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COMBAT VEHICLE COMMAND & CONTROL (93) TECHNICAL REPORT (FINAL)

Evaluation Of The Combat Vehicle Command And Control System: Operational Effectiveness Of An Armor Battalion

Submitted By:
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Simulation, Training & Instrumentation Command
Orlando, Fl

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Dr. Kathleen A. Quinkert
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SUBJECT: Transmittal of Final CVCC Battalion Evaluation Operational Effectiveness Technical Report

Dear Dr. Quinkert:

BDM Federal is pleased to deliver the final technical report entitled "Evaluation of the Combat Vehicle Command and Control System: Operational Effectiveness of an Armor Battalion." This report is the result of work performed under Combat Vehicle Command and Control Delivery Order 0003 (Advanced Distributed Simulation Technology, Contract No. N61339-91-D-0001/0025).

This final revision of the technical report is based on comments received on 12 January 1994, which resulted from the ARI peer review process. Comments were received from Mr. Kraemer, Ms. Salter, and members of the Future Battlefield Conditions (FBC) Team. The following paragraphs summarize the actions taken to address the reviewers' written comments.

1. Ms. Salter's comments: We have incorporated all of Ms. Salter's suggestions, implementing her editorial corrections fully.

2. Mr. Kraemer's comments: We have incorporated nearly all of the general suggestions in Mr. Kraemer's memorandum dated 4 January 1994. In addition, we have made the specific editorial corrections indicated by Mr. Kraemer in his annotated copy of the draft final report.

a. All margins have been verified or corrected.

b. All acronyms have been defined the first time they are used in the text.

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c. All abbreviations used in tables and figures have been defined when first used, and the list of acronyms has been expanded to include abbreviations. However, because of occasional formatting problems, some abbreviations within tables and figures have not been spelled out or footnoted. These abbreviations should be familiar to the reader and can be double-checked in the List of Acronyms and Abbreviations.

d. Figure 1, which was missing from the draft final version, has been incorporated.

e. Each section of the report has been continued in run-on fashion, instead of beginning on a new page.

f. Where appropriate, tables in the appendixes have been modified to flow in run-on fashion.

g. Figure 2 has been reduced in size and positioned in portrait orientation.

h. Tables spanning more than a single page have been reformatted in accordance with American Psychological Association (APA) guidelines.

i. The specification of the probability level required for statistical significance has been added to the Data Reduction and Analysis subsection of the Method section.

j. The in-text presentation of the t-test statistic has been reformatted to conform with APA standards.

k. Regarding the proper usage of n versus N, we have followed the APA guidelines as closely as possible, given the multi-echelon and two-group structure of the database.

l. Issues and hypotheses have been numbered in the Results and Discussion section.

m. Numeric means have been removed from each bar graph figure, and the figure legend has been repositioned to the top right hand corner.

n. References cited in the text have been verified against the Reference list. All references have been checked to ensure that they are formatted as specified in ARI Reg. 70-3 and the APA manual. In addition, Department of the Army publications in the Reference list have been reformatted in accordance with guidance received from ARI-Fort Knox on 25 January 1994. References to Working Papers have been changed to Research Notes.

o. The accuracy of the Table of Contents has been verified, including page numbers and titles of tables and figures.

p. In the subsection describing the limitations of the evaluation, wording about minimal impact on results has been modified to indicate that specific impacts are discussed in the Results and Discussion section.

3. FBC Team comments: We have incorporated all but one of the FBC Team's specific suggestions contained in Dr. Quinkert's letter dated 12 January 1994. In addition, a few changes have been made in response to discussions held on 24 January 1994.

a. All of the minor stylistic and editorial modifications have been incorporated as suggested.

b. Ordinate labels of bar chart figures have been modified as requested. All axis labels have been made completely upper case, as agreed in the 24 January discussions.

c. Table 7 has been modified as recommended, including supplemental input received in the 24 January discussions.

d. Interpretive and explanatory clarifications have been incorporated in the Results and Discussion section, as suggested in a number of comments. The discussion of the kills per hit data has been modified as suggested.

e. Statements pertaining to the Lickteig et al. (1992) paper have been modified as requested.

f. Alignment of columns in Tables 16 and 17 has been adjusted.

g. Explanation of Situational Assessment (SA) data has been modified as suggested. However, as agreed in follow-on discussions, a nonparametric analysis of SA data has not been performed and a composite confidence rating has not been added.

h. A reference to an ARI simulation training tools report has been added.

i. Table 24 has been revised to eliminate wordiness.

j. Use of the acronym "DIS" has been eliminated.

k. A paragraph has been added to the Acknowledgments section explaining the allocation of detailed methodological materials across the family of reports from the battalion evaluation.

Included in this final delivery are an original copy, three Xerox copies, and electronic files on floppy diskettes. All text files are in WordPerfect 5.1 format on a labeled diskette. Bar charts created with GEM Graph and Gem Draw exist on a second labeled disk. Figures created with Macintosh applications are on a third labeled disk. No electronic copies of Figure 3 (Vehicle commander's station) and Figure 7 (Diagram of voice radio networks) are available.

The BDM Federal Team appreciates the peer review comments of Mr. Kraemer, Ms. Salter, and FBC Team members, as well as earlier review comments by the FBC Team. The ARI comments and input have greatly enhanced the quality of this final report.

Please direct questions concerning this report to myself.

BDM FEDERAL, INC.

Bruce C. Leibrecht

Bruce C. Leibrecht, Ph.D.
Manager, Human Factors and Simulation

Enclosure: as stated

CF: Dr. Doherty
Gen Heiden
Mr. Uliano

Technical Report XXX

Evaluation of the Combat Vehicle Command and Control System: Operational Effectiveness of an Armor Battalion

Bruce C. Leibrecht, Glen A. Meade, Jeffrey H. Schmidt,
William J. Doherty

BDM Federal, Inc.

Carl W. Lickteig

ARI Fort Knox Field Unit

January 1994

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13. ABSTRACT *(Maximum 200 words)*

In support of Army initiatives to meet future command, control, and communications (C3) challenges, the Combat Vehicle Command and Control (CVCC) research and development program has evaluated automated C3 technology, using soldier-in-the-loop simulation. The CVCC system includes a digital Position Navigation system, a digital Command and Control Display, the Commander's Independent Thermal Viewer, and digital workstations in the Tactical Operations Center. The evaluation reported here compared the CVCC system with Baseline (conventional) capabilities in terms of a battalion's operational effectiveness. Using M1 tank simulators in the Mounted Warfare Test Bed at Fort Knox, Kentucky, unit commanders and executive officers with crews were integrated with semiautomated vehicles under their control to form complete tank battalions. Each battalion completed three days of training, followed by a simulated combat test scenario. One of a series, this report documents improvements in the performance of unit and vehicle commanders by key Battlefield Operating Systems, along with lessons learned. Companion reports address training issues, soldier-machine interface findings, and performance from a tactical perspective. The collective findings help determine combat doctrine, materiel requirements, and training requirements for future automated C3 systems for mounted warfare.

14. SUBJECT TERMS

CVCC	Command and control	C3 training requirements
CITV	Operational effectiveness	Soldier-in-the-loop
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Training Simulation

FOREWORD

The Fort Knox Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) investigates Training Requirements for the Future Integrated Battlefield, using soldier-in-the-loop simulation. Research under this program is supported by Memoranda of Understanding (MOU) with (a) the U.S. Army Armor Center and Fort Knox, Subject: Research in Future Battlefield Conditions, 12 April 1989, and (b) the U.S. Army Tank-Automotive Command (TACOM), Subject: Combat Vehicle Command and Control (CVCC) Program, 22 March 1989.

The CVCC research program investigates advanced digital and thermal technologies to enhance mounted forces' command, control, and communications (C3) capabilities. The CVCC system integrates a variety of digital features--report preparation and management, tactical map and overlays, transmission of reports and overlays--together with positioning/navigation functions and independent thermal viewing for unit and vehicle commanders. This system provides an excellent paradigm for investigating training requirements of future automated technology for mounted combat units. The research reported here used distributed interactive simulation (DIS) to conduct a battalion-level evaluation of the CVCC capabilities.

As one of three reports resulting from the evaluation, this report documents the CVCC system's impact on the operational effectiveness of an armor battalion. Companion reports address training issues, soldier-machine interface questions, and tactical performance. The findings presented in this report support Army developers in determining user requirements, specifying training requirements, and assessing operational effectiveness of automated C3 systems for mounted forces. In addition, the training and simulation techniques developed for this effort are of use to other Army training and testing agencies.

Information resulting from this research has been briefed to the following personnel: Commanding General, U.S. Army Training and Doctrine Command; Commanding General, U.S. Army Armor Center and School; Deputy Commanding General for Combat Developments, U.S. Army Combined Arms Command; Deputy Chief of Staff for Training, U.S. Army Training and Doctrine Command; Chief of Staff, U.S. Army Armor School; Director, Directorate of Combat Developments, U.S. Army Armor School; and Director, Mounted Warfighting Battlespace Lab.

EDGAR M. JOHNSON
Director

ACKNOWLEDGMENTS

The following members of ARI's Fort Knox Field Unit provided invaluable input to this evaluation: Dr. Kathleen Quinkert, Leader of the Future Battlefield Conditions (FBC) Team; Mr. Gary Elliott, FBC Team member; and MAJ James Whitehead, the Field Unit's Research and Development Coordinator. Mr. Ronald Kraemer, of the ARI-Fort Knox Field Unit, and Ms. Margaret Salter, of ARI's Fort Benning Field Unit, thoroughly reviewed the final draft of the report.

In addition to the authors, the BDM Federal, Inc. research staff included Dr. Nancy Atwood, Dr. Beverly Winsch, Dr. Laura Ford, Ms. Alicia Sawyer, Mr. Paul Smith, Ms. Frances Ainslie, MG (Ret.) Charles Heiden, Mr. Robert Sever, Mr. Owen Pitney, and Mr. Ryszard Lozicki. Research Assistants supporting the project included Mr. Silver Campbell, Ms. Ann Cash, Mr. Kenneth Fergus, Mr. Brian Gary, Mr. Gary Gulbranson, Mr. Michael Gustafson, Mr. John Jawor, Mr. David Johnson, Mr. William Myers, Ms. Khristina Orbock, Mr. Robert Pollock, Mr. Ronald Reyna, Mr. Charles Sawyer, Mr. Daniel Schultz, Mr. Timothy Voss, Mr. Harold Wager, and Mr. Charles West.

Personnel of the on-site support contractor, Loral Training and Technical Services, supported simulation equipment and data collection/analysis. These included Mr. Jimmy Adams, Mr. Frederick Brady, Mr. David Clippinger, Mr. Michael Krages, Mr. Paul Monday, Mr. Thomas Radgowski, Mr. Rob Smith, and Ms. Diane York.

To present the large, multifaceted set of data resulting from the evaluation, a family of three reports has been organized. Each report focuses on a different aspect of the data--operational effectiveness, tactical performance, and training and user interface issues. To avoid unnecessary redundancy across these reports, the detailed descriptions of specific materials and procedures generally have been allocated to one or another of the reports. Thus, by design the reports are mutually supporting, and the reader will be referred frequently to companion reports for methodological detail.

EVALUATION OF THE COMBAT VEHICLE COMMAND AND CONTROL SYSTEM: OPERATIONAL EFFECTIVENESS OF AN ARMOR BATTALION

EXECUTIVE SUMMARY

Research Requirement:

The speed, intensity, and dispersion of the future battlefield will severely challenge combat units' command, control, and communications (C3) capabilities. Overcoming future C3 challenges has been the focus of recent U.S. Army initiatives, including automation of C3 functions, digitization of the battlefield, and horizontal integration of combat activities. Research and development efforts supporting these initiatives include the Combat Vehicle Command and Control (CVCC) program, which integrates advanced digital and thermal technologies. Using simulation-based, soldier-in-the-loop methodology, previous CVCC research evaluated performance of tank crews, platoons, companies, and the battalion Tactical Operations Center (TOC). The need for data on performance of unit commanders and executive officers led to the battalion-level evaluation.

Procedure:

The evaluation compared tank battalion performance under two conditions: (a) Baseline, using conventional C3 capabilities (voice radio and paper map-based techniques), and (b) CVCC, modeling Baseline tools plus a digital Position Navigation (POSNAV) system, a digital Command and Control Display (CCD), the Commander's Independent Thermal Viewer (CITV), and digital TOC workstations. During each test week, a tank battalion was formed by integrating eight qualified armor crews (battalion commander, battalion operations officer, three company commanders, and three company executive officers, each working with a gunner and driver), a limited TOC staff, and semiautomated elements under unit commanders' control. Each of the eight crews operated an autoloading tank simulator in the Mounted Warfare Test Bed (MWTB) at Fort Knox, Kentucky. Six Baseline and six CVCC-equipped battalions each completed three days of training, followed by a simulated combat test scenario. The same set of training and test scenarios was completed by all battalions, with only the available C3 equipment differentiating the two conditions.

Findings:

The results of the evaluation revealed that the CVCC capabilities significantly enhanced battalion performance across a broad range of measures. The CVCC system's digital communications capabilities enabled more rapid and thorough dissemination of orders and INTELLIGENCE reports, while reducing substantially the volume of voice radio traffic. CVCC-equipped

unit and vehicle commanders generated more accurate CONTACT, CFF (Call for Fire), and SPOT reports, and the volume of fully usable information contained in these reports increased considerably.

The consistency and completeness of digital transmissions constituted a major advantage, with clarity of orders benefitting greatly. The CVCC system's advantages in acquiring information, especially precise location information, produced more accurate report elements representing location and type of enemy vehicles. The automated reporting of friendly vehicle locations and logistics status greatly reduced the need to report the unit's status.

Due largely to automated navigation capabilities, CVCC-equipped battalions reached their counterattack objectives more quickly, achieved greater consistency in timing their movements, and completed combat missions more quickly. They also maintained safer end-of-stage stand-off distances. CVCC participants exhibited greater freedom of movement during combat missions.

The CITV's hunter-killer capabilities produced faster target acquisition at greater maximum ranges. CVCC-equipped battalions completed their counterattack missions with fewer friendly losses and fewer losses per enemy kill. The use of CVCC equipment did not distract crews from processing and engaging direct fire targets.

Utilization of Findings:

The battalion evaluation's findings provide useful information for Army developers determining combat doctrine, materiel requirements, training requirements, and operational effectiveness parameters for future automated C3 systems supporting horizontal integration of the battlefield. Further, the training and simulation methods are of use to other Army training and testing efforts.

EVALUATION OF THE COMBAT VEHICLE COMMAND AND CONTROL SYSTEM: OPERATIONAL EFFECTIVENESS OF AN ARMOR BATTALION

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

CONTENTS (Continued)

LIST OF FIGURES

CONTENTS (Continued)

EVALUATION OF THE COMBAT VEHICLE COMMAND AND CONTROL SYSTEM: OPERATIONAL EFFECTIVENESS OF AN ARMOR BATTALION

Introduction

The future battlefield will be characterized by rapid, intense, and highly fluid operations, with combat elements widely dispersed at times (U.S. Department of the Army, 1993). Such a combat environment will severely challenge the command, control, and communications (C3) capabilities of combat units. High-mobility mounted warfare operations will depend on timely, effective coordination with adjacent and supporting units. The rapid operational pace will demand faster, more reliable gathering and exchange of tactical information, in order to support shorter planning and decision cycles. In the midst of a highly fluid battlefield, accurate, up-to-date situational awareness will be essential to achieving timely, effective massing of direct and indirect fires while avoiding fratricide. In response to advanced threat systems which will severely jeopardize the survivability of friendly forces, C3 systems must support highly flexible, dispersed maneuver while guarding against electronic surveillance and electronic countermeasures. Across the battlefield, timely and accurate logistics information will be required to sustain rapid, highly mobile initiatives, especially during engagements with enemy forces. The lessons learned in Desert Storm graphically illustrate many of the C3 problems of a rapid-tempo, highly fluid battlefield, such as navigation difficulties, delays or interruptions in disseminating information, confusion about friendly and enemy locations, and deadly examples of fratricide (U.S. Department of Defense, 1992).

The C3 challenges of the future battlefield have led to important modernization initiatives capitalizing on advanced digital technology. These initiatives include development of automated C3 equipment (e.g., Knudson, 1990), digitization of the battlefield (e.g., Goodman, 1993), and horizontal integration of the battlefield (Foley, 1992). A common thread among these thrusts is reliance on an extensive battlefield network of digital nodes that are capable of rapidly and reliably exchanging combat-critical information. The key to these efforts is innovative research and development, with a focus from the outset on training requirements to ensure fielding and deployment of combat-effective digital systems on the combined arms battlefield (Knudson, 1990).

Prominent among the C3 automation efforts has been the U.S. Army's Combat Vehicle Command and Control (CVCC) program. A United States-German bilateral research and development effort sponsored by the U.S. Army Tank-Automotive Command (TACOM), this effort addresses automated C3 requirements for ground combat vehicles. The program is managed by four teams, each with a counterpart German team: the Data Elements, Operational, and Organizational Concepts Team, chaired by the Directorate of Combat Developments, U.S. Army Armor School; the Communications

Team, chaired by the U.S. Army Communications-Electronics Command (CECOM); the Soldier-Machine-Interface and Simulation Team, chaired by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI); and the Vehicle Integration Team, chaired by TACOM. The efforts of the four teams are interdependent and mutually supportive.

