLREP Report Indirect Fire Activity (80 points possible)	32.25	40%	10.74	0/46	.33
BP Select and Occupy Battle Positions (12 points possible)	4.08	34%	3.90	0/9	.96

The room for improvement in C^3 task performance, on the average, for the small unit commanders evaluated was especially clear from an examination of the mean percent of points per C^3 task that commanders achieved. On the average, the tank crew and platoon commanders evaluated achieved scores reflecting from 34 percent (BP) to 74 percent (CPREP) of the points possible per task. On the average, commanders did not achieve half the points possible for the battle position (%tot=34), change of mission (%tot=39), contact report (%tot=40), and shell report (%tot=40) tasks.

An examination of the composite measure value COV and standard deviation values still indicated considerable variance for at least six of the nine composite measures. Only three composite measures, spot reports, control measure reports, and own location reports, have COVs less than one-third of the measure's mean value. Moreover, the range of values associated with each measure, indicated by the minimum and maximum values in Table 8, revealed substantial commander differences in performance. In fact, the range of composite measure values associated with the change of mission, bypass, call for fire, contact report, shell report, and battle position tasks covered nearly the entire range of individual task scores possible.

Reliability Analyses

Internal consistency (Cronbach's alpha) and equal length, Spearman Brown corrected, split-half reliability coefficients for each of the criterion-oriented composite measures are contained in Table 9. The battle position (BP) task was only required once during the small unit C^3 exercise. Hence, these reliability estimates were not applicable for this task.

Overall, across both the split-half and Cronbach's alpha indices, reliability values ranged from .13 (BYPASS) to .80 (CONREP). Six of the eight measures possessed reliability values, both split-half and alpha, above .50. Reliability values were larger for those tasks required more frequently during the small unit C^3 exercise. For example, the composite measures for the change of mission (FRAGO) and obstacle bypass (BYPASS) tasks, required twice during the prototype C^3 exercise, both possessed reliability values less than .40.

To further evaluate the consistency of commander performance across each of the C^3 items, Table 10 shows the means, standard deviations, and coefficients of variation for each of the prototype C^3 exercise items. Overall, differences between most task item means were not large, with most item means falling within a one to two point range.

Table 9

Armor Small Unit C^3 Exercise: Criterion-Oriented Composite Measure Split-Half (SPLIT) and Internal Consistency (ALPHA) Reliability

C^3 Composite Measure	SPLIT	ALPHA
FRAGO React to a change of mission	.38	.37
BYPASS Bypass Obstacles	.14	.13
CFF Issue Calls For Fire	.57	.51
LOCREP Report Own Location	.64	.60
CPREP Report Control Points	.54	.50
CONREP Report Enemy Contacts	.71	.80
SPOTREP Report Battlefield Activity	.60	.58
SHELLREP Report Indirect Fire Activity	.73	.72

Note: BP (Select and occupy battle positions (BPs)) only prompted once, so reliability indices are not applicable. SPLIT is equal-length Spearman Brown corrected reliability coefficient. ALPHA is coefficient alpha (internal consistency) reliability coefficient.

Table 10

Armor Small Unit C^3 Exercise Item Statistics: Item Means (M), Standard Deviations (SD), and Coefficients of Variations (COV)

C^3 Task/Item	M	SD	COV
FRAGO React to a change of mission (12 points possible per item)			
FRAGO1	5.25	5.04	.95
FRAGO2	4.08	3.90	.96
BYPASS Bypass Obstacles (10 points possible per item)			
BYPASS1	4.87	4.66	.96
BYPASS2	5.42	4.74	.87
CFF Issue Calls for Fire (20 points possible per item)			
CFF1	10.38	7.14	.69
CFF2	13.13	6.52	.50
CFF3	8.54	6.90	.81
LOCREP Report Own Location (8 points possible per item)			
LOCREP1	5.46	2.25	.41
LOCREP2	5.50	1.74	.32
LOCREP3	4.79	2.15	.45
LOCREP4	5.71	1.37	.24
CPREP Report Control Measures (4 points possible per item)			
CPREP1	3.17	1.58	.50
CPREP2	2.37	1.61	.68
CPREP3	3.75	.85	.23
CPREP4	3.25	1.42	.44
CPREP5	3.04	1.37	.45
CPREP6	2.46	1.41	.57
CPREP7	2.54	1.64	.63

Table 10 (Continued)

Armor Small Unit C^3 Exercise Item Statistics: Item Means (M), Standard Deviations (SD), and Coefficients of Variations (COV)

C^3 Task/Item	M	SD	COV
CONREP Report Enemy Contacts (5 points possible per item)			
CONREP1	2.96	2.05	.69
CONREP2	1.79	1.86	1.04
CONREP3	2.08	1.86	.89
CONREP4	1.79	2.06	1.15
CONREP5	2.00	1.77	.89
CONREP6	1.33	1.97	1.48
SPOTREP Report Battlefield Activity (12 points possible per item)			
SPOTREP1	8.06	1.61	.20
SPOTREP2	6.25	2.89	.46
SPOTREP3	8.46	1.74	.21
SPOTREP4	7.79	3.97	.51
SPOTREP5	7.00	2.47	.35
SPOTREP6	4.96	4.54	.92
SHELLREP Report Indirect Fire Activity (10 points possible per item)			
SHELLREP1	3.33	1.81	.54
SHELLREP2	4.71	1.99	.42
SHELLREP3	4.00	1.98	.54
SHELLREP4	4.37	2.45	.56
SHELLREP5	3.63	2.30	.63
SHELLREP6	4.71	2.61	.55
SHELLREP7	4.71	2.48	.53
SHELLREP8	2.79	2.75	.99

An examination of the item means for the obstacle bypass (BYPASS) and call for fire (CFF) tasks revealed some interesting differences. The small unit commanders demonstrated poorer performance on the impromptu NBC area bypass than on the original mission overlay minefield bypass. Moreover, commanders performed poorest on CFF3, where moving targets were presented.