The CVCC program combines advanced technologies, both digital and thermal, to provide near real-time acquisition, processing, and dissemination of combat-critical information. The system integrates digital map functions, digital reporting capabilities, robust automated navigation features, thermal viewing for the vehicle commander (independent of the gunner's sighting system), and digital battalion staff planning capabilities (Leibrecht et al., 1993). The principal components include a Command and Control Display (CCD), a Position Navigation (POSNAV) system, a Commander's Independent Thermal Viewer (CITV), and automated battalion staff workstations. The CVCC system's capabilities are designed to enable faster, more accurate, and more effective C3 to meet critical challenges of a rapid-pace, high-mobility, wide-dispersion battlefield.

The Future Battlefield Conditions (FBC) Team of the ARI Fort Knox Field Unit has conducted a series of experiments systematically evaluating the CVCC capabilities during the course of the system's evolution. Initially evaluating individual components at the crew and platoon levels (Du Bois & Smith, 1989, 1991; Quinkert, 1990), the research progressed to an evaluation of integrated components at the company level (Leibrecht et al., 1992). The next effort advanced the research to the battalion level, with a limited evaluation focusing on the role of the battalion Tactical Operations Center (TOC) equipped with automated workstations (O'Brien et al., 1992a). The full-scale battalion evaluation described in this report was a logical extension of the earlier experiments, catalyzed by a focus on performance of unit commanders and executive officers.

Building on the earlier CVCC research, the goal of the final evaluation was to compare the performance of CVCC-equipped armor battalions with that of conventionally-equipped battalions, focusing on unit commanders and executive officers as well as overall battalion capabilities. Specific objectives were to (a) evaluate operational effectiveness, (b) investigate training issues, and (c) identify critical soldier-machine interface (SMI) issues.

As part of a family of reports documenting the battalion evaluation, this report presents the performance findings in an operational effectiveness framework. A second report (Meade, Lozicki, Leibrecht, Smith, & Myers, in preparation) analyzes combat performance in the context of armor doctrine and tactics, including unit standing operating procedures (SOPs). A third report (Atwood, Winsch, Sawyer, Ford, & Quinkert, in preparation) discusses training considerations and SMI issues. Together,

these reports provide a comprehensive account of the battalion evaluation's methods, findings, conclusions, and recommendations.

Six major sections provide the organizing structure for the remainder of this report:

1. Background and Review of Key Literature - reviews operational and research publications dealing with conventional and automated C3, Army combat digitization efforts, horizontal integration of the battlefield, distributed interactive simulation capabilities, and previous CVCC research.

2. Design of the Evaluation - discusses the objectives and issues underpinning the evaluation, along with the research approach and the experimental design.

3. Method - describes the test battalions, facilities, equipment, materials, procedures, and performance measures supporting the evaluation; discusses methodological limitations.

4. Results and Discussion - presents and interprets the findings regarding performance of unit leaders, with emphasis on operational effectiveness.

5. Lessons Learned - discusses operational and methodological lessons learned during the course of the evaluation.

6. Conclusions and Recommendations - highlights key findings and outlines imperatives for future research.

Background and Review of Key Literature

This section develops the background underpinning the CVCC battalion evaluation. Recent Army developments relating to C3, with a focus on automated and digital technologies, form the larger context for the current research. An overview of the CVCC program and the distributed interactive simulation facilities supporting the evaluation set the stage for a review of previous CVCC research, which concludes the section.

Command, Control, and Communications

C3 encompasses the process and means for planning, directing, coordinating, and controlling a combat unit's activities, for the singular purpose of accomplishing the unit's mission (U.S. Department of the Army, 1993). The importance of C3 to the successful accomplishment of combat operations is reflected in the Army's Blueprint of the Battlefield (U.S. Department of the Army, 1991), in which one of seven Battlefield Operating Systems deals entirely with command and control. C3 comprises systems and procedures designed to achieve a common goal: successful accomplishment of the current mission while retaining sufficient combat capability to continue follow-on missions in accordance with the commander's intent. The enhancement of C3 processes in a mounted warfighting environment forms the heart of the research presented in this report.

Conventional C3

The literature on conventional C3 is found mainly in articles published in Army periodicals such as Military Review (e.g., Burkett, 1990), in informal papers originating in the combat development/training development communities, and in Army field manuals and tactics, techniques, and procedures (TTPs) publications (e.g., U.S. Department of the Army, 1993). Observations and lessons learned from the U.S. Army's National Training Center (NTC) highlight the critical relationship between effective C3 and battlefield success. These conclusions emphasize that the commander must "see" the battlefield--that is, know the location, activities, and status of both friendly and enemy forces. He does this through fast and accurate reporting, and with the support of the TOC for information processing, planning, and coordination (R. S. Sever, personal communication, March 24, 1993).

More recent observations of combat operations during Desert Storm support the NTC conclusions. In the Defense Department's final report to Congress on the Persian Gulf War (U.S. Department of Defense, 1992), authorities identified several shortcomings of the M1A1 main battle tank. These shortcomings included the lack of an on-board navigation device and the lack of a positive combat vehicle identification system (such as a thermal sight with higher resolution to improve target detection, recognition and identification). Solutions to these shortcomings are being implemented in the M1A2 by fielding a CITV and a POSNAV device for each vehicle (Garth, 1992).

Conventional command and control procedures depend typically on the Army's fielded, voice-based radio systems as well as manual tools--mapboards, acetate, grease pencils, and hand-written/maintained logs, journals, and workbooks (Lickteig, 1991). These procedures are cumbersome and inefficient at best, and, in the heat of battle, may result in the loss of critical information or misinterpretation of instructions or intent. In contrast, automated tools using improved communications linkages have the potential not only to enhance the accuracy and speed of the command and control process, but, importantly, to enable the commander and his staff to "see" the battlefield in a much more comprehensive manner (Lickteig, 1991).

Automated C3

Under the Army Command and Control Master Plan, automation of C3 functions is a prominent thrust (Anderson, 1990; Knudson, 1990). At the corps level and below, the Army Tactical Command and Control System (ATCCS) integrates five functional systems (for example, the Maneuver Control System), each with its associated battlefield automation system. A driving goal is the real-time processing, integration, and display of critical battlefield information. In line with the central role of automation, research and development targets include artificial intelligence applications (e.g., decision aids); high-speed, portable, rugged computers; real-time information exchange technology; and continuous, robust, secure communications capabilities (Knudson, 1990).

The U.S. Army Armor Center (USAARMC) has forged a leadership role in developing automated C3 concepts. Nowhere is that role more apparent than in the Army's new M1A2 main battle tank (e.g., Garth, 1992). The M1A2's advanced systems--which include an Intervehicular Information System (IVIS), a POSNAV system, and a CITV--all incorporate significant advancements in C3 automation. In discussing future armored force technology, Foley (1991) outlined requirements for new C3 developments, including capabilities to streamline fusion, synthesis, and presentation of battlefield information and the means to simplify the generation of reports, orders, and overlays.

The CVCC program introduced in the preceding section was designed to upgrade the M1A2's capabilities and to point the way to future automated C3 systems. The range of functional capabilities integrated in the CVCC system is outlined in a subsequent subsection--The Combat Vehicle Command and Control Program--of this report. A review of previous CVCC experiments appears later in this Background and Review of Key Literature section. The cumulative findings of this program, spanning performance, training implications, and SMI issues up to the battalion level, provide a solid foundation for future research on automation of C3 functions.

The emerging automated command and control tools coupled with improved communications equipment (e.g., Single Channel Ground and Airborne Radio System [SINCGARS]) offer significant improvements in the processes and outcomes of command and control in combat. As stated in a recent Army concept paper, the introduction of devices such as the IVIS "is expected to provide an exponential increase in the ability of the commander and staff to plan, execute, and support missions, as well as enhance the ability of the crew to acquire, engage, and destroy enemy targets" (U.S. Army Armor Center, 1992, p. 1).

In developing automated C3 concepts, simulation building blocks such as POSNAV, CCD, IVIS, CITV, and automated battalion staff workstations form a high technology foundation for research and development efforts. Among past and current efforts contributing to this foundation are the just-concluded series of CVCC evaluations, a recent demonstration of IVIS in a combined arms environment (Courtright et al., 1993), and an assessment of the M1A2 and its C3 enhancements (U.S. Department of the Army, 1992). The soldier-in-the-loop nature of the distributed interactive simulation environment has provided a distinct advantage in these efforts. Future efforts are planned to capitalize on established automated C3 building blocks plus the distributed interactive simulation capabilities. The planned efforts include a Combined Arms Command and Control initiative sponsored by CECOM, interactive integration with a Fort Leavenworth corps battle simulation exercise, and "seamless" support to large-scale Army training exercises.

<u>Digitization of the Battlefield</u>

Recent trends in Army modernization have set the stage for "digitization" of the battlefield (e.g., Goodman, 1993). In the context of the modern battlefield, digital technology encompasses portable computers, high speed communications networks capable of transmitting digitized data, and specialized display devices for presenting combat-critical information. This modern technology contrasts dramatically with voice radio technology and manual processing of information, still the standard among combat units.

Digital technology has given rise to the term "electronic battlefield" (e.g., Robinson, 1991). This technology provides powerful capabilities to acquire, process, integrate, correlate, display, disseminate, and manage large quantities of battlefield information. Operational advantages include increased speed and reliability, greater accuracy of input information, automatic posting to digital map displays, and automatic reporting of selected data such as ammunition and fuel status.

With the advent of powerful, miniaturized, ruggedized computers, the Army has made substantial strides to incorporate digital technology in combat systems. For example, the Maneuver Control System (MCS) is designed to provide combat maneuver elements with digital planning and control capabilities down to the battalion level (Anderson, 1990). This system was used by some divisions during Desert Storm operations (Robinson, 1991). As another example, TACFIRE is a well-known system enabling fire support personnel to coordinate indirect fires by digitally exchanging reports, messages, and some graphics (U.S. Army Training and Doctrine Command, 1991).

An important facet of digitizing the battlefield has been the development of accurate, portable systems to support the difficult task of tactical navigation. One such system is the POSNAV system developed for the M1A2 tank (Garth, 1992). Using on-board inertial technology, POSNAV provides the tank crew with precise information about the location and heading of its own tank. Using POSNAV input, the integrated system disseminates information so that the crew knows the locations of other friendly vehicles. The system also enables the tank commander to create graphic navigation routes which are used to display steering information to the driver to guide him to established waypoints. POSNAV functions have been integrated in the experimental CVCC system (O'Brien et al., 1992a). Another navigation aid is the Global Positioning System (GPS) being developed as a complement or replacement for the POSNAV system. The GPS capitalizes on orbiting satellite technology and can display the user's location with a horizontal error of only 5-10 m (Robinson, 1991).

Collection and transmission of large quantities of battlefield digital data require secure, high-speed, high-capacity data distribution systems. Two such systems recently fielded by the Army are notable. The SINCGARS system handles data and voice transmissions by means of digital burst technology (Association of the U.S. Army, 1992). It is intended as the primary communications means within the brigade. The Mobile Subscriber Equipment (MSE) system is designed to provide secure voice, data, and facsimile communications at the division and corps levels (Association of the U.S. Army, 1992). This all-digital network supports mobile as well as stationary users. Both the SINCGARS and MSE systems were deployed in Desert Storm, where they played key roles in tactical C3 activities (Robinson, 1991).

Recent developments in digitizing the battlefield have led some to talk about providing the "battlefield picture at a glance" to commanders at all levels, as well as to aviators and air defense crewmembers (Keller, 1993, p. 39). This graphically reflects the striking trend towards powerful capabilities to rapidly collect, integrate, display, and disseminate large quantities of battlefield information during tactical combat operations.

Horizontal Integration of the Battlefield

Current military doctrine emphasizes combined and joint operations as essential to meeting a wide spectrum of threats to national security (Anderson, 1990). In large measure, success of combined and joint operations depends on robust capabilities for coordination (i.e., real-time exchange of information) among diverse collaborating units. Acknowledging this, the Army Command and Control Master Plan calls for separate automated C3 systems to interface electronically, to support automated sharing of information (Knudson, 1990). A further requirement exists for interoperability with C3 systems of other military services, including those of our allies.

The immutable relationship between C3 processes and the synchronization of battlefield activities has been articulated by many. For example, Burkett (1990, p. 61) writes: "The command and control battlefield operating system is an umbrella system that must be designed and equipped to produce synchronized operations." Foley (1992) discusses the future battlefield from a mounted warfighting perspective, outlining several key elements: real-time gathering of intelligence, rapid massing of fires on enemy targets, and constant automated communications across the combined arms team. This highlights the importance of synchronizing the combat activities of separate units which will often be widely dispersed. Battlefield synchronization--synergistically focusing combined and joint assets in space and time--will be a key in maximizing the available combat power to bring the greatest pressure to bear against the enemy.

The parallel emphases on combined and joint operations and on synchronizing activities of disparate and dispersed combat units are two sides of the same coin. They represent concerns which have set the stage for an emerging Army focus on "horizontal integration of the battlefield" (e.g., Goodman, 1993). This concept refers to the establishment of a common C3 network capable of linking combined arms and joint forces so that all elements will have an accurate, up-to-date picture of the battlefield. Under this new thrust, attention has focused initially on extending established automated technologies to platforms beyond those for which they were originally designed. For example, the Army plans to adapt the IVIS, originally developed for the M1A2 tank, for Bradley fighting vehicles and for scout and attack helicopters (Hewish, 1993).

As with the development of automated C3 technology, the USAARMC has taken a lead role in horizontal integration of the battlefield. The kick-off research effort, a soldier-in-the-loop simulation demonstration of battlefield synchronization (Courtright et al., 1993), used CVCC technology to create a common digital network among elements of a combined arms company/team. The combined arms components included armor, mechanized infantry, artillery, anti-armor (Line-of-Sight/Anti-Tank), and aviation. The demonstration focused on the potential contributions of an IVIS-like device to communications, combat effectiveness, and TTPs.

The USAARMC followed the simulation demonstration with a field demonstration of battlefield synchronization (Goodman, 1993). Actual vehicles (M1A2 tanks, M2 infantry fighting vehicles, a fire support team vehicle, and OH-58D helicopters) of a combined arms force were able to exchange digital data and reports using a common network. The field demonstration clearly extended the feasibility envelope for digitizing and integrating combined arms C3.

In keeping with its leadership role in automated C3 and horizontal integration of the battlefield, the USAARMC has established a horizontal integration initiative to develop and demonstrate suitable concepts and TTPs. Building on the battlefield synchronization efforts conducted in the simulation environment (Courtright et al., 1993) and in the field (Goodman, 1993), this initiative is designed to expand the foundation supporting the enhancement and integration of C3 across combined arms and joint forces. In terms of battlefield payoff, the initiative is expected to improve situational awareness, massing of direct and indirect fires, real-time intelligence gathering, and hand-off of targets from one force to another (Goodman, 1993).

The Combat Vehicle Command and Control Program

Among the pioneering research efforts in automated C3 has been the CVCC program. Spearheaded by TACOM and closely supported by ARI's Fort Knox Field Unit as well as other organizations, this bilateral (United States-Germany) research and development program has systematically investigated requirements and specifications for automated C3 systems for ground combat vehicles (e.g., Leibrecht et al., 1992; O'Brien et al., 1992a). The program has aggressively pursued innovative applications of advanced technology to meet the harsh C3 challenges of the future battlefield. In essence, CVCC research has built on the M1A2 program to develop a technology base required for future automated C3 systems operating in a combined arms environment. Indeed, the CVCC technology provided the foundation for the distributed simulation demonstration of combined arms battlefield synchronization (Courtright et al., 1993).

The capabilities of the CVCC conceptual system span communication, navigation, mission planning, battle monitoring, and target acquisition. The primary functional features include digital reporting capabilities, digital tactical map and overlay functions, automated positioning and navigation aids, independent thermal viewing for the vehicle commander, and automated planning and control tools for the battalion staff. At the heart of the system, the CCD integrates digital reporting, map, and navigation functions with the POSNAV system. The CITV affords the vehicle commander his own capability to search the battlefield. Battalion TOC workstations enable the battalion staff to support the maneuver elements by preparing digital orders, overlays, and messages and by digitally monitoring the battle. Presentation of processed data in graphic or pictorial form makes it easier for users at all levels to assimilate battlefield information. Exchange of data among vehicles and staff elements is accomplished via digital burst transmission. The collective capabilities of the CVCC system provide near real-time acquisition, processing, and dissemination of combat-critical information.

The overall goal of the CVCC program is to improve the speed, efficiency, and effectiveness of tactical C3, thereby enhancing combat effectiveness. The greater accuracy and consistency of information transmitted across echelons will improve the overall quality of C3 processes. The near real-time exchange of combat-critical information and graphic presentation of processed data will enhance situational awareness, due largely to precise information on locations of friendly and enemy elements. This in turn will enable more effective mission planning and execution. More rapid exchange of information will speed the plans-orders cycle, enabling commanders to react more effectively to mission changes in a dynamic environment. Battlefield lethality will benefit from more rapid and more accurate application of decisive combat power, including direct and indirect fires. Force survivability will increase through

enhanced tactical dispersion and reduced electronic signature. Improved situational awareness, together with better coordination of direct and indirect fires, will reduce the incidence of fratricide. These anticipated battlefield benefits can be expected to bring about striking improvements in force effectiveness.

The soldier-in-the-loop research on the CVCC system has been conducted using USAARMC's Mounted Warfare Test Bed (MWTB). The following subsection describes the MWTB and its capabilities. The concluding subsection reviews the previous CVCC evaluations conducted by ARI-Fort Knox, spanning crew-level to battalion-level efforts.