Table 11 shows the estimated number of additional repetitions per C^3 task that should be included in a final small unit C^3 test to achieve a split-half reliability coefficient of at least .70. These requirements are based on a variation of the Spearman-Brown correction formula (Ghisseli, Campbell, and Zedeck, 1981). The accuracy of this formula is dependent on the assumption that the additional task items are similar to those already contained in the prototype C^3 exercise.

Overall, the estimated task repetition requirements shown in Table 11 suggested that a revised small unit C^3 exercise should contain nearly twice as many task requirements as the exercise evaluated in this research. While some tasks may require minimal additional repetitions to reliably assess (e.g., contact reports, spot reports, calls for fire, location reports, control measure reports, and shell reports), the bypass obstacles and change of mission (FRAGO) tasks may require several additional requirements. For example, to reliably assess the bypass obstacles task, a small unit C^3 exercise should contain over 30 additional bypass requirements. The bypass reliability coefficient obtained in this research, however, is likely constrained by the difference in the nature of the two bypass items included in the prototype C^3 test. Hence, the estimated requirement for the bypass task is probably quite conservative.

Based on an estimated doubling of overall task requirements, a revised small unit exercise would require about eight hours to execute (i.e., about twice as long as the current prototype exercise). These task requirement estimates, however, were based on obtained split-half reliability coefficients. Test-retest reliability values are probably more relevant for these analyses.

Table 11

Estimated Repetitions Per C^3 Task to Achieve Reliability Coefficients of at Least .70: Based on Spearman-Brown Correction Formula

C^3 Task	Current Requirement	Estimated Requirement
FRAGO React to a change of mission	2	8
BYPASS Bypass Obstacles	2	32
CFF Issue Calls For Fire	3	6
LOCREP Report Own Location	4	6
CPREP Report Control Points	7	14
CONREP Report Enemy Contacts	6	6
SPOTREP Report Battlefield Activity	6	10
SHELLREP Report Indirect Fire Activity	8	8

Note: BP (Select and occupy battle positions (BPs)) only prompted once, so reliability indices are not applicable. All corrections based on obtained equal-length split-half reliability value.

Discussion

Overall, this research, through the development and evaluation of a prototype C^3 exercise, demonstrated that the content of the small unit C^3 domain can be selectively sampled and assessed in SIMNET-D. Selected C^3 task requirements can yield simulation-based criterion-referenced work samples for diverse uses, including: (a) the generation of C^3 measures for multivariate simulation-based evaluations of advanced C^3 concepts; (b) the assessment and diagnosis of C^3 training needs; and (c) the measurement of job performance.

There are, however, several additional research requirements necessary to further evaluate the utility of command and control assessment using SIMNET-D. These research requirements include: (a) evaluating effects of soldier background on soldier C^3 performance; (b) evaluating additional psychometric properties of the SIMNET-D based small unit C^3 exercise; and, (c) evaluating other SIMNET-D based C^3 training and measurement approaches.

Research Requirements

Effects of Soldier Background on Performance

While the backgrounds of the soldiers evaluated in this research appeared consistent with the characteristics of soldiers used in other Armor research (e.g., Du Bois & Smith, 1989), platoon leaders did possess lower experience than might be expected. This platoon leader inexperience, as well as the small sample size (i.e., 24 crews) of this C^3 evaluation, did not afford reliable evaluations of the relationship between soldier experience and aptitude on small unit C^3 task performance.

Nevertheless, future research should examine these relationships. These analyses could have many implications for exercise development. For example, if greater previous SIMNET experience corresponds with higher SIMNET-D based C^3 performance, training and other corrections may be required to reduce SIMNET experience effects. Du Bois (1987), for instance, demonstrates the potential for previous COFT experience to impact on standardized COFT evaluations used in research.

C^3 Test Psychometric Properties

Reliability. While the prototype small unit C^3 tasks evaluated in this research possessed relatively low split-half and internal consistency reliability coefficients, these low values were not surprising for at least three reasons.

First, the assessment time afforded this research limited the number of C^3 task items included in the prototype C^3 exercise. Nevertheless, it was encouraging, indeed, that six of the nine measures possessed reliability coefficients above .50. Moreover, estimated task item requirements outlined in Table 14 showed that by doubling the length of the prototype C^3 exercise, all of the C^3 tasks included in this evaluation could be assessed with more acceptable reliability (i.e., split-half reliability greater than .70). This revised exercise would require about one day for most commanders to execute.

Second, the small number of diverse subjects included in this research also placed limits on the reliability of the measures collected. Further research, with larger sample sizes, could result in more stable and acceptable estimates of reliability.

Third, the time and simulation resources available, as well as logistical constraints involved in troop support, precluded an evaluation of the test-retest reliability of the prototype Armor small unit C^3 exercise. Test-retest reliability, by indicating the stability of the C^3 task scores over time, would be more appropriate, particularly with respect to training and sustainment of C^3 skills. The lack of consistent performance among the C^3 task items included in the prototype exercise may have simply verified the diversity of conditions and task requirements for C^3 tasks, especially for the change of mission (FRAGO) and obstacle bypass (BYPASS) tasks. Further research is needed to evaluate the stability over time of C^3 exercise task performance.

<u>Validity</u>. This research involved developing a prototype C^3 exercise for assessing only selected small unit C^3 tasks. Small unit C^3 tasks selected were of necessity keyed to the domain compatible with SIMNET-D assessment and applicable to our assessment exercise approach and to the IVIS concept evaluation with which we concurrently shared resources. The prototype exercise does not attempt to provide items representative of the complete small unit C^3 domain. Further research is needed to more completely define and review the C^3 domain to support the development of a content valid simulation-based small unit C^3 exercise. Recent or expected SIMNET-D software and hardware improvements, such as the addition of more realistic minefields, should also be incorporated in a final small unit C^3 exercise.

In addition to improving the content validity of the small unit C^3 exercise, further investigations should be conducted to evaluate the criterion-related and construct validity of the small unit C^3 exercise measures. For example, to assess the construct validity of the small unit C^3 measures, a multi-method multi-trait evaluation could be conducted. Multiple measures, including simulation and field-based measures, of small unit command and control performance should be correlated with field and simulation-based measures of other small unit performance constructs to ensure that appropriate relationships exist.

A weak relationship between field and SIMNET-D based C^3 performance measures, however, may not imply that the SIMNET-D based measures are unreliable and not valid. While field performance is often viewed as the success criterion for criterion-related validity studies, both field and simulation-based measures attempt to assess skills related to the same ultimate performance criterion--actual combat performance. It is possible, for example, that both SIMNET-D and field-based measures could be related to this ultimate criterion, combat performance, yet not be significantly related to each other.

For example, the prototype SIMNET-D based C^3 test evaluated in this research allows for highly objective, discrete, criterion-oriented measurements for specific small unit C^3 requirements. In comparison, field C^3 measures tend to be more global, subjective, and collective in nature. While the SIMNET-D based C^3 test may relate more to the individual task performance elements of actual combat performance, field-based C^3 measures may relate to the more collective, mission success components of combat performance.

Moreover, the less than maximum performance of commanders in the current evaluation may be related to the combat-intensive and stressful nature of the prototype C^3 exercise, as well as the objective, military standard-based measurement approach used. Current field exercise C^3 measures, by measuring more global, mission success related measures, may not allow for specific diagnosis and feedback for specific small unit command, control, and communication measures. Nevertheless, the low performance of soldiers may also be related to the limitations of SIMNET.

Additional Measurement Approaches

Testing approaches. This research evaluated only one assessment approach, a tactical exercise approach, for assessing small unit command and control performance. Future research should identify and evaluate other approaches for assessing small unit C^3.

For example, researchers could evaluate the feasibility of developing discrete C^3 task performance items or combat vignettes for simultaneous administration to multiple commanders. This approach would require the SIMNET technology to be configured to allow multiple commanders to be located at identical battlefield locations but unable to hear or see each other. Commanders would observe and react to standardized sets of visual and auditory stimuli prompting the performance of critical C^3 tasks. Combat vignettes would be the simulation-based equivalent of written test items.

The current research provides a test item data bank, as well as estimated task item requirements, useful for developing a reliable combat vignette-based C^3 exercise. A complete small unit C^3 exercise, composed of multi-dimensional task measurement approaches and measures, could support more reliable and efficient C^3 assessments.

<u>Measurement approaches</u>. This research only begins to explore the numerous, relevant small unit C^3 criterion measures capable of measurement in SIMNET-D. For example, the addition of digital voice recording capabilities in SIMNET-D could support the collection of relevant communication and information flow measures.

Moreover, future SIMNET-D improvements, including the capability to embed digitized mission overlays into the SIMNET-D database, could support the automated measurement of other relevant C^3 constructs, including the ability of units to stay within assigned boundaries and report control measures.

Researchers should also explore means of evaluating C^3 constructs related to the ability of units to maintain cover and concealment. Tactical movement is a critical combat requirement, yet current evaluations of utilized cover and concealment are often subjective. SIMNET-D provides line of sight, movement formation, and other data necessary for generating a tactical movement measure.

Moreover, SIMNET-D provides an excellent test bed for evaluating the utility of additional criterion measure generation strategies. For example, as demonstrated in this research, SIMNET-D administration lends itself to flexible composite criterion-oriented measurement scaling. Since scaling rules and strategies can be embedded in relatively flexible data analysis routines, other scoring approaches can be evaluated easily. Moreover, as battlefield requirements and military standards change with the addition of new C^3 technologies or doctrine, these scoring strategies can be easily refined.

Conclusions

Overall, this research demonstrated the potential of SIMNET-D for supporting reliable Armor small unit C^3 performance assessments. A prototype C^3 exercise was developed and reliability coefficients greater than .50 were demonstrated for six of nine small unit C^3 task criterion-oriented composite measures. Moreover, estimates suggested that by doubling the length of the prototype exercise, reliability coefficients could exceed .70 for all composite measures.