The Mounted Warfare Test Bed

The MWTB is a pioneering application of distributed interactive simulation technology. An asset of the U.S. Army Armor Center, the MWTB was formerly known as the Close Combat Test Bed. It provides a low-cost, unit-level battlefield simulation environment using families of simulators supported by site-specific microprocessors and connected by means of local and long-haul networking (Du Bois & Smith, 1989; Miller & Chung, 1987). Using a soldier-in-the-loop approach, the MWTB emulates a realistic C3 and battlefield environment in which to assess experimental configurations and training approaches.

The development of the MWTB began as part of a Defense Advanced Research Projects Agency (DARPA) initiative called SIMulation NETworking (SIMNET) to demonstrate the feasibility of linking manned and unmanned simulators via computer network. The evolution of SIMNET has been documented by Alluisi (1991). An important design feature called for flexibility of the SIMNET architecture, including reconfigurability of simulators and networks. As a result, the MWTB's architecture can be modified to accommodate a broad range of soldier performance research and development requirements. For example, combat, training, and materiel developers can put their ideas on trial in the MWTB environment before locking in concepts or system designs.

The MWTB's research capabilities are thoroughly described by O'Brien et al. (1992a). Central to the test bed are the manned vehicle simulators, which model actual vehicles to the minimum degree necessary for soldiers to accept them as realistic and useful (Chung, Dickens, O'Toole, & Chiang, 1988). This selective fidelity enables the battlefield-oriented perceptual cues within the test bed to be exploited without having to employ more expensive operational technology. Sound and visual simulation components reproduce key aspects of the battlefield operating environment. A variety of computer-based systems provides tactical communications, scenario control and monitoring capabilities, and robust data collection and analysis support. Table 1 summarizes these capabilities, and Figure 1 shows a schematic of the basic system architecture.

Table 1

The Mounted Warfare Test Bed's Major Features

Features	Description
Manned simulators	Selective fidelity crewstations, with supporting hardware and software, including terrain database.
TOC workstations	Automated workstations for selected TOC staff, with supporting hardware and software, including large-screen display and screen printer.
Tactical communications	Simulated SINCGARS network for linking manned simulators, TOC workstations, and control stations; capable of both voice and digital burst transmission.
Surrogate vehicles	Semiautomated forces (SAFOR) program for creating and controlling unmanned vehicles and aircraft, both friendly and enemy; provides digital message traffic.
Scenario control	Management, Command and Control (MCC) system for initializing and monitoring manned simulators and implementing fire support. Workstation for inserting and monitoring digital messages.
Scenario monitoring	Plan View Display (PVD) providing a "bird's eye view" of a simulation exercise; supports map manipulation and event flagging. Stealth station for out-the-window viewing of the battlefield.
Data recording and analysis	Data Collection and Analysis system for on-line recording of automated data and off-line reduction and analysis; supports playback. Includes DataLogger, DataProbe™, and RS/1™ (Registered trademarks of BBN Software Products Corporation).
Utilities	Network control station, capability to save and restart exercise states, SAFOR report generation, LISTEN system to record digital messages, and playback support.

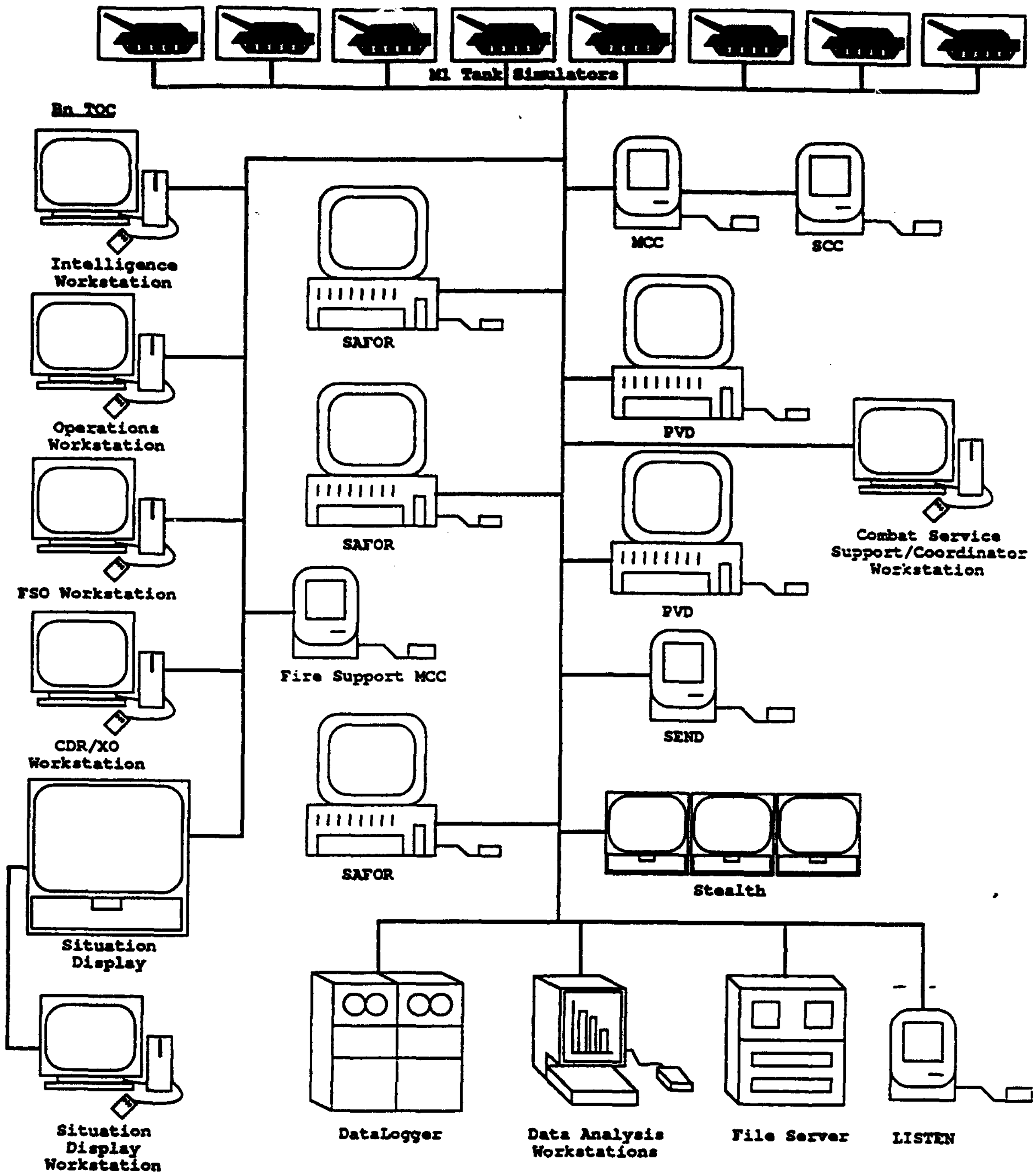

Figure 1. Schematic of the basic simulation network in the Mounted Warfare Test Bed. (Tank simulators and battalion TOC workstations represent the battlefield environment. MCC [Management, Command, and Control], SAFOR [semiautomated forces], and PVD [Plan View Display] elements are exercise control systems. DataLogger, data analysis workstations, and file server are part of the Data Collection and Analysis system.)

Armor crew and unit performance-oriented research carried out within the test bed in recent years has produced data of substantial operational significance (Atwood et al., 1991; Du Bois & Smith, 1991; Leibrecht et al., 1992). This is directly related to the MWTB's inherent advantages, which have been discussed by O'Brien et al. (1992a). Chief among the advantages are full-mission flexibility, force structure versatility, standardization of experimental procedures, automated data recording and analysis, unique playback capabilities, and relatively low cost.

As with any large-scale simulation, the MWTB has several constraints in its representation of operational combat settings. These limitations have been fully addressed by Leibrecht et al. (1993). The limitations of significance for the battalion evaluation are discussed at the end of the Method section. To help compensate for many of the limitations, special research procedures have been developed (O'Brien et al., 1992a). For example, to counter the limited visual fidelity of out-the-window views, crews are provided with special topographic paper maps which represent buildings, rivers, roads, etc. as they appear on the simulated battlefield.

ARI-Fort Knox CVCC Research Program

The ARI-Fort Knox FBC Team has pioneered and sustained the use of the MWTB's facilities to evaluate emerging armor concepts. Early work with promising components led to progressive evaluations of the fully integrated CVCC system, originally aimed at upgrading the M1A2's automated C3 capabilities. A design-evaluate-redesign-reevaluate approach has ensured the systematic evolution of the CVCC system, based on input from armor subject matter experts (SMEs) and on feedback from qualified tank crewmembers with hands-on experience using the system. As this iterative approach has refined and advanced the CVCC's functional capabilities, the research methods have been modified in parallel. Based on the lessons learned in each evaluation, the experimental design, training approach, simulated combat scenarios, measures of performance, and data collection instruments have all been revised and expanded in concert. This subsection summarizes the research leading up to the battalion evaluation.

In a ground-breaking study, Du Bois and Smith (1989) empirically evaluated a system which integrated POSNAV functions with digital map and navigation capabilities. The performance of armor crews using the enhanced system was compared with that of crews using conventional navigation techniques. Crews using the experimental capabilities were able to navigate more accurately and efficiently than crews using conventional means in virtually all battlefield situations.

In a similar effort, Du Bois and Smith (1991) evaluated the IVIS, the automated C3 display designed for the M1A2, using the MWTB. Findings indicated that tank crews and platoons equipped with IVIS performed significantly better than conventionally-equipped control crews and platoons in every capacity evaluated. The benefits of IVIS were attributed almost solely to the system's positioning and navigation capabilities, as opposed to the automated report functions. This may have resulted, at least in part, because the platoon echelon was too limited to fully reveal the advantage of the automated C3 equipment. This underscored the importance of extending the research to the company and battalion levels.

Quinkert (1990) examined the performance enhancement capabilities of the CITV, using Unit-Conduct of Fire Trainer (U-COFT) facilities. The CITV is a surveillance and target acquisition system for use in the Army's main battle tank. It allows a vehicle commander to independently search a sector, identify and hand-off targets to the gunner, and continue searching for targets while the gunner engages another. The increase in "hunter-killer" efficiency afforded by the CITV led to a reduction in the time to detect and engage multiple threat targets. Recommended improvements included a directional own-vehicle icon, shorter fire control commands, ergonomic enhancements to the control handle, and increased emphasis on crew coordination training.

In a follow-on effort, Leibrecht et al. (1992) examined the CVCC's impact on company-level performance. The company-level effort integrated the POSNAV, IVIS, and CITV components in each crewed vehicle. The study found that the enhanced capabilities improved the tank company's operational effectiveness, as well as accuracy and timeliness of orders and key reports. The findings pointed to the need to reduce redundant reports, provide feedback verifying report reception, and provide free text capabilities.

The battalion TOC evaluation (O'Brien et al., 1992a, 1992b) built on previous CVCC efforts by extending the research to the battalion level, integrating the CVCC into battalion C3 activities. To fully achieve this integration, automated TOC workstations were developed to interact with the digital data capabilities of the CVCC-equipped vehicles. Procedures for successfully integrating the TOC with the other CVCC elements were developed and assessed. This effort established the foundation for a full-scale battalion-level evaluation.

The evaluation described in this report, which concluded ARI-Fort Knox's CVCC research program, modeled the full tank battalion. Applying the cumulative lessons learned from the preceding research, the battalion evaluation integrated the full range of CVCC capabilities, including enhanced vehicle-based digital functions and expanded staff planning tools. With a focus on performance of unit commanders and executive officers, the evaluation was designed to extend substantially the CVCC performance database. The cumulative CVCC database provides an important foundation for evolving from the M1A2's C3 capabilities into future C3 systems capable of supporting combined arms operations on the high-technology battlefield.

This report and its companion reports (Atwood et al., in preparation; Meade et al., in preparation) document the battalion evaluation's complete database. The reader is encouraged to consult all three reports to obtain a complete account of the evaluation's methods and findings.

Design of the Evaluation

Research Issues

Previous CVCC research focused on battlefield contributions at the company level and below. The cumulative findings of that research led to an emerging interest in the CVCC's impact on battalion commanders interacting with company commanders. In addition, lessons learned from the battalion TOC evaluation (O'Brien et al., 1992a) and contemporary developments in armor doctrine (e.g., Faulconbridge, 1991) brought into focus the potential role of the company executive officer (XO). These converging factors led to the current battalion evaluation, with several questions of primary interest. How does the CVCC system impact combat effectiveness and performance of tank battalions? How would the dynamics between company commanders and their XOs influence C3 processes within the battalion, especially flow of information? What might be the impact of operational utilization of CVCC capabilities on armor battalion TTPs? How will the CVCC system affect requirements for training armor unit leaders and crews? What modifications in CVCC design are necessary to optimize utilization by unit commanders, XOs, and TOC personnel?

With these questions forming a foundation, the battalion evaluation was designed to establish a database to help guide TTP and training developments to support utilization of the CVCC system in the armor environment, and to provide input to decisions regarding design of the CVCC system itself. Based on the questions of interest, the planning and execution of this evaluation incorporated three overall objectives:

1. Evaluate the operational effectiveness of armor battalions using the CVCC Experimental configuration, compared to conventionally-equipped battalions.

2. Investigate operational training issues and concerns associated with the CVCC.

3. Identify critical SMI concerns and make recommendations regarding CVCC design and utilization.

Each of these objectives formed the basis for specific research issues. In generating the research issues linked to the operational effectiveness objective, the Blueprint of the Battlefield (U.S. Department of the Army, 1991) provided an established doctrinal basis. An integration of current warfighting principles, the Blueprint of the Battlefield is a systematic framework for organizing tactical activities. The framework consists of seven Battlefield Operating Systems (BOSs), each of which encompasses a family of related functions required for effective combat operations. Meade et al. (in preparation) discuss the BOSs in greater detail, including their relative utility in the context of the battalion evaluation. Because of the expected contributions of the CVCC system to armor battalion operational effectiveness, the following four BOSs were selected for use in this evaluation: Command and Control, Maneuver, Fire Support, and Intelligence. Based on these BOSs, four research issues were generated to identify key areas where the CVCC system was expected to improve performance relative to the Baseline system, as follows:

1. Does the CVCC system enhance the Command and Control BOS?

2. Does the CVCC system enhance the Maneuver BOS?

3. Does the CVCC system enhance the Fire Support BOS?

4. Does the CVCC system enhance the Intelligence BOS?

The training and SMI objectives gave rise to the remaining research issues, addressed in the companion report by Atwood et al. (in preparation):

5. What training considerations and implications are important in training unit commanders and crews to operate and utilize the CVCC system?

6. What SMI factors critically affect utilization of the CVCC configuration, and how do they impact CVCC design?

Hypotheses for each of the BOS-based research issues were developed to articulate expected performance impacts of the CVCC system. These hypotheses are presented in the Performance Measures subsection of this report's Method section.

Approach

The evaluation compared combat performance and effectiveness of tank battalions using the CVCC's automated C3 tools with Baseline battalions using conventional C3 tools. In the Baseline condition, C3 functions were accomplished by means of voice radio, paper maps, manual navigation techniques, and manual recording and processing of messages. In the Baseline TOC, battlefield information was processed manually with the aid of wall charts and staff journals. In the CVCC condition, the manual means available in the Baseline condition were supplemented with the CVCC's enhanced capabilities, principally the CCD integrated with the POSNAV, the CITV, and a digital link between the CVCC system and the SINCGARS communications system. The CVCC TOC incorporated automated workstations designed to support digital processing of battlefield information. These workstations simulated the link between the maneuver elements and the TOC staff, providing a robust capability to exchange digital information.

Following an independent groups approach to compare the Baseline and CVCC conditions, half of the participating armor battalions used Baseline-configured simulators while the other half used CVCC-configured simulators interacting with battalion TOC elements. The methodology combined MWTB tank simulators modeling an autoloader, a doctrinally-based combat scenario designed to fully exercise the C3 capabilities of an armor battalion, and a variety of data collection methods. To ensure comparability of data across test weeks and reduce instances of missing data, manned simulators were not permitted to be killed.

Serving as participants were qualified armor soldiers, forming the following crews within the battalion: battalion commander, battalion S3, three company commanders, and three company XOs, each working with a gunner and driver. The autoloader eliminated the need for a loader/crewmember. This manning structure was shaped by the evaluation's focus on the C3 interactions among battalion and company leaders, battalion TOC evaluation lessons regarding the importance of the company XO, the relative availability of supporting troops, and the number of available tank simulators. A full tank battalion was constituted by integrating the eight crews formed by the participants with SAFOR under the control of the battalion commander or company commanders.

Test support personnel role-played other battalion personnel, generally corresponding to key TOC staff and SAFOR vehicle commanders. The TOC staff, which included military SMEs, assumed the roles of the battalion XO, intelligence officer (S2), assistant operations officer (assistant S3), and fire support officer (FSO). Other support staff members played the roles of the brigade commander, adjacent unit commanders, and platoon leaders. Semiautomated opposing forces (OPFOR) units comprised the entire enemy force and were controlled by test support personnel to simulate a realistic threat environment.

Progressive training incorporated classroom, supervised hands-on, and crew and unit practice exercises.

Providing the environment for test data collection was a single multi-stage simulated combat scenario, incorporating both defensive and offensive stages: an initial delay mission, then a counterattack, followed by a concluding delay operation. This structure sampled different types of combat activities. The complete test scenario was constructed to be briefed, executed, and debriefed in two-thirds of a day. Each week's participating battalion executed the test scenario only once.