This research also outlined numerous research requirements necessary for further evaluating SIMNET-D small unit C^3 measurement issues, including the evaluation of the relationship between soldier background and SIMNET-D based C^3 performance, the evaluation of additional small unit exercise psychometric properties, including test-retest reliability and construct validity, and an evaluation of alternative SIMNET-D C^3 measurement approaches.

The final set of SIMNET-D Armor small unit C^3 exercises resulting from this and future research could serve several different purposes, including serving as simulation-based work samples for job performance measurement and for training needs assessment and diagnosis, as well as providing instruments for generating criterion measures for multivariate simulation-based experiments of advanced C^3 concepts.

References

Archer, M. A., Fineberg, M. L., & Carter, C. F. (1984). Command group behavior, Objective 1, Final Report: Identification and analysis of battalion command group behavior. McLean, VA: Science Applications International Corporation.

Baker, H. F., & Cook, J. G. (1962a). User manual for the Miniature Armor Battlefield (MAB) (revised) (Human Resources Research Office Technical Report). Alexandria, VA: The George Washington University.

Baker, H. F., & Cook, J. G. (1962b). User manual for the Armor Combat Decisions Game (CDG) (Human Resources Research Office Technical Report). Alexandria, VA: The George Washington University.

Baker, H. F., & Cook, J. G. (1963). The development and evaluation of the tank platoon combat readiness check (Human Resources Research Office Technical Report). Alexandria, VA: The George Washington University.

Barron, R. C., Lutz, W. G., Degelo, G. J., Havens, J. W., Talley, J. W., Smith, J. R., & Walters, R. F. (1976). Degradation of tank effectiveness (TRADOC Test Report 325). Department of the Army. Fort Hood, TX: Training and Doctrine Command Combined Arms Test Activity.

Berry, F. C. (1978). Tactical C^3: Bringing order out of chaos. Armed Forces Journal International, 15(8), 13-15.

Bolt, Beranek, & Newman, Inc. (1986). Developmental SIMNET data handbook. [DRAFT]. Cambridge, MA: BBN Laboratories.

Chung, J. W., Dickens, A. R., O'Toole, B. P., & Chiang, C. J. (1988). SIMNET M1 Abrams main battle tank simulation: Software description and documentation [Revision 1] (BBN Report 6623). Cambridge, MA: BBN Systems and Technologies Corporation.

Cooper, M. A., Shiflett, S., Korotkin, A. L., & Fleishman, E. A. (1984). Command and control teams: Techniques for assessing team performance. Bethesda, MD: Advanced Research Resources Organization.

Crumley, L.M. (1988). Review of research and methodologies relevant to Army command and control performance requirements. (ARI Technical Report 825). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A211 247)

Cyrus, M. L. (1987). SIMNET computer image generation system. Bellevue, WA: BBN Delta Graphics, Inc.

Defense Systems, Inc. (1984). The headquarters effectiveness assessment tool: User's manual. McLean, VA.

Department of the Army. (1986). Field Manual (FM) 100-5: Operations. Fort Knox, KY: U.S. Army Armor School.

Directorate of Combat Developments. (1988). Abrams Tank Block II Product Improvement Package: SIMNET evaluation. Fort Knox, KY: U.S. Army Armor Center.

Directorate of Training and Doctrine. (1987). Master task list. Fort Knox, KY: U.S. Army Armor Center.

Du Bois, R. S. (in preparation). Simulation based assessment of automated command, control, and communication capabilities on Armor crews and platoons: The Intervehicular Information System (Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Du Bois, R. S., & Smith, P. G. (1989). A simulation-based evaluation of a Position Navigation system for Armor: Soldier performance, training, and functional requirements (ARI Technical Report 834). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A210 696)

Du Bois, R. S. (1987). A psychometric evaluation of a tank gunnery testing device: The unit-conduct of fire trainer. Unpublished master's thesis, Western Kentucky University.

Garlinger, D. K., & Fallesen, J. J. (1988). Review of command group training measurement methods (ARI Technical Report 798). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A201 753)

Ghiselli, E. E., Zedeck, S., & Campbell, J. P. (1981). Measurement theory for the behavioral sciences. San Francisco, CA: W. H. Freeman and Company.

Graham, S. E. (1987). Training command, control, and communication skills on SIMCAT (ARI Research Report 1449). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A190 584)

Gound, D., & Schwab, J. (1988). Concept evaluation program of Simulation Networking (SIMNET) (AFB Technical Report 86-CEP-0345). Department of the Army. Fort Knox, KY: Armor and Engineer Board.

Jones, D. R., Wylie, P. B., Henriksen, K. F., Shriver, E. L., & Hannaman, D. L. (1980). Battle simulation board games: An analysis in terms of design characteristics and leader skills (ARI Research Note 80-2). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A082 930)

Kaplan, I.T. (1987). Lessons learned in research on command group training. (ARI Technical Report 751). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A186 996)

Kaplan, I. T. (1980). Information flow in battalion command groups (ARI Technical Report 499). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A109 469)

Kaplan, I. T., & Barber, H. F. (1979). Training battalion command groups in simulated combat: Identification and measurement of critical performances (ARI Technical Paper 376). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A075 414)

Kristiansen, D. M. (1987). Simulation in combined arms training: A platoon-level battlefield simulation (ARI Research Report 1439). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A182 172)

Lampton, D. R. (in preparation). Evaluation of a low fidelity battle simulation for training and evaluating C^3 skills for the Armor platoon leader (ARI Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Levis, A. H., & Athans, M. (1987). The quest for a C^3 theory: Dreams and realities. Paper presented at the 1987 Symposium on C^3 Research. Cambridge, MA.

Lewman, T. J. (1987). Mission critical tasks at the National Training Center (Research Product BDM/ARI-TR-0017-87). Monterey, CA: The BDM Corporation.

Metlay, W., Liebling, D., Silverstein, N., Halatyn, A., Zimberg, A., and Richter, F. (1985). Methodology for the assessment of the command group planning process. Hofstra University. Department of Psychology, Applied Research and Evaluation Doctoral Program, Research Report Series.

Miller, D. C., & Chung, J. W. (1987). SIMNET-D capabilities and overview. Cambridge, MA: BBN Laboratories, Inc.

O'Brien, R. E., & Drucker, E. H. (1981). Mission-based analyses of Armor training requirements [Volumes 1-6] (HumRRO Report MDA903-80-C-0229). Alexandria, VA. Human Resources Research Organization.

Olmstead, J. A., Baranick, M. J., & Elder, B. L. (1978a). Training for brigade command groups: Training objectives and strategies (Technical Report TM-6008/001/00). Santa Monica, CA: Systems Development Corporation.

Olmstead, J. A., Baranick, M. J., & Elder, B. L. (1978b). A training feedback system for brigade command groups (ARI Technical Report 78-A19). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A056 342)

Olmstead, J. A., Baranick, M. J., & Elder, B. L. (1978c). Research on training for brigade command groups: Factors contributing to unit combat readiness (Technical Report 73-19). Alexandria, VA: Human Resources Research Organization.

Olmstead, J. A., Christensen, H. E., & Lackey, L. L. (1973). Components of organizational competence: Test of a conceptual framework (Technical Report 73-19). Alexandria, VA: Human Resources Research Organization.

Olmstead, J. A., Christensen, H. E., Salter, J. A., & Lackey, L. L. (1975). Effects of work contexts in public welfare financial assistance agencies (Technical Report 75-7). Alexandria, VA: Human Resources Research Organization.

Pate, D. W., Lewis, B. D., & Wolf, G. F. (1988). Innovative test of the simulator network (SIMNET) system (TRADOC Technical Report 88-FD-0158). Fort Bliss, TX: U.S. Army Air Defense Artillery Board.

Perceptronics, Incorporated. (1986). SIMNET company/platoon user's manual. Woodland Hills, CA: Training and Simulation Division.

Pope, A. R. (1988). The SIMNET network and protocols (BBN Report 6787). Cambridge, MA: BBN Laboratories, Inc.

Pope, A. R., Langevin, T., Lovero, L., & Tosswill, A. R. (1988). The SIMNET Management, Command, and Control System (BBN Report 6473 [Revised]). Cambridge, MA: BBN Systems and Technologies Corporation.

Quinkert, K. A. (in preparation). An evaluation of the Commander's Independent Thermal Viewer using SIMNET-D (ARI Technical Report). Fort Knox, KY: U.S. Army Research Institute for the Behavioral and Social Sciences.

Robins, J. E., Buffardi, L., & Ryan, T. G. (1974). Research on tactical decision making: Application of a decision prediction concept in a SIMTOS environment (ARI Technical Report 246). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD 780 812)

Schwab, J. R. (1987). Innovative test of Simulation Networking-Developmental (SIMNET-D) (Technical Report 87-0000778). Department of the Army. Fort Knox, KY: Armor and Engineer Board.

Solick, R. E., & Lussier, J. W. (1988). Design of battle simulations for command and control and staff training (ARI Technical Report 788). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A196 655)

Sulzen, R. H. (1986). Annotated bibliography of tactical engagement simulation 1966-1984 (ARI Technical Report 725). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 671).

Taylor, E.N. (1983). A review of literature relevant to unaided tactical decision making (ARI Research Note 83-35). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A136 549)

Thomas, G. S., Barber, H. F., & Kaplan, I. T. (1984). The impact of CATTS system characteristics on selected measures of battalion command group performance (ARI Technical Report 609). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A140 231)

U.S. Army. (1981). ARTEP 71-2: Army training and evaluation program for mechanized infantry/tank task force. Washington, DC: Headquarters, Department of the Army.

U.S. Army Armor Center. (1988). ARTEP 17-237-10 MTP: Tank platoon. Fort Knox, KY: U.S. Army Armor School.

U.S. Army Armor School. (1987). CMF 19/SC 12 Master Task List. Fort Knox, KY: Directorate of Training and Doctrine.

U.S. Army Science Board. (1987). C^3I requirements for AirLand battle. Final report of the 1986 summer study. Washington, DC: Department of the Army.