Experimental Design

The primary independent variable, condition, formed a between-subjects variable with two levels--CVCC and Baseline.

These conditions were defined in the preceding subsection. A secondary independent variable resulted from the two echelons of manned positions within the battalion's organizational structure: battalion command group--battalion commander and S3--and company command elements--company commanders and XOs. This structure resulted in a between-subjects variable with two levels, the number of subjects varying between echelons by the ratio 2:6.

In addition, one incidental variable, stage, completed the design. The test scenario's three stages--delay, counterattack, delay--represented different types of combat missions sharing a unifying overall structure. Thus, there were three levels of this repeated measures variable. However, the performance requirements were quite different across the three stages. In particular, enemy force structures varied widely between the delay and counterattack stages, and the largely static character of the delay stages contrasted with the largely mobile character of the counterattack stage. Because of these and other differences, direct comparison of the stages was not appropriate. Thus, no statistical comparisons were planned for this variable.

Measures of performance were designed to provide quantitative information regarding the four performance research issues outlined earlier in this section. Data collection was accomplished through a combination of direct observation, self-report questionnaires, automated data collection, transcription of recorded radio traffic, and post-scenario debriefings.

Method

This section describes the research methods supporting the evaluation, with an emphasis on experimental procedures directly related to collection of performance data. In addressing SMI, training, and tactical aspects, the subsections provide summary information and refer the reader to companion reports (Atwood et al., in preparation; Meade et al., in preparation) for greater detail, as appropriate. In addition, this section occasionally refers the reader to previously published reports for details on selected materials, facilities, and procedures, as well as measures of performance. This strategy was chosen to reduce the redundancy of methodological verbage across the family of reports from the battalion evaluation.

Participants

A total of 282 U.S. Army personnel and one U.S. Marine participated in the six Baseline and six CVCC test weeks. This total included 95 commissioned officers and 188 non-commissioned officers (NCOs) and enlisted men. Ranging in age between 18 and 43, all participants were active duty male soldiers stationed at Fort Knox, Kentucky.

For ten of the twelve test weeks, 24 personnel--eight officers and sixteen NCOs or enlisted personnel--were provided by supporting units. In one CVCC test week, no S3 was available; this resulted in one three-man crew being dropped. In one of the Baseline test weeks, only seven gunners were available so the S3 crew operated without a gunner. One enlisted person served in two separate test weeks.

All participants, including the Marine Corps officer, held an armor Area of Concentration or were currently qualified in armor Military Occupational Specialties (MOSs). Each group included one major who served as the battalion commander. The remaining officers were assigned the following roles: one battalion S3, three company commanders, and three company XOs. These assignments were based on rank, experience in relevant duty positions, and the battalion commander's judgment. Each officer commanded two crewmembers (gunner and driver) assigned by the battalion commander from the available enlisted personnel. In general, members of a given crew had not worked together before.

Battalion Configuration

In each test week the participants were organized into a test battalion forming the core of the evaluation. The unit modeled a tank-pure armor battalion composed of four tank companies, a six-vehicle scout platoon, and a command group. Participants manned the battalion commander and battalion S3 vehicles in the command group, as well as the company commander and company XO vehicles in A ("Alpha"), B ("Bravo"), and C ("Charlie") companies. The battalion's remaining combat vehicles--the tank platoons, all of D ("Delta") Company, and the scout platoon--were represented by SAFOR elements controlled by unit commanders and operated by role-playing test personnel. Blue Forces (BLUFOR), consisting of all manned vehicles and the SAFOR vehicles under their control, comprised the entire friendly forces. Figure 2 illustrates the test battalion configuration, minus the scout platoon and the battalion TOC, differentiating between the manned simulators and SAFOR.

The OPFOR consisted entirely of SAFOR under the control of test support personnel.

Support Personnel

A variety of support personnel (contract employees) participated in executing the evaluation, role-playing assigned positions and exercising various control functions. In general, the support personnel operated in three primary areas--the battalion TOC, the Exercise Control Room (ECR), and the simulators--as they supported training and test exercises.

Battalion TOC Staff

Four support personnel staffed the battalion TOC, emulating the functions of a battalion main command post. These personnel,

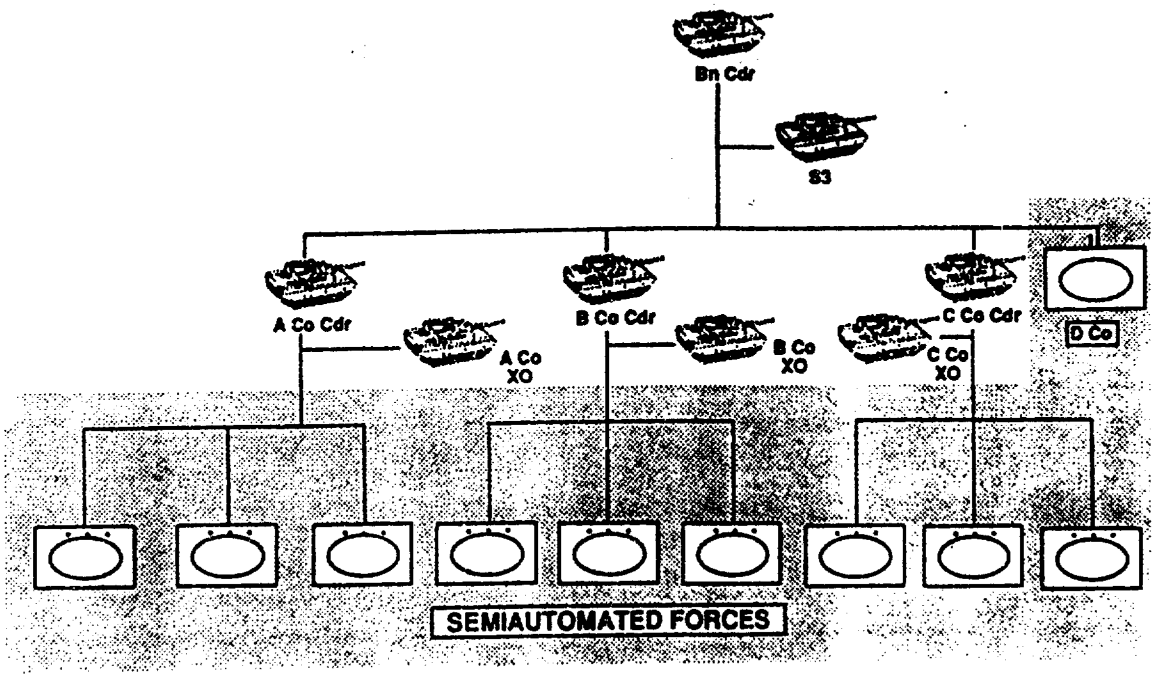

Figure 2. Illustration of the battalion configuration. (Minus the Tactical Operations Center [TOC] and scout platoon.)

SMEs in the areas of command and control, operations, intelligence, and fire support, role-played the positions of battalion XO, assistant S3, S2, and FSO. The TOC staff provided C3 support for combat operations in a standardized and doctrinally-based manner, performing as an integral part of the battalion organization for combat. In the CVCC condition, these individuals performed their tasks using the TOC workstations augmented by voice radio. In the Baseline condition, these staff members performed their tasks manually and communicated with the simulators solely by voice radio. A detailed list of the responsibilities assigned to members of the battalion TOC staff can be found in Leibrecht et al. (1993).

Exercise Control Staff

The exercise control staff was responsible for training participants, controlling all scenarios and exercises, and operating the ECR stations. This staff also administered manual data collection instruments. Table 2 summarizes the primary responsibilities assigned to each member of the control staff during the training and testing scenarios.

The Exercise Director retained overall decision-making authority for all matters regarding the conduct of training and testing. The Event Coordinator, Battle Master, Floor Monitor, and others assisted the Exercise Director in ensuring proper execution of events. This permitted decentralized execution consistent with the research plan.

Table 2

Responsibilities of the Exercise Control Staff During Scenarios

Exercise Director
- Oversee overall scenario execution
- Implement procedures for accommodating unplanned events
- Serve as Assistant Battle Master
- Monitor and operate CSS workstation (CVCC condition)
- Operate SEND program
- Administer questionnaires to gunners and drivers

Event Coordinator
- Inform Exercise Director and ECR staff of simulator and TOC status
- Troubleshoot and coordinate site support in the event of equipment malfunctions
- Document equipment problems
- Oversee VCR operation
- Administer questionnaires to vehicle commanders
- Coordinate automated data collection

Battle Master
- Initialize MCC and CSS workstation
- Supervise scenario execution within control room
- Supervise control room staff
- Conduct brigade orders briefing for participants
- Maintain Battle Master log
- Assume roles of brigade commander, adjacent unit commanders, brigade staff
- Conduct post-scenario debriefings
- Maintain contact with TOC to coordinate scenario execution

OPFOR Operator (SAFOR)
- Initialize OPFOR workstation prior to execution
- Control actions of OPFOR
- Coordinate OPFOR activities with Battle Master

BLUFOR Operators (SAFOR)
- Initialize BLUFOR/SAFOR workstation prior to execution
- Implement company commanders' orders/directives to platoons in A, B, and C companies
- Implement battalion commander's orders/directives to D company and scouts
- Coordinate BLUFOR/SAFOR activities with Battle Master
- Coordinate radio messages with Radio Operator

Radio Operators
- Role-play platoon leaders, company commanders, and XOs
- Coordinate radio communication between BLUFOR elements and M1 simulators

(table continues)

(Table 2 continued)

PVD Monitor
- Record significant events using log and PVD flags
- Record breakdowns and other contingencies on PVD Log
- Maintain PVD Log

Floor Monitor
- Supervise Research Assistants (RAs) during scenarios
- Coordinate with RAs and simulator technicians to help resolve equipment problems

Research Assistants (in simulators)
- Train crews and answer questions
- Record key performance events on log
- Notify Floor Monitor of system malfunctions and troop problems
- Record equipment problems on maintenance log
- Administer Situational Assessment questionnaire

Based in the ECR, the Exercise Director supervised the overall conduct of the scenarios and served as the Assistant Battle Master. The Battle Master, two BLUFOR operators, two radio operators, an OPFOR operator, and a PVD monitor also worked in the ECR. The Event Coordinator primarily coordinated activities between the ECR, battalion TOC, and the vehicle simulators throughout the training and test scenarios.

The Battle Master maintained primary responsibility for scenario execution. The Battle Master, assisted by the ECR staff, role-played the brigade commander and staff, adjacent and supporting unit personnel, and other tactical elements. He also presented the brigade operations order (OPORD) pre-mission briefing, and ensured the ECR was set up prior to the start of each exercise. In addition, he supervised the ECR staff during execution to ensure strict adherence to the operating procedures and to the scenario events list. At the conclusion of each scenario, the Battle Master conducted the debriefing.

Eight Research Assistants (RAs) served as vehicle trainers/monitors. Their responsibilities included training participant crews on the operation of the simulators (Baseline and CVCC) and the CVCC equipment (CVCC only). During the test scenario, four vehicle monitors collected data on crew performance. The Floor Monitor supervised the trainers/monitors. The Floor Monitor also assisted the Event Coordinator by notifying site support staff during equipment malfunctions, and tracking the status and resolution of these problems.

Test Facilities

This subsection describes the test facilities and equipment used to control and support training and testing. It also

describes the equipment used to collect and analyze the data from this evaluation.

MWTB facilities used in this evaluation included a classroom, eight vehicle simulators, a SINCGARS radio network, the TOC, the ECR with simulation control equipment, a Stealth station, and the Data Collection and Analysis (DCA) system. More complete facility descriptions may be found in previous CVCC publications, especially O'Brien et al. (1992a). Details on the principal equipment are presented in the following paragraphs.

Baseline M1 simulators

Eight M1 tank simulators were used in the evaluation. Each M1 simulator consisted of two major sections: a driver's compartment and a turret crew compartment. The turret crew compartment contained stations for the vehicle commander, gunner, and loader. More detailed descriptions of the basic simulator components and operation may be found in the M1 SIMNET Operator's Guide (U.S. Army Armor School, 1987).

As a general rule, M1 simulators in the MWTB contain the following major functional components: a simulation host computer, a computer image generation (CIG) system, a sound system, and several interactive device controller (IDC) boards. The simulation host computer simulates the vehicle dynamics, kinematics, and the hydraulic, electrical, and fuel systems. The IDC boards read the status of crew controls and send the information to the host computer. The host processes this information, along with information from other simulation elements transmitted over the simulation Ethernet. The host then sends messages to the CIG system, the sound system, and the IDC boards. Messages about the current vehicle status are transmitted over the simulation Ethernet to other simulators and exercise control systems.

The MWTB simulators were developed using a selective functional fidelity approach. That is, the simulators do not include all functions and controls found in an actual M1 tank--only those necessary to support unit training exercises (Alluisi, 1991). The simulator is equipped with a 105 mm main gun capable of firing HEAT and SABOT rounds, three out-the-window views in the driver's and vehicle commander's stations, a gunner's primary sight (GPS), a GPS extension (GPSE) at the commander's station, and a single rotatable view in the loader's station. The vehicle commander's station also includes a rotatable cupola allowing him to manipulate his three out-the-window views. A headset with boom microphone is used for radio and intercom communication. The M1 simulators do not have the machine guns, Muzzle Reference System (MRS), Gunner's Auxiliary Sight (GAS), nor open-hatch views available on the fielded M1. The visual system is limited to views out to 3500 meters.

The sound system recreates realistic battlefield sounds from simulated vehicle operation, weapons fire, and impacts.

Vehicle sounds include engine whine, track movement, turret/main gun movement, and the opening or closing of the ammunition doors. Weapons fire sounds include direct fire, indirect fire, aerial fire, and own-vehicle fire. Impact sounds include impacting rounds and misses.

CVCC simulators used in both the Baseline and CVCC conditions contained several modifications not found in other MWTB M1 simulator configurations. The GPS was equipped with a Thermal Imaging System (TIS) which could be toggled for the normal daylight view. The simulator also included a simulated autoloader with a basic load of 27 SABOT rounds and 13 HEAT rounds. The full cycle time to reload a round after firing was approximately eight seconds. During the first three and one-half seconds, the system waited for the gunner to select the desired ammunition type. In the remaining four and one-half seconds, the system opened the breech and the ammunition doors, loaded a round of the selected type, and closed the breech and ammunition doors. The autoloader was also capable of unloading a round when the gunner changed the ammunition select switch before firing.

Each simulator was also equipped with two simulated SINCGARS radios. These radios replaced the CB (Citizen's Band) radios found in other MWTB simulators. The radios converted voice transmissions into digital signals which were broadcast over the simulation Ethernet, allowing voice transmissions to be recorded for subsequent playback.

CVCC M1 Simulators

The same M1 simulators used in the Baseline condition were also used in the CVCC condition, with additional capabilities operational. In addition to the basic M1 simulator hardware and software described in the previous paragraphs, the CVCC configuration included several other major capabilities. Table 3 summarizes the key functional differences between the M1 simulators used in the Baseline and CVCC conditions. The major components distinguishing the CVCC M1 from the Baseline M1 were the CCD, POSNAV, and CITV. These components were located primarily in the vehicle commander's station, illustrated in Figure 3. Basic CVCC simulator documentation may be found in the SIMNET Users' Guide (U.S. Army Armor School, 1989) and in the SIMNET Combat Vehicle Command and Control (CVC2) System User's Guide (Smith, 1990).

The CVCC software used in this evaluation was Version 1.9, which equated to the working designation "Version 7.0" appearing on the user's screen upon initialization of the system.

Table 3

Comparison of Baseline and CVCC M1 Simulator Capabilities

	Baseline	CVCC
Navigation		
Out-the-window views (vision blocks)	X	X
Paper map with overlays	X	X
Odometer	X	X
Grid azimuth indicator	X	X
Turret-to-hull reference display	X	X
Main gun laser range finder (LRF)	X	X
CCD tank icon and status information		X
Digital terrain map and tactical overlays		X
Digital navigation routes		X
Driver's navigation display		X
Target acquisition and engagement		
Out-the-window views (vision blocks)	X	X
GPS/GPSE with TIS, magnification, main gun LRF	X	X
Turret-to-hull reference display	X	X
[illegible]toloader with 8-second reload cycle	X	X
[illegible] round basic load (27 SABOT, 13 HEAT)	X	X
CITV with LRF, IFF, 3 scan modes, magnification, polarity		X
CITV target designate		X
Communications		
Radio intercom	X	X
SINCGARS radios (voice communication)	X	X
SINCGARS radio interface unit (data communication)		X
Digital combat report communication		X
LRF/location input to combat reports		X
Digital tactical overlay communication		X
Digital navigation route communication		X

Table 4 lists the basic capabilities of the integrated CVCC system. A guide to the functionality and operation of the system is available in the form of a job aid (Smith & Heiden, in preparation). A detailed description of functional capabilities can be found in Leibrecht et al. (1993). A brief overview of the CCD, POSNAV, and CITV components follows.