Wheaton, G. R., Allen, T. W., Johnson, III, E., Drucker, E. H., Ford, P., & Campbell, R. C. (1980). Methods of evaluating tank platoon battle run performance (ARI Technical Report 457). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A096 369)

Wheaton, G. R., & Boycan, G. G. (1982). Methods of evaluating tank platoon battle run performance: A perspective (ARI Technical Report 574). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A135 486)

Witus, G., Patton, J., Cherry, P., and Blake, A. (1985). Automated assistance for fire support command, control, communications, and intelligence (C^3I). (ARI Research Product 85-1). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A169 667)

Appendix A

Armor Small Unit C^3 Exercise Administration Materials

Week # ______ Date ____________ PLANTIME: ________
Crew # ________ PL PS PLW PSW

IVIS EXPERIMENT

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

____ 1. Start Time: ____________

____ 2. Shell Report Sent? Y N

____________ Where? ____________ Y N
ES856652

TIME: ____ seconds (from rounds fall
to report transmission complete)

____ 3. Own Location Report Sent? Y N

____________ Where? ____________ Y N
ES842653 Lost (>1 km)? Y N
Grid Given? Y N

TIME: ____ seconds (from request to grid report transmission)

____ 4. Contact Report Sent? Y N

3 T72s What? ____________ Y N
ES83006560 Where? ____________ Y N
ES83006565
ES83006570

____ 5. Spot Report Sent? Y N

3 #? ____________ Y N
T72s What? ____________ Y N
ES83006560 Where? ____________ Y N
ES83006565
ES83006570

TIME: ____ seconds (from all targets destroyed to spot report transmission)

____ 6. Shell Report Sent? Y N

____________ Where? ____________ Y N
ES820666

TIME: ____ seconds (from rounds fall to grid
report transmission)

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

______	7.	Contact Report	Sent?	Y	N		
		1 BMP	What? ________________			Y	N
		ES80756550	Where? ________________			Y	N
______	8.	Spot Report	Sent?	Y	N		
		1 BMP	#? ________________		Y	N	
		ES80706550	What? ________________			Y	N
			Where? ________________			Y	N

TIME: ____ seconds (from all targets destroyed to spot report transmission)

______	9.	CP1 (Arrival)	Lost (>1 km)?	Y	N		
		________________	Where? ________________			Y	N
		ES804647	Stall time: ________________				

______ 10. Receive FRAGO

Time Given: ________________
Time Moved Out: ______________

TIME: ____ seconds (from frago given to crew moves out)

FRAGO SCRIPT:

if Baseline: Red 1. This is Black 6. Frago Follows. Over.
NBC Area reported. Coordinates of the corners of the
contaminated area follow:
(Break)
ES8066, ES7966,ES7964,ES8064
(Break)
This is a two grid square area.
How copy? Over.
Bypass this area to the North, and
move to ES783650 (CP 2). Acknowledge.
Over.
Black 6. Out.

if IVIS: Red 1. This is Black 6. Graphics sent
over IVIS display. Acknowledge receipt.
Over.

Two grid square NBC area reported. Bypass
North along Route Frago and move to
ES783650 (CP 2). Acknowledge. Over.

Black 6. Out.

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

_____ 11. Own Location Report   Sent?   Y   N

ES802658   Where? _______________
Lost (>1 km)?   Y   N
Grid Given?   Y   N

TIME: ____ seconds (from request to grid report transmission)

_____ 12. Shell Report   Sent?   Y   N

ES788652   Where? _______________   Y   N

TIME: ____ seconds (from rounds fall to report transmission)

_____ 13. Bypass NBC Area

Bypassed Successfully?   Y   N
Bypassed North?   Y   N

DRAW PICTURE SHOWING CREW'S PATH FOR NBC BYPASS TASK?-->

_____ 14. CP2 (Arrival)?   Lost (>1 km)?   Y   N

ES783650   Where? _______________   Y   N

_____ 15. Contact Report   Sent?   Y   N

2 BMPs   What? _______________   Y   N
ES77006460   Where? _______________   Y   N
ES77056460

_____ 16. Spot Report   Sent?   Y   N

2   #? _______________   Y   N
BMPs   What? _______________   Y   N
ES77006460   Where? _______________   Y   N
ES77056460

TIME: ____ seconds (from all targets destroyed to spot report transmission)

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

_____ 17. CP3 (Arrival)? Lost (>1 km)? Y N

_______________ Where? _______________ Y N
ES771646

____

REMINDER ---- Use no direct fire during this segment. Use artillery for all fires. Adjust until you achieve target effect (all targets destroyed) or until you fail to adjust on target 5 times.

_____ 18. Shell Report Sent? Y N

_______________ Where? _______________ Y N
ES778665

TIME: _____ seconds (from rounds fall to grid report transmission)

_____ 19. CFF w/ Adjust Initial CFF Sent? Y N

4 T72s What? _______________ Y N
ES77806820 Where? _______________ Y N
ES77806825
ES77756820
ES77756825

____ # Dead _____

TIME: _____ seconds (from target identification to target effect_ or failure to achieve target effect)

Adjust 1: Y N _______________ # Dead _____

Adjust 2: Y N _______________ # Dead _____

Adjust 3: Y N _______________ # Dead _____

Adjust 4: Y N _______________ # Dead _____

Adjust 5: Y N _______________ # Dead _____

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

______ 20. CFF w/ Adjust   Initial CFF Sent?   Y   N

4 T72s   What? ______________   Y   N
ES77306960   Where? ______________   Y   N
ES77306965
ES77256960
ES77256965

____ # Dead_____

TIME: ____ seconds (from target identification to target effect_ or failure to achieve target effect)

Adjust 1:   Y   N   ______________ # Dead_____

Adjust 2:   Y   N   ______________ # Dead_____

Adjust 3:   Y   N   ______________ # Dead_____

Adjust 4:   Y   N   ______________ # Dead_____

Adjust 5:   Y   N   ______________ # Dead_____

______ 21. Own Location Report   Sent?   Y   N

_______________   Where? _______________
ES774699   Lost (>1 km)?   Y   N
Grid Given?   Y   N

TIME: ____ seconds (from request to grid report transmission)

______ 22. Shell Report   Sent?   Y   N

_______________   Where? _______________   Y   N
ES762714

TIME: ____ seconds (from rounds fall to report transmission)

______ 23. CP4 (Arrival)?   Lost (>1 km)?   Y   N

_______________   Where? _______________   Y   N
ES766722

REMINDER ---- You are now free to use your main gun.

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

____ 24. Shell Report Sent? Y N

ES775715 ________ Where? ________ Y N

TIME: ____ seconds (from rounds fall to grid report transmission)

____ 25. Contact Report Sent Y N

1 T72 What? ________ Y N

ES79307200 Where? ________ Y N

____

____ 26. Spot Report Sent? Y N

1 T72 #? ________ Y N

ES79307200 What? ________ Y N

Where? ________ Y N

TIME: ____ seconds (from all targets destroyed to spot report transmission)

____ 27. CP5 (Arrival)? Lost (>1 km)? Y N

ES796722 ________ Where? ________ Y N

____

____ 28. Bypass minefield. Successful? Y N

____

DRAW MINEFIELD AND SHOW CREW'S PATH IN BYPASSING IT: --->

____ 29. Own Location Report Sent? Y N

ES796737 ________ Where? ________ Y N

Lost (>1 km)? Y N

Grid Given? Y N

TIME: ____ seconds (from request to grid report transmission)

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

_____ 30. Shell Report Sent? Y N

_____________ Where? _____________ Y N
ES807737

TIME: _____ seconds (from rounds fall to grid report transmission)

_____ 31. CP6 (Arrival)? Lost (>1 km)? Y N

_____________ Where? _____________ Y N
ES814736

_____ 32. Own Location Report Sent? Y N

_____________ Where? _____________ Y N
ES814736 Lost (>1 km)? Y N
Grid Given? Y N

TIME: _____ seconds (from request to grid report transmission)

_____ 33. Receive FRAGO

Time Given: _____________
Time Moved Out: _____________

TIME: _____ seconds (from FRAGO given to crew moved out)

FRAGO SCRIPT:

if baseline: Red 1. This is Black 6.
Prepare for change of mission. Over.

if IVIS: Red 1. This is Black 6.
Prepare for change of mission.
Graphics sent over IVIS. Acknowledge receipt. Over.

Move to CP7 at ES835720 and set up hasty defensive positions. Orient your gun tube so you can see the battlefield between 2 TRPs - grids follow: TRP 1 at ES832739 and TRP 2 at ES843726. After selecting your best firing position on the hilltop where CP7 is located, observe for enemy activity and report. Use direct fire on moving targets. Use indirect fire on stationary targets. How copy? Over.

Black 6. Out.

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

_____ 34. Contact Report Sent? Y N

2 PCs	What? ____________		Y	N
ES82907260	Where? ____________		Y	N
ES82907265				

_____ 35. Spot Report Sent? Y N

2	#? ____________		Y	N
PC	What? ____________		Y	N
ES82907260	Where? ____________		Y	N
ES82907265				

TIME: ____ seconds (from all targets destroyed to spot report transmission)

_____ 36. Shell Report Sent? Y N

____________ Where? ____________ Y N
ES835731

TIME: ____ seconds (from rounds fall to grid report transmission)

_____ 37. CP7 (Arrival)? Lost (>1 km)? Y N

____________ Where? ____________ Y N
ES835720

____

DID THE CREW CORRECTLY EXECUTE FRAGO? Y N

Orientation Correct? Y N
BP Location Correct? Y N

____

GRAPHICALLY SHOW ORIENTATION AND LOCATION RELATIVE TO BP LOCATION SPECIFIED IN FRAGO AND TRPs?

ARMOR SMALL UNIT COMMANDER C^3 EXERCISE

FLAG

______ 38. Contact Report Sent? Y N
4 T72s Moving What? ______________ Y N
ES849736 Where? ______________ Y N
to
ES833737

______ 39. Spot Report Sent? Y N

4 #?______________ Y N
T72 Moving What? ______________ Y N
ES849736 Where? ______________ Y
N
to
ES833737

TIME: ____ seconds (from all targets destroyed to spot report transmission)

______ 40. CFF w/ Adjust Initial CFF Sent? Y N

4 T72s What? ______________ Y N
ES Where? ______________ Y N

____# Dead_____

TIME: ____ seconds (from target identification to target effect_
or failure to achieve target effect)

Adjust 1: Y N ______________# Dead_____

Adjust 2: Y N ______________# Dead_____

Adjust 3: Y N ______________# Dead_____

Adjust 4: Y N ______________# Dead_____

Adjust 5: Y N ______________# Dead_____

______ 41. End Time: ________________________

ARMOR SMALL UNIT COMMANDER C3 EXERCISE

TARGET AND OPFOR PLACEMENT

MCC filename: cte

Gunnery Target List:

Target Name	Target Type	Location	Heading
t1a	T72	ES83006560	1800
t1b	T72	ES83006565	1800
t1c	T72	ES83006570	1800
t2	BMP	ES80756520	1600
t3a	BMP	ES77006460	1600
t3b	BMP	ES77056460	1600
t4a	T72	ES77806820	3200
t4b	T72	ES77806825	3200
t4c	T72	ES77756820	3200
t4d	T72	ES77756825	3200
t5a	T72	ES77306960	2000
t5b	T72	ES77306965	2000
t5c	T72	ES77256960	2000
t5d	T72	ES77256965	2000
t6a	T72	ES79307200	4500
t7a	BMP	ES82907260	5600
t7b	BMP	ES82907265	5600