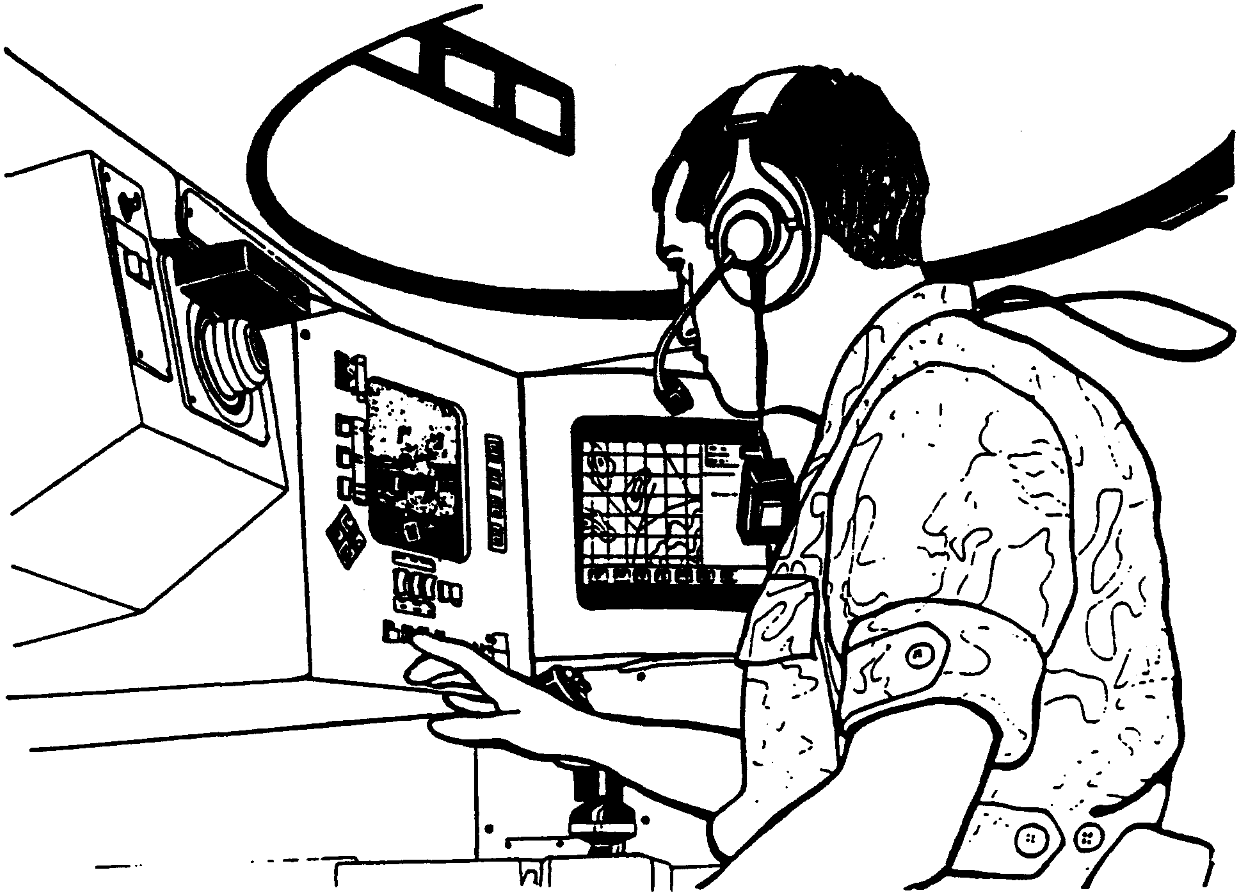

Figure 3. Vehicle commander's station as seen in the CVCC condition.

Command and Control Display (CCD). The CCD is designed to provide commanders with rapid access to accurate battlefield information and to speed the unit and vehicle commanders' decision cycles. The CCD can be used to prepare and send digital reports, and to receive, view, relay, and store both digital reports and overlays. The following types of reports, referred to as "named" reports, can be prepared: CONTACT, CALL FOR FIRE, ADJUST FIRE, SPOT, SHELL, SITREP (Situation Report), INTEL (Intelligence Report), and NBC (Nuclear/Biological/Chemical Report). Formats for these digital reports appear in Appendix E. FRAGOs (fragmentary orders), FREE TEXT reports, and graphic overlays can be received from the TOC and processed. The CCD integrates input from the main gun and CITV LRFs (laser range finders) to allow entry of precise location information in reports.

Table 4

Capabilities of the Integrated CVCC Configuration

<u>Navigation</u>
Digital tactical map with selectable grid lines, scales, and terrain features
Digital tactical overlays
Own-vehicle location: grid and icon
Own-vehicle orientation: azimuth heading and directional icon
Friendly vehicle location icons
Report-based icons
Graphic navigation routes with waypoints
Navigation waypoint autoadvance
Driver's display with steer-to-indicator
<u>Digital Communication</u>
Combat reports: prepare/send/receive/view/relay/store
LRF/location input to combat reports: CITV and main gun LRFs
Tactical overlays and orders: receive/display/relay/store
Navigation routes: prepare/send/receive/view/relay/store
Friendly vehicle locations--mutual POSNAV
Automated logistics reports, with autorouting
<u>Battlefield Surveillance and Targeting</u>
Independent thermal search, with manual and autoscan modes
Hands-off scanning of designated sector
Independent laser range finder
Identification Friend or Foe (IFF)
Target designation/hand-off to gunner
<u>Interface Control Options</u>
Commander's control handle input (CCD and CITV)
Touchscreen input (CCD only)
Push-button/toggle switch input (CITV only)

The CCD is designed to transmit and receive digital reports and overlays via the radio interface unit (RIU). However, the RIU was not used in the current evaluation. Instead, digital data were transmitted directly over the Ethernet.

A digital tactical map with own-vehicle icon enables the vehicle commander to easily monitor on graphic terrain his location and heading, based on POSNAV input, and to display graphic overlays. The map automatically displays icons showing the locations of other friendly vehicles, which can be aggregated to section and unit levels. This function is known as "mutual POSNAV." The CCD also provides the means to create graphic routes, display them on the tactical map, transmit them to other vehicles, and display navigational information to the driver. The driver uses the information from his display to steer to the next waypoint.

An Information Center augments the graphic vehicle status information shown by the own-vehicle icon. This center displays in text form the date, time of day, vehicle call sign, own-vehicle heading in degrees, and the six-digit own-vehicle grid location. The status information updates as the vehicle moves along the terrain or at a rate of approximately every ten seconds.

The position and logistics status of all friendly vehicles is transmitted automatically at regular intervals, enabling unit and vehicle commanders to monitor readily their unit's status.

The CCD configuration used in this experiment (Version 1.9) was upgraded from previous versions to enhance the processing speed and to capitalize on findings and lessons learned in the battalion TOC evaluation (O'Brien et al., 1992a, 1992b). For example, the automated reporting of logistics status was added, and capabilities for preparing, viewing, and tracking reports were improved. Leibrecht et al. (1993) describe the recent changes in the CCD functionalities.

CCD interface overview. Mounted to the right of the vehicle commander, the CCD's user interface occupies a 7 by 5.75 inch rectangular working area of a cathode ray tube with a touch sensitive screen. Figure 4 shows this interface/display in a representative operational state. At the bottom of the display are the main function keys. When the unit or vehicle commander presses a function key, the corresponding menu appears in the variable menu area. The variable menu area displays the menus and the submenus when primary keys such as MAP and secondary keys such as Exit are pressed. The tactical map area comprises most of the left portion of the display and shows the features of the terrain database in color. In the upper-right corner of the display the Information Center displays date/time information along with own-vehicle status elements.

The unit or vehicle commander controls the operation of the CCD by manipulating a cursor appearing on the display screen. He selects menus and functions by positioning the cursor on the desired key. The CCD has two input modes, finger touch control utilizing the touch sensitive screen and the thumb control mounted on the commander's control handle.

POSNAV. The POSNAV component provides information on own-vehicle location and heading, based on a simulated on-board inertial system. This information is updated automatically as the vehicle moves across the terrain, but not less often than approximately every ten seconds. The POSNAV information is input to the CCD for integration with tactical map, vehicle icon, navigation, Information Center, and status reporting functions.

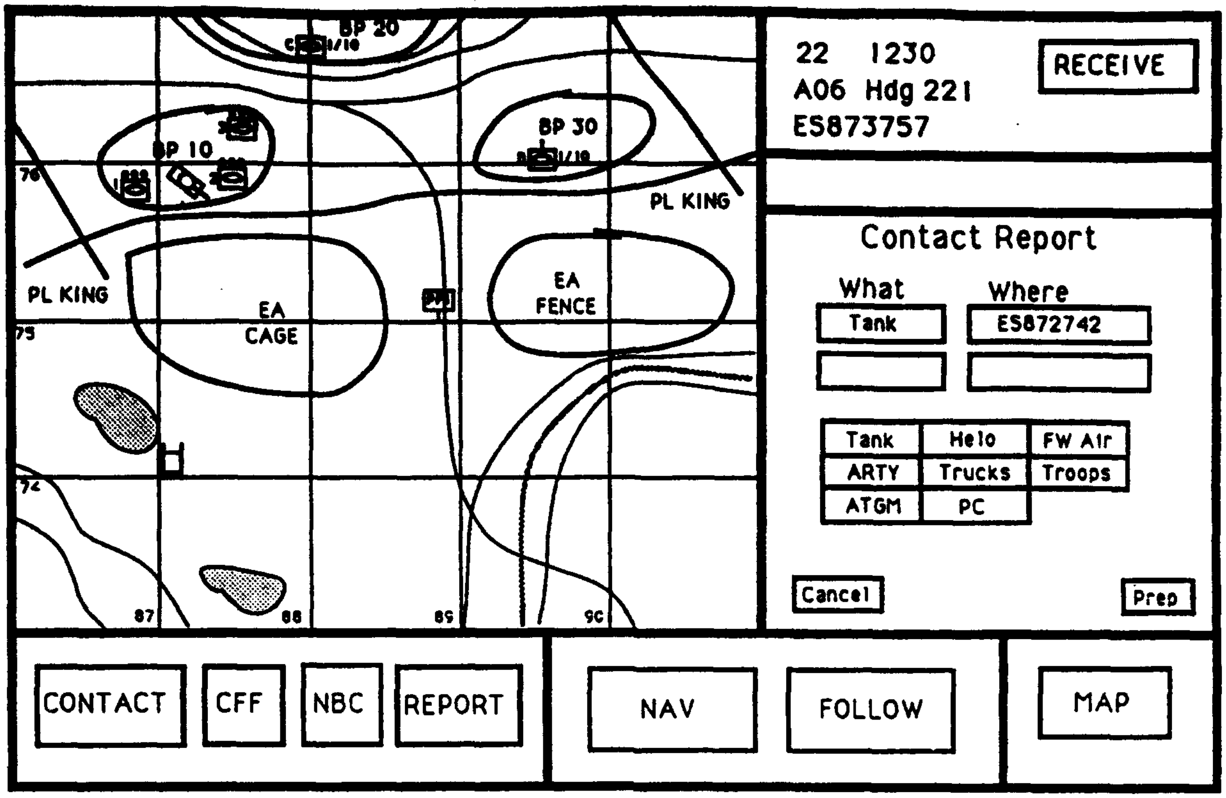

Figure 4. Command and Control Display (CCD) interface. (See text for description.)

Commander's Independent Thermal Viewer. The CITV affords the vehicle commander an independent battlefield viewing capability and an independent LRF. The CITV's capabilities assist in the performance of navigation, battlefield surveillance, target acquisition and identification, and fire control tasks. The SIMNET Combat Vehicle Command and Control User's Guide (Smith, 1990) explains the operating features of the CITV. A brief overview of the system follows.

The CITV's independent thermal viewing capability enables the vehicle commander to search the battlefield while the gunner searches another sector or engages identified targets. The commander can manually control his search pattern, or he can set up a sector for the CITV to search automatically in a back-and-forth sweeping pattern. With the CITV's LRF capability, both the commander and the gunner can lase to different targets at the same time, substantially increasing the crew's ability to acquire targeting information for indirect and direct fire targets. In addition, the commander can use the CITV's IFF function, which models an 80 percent accuracy rate, to facilitate definitive target identification. As the commander acquires and identifies targets, he can hand them off to his gunner by selecting the target designate function, which rapidly slews the main gun to the vicinity of the desired target. This teamwork capability, with the commander "hunting" targets and the gunner "killing" them, is known as the "hunter-killer" advantage of the CITV.

As a result of CITV-CCD integration, the CCD can use the LRF input from the CITV to generate precise location information in pertinent combat reports.

CITV interface overview. Mounted directly in front of the vehicle commander, the CITV display includes control switches around three sides of a central display screen (Figure 5). The commander controls operation of the CITV via inputs from the functional switches and control handle. The 6.5 by 5.88 inch monochrome display screen includes an own-vehicle icon and a sighting reticle. Primary operating modes include manual search, autoscanning of user-set sectors, and main gun line of sight (GLOS) lock-on. As in the battalion TOC evaluation (O'Brien et al., 1992a), the target stack function was inoperative in this evaluation.

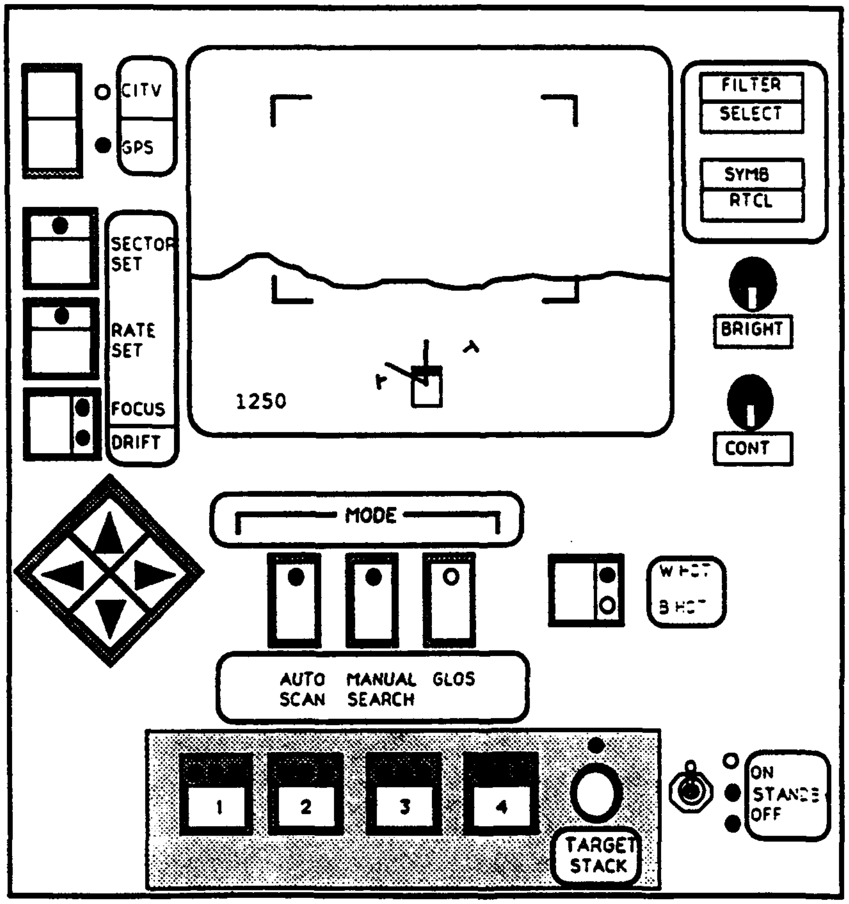

Figure 5. Commander's Independent Thermal Viewer (CITV) interface. (See text for description. Target stack functions, in the bottom shaded area, were inoperative.)

Tactical Operations Center

In addition to the vehicle simulators, a battalion TOC supported tactical operations in both the Baseline and CVCC conditions. The battalion TOC was located in a Standard Integrated Command Post System (SICPS) tent, the same type designed for a field-deployed TOC. The automated TOC in the CVCC condition provided an extension of the CVCC technologies available in the vehicle simulators. The following paragraphs describe the battalion TOC configuration for each condition.

Baseline battalion TOC. The Baseline TOC was configured to represent the current conventional capabilities among units in the field. Battle reports, unit locations and status, and other pertinent information were maintained on wall charts and maps. The TOC staff updated staff journals manually. The radio configuration in the battalion TOC permitted voice communications using the brigade command net, brigade operations and intelligence (O&I) net, the battalion command net and the battalion O&I net.

CVCC battalion TOC. The automated TOC included four automated workstations and a large-screen Situation and Planning Display (SitDisplay) in lieu of paper-based maps and wall charts. The four workstations supported the tasks and responsibilities of the battalion commander/XO, the assistant S3, the S2, and the FSO. A fifth workstation, supporting the SitDisplay, was located just outside the TOC. It controlled the view shown on the SitDisplay screen and served as a technical "troubleshooting" station. The SitDisplay provided a centralized location for individual workstations to post various mission overlays to gain a composite tactical picture. A sixth workstation was located in the ECR and was used to emulate higher and adjacent headquarters. The workstations exchanged data on a TOC local area network, which in turn connected to the CVCC network. This linkage provided the means of implementing command and control procedures and exchanging information with the vehicle commanders in the manned simulators.

The battalion TOC workstations each consisted of a central processing unit, two 19-inch color monitors, a keyboard, and a mouse (see Figure 6). The left-hand monitor was a Map Display, portraying a digital military topographical map and manipulated through the keyboard and mouse. This display allowed the user to create, edit, store, and transmit overlays and reports generated from his workstation. The right-hand monitor, called the Communication and Planning Display, presented textual information received from other sources and enabled the creation and processing of overlays.

The TOC workstations permitted TOC personnel to perform key command and control functions such as receiving combat information, generating combat orders and overlays, and communicating information within the TOC and throughout the battalion. All TOC workstations had common hardware and

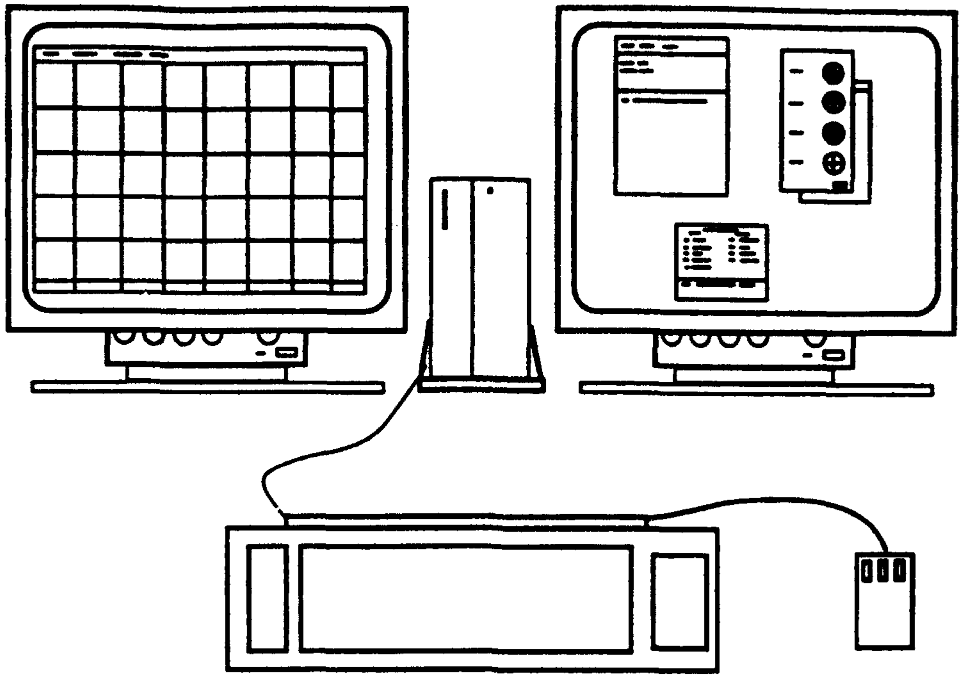

Figure 6. Automated workstation used in the battalion Tactical Operations Center for the CVCC condition.

functional features, described in Leibrecht et al. (1993). A complete guide to the functionality and operation of the TOC workstations may be found in the Battalion Tactical Operations Center (TOC) Job Aid (Sever & Heiden, in preparation).

Radio network

The simulated SINCGARS radio network supported six voice radio nets--brigade command, battalion command, battalion O&I, and three company command nets. Figure 7 shows the voice radio networks and configuration used in the Baseline and CVCC conditions. All but the brigade command and battalion O&I nets were available for digital burst transmission of reports and overlays. There was only one battalion digital net, but there were two battalion voice nets, with company XOs on the O&I voice net.

Seven stand-alone radio-transmitters were used to monitor operational radio nets in the ECR. Six of these were stand-alone SINCGARS simulators. The brigade command net, located at the brigade PVD station, was used by the Battle Master to control the execution of the scenarios and to represent adjacent battalions. During the training and test scenarios, BLUFOR/SAFOR operators used three company nets, the battalion command net, and the battalion O&I net. A battalion command net monitor was located next to the battalion PVD. An additional CB radio at the Battle

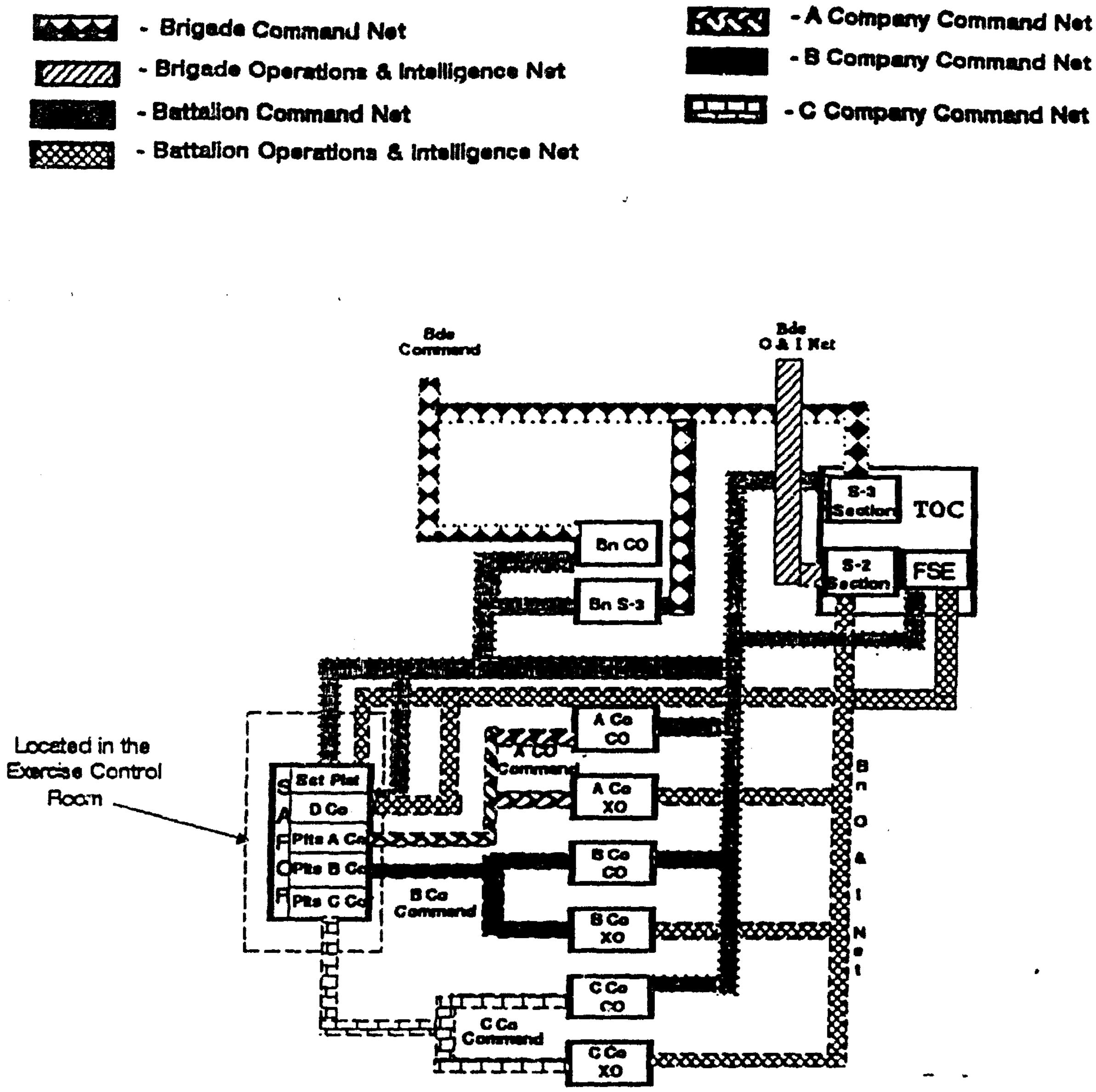

Figure 7. Diagram of the tactical voice radio networks implemented in the battalion evaluation.

Master's position (brigade O&I net) permitted private radio communication between the battalion TOC and the ECR.

During both conditions, radio operators role-played subordinate platoon leaders and the D company commander and XO. SAFOR software routines automatically generated and sent event-driven digital reports to the appropriate company nets in the CVCC condition. These CCD-compatible reports were as follows: CONTACT, SPOT, SITREP, and SHELL reports. The SAFOR reports were generated according to established criteria, including intervisibility and timing, in response to actual events as they occurred on the battlefield. The report generation criteria ensured that response times and number of reports were realistic as well as consistent across test weeks. In the Baseline condition, the same reports appeared on the SAFOR workstation and were then relayed by the radio operator. In both conditions, coordination items (e.g., "Set on objective") were also sent by voice.

Exercise control equipment

The stations controlling the training events, training exercises, and training and test scenarios were located in the ECR. Table 5 lists the control equipment operational during the evaluation.

Table 5

List of Exercise Control Equipment

Equipment	Quantity
Plan View Display (PVD)	2
SINCGARS simulators (stand-alone)	6
CB radio	1
Management, Command, & Control terminal	1
SIMNET Control Console	1
Semiautomated forces (SAFOR) workstation	3
Battalion TOC workstation (CSS)	1
LISTEN station	1

One PVD was used for brigade-level monitoring and one for battalion-level monitoring. The six stand-alone SINCGARS simulators and one CB unit supported administrative control, as well as tactical radio communications. The Management, Command, and Control (MCC) system monitored and controlled the status of the simulators, while a LISTEN station monitored the digital message traffic. The three SAFOR stations (two for BLUFOR/SAFOR and one for OPFOR) supported implementation of all SAFOR activities. A TOC workstation configured as a Combat Service Support (CSS) station allowed digital communication (e.g., transmission of messages and overlays) between the TOC and ECR. The CSS workstation also accommodated the SEND utility for preparing, retrieving from storage, and transmitting electronic reports from higher and adjacent units. Figure 8 depicts the configuration of the ECR during the battalion evaluation. A description of each station and its use can be found in Leibrecht et al. (1993).

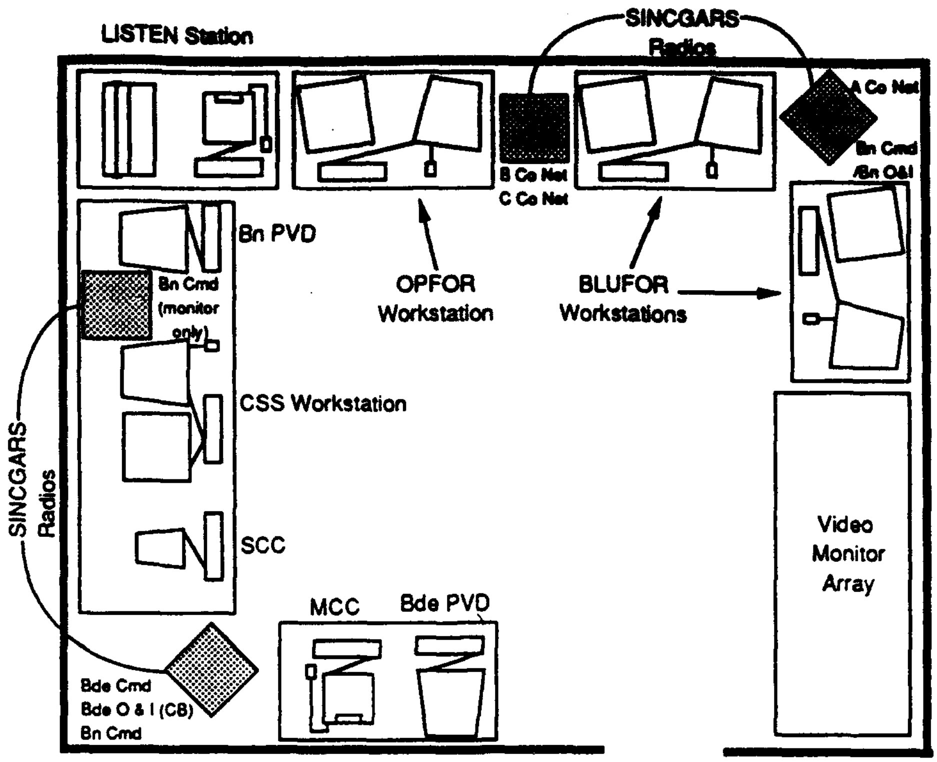

Figure 8. Floor plan of the Exercise Control Room.

Remote communication devices. Each vehicle trainer wore a Maxon 49-HX communicator (walkie-talkie). These communicators operated as single-channel two-way communication devices permitting each vehicle trainer to communicate with the Floor Monitor. The Floor Monitor could pass administrative information such as the status of a breakdown to the vehicle trainers using the walkie-talkies in order to minimize disruptions and sustain operations.

Automated data collection and analysis system. The DCA system provided automated data recording, reduction, management, and analysis capabilities. DataLogger, one of the elements of the DCA system, recorded simulation network data traffic transmitted over the Ethernet in the form of data packets. A variety of data packets were generated by operator-initiated events (e.g., a CCD soft-switch press) or by timed cycles (e.g., periodic vehicle appearance packets conveying location and orientation). DataLogger permitted real-time digital data recording by storing all data packets broadcast by every simulation element on magnetic tape. These recordings were then available for later reduction and analysis. The two PVD stations in the control room were used to embed event flags in the DataLogger recordings. These flags indicated key events such as the start of an exercise, a radio transmission, or crossing the LD (line of departure). CCD report contents as well as voice radio transmissions broadcast over the simulation network were available for subsequent analysis.

DCA capabilities were used to reduce and analyze DataLogger recordings. Special data management software routines extracted data elements from the DataLogger recordings and structured them into intermediate files. These routines defined and labeled the various data packets, enabling the accurate isolation of data elements of interest. RS/1™, an interactive, programmable advanced statistics software package, was used to analyze data from these intermediate files. The RS/1™ software routines were developed mainly during the battalion TOC evaluation (O'Brien et al., 1992a) based on the functional definitions of the measures.

Training and Test Materials

Training Materials

Participant training followed the "crawl-walk-run" approach, beginning with individual training on the use of the various systems and progressing through crew, company, and battalion exercises. The scope of this wide range of activities required a variety of training materials. These included detailed lecture materials for classroom training, outlines and performance-based skills tests for hands-on training, trainer checklists, battalion SOP, navigation aids, and operational exercise-control specifications for unit exercises.

Descriptions of materials for individual and crew training can be found in Atwood et al. (in preparation), and Meade et al. (in preparation) outline the unit training scenarios. The support package for the battalion evaluation (Sawyer, Meade, Ainslie, & Leibrecht, in preparation) contains the actual materials used in the course of this effort, such as lesson plans and briefing charts.

Individual training differed between the two test conditions, with CVCC crewmembers receiving special training in the use of the CCD and CITV. Baseline crewmembers received special training in SIMNET navigation. The training program was designed to ensure equivalence of training for both conditions despite content differences driven by the CVCC condition's experimental equipment.

The battalion SOP was provided in paper form to all crews; a copy appears in Meade et al. (in preparation). Actually an SOP "extract," this document included general guidelines regarding maneuver, engagement, communication and reporting, combat support, combat service support, and command and control. The SOP for both Baseline and CVCC conditions specified the formats to be used for combat reports. The report formats used in the CVCC condition can be found in Appendix E.

During crew training, each crew navigated a designated route, sent tactical reports, identified targets, and engaged enemy vehicles. In the CVCC condition, crews were encouraged to use automated navigation aids and digital reports to meet the training objectives.

The tactical training exercises provided the participants with opportunities to practice using the equipment to accomplish critical C3 tasks during a tactical mission. Three unit training exercises were used in this evaluation: the company situational training exercise (STX), the battalion STX, and the battalion training scenario. These exercises were based on current doctrine and combined typical elements of realistic offensive and defensive combat operations staged on the terrain surrounding Fort Knox, Kentucky. For these exercises, detailed overlays, OPORDs, scenario events lists, SAFOR exercise files, and battalion TOC checkpoint files (CVCC only) were prepared. These materials helped the support staff initialize and execute the exercises in a standardized manner.

Test Materials

Battalion test scenario. The test scenario was developed with the assistance of and approved for use by the Directorate of Combat Developments (DCD), U.S. Army Armor School, Fort Knox, Kentucky. It was executed in three stages: a delay, counterattack, and delay. Table 6 presents an overview of the tactical structure of this scenario. A brief description of each stage can be found in Appendix A on the cover sheet of the RA log. Refer to Meade et al. (in preparation) for a more detailed description of the scenario.

Manual data collection logs. In addition to the DCA's automated data collection capability, various manual data collection instruments were used. Battle Master, PVD, TOC, and RA logs were completed by ECR, TOC, and vehicle monitoring personnel, respectively. These logs were designed for recording observed and reported events, such as crossing PLs or reporting "set" on a battle position (BP), as well as observer assessments or judgments. Sample copies of these logs, except the PVD log, appear in Appendix A. The PVD log, with its focus on events at the company level, was very similar to the Battle Master log which focused on events at the battalion level. Because of the similarity, the PVD log is not included in Appendix A; a copy can be found in Sawyer et al. (in preparation).

Two participant-completed questionnaires were used to capture key information. The Biographical questionnaire was designed to obtain selected background information on demographic variables and military experience. Officers and enlisted personnel completed the same questionnaire, which requested basic information such as rank, military specialty, time in armor units, and experience with various armored vehicles. A copy of this questionnaire can be found in Leibrecht et al. (1993). The Situational Assessment questionnaire was designed to measure a unit or vehicle commander's awareness of his unit's performance as it related primarily to enemy vehicles destroyed and

Table 6

Tactical Structure of the Battalion Test Scenario

Stage	Major Activities
Initial Planning	Mission briefing, planning, leader's reconnaissance
1. Delay to battle positions	
A. Pre-engagement	Set up defense
B. Enemy engagement	Fight two Motorized Rifle Battalions (reinforced)
C. Displacement	Delay to Phase II battle positions
D. FRAGO 1 preparation	Receive brigade FRAGO, plan
2. Counterattack to objective	
A. Pre-engagement	Receive FRAGO, plan, move to objective
B. Enemy engagement	Fight Motorized Rifle Battalion (reinforced)
C. FRAGO 2 preparation	Receive brigade FRAGO, plan
3. Delay to phase line	
A. Pre-engagement	Receive FRAGO, plan, move to battle positions
B. Enemy engagement	Fight two Motorized Rifle Battalions
C. Chemical attack	Delay to subsequent battle positions

casualties sustained. Structured for completion at the end of the test scenario, this instrument asked the participants to recall information, such as the number of tanks destroyed, from the just-completed stage. Appendix A contains a copy of this questionnaire.

Control staff operating rules. To ensure consistent implementation of training and testing exercises, two types of exercise control documents specified the procedural rules for control personnel. The first type included operating guidelines for the ECR and TOC staff. Especially important in the ECR were the SAFOR operating guidelines, including voice radio protocols. The second type, contingency rules, specified the decision process and options for handling technical and personnel problems. These rules helped to ensure contingencies were handled in a consistent manner across test weeks. Copies of the control staff operating guidelines and the contingency rules can be found in Meade et al. (in preparation).

Procedures

This section describes the participant instructions, evaluation schedule, training and test procedures, and data collection and analysis methods. Refer to Atwood et al. (in preparation) for details regarding training procedures, and to Meade et al. (in preparation) for more complete descriptions of the test procedures. A summary of the procedures follows.

General Instructions to Participants

Upon reporting to the MWTB, participants received a classroom briefing to explain the purpose and methods of the evaluation. Each participant received a weekly schedule, and the general requirements regarding their support were discussed. Any immediate schedule conflicts of personnel were addressed with the aid of the battalion commander.

Prior to each training exercise, the battalion received a briefing by the Battle Master. This included training objectives for the session and key milestones: in-simulator time, REDCON-1 time (readiness condition 1, signifying readiness to execute the mission), and mission start time. The Battle Master also provided special instructions for the exercise at hand, such as exercise-specific communication or coordination provisions.

At the beginning of each training and test scenario, the battalion received a brigade OPORD briefing by the Battle Master followed by a battalion OPORD briefing by the battalion XO. These briefings were presented to all participants using the actual OPORD as a guide to ensure standardization across test weeks. View graphs presented the unit's task organization, enemy composition and disposition, operational graphics on map displays, and reporting requirements.

Evaluation Week Schedule

Each evaluation week consisted of a standard sequence of training and testing events. Figure 9 provides an overview of the schedule of events for the CVCC condition; the following sections describe the major events. Copies of all lesson materials are available in the support package for this evaluation (Sawyer et al., in preparation).

The general introduction described the battalion evaluation program and schedule, the evaluation's importance to the Army's long range goals for improving battlefield performance, and the test facilities and general procedures to be followed throughout the evaluation. All participants received this introduction as a group. At the end of the session, each participant completed a Privacy Act statement and the Biographical questionnaire.

A classroom session highlighted major differences between the M1 simulator and the M1 tank. Both Baseline and CVCC vehicle commanders participated. Following this session, the Baseline

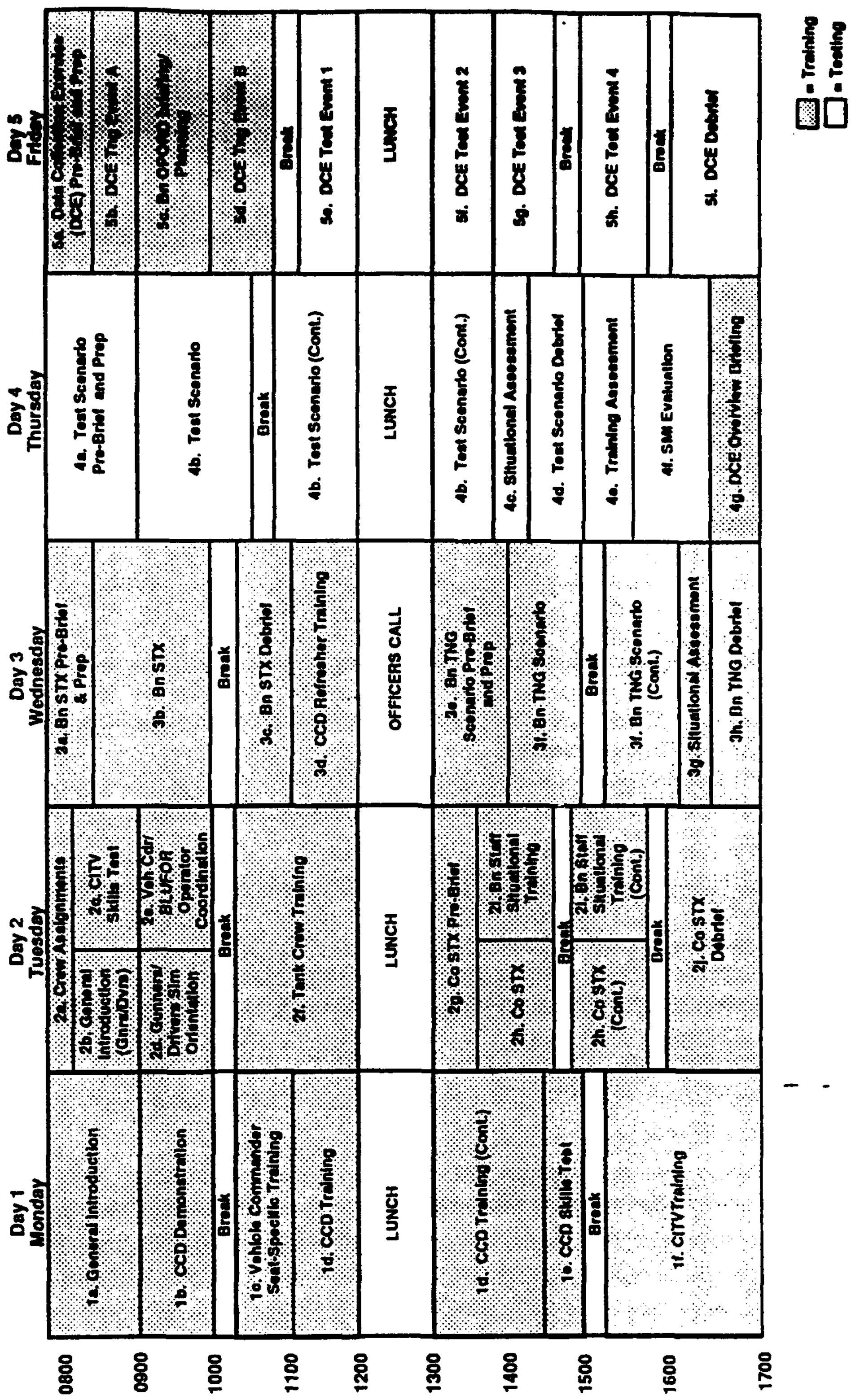

Figure 9. Weekly training and testing schedule for the CVCC condition. (DCEs--Data Collection Exercises--are described in Lickteig, Williams, & Smart, 1992.)

vehicle commanders received training on navigating in the SIMNET environment. This session began with a classroom presentation reviewing conventional navigation procedures, such as polar plotting and resection, plus the special tools available in the M1 simulators--for example, the LRF and grid azimuth indicator. Hands-on training in simulators followed, with participants paired so one drove while the other navigated. Each participant navigated to at least three checkpoints, responding to control staff queries requiring determination of current location or identification of prominent terrain features.

Working one-on-one with commanders in the M1 simulators, vehicle trainers explained the simulator's features during seat-specific training. While the trainers gave a global orientation on most simulator features, they focused on features different from an actual M1's (e.g., the turret-to-hull reference display and the grid azimuth indicator).

CVCC commanders received detailed instruction in operating the CCD and the CITV. CCD training began with a group demonstration of basic functionality, using a large-screen monitor mimicking a working CCD display. An initial classroom session introduced CITV functions and suggested practical uses. Vehicle trainers provided detailed instruction and hands-on practice on the operation of the CCD and CITV, working one-on-one with the CVCC commanders in the M1 simulators. Hands-on training followed a uniform sequence for each function: an explanation of the function's purpose, followed by a step-by-step explanation and demonstration, and ending with practice by the vehicle commander.

At the end of CCD training, and then again at the end of CITV training, vehicle trainers administered skills tests. These tests evaluated each commander's proficiency in operating the special equipment. The vehicle trainer read task instructions to the participant and observed his performance, recording a "Go" or "No-Go" for each task. If necessary, upon completion of the test, the vehicle trainer conducted remedial training until the participant could perform each task.

Gunners and drivers in both conditions received an orientation to the features and functions of their respective simulator crew stations. Vehicle trainers conducted these orientations in the M1 simulators, one trainer working with two gunners or drivers.

Baseline and CVCC commanders received a classroom briefing and orientation to BLUFOR (SAFOR) operation. The briefing explained the coordination required between the commanders and BLUFOR operators who would, in accordance with the mission, intent, and specific directives, control their subordinate forces during tactical execution. It was emphasized that unit commanders in the manned simulators exercised control through immediate directives or FRAGOs. The capabilities and operating characteristics of the SAFOR were addressed in detail, to include

formations, rate of movement, response time, coordination of fires, and engagement criterion. Limitations such as lack of platoon fire commands and inability to split sections were also addressed. At the end of this session there was a brief review of the battalion SOP and the role of company XOs in reporting.

During crew training, Baseline and CVCC crews practiced collective tasks and skills focusing on crew coordination, navigation, and terrain negotiation. Opportunities for initial practice of target identification, target engagement, and combat reporting tasks were also provided. Each crew navigated a six-waypoint route laid out in a 5 km by 5 km terrain square or "sandbox." SAFOR elements provided engagement opportunities and commanders were instructed to send reports based on events encountered during the exercise. When a crew completed its route, its simulator was re-initialized in a new sandbox to negotiate another route. This process continued until the time allotted for the module had expired.

The first unit training exercise consisted of the company STX, designed to provide the company commanders and XOs practice in working with SAFOR platoons. Pre-mission activities for the company STX included an overview briefing by the Exercise Director, an OPORD briefing by the Battle Master, mission preplanning by participants, and a battalion command group briefing conducted by the Exercise Director and battalion XO. Company commanders, XOs and their crews executed the company level missions with minimal involvement of the TOC.

Concurrent with the company STX, the command group--the battalion commander and S3--and the TOC staff practiced working together in parallel with the company STX battlefield activities. Training objectives were to (a) familiarize the command group with TOC capabilities and limitations, (b) provide the TOC staff an opportunity to understand the operating "style" of the commander and S3, and (c) practice providing TOC support to the maneuvering tank companies. As the companies executed their missions, the command group operated strictly as observers, interacting only with the TOC while the Battle Master role-played the commander/S3. This allowed the command group to become familiar with the capabilities and procedures of TOC operations.

The remaining unit training exercises were the battalion STX and the battalion training scenario. Both scenarios consisted of a delay or defense stage followed by a counterattack stage. Preparation and mission execution activities were similar for the two scenarios. During the pre-mission phase, the battalion XO briefed the battalion OPORD and the participants conducted mission planning and preparation, with the TOC staff taking part in coordination and preparation. As part of the mission preparation for the Baseline condition, an execution matrix was provided to the battalion commander and the S3 depicting the phases of the operation and indicating the sequence of activities for each subordinate unit. For the CVCC condition, the execution matrix was replaced with a mission orientation which capitalized on the automated capabilities of the CVCC TOC. The battalion XO "walked through" the operation for the battalion commander, S3, and company commanders on the large-screen display, using sequenced overlays to show anticipated locations and movements. During the battalion training scenario, the pre-mission activities also included a brigade OPORD briefing by the Battle Master and a leader's reconnaissance conducted at the Stealth station for the battalion commander, S3, and company commanders.

During mission execution in the battalion STX and battalion training scenario, all elements in the battalion, including the battalion TOC staff, participated in the exercise. In stage one, the brigade issued a warning order followed by the counterattack FRAGO, which initiated the battalion planning process during the conduct of the defense/delay. Stage two was initiated with the issuance of the battalion counterattack FRAGO. To ensure consistency of the starting conditions, a standardized FRAGO was issued in lieu of the one developed by the commander and staff. The participants were given a brief re-orientation, if required, prior to beginning stage two.

All unit training exercises ended with a group debriefing. Immediately following completion of mission execution, the Battle Master reviewed the training objectives and summarized the sequence of events as they happened in each stage. He pointed out instances in which participants did not act in accordance with the battalion SOP or scenario instructions and described procedures for correcting these discrepancies. The support staff, including TOC staff members, provided feedback regarding issues such as submitting reports, requesting indirect fires, and coordination among units. The Battle Master solicited participants' comments on various aspects of the tactical execution as well as problems in using the equipment. Throughout each debriefing, a support staff member recorded comments made by the participants.

Immediately following the completion of the battalion STX debriefing, both Baseline and CVCC participants received refresher training on key tasks. Baseline crews practiced SIMNET navigation in an exercise similar to the earlier crew training exercise. In the CVCC condition, unit and vehicle commanders received refresher training to reinforce proper use of the CCD. This session began with an abbreviated CCD demonstration highlighting common problems, and concluded with a message processing exercise.

Prior to beginning the battalion training scenario, an "officers call" was held for all commanders. The purpose of this session was to clarify role-playing responsibilities, with special reference to key issues, and to allow research staff members to answer participants' questions. The key issues addressed were: (a) the protection of manned simulators from being killed; (b) the possibility of unrealistically aggressive behavior (dubbed "Rambo" behavior); and (c) the potential for crews to follow friendly SAFOR vehicles instead of navigating on their own. For each of these issues, the basic research concerns were explained, the potential impacts on the evaluation's findings were discussed, and guidelines for role-playing behavior were provided. This session was conducted in an informal manner, with the research staff exercising an "honest-broker" role.

The test scenario followed the same basic sequence as did the battalion training scenario: pre-mission briefings and planning, including a leader's reconnaissance; mission execution; and group debriefing. The battalion executed a tactical scenario with three stages: delay, counterattack, and delay. Stages one and two were similar to their counterpart stages in the battalion training scenario, but force orientation was different. Stage three was a continuation of the delay after completion of the brigade-directed counterattack. The same sequence of events linking stages one and two (i.e., brigade warning order/FRAGO, battalion planning/FRAGO) was also used to accomplish the transition from stage two to stage three. Each battalion was allotted up to 2.25 hours, plus or minus 15 minutes, of actual mission execution time. If the allotted time was not sufficient for a unit to complete all three stages, the Exercise Director terminated mission execution at a tactically logical point.

The battalion test scenario debriefing was conducted in the same manner as the debriefings which concluded the training scenarios. In addition, participants were queried as to techniques they used to accomplish certain tasks, such as target acquisition, IFF, and navigation methods.

Training of Participants

Throughout the course of training, the Exercise Director and other support staff members carefully supervised and monitored all training activities. The training events and their basic procedures were outlined in the preceding subsection, Evaluation Week Schedule. In executing all individual, crew, and unit training exercises, the standard training materials were followed closely to ensure consistency across test weeks. In the simulators, vehicle trainers used scripts and checklists to help standardize training procedures. Equipment and personnel problems were resolved in accordance with the established contingency rules, the goal being to ensure crewmembers developed acceptable levels of proficiency by the end of training.

Individual training was tailored according to the test condition and the participant's role. For all events subsequent to individual training, the exercises and procedures were identical for the Baseline and CVCC conditions. Atwood et al. (in preparation) discuss the individual and crew training procedures in substantial detail, while Meade et al. (in preparation) provide greater detail regarding unit training procedures.

Professional role playing. To ensure realistic performance on the part of the participants, professional role playing was encouraged. Unrealistic behavior had a strong potential to compromise test integrity and skew test results by leading to outcomes such as unrealistic force attrition or tactical maneuvers. As a result, the test support staff monitored participants and implemented corrective action when unrealistic behavior was observed. Feedback to the participants included individual counseling, use of the chain-of-command, and non-attributed examples at the debriefings.

This evaluation utilized a kill-suppress option to protect manned vehicles, which may have contributed to risk-taking behavior. The "officers call," discussed earlier, placed special emphasis on the "Rambo" factor to discourage unrealistic risk-taking.

Scenario Execution

Each scenario was executed according to established control procedures to maintain consistency between conditions and rotations. The battalion TOC staff, role-played by members of the support staff, assisted the battalion commander by preparing tactical overlays, synthesizing critical battlefield information, and maintaining a broad picture of the entire battlefield. While exercise participants could conduct pre-mission planning and coordination in the TOC, they were not permitted to enter the TOC during the exercises. The Battle Master advised the battalion commander that the realistic pace of battlefield activities did not accommodate battalion commander or S3 visits to the TOC. Detailed discussion of the procedures followed in executing and controlling training and test scenarios can be found in Meade et al. (in preparation).

Data Collection

Standard DataLogger procedures were employed in collecting automated data. All test exercises were recorded on magnetic tape for subsequent data reduction and analysis. PVD operators entered flags--electronic event markers--corresponding to key tactical and administrative events. Examples of these events included the start and end points of the scenario, scheduled breaks, significant equipment breakdowns, significant vehicle/unit movement events such as crossing the LD, and selected data elements. The PVD operators recorded specific information related to the flags, as appropriate. The flags and logs were used to break scenario recordings into discrete stages, and to adjust performance measures for unscheduled breaks. PVD logs also served as important sources of data during manual data reduction.

In addition, vehicle monitors completed RA logs for selected vehicles (battalion commander, S3, B company commander, B company XO) in the test scenario. Recorded observations of the participant's behavior included actions such as equipment operation, radio communications, use of paper map and visual display devices, and interactions among crewmembers. The vehicle monitors also recorded observations they felt might help explain unusual performance by a crewmember (e.g., a vehicle commander who complained about lack of sleep after pulling night duty).

Significant departures from established control procedures, as might be necessitated by personnel or equipment problems, were noted on the Battle Master logs and later reviewed by the research staff for impact on the data collected. Where necessary, data reduction or analysis was adjusted to account for departures from planned procedures.

All participants completed Biographical questionnaires at the end of the general introduction. Unit and vehicle commanders completed Situational Assessment questionnaires following completion of the test scenario execution. Additional data collected with the Training Assessment and SMI questionnaires are discussed by Atwood et al. (in preparation). During the debriefings following the training and test scenarios, participants' comments and suggestions were transcribed by test support personnel.

Data Reduction and Analysis

The data reduction and analysis procedures supporting this evaluation were the same as those developed during the battalion TOC evaluation (O'Brien et al., 1992a). A brief summary of the procedures follows.

To protect the privacy of individual soldiers, each participant was assigned a unique number at the start of the evaluation. This number was used in place of the individual's name on all data collection instruments, except for the Biographical questionnaire. This numbering system identified individual cases in all database activities.

Reduction and analysis of data proceeded through four steps: database management (data entry and quality control [QC]), data reduction, descriptive analyses, and inferential analyses. The first two steps of this sequence were tailored for automated and manual data, respectively. Each step is summarized below.

Database management. To organize the manually collected data, a set of database management system (DBMS) files was created. Individual files were created for each manual data collection instrument--for example, the Biographical questionnaire. Test support personnel entered data into these files using dBASE III+™ customized data entry screens on a personal computer. (dBASE III+ is a registered trademark of Ashton-Tate, Inc.) Quality control procedures were implemented to verify the accuracy of data entry, using 100% review of print-outs.

In the case of automated data collected by DataLogger, DCA data management routines extracted raw data from magnetic tapes recorded during the test scenario, and RS/1™ organized the resulting data into files. Research team members reviewed descriptive summaries of these files, checking for out-of-range or inconsistent data. These files provided intermediate data for the reduction process described in the following section.

Data reduction. Test support personnel used playback of radio communications recorded during execution of the scenarios to transcribe individual voice transmissions. Transcription was accomplished for all Baseline and CVCC test weeks. Working as a team, two test support personnel listened to one radio net at a time while observing tactical progress on a PVD. A complete, literal transcription was recorded, playing through individual transmissions as many times as necessary to verify what was said. A time stamp was obtained for each transmission. Once playback of radio traffic was complete, test support personnel reduced the data for selected measures (e.g., counts of voice radio messages, voice report transmission time, consistency of voice transmitted FRAGOs) using manual data reduction forms. Data reduction forms guided the data reducer carefully through each step, and test personnel received training in using these forms. Experienced behavioral scientists on the test support team spot-checked the data reduction forms, then the data were directly entered into DBMS files for subsequent analysis.

To reduce the automated data, data packets from the DataLogger-recorded files established during creation of the automated database were combined by RS/1™ to produce specified measures. The data elements defined for each performance measure were used to set up the DCA analysis routines. This lengthy process resulted in a set of American Standard Code for Information Interchange (ASCII) files containing DataLogger-based data for all test weeks.

Descriptive analyses. Prior to analyzing manual and automated data, procedures for accommodating missing and contaminated data were applied. Missing data may have resulted from a unit's failure to complete the test scenario due to equipment failures or participant absences. Also, participants occasionally skipped a question on a questionnaire. Contaminated data could be produced by equipment malfunctions or crew adjustments due to participant absences. The general rule for handling both missing and contaminated data was to code the affected values as missing, resulting in unequal sample sizes across cells and across measures.

The Statistical Package for the Social Sciences for the IBM Personal Computer (SPSS/PC+™, V2.0) was used for all descriptive data analyses. (SPSS/PC+ is a registered trademark of SPSS Inc.) The REPORT procedure computed means, medians, and standard deviations. The CROSSTABS procedure generated frequency distributions, including percent response breakouts for questionnaire items. Other procedures included MEANS and COMPUTE.

__Inferential analyses__. To test performance effects, parametric analyses of most individual measures were accomplished using SPSS' univariate ANOVA--Analysis of Variance--procedures (SPSS Inc., 1988). Sometimes performance measures for individual stages were analyzed using *t*-tests (Bruning & Kintz, 1968). Occasionally, nonparametric analyses were performed using chi-square or Mann-Whitney tests (Siegel, 1956). A probability level of .05 or less (one-tailed for *t*-tests and Mann-Whitney tests) was required for an effect to be considered statistically significant.

The principal independent variables guiding these analyses were: condition, a between-subjects variable with two levels, CVCC and Baseline; echelon, a between-subjects variable with two levels, battalion and company; and stage, a within-subjects variable with three levels. In computing *F*-ratios for stage, a pooled error term was used because of the general de-emphasis on performance differences between stages. Contaminated and missing data were treated as simple missing cases, with no values being estimated by cell means, grand means, etc. No special procedures were used to adjust for the resulting unequal sample sizes.

Performance Measures

This subsection explains the set of measures developed to quantify the performance impact of the CVCC system, including the hypotheses and the structure organizing them.

As discussed earlier in the Design of the Evaluation section, the research issues spanned command and control, tactical maneuver, fire support, and intelligence activities. The measures supporting this evaluation quantified a comprehensive cross-section of unit performance. The measurement categories encompassed tactical movement and navigation, target acquisition and engagement, control of terrain, gathering and processing of battlefield information (enemy and friendly), situational assessment, and usage of equipment.

The current set of performance measures was derived from the battalion TOC evaluation (O'Brien et al., 1992a). In turn, the measures used in the battalion TOC evaluation were based on measures from earlier CVCC efforts (e.g., Du Bois & Smith, 1989, 1991; Leibrecht et al., 1992; Quinkert, 1990). Thus, this current set of performance measures was built on preceding CVCC efforts, based on the results of data analysis and lessons learned. The process followed in developing the measures has been documented by Leibrecht et al. (1993).

Organization of Measures

The operational issues underpinning the evaluation have been presented in the Design of the Evaluation section of this report. Based on four BOSs from the Blueprint of the Battlefield (U.S. Department of the Army, 1991), these operational issues provided the foundation for organizing hypotheses to describe the expected differences between the CVCC and Baseline conditions. In general, hypotheses were linked to specific combat functions under each BOS. The operational issues and hypotheses follow.

Issue 1: Does the CVCC system enhance the Maneuver BOS? The CVCC system's CITV, steer-to display, and tactical map with own vehicle and friendly vehicle icons plus overlays were expected to provide an overall advantage for a subset of Maneuver BOS functions.

Hypotheses 1.1 through 1.5, respectively, stated the CVCC units' performance on the battlefield was expected to be significantly better than the Baseline units' regarding the ability to: (a) move on the surface; (b) navigate; (c) process direct fire targets; (d) engage direct fire targets; and (e) control terrain.

Issue 2: Does the CVCC system enhance the Fire Support BOS? Only a very limited subset of the Fire Support BOS was addressed in this evaluation. The inputting of target location grids by lasing or touching the tactical map combined with the CCD's digital messaging capability was expected to provide an advantage for fire support functions under the CVCC condition.

Hypothesis 2.1: The CVCC units' ability to process ground targets for indirect fire on the battlefield was expected to be significantly better than the Baseline units.

Issue 3: Does the CVCC system enhance the Command and Control BOS? The CVCC's enhanced features, including digital report capabilities and the tactical map with digital overlays, were expected to improve command and control performance.

Hypotheses 3.1 through 3.3, respectively, stated the CVCC units' performance on the battlefield was expected to be significantly better than the Baseline units' regarding the ability to: (a) receive and transmit the mission; (b) receive and transmit enemy information; and (c) receive and transmit friendly troop information.

Hypotheses 3.4 and 3.5 stated the CVCC unit leaders' performance on the battlefield was expected to be significantly better than the Baseline unit leaders' regarding the ability to: (a) manage means of communicating information; and (b) direct and lead subordinate forces.

A related hypothesis stated that the CVCC unit leaders' performance on the battlefield was expected to be significantly better than the Baseline unit leaders' regarding the ability to assess the battlefield situation.

Issue 4. Does the CVCC system enhance the Intelligence BOS? The advantages provided by the CVCC system for gathering enemy information using the tactical map, such as inputting enemy locations by lasing or touch, and digital reporting via the CCD were expected to allow CVCC groups to outperform Baseline groups in collecting threat information.

Hypothesis 4.1: The CVCC unit leaders' ability to collect threat information on the battlefield was expected to be significantly better than the Baseline units'.

List of Measures

Table 7 presents the operational measures supporting the four BOSs, organized by the individual hypotheses within each BOS. Hypotheses were stated in the preceding subsection. The measure numbers used in Table 7 correspond to the numbering system used in Appendix B.

The operational definitions for the basic set of measures were developed during the battalion TOC evaluation and have been documented by O'Brien et al. (1992a). The definitions of several measures have changed since the battalion TOC evaluation, and a number of new measures have been developed. Appendix B contains operational definitions for the modified and new measures. In addition, Appendix B includes a sampling of unchanged measures to ensure each BOS is represented. The sampling approach in Appendix B, in lieu of listing definitions for all measures, was chosen to avoid unnecessary redundancy across reports.

Table 7

Performance Measures by Battlefield Operating Systems (BOSs) and Functions

Numbers	Measure Titles
	MANEUVER: MOVE ON SURFACE
1.1.1	Distance between BLUFOR and OPFOR center of mass
1.1.2	Time to reach line of departure
1.1.3	Exposure index
1.1.4	Range to OPFOR at displacement
1.1.5	Time for companies to reach objectives

(table continues)

(Table 7 continued)

Numbers	Measure Titles
	MANEUVER: NAVIGATE
1.2.1	Distance travelled
1.2.2	Fuel used
1.2.3	Mean time out of sector/axis
1.2.4	Mean time misoriented
1.2.5	Time to complete stage
	MANEUVER: PROCESS DIRECT FIRE TARGETS
1.3.1	Time to acquire targets
1.3.2	Time between lases to different targets
1.3.3	Time from first lase to first fire
1.3.4	Maximum lase range
1.3.5	Number of fratricide hits by manned vehicles
1.3.6	Number of fratricide kills by manned vehicles
	MANEUVER: ENGAGE DIRECT FIRE TARGETS
1.4.1	Percent of OPFOR killed by end of stage
1.4.2	Percent of BLUFOR killed by end of stage
1.4.3	Losses/kill ratio
1.4.4	Mean target hit range
1.4.5	Mean target kill range
1.4.6	Percent OPFOR vehicles killed by all manned vehicles
1.4.7	Hits/round ratio, manned vehicles
1.4.8	Kills/hit ratio, manned vehicles
1.4.9	Kills/round ratio, manned vehicles
1.4.10	Number of manned vehicles sustaining a killing hit
1.4.11	Number of rounds fired by manned vehicles
1.4.12	Number of OPFOR vehicles killed south of PL King
1.4.13	Number of OPFOR vehicles killed south of PL Club
1.4.14	Number of OPFOR vehicles killed south of PL Queen
1.4.15	Number of OPFOR vehicles killed south of PL ACE
	MANEUVER: CONTROL TERRAIN
1.5.1	Number of OPFOR vehicles penetrating designated line (counterattack)
1.5.2	Was the battalion bypassed by the OPFOR?
1.5.3	Number of OPFOR vehicles penetrating designated line (delay)
1.5.4	Number of OPFOR vehicles that crossed PL Queen

(table continues)

(Table 7 continued)

Numbers	Measure Titles
	FIRE SUPPORT: PROCESS GROUND TARGETS
2.1.1	Mean accuracy of CFF locations
2.1.2	Percent of CFFs with correct type
	COMMAND AND CONTROL: RECEIVE AND TRANSMIT MISSION
3.1.1	Elapsed time from battalion transmission of FRAGO to receipt by company commander/XO
3.1.2	Duration of requests by company commander/XO to clarify FRAGO/overlay
3.1.3	Consistency of FRAGO received
3.1.4	Number of requests by company commander/XO to clarify FRAGO/overlay
	COMMAND AND CONTROL: RECEIVE AND TRANSMIT ENEMY INFORMATION
3.2.1	Time to transmit INTEL report full net
3.2.2	Consistency of INTEL received
3.2.3	Number of requests to clarify INTELs
	COMMAND AND CONTROL: RECEIVE AND TRANSMIT FRIENDLY TROOP INFORMATION
3.3.1	Mean time to transmit SITREP full net
3.3.2	Mean duration of voice transmissions between battalion commander/S3 and TOC
3.3.3	Deviation of BLUFOR location reported in SITREP from actual location
3.3.4	Delay between observed phase line or line of departure crossing and reported crossing
3.3.5	Delay between observed battle position arrival and reporting SET at battle position
3.3.6	Elapsed time from request for fuel and/or ammunition report until received by battalion TOC (Baseline only)
3.3.7	Number of voice transmissions between battalion commander/S3 and TOC

(table continues)

(Table 7 continued)

Numbers	Measure Titles
	COMMAND AND CONTROL: MANAGE MEANS OF COMMUNICATING INFORMATION
3.4.1	Average length of voice radio transmissions
3.4.2	Total number of voice radio transmissions
3.4.3	Total time on voice radio network
3.4.4	Number of named voice reports
	COMMAND AND CONTROL: DIRECT AND LEAD SUBORDINATE FORCES
3.5.1	Did Task Force prevent decisive engagement?
3.5.2	Did the battalion withdraw intact?
3.5.3	Number of counterattacking companies engaging OPFOR
3.5.4	To what extent did the battalion meet the brigade commander's intent?
3.5.5	Battalion command effectiveness composite index
	COMMAND AND CONTROL: ASSESS SITUATION
SA1.1	During the last stage, *how many* OPFOR tanks did your company or battalion destroy?
SA1.2	During the last stage, how many BMPs did your company or battalion destroy?
SA1.3	During the last stage, did your company or battalion destroy any enemy vehicles after the order to delay was given?
SA1.4	During the last stage, how many tanks in your company or battalion were destroyed?
SA1.5	During the last stage, how far was your initial battle position from your subsequent battle position?
SA1.6	Composite situational assessment index
	INTELLIGENCE: COLLECT THREAT INFORMATION
4.1.1	Accuracy of SPOT report locations
4.1.2	Correctness of SPOT report number and type
4.1.3	Accuracy of SHELL report locations
4.1.4	Accuracy of CONTACT report locations
4.1.5	Percent CONTACT reports with correct type

Methodological Limitations

A number of methodological limitations stemmed from the simulation technology itself, from certain design choices, and occasionally from implementing procedures. These limitations, which may have impacted the evaluation's results and their interpretation, included the following:

1. Limited CIG processing capacity, resulting in occasional loss of vision block imagery, especially for the driver.

2. Inability to conduct open hatch operations, which, together with limited visibility through the vision blocks, constrained the vehicle commander's view of the battlefield and complicated navigation.

3. Limited gunnery capabilities resulting from simplified visual fidelity of the M1 simulator's out-the-window views and unrealistic implementation of automatic target lead functionality.

4. Absence of some M1 components, including the GAS, the MRS, machine guns, and on-board smoke grenades.

5. Limited fidelity of the dynamic battlefield environment, including a zero-motion platform, lack of dynamic terrain, absence of weather variations and atmospheric degradations, and limited representation of combat noises.

6. Digital transmission directly via the Ethernet instead of the RIU (radio interface unit), resulting in near-zero transmission times and error-free reception of digital reports and overlays.

7. The relatively horizontal allocation of actual crews, leaving only SAFOR elements operative below the company XO level. This limited the ability to study transmission of reports across echelons. Because of this limitation, the fifth day of testing in this evaluation put the battalion through a series of Data Collection Exercises with four of the crews reallocated to form a complete manned platoon (Lickteig et al., 1992).

8. Radio net differences between the voice and digital networks, such that the CVCC-equipped company XOs had a digital battalion command net instead of a digital O&I net.

9. Potential distractors to crewmembers' realistic role-playing, such as the use of kill suppress to protect manned vehicles and the option for vehicle commanders to follow SAFOR vehicles instead of navigating on their own.

10. Unrealistic behavior of SAFOR vehicles, including perfect identification of targets, limited maneuver options, unrealistic fire control and distribution, and the absence of electronic signatures and electronic countermeasures.

These limitations may have impacted specific measures of performance. For example, the radio net differences between the voice and digital networks available to the company XOs made it difficult to compare selected aspects of communications between the two conditions, such as time to transmit INTEL reports and FRAGOs. As another example, bypassing the RIU led to unrealistically short digital transmission times, especially for overlays. Potential impacts on specific measures of performance will be discussed as data are presented in the Results and Discussion section. It is worth noting that most of the limitations applied equally to the Baseline and CVCC conditions, so they should not have influenced performance differences between the two conditions. During the course of training the limitations were explained to participants in both conditions, and they were encouraged to ask questions about any procedural aspect.

As with other distributed interactive simulation evaluations, the methodological limitations, including those common to both conditions, constrain the generality of the results of the evaluation. For example, target engagement performance in this evaluation cannot be considered representative of actual tank battalion gunnery performance, because of the simplified modeling of target acquisition and fire control functionality. As another example, the absence of actual crews below the company XO level may have limited the flow of information within the battalion. Thus, the reader should exercise caution when attempting to apply this evaluation's findings to other environments, including actual combat.

Results and Discussion

This section describes and discusses the results of the evaluation, with emphasis on the battalion's operational effectiveness as well as performance of unit commanders and company XOs. General considerations lead the presentation of data, including an examination of the comparability of the independent samples assigned to the Baseline and CVCC conditions.

With its focus on operational effectiveness, this report presents only part of the results from the battalion evaluation. Atwood et al. (in preparation) document the results pertaining to training and SMI issues, with