OPFOR List:

Type	Location	Heading	Move To
Arty	ES856652	N/A	N/A
Arty	ES820666	N/A	N/A
Arty	ES842915	N/A	N/A
Arty	ES778665	N/A	N/A
Arty	ES762714	N/A	N/A
Arty	ES775715	N/A	N/A
Arty	ES807737	N/A	N/A
Arty	ES835731	N/A	N/A
T72 (PLT-4)	ES849736	270	ES833737

Appendix B

Criterion-Oriented C^3 Composite Measures: Definitions and Scoring Strategy

Table B-1

Criterion-oriented composite and supporting C^3 measures: Definitions and scoring strategy

Measure	Definition/Scoring Strategy Summary
FRAGO	Total "react to change of mission (FRAGO)" score (24 points possible--12 points/FRAGO)
plan	Time in seconds to plan FRAGO (per FRAGO--2 points if > 1 SD below M, 1 point if < 1 SD from M)
execute	Time in seconds to execute FRAGO (per FRAGO--4 points if within march time, 2 points if within twice march time, 1 point otherwise)
success	FRAGO execution success (per FRAGO--6 points if successful, otherwise no points <u>overall</u>).
BYPASS	Total "bypass obstacles" score (20 points possible --10 points/bypass)
time	Time in seconds to execute bypass task (per bypass --4 points if within march time, 2 points if within twice march time, 1 point otherwise)
success	Bypass task execution success (per bypass--6 points if successful, no points <u>overall</u> otherwise)
LOCREP	Total "report own location" score (32 points possible--8 points/report)
time	Time in seconds from report prompt to report transmission (per report--4 points if <= 30sec, 3 points if <= 90sec, 1 point if <= 300sec)
error	Deviation in meters between actual and reported grid location (per report--4 points if <= 200m, 3 points if <= 500m, 1 point if <= 1000m)
CPREP	Total "report graphic control points" score (28 points possible--4 points/report)
error	Deviation in meters between actual and reported grid location (per report--4 points if <= 200m, 3 points if <= 500m, 1 point if <= 1000m)

Table B-1 (Continued)

Criterion-oriented composite and supporting C^3 measures: Definitions and scoring strategy

Measure	Definition/Scoring Strategy Summary
CONTACT	Total "report enemy contact (CONTACT report)" score (30 points possible overall--5 points/report)
sent	Report sent (3 points per report sent)
what	Accuracy of "what" (1 point per "what" correct)
where	Accuracy of "where" (1 point per "where" correct)
SPOTREP	Total "report battlefield activity (SPOT report)" score (72 points possible overall--12 points/report)
sent	Reports sent (2 points per report sent)
what	Accuracy of "what" (1 point per "what" correct)
count	Accuracy of "count" (1 point per "count" correct)
time	Time in seconds from engagement end to report sent (per report--4 points if <= 30sec, 3 points if <= 90sec, 1 point if <= 300sec)
error	Deviation in meters between actual and reported grid location (per report--4 points if <= 200m, 3 points if <= 500m, 1 point if <= 1000m)
SHELLREP	Total "report indirect fire activity (SHELL report)" score (80 points possible--10 points/report)
sent	Reports sent (2 points per report sent)
time	Time in seconds from initial shell impact to report transmission (per report--4 points if <= 30sec, 3 points if <= 90sec, 1 point if <= 300sec)
error	Deviation in meters between actual and reported impact grid location (per report--4 points if <= 200m, 3 points if <= 500m, 1 point if <= 1000m)

Table B-1 (Continued)

Criterion-oriented composite and composite C^3 measures: Definitions and scoring strategy

Measure	Definition/Scoring Strategy Summary
CFF	Total "issue calls for fire (CFFs) score (60 points possible--20 points/CFF)
time	Time in seconds from target acquisition to complete CFF task (reach target effect* or use 6 CFFs without effect) (per CFF--4 points if <= 90sec, 3 points if <= 300sec, 1 point if <= 600sec)
adjs	Number of adjustments used to reach target effect or use 6 fire missions without effect) (per CFF--4 points if effect with 1 CFF, 3 points if within 3 CFFs, 1 point if within 6 CFFs)
error	Deviation in meters between initial CFF reported and actual target grid location (per CFF--4 points if <=200m, 3 points if <= 500m, 1 point if <= 1000m)
success	CFF success (per CFF--8 points if effect, 1 point <u>overall</u> if no effect, 0 points <u>overall</u> if kill self)
BP	Total score for "select and occupy battle positions (BPs)" task (12 points possible)
plan	Time in seconds to plan BP task (2 points if > 1 SD below M, 1 point if <= 1 SD from M)
exec	Time in seconds to execute BP task (4 points if <= march time, 2 point if <= twice march time, 1 point otherwise)
orient	Accuracy of tank orientation on BP (2 points if main gun oriented within assigned sector)
error	Deviation in meters between reported and actual BP location (4 points if >= 200m, 2 points if <= 500m, 0 points <u>overall</u> if > 500m)

* Target effect occurs when indirect fire impacts within 200 meters of actual target grid location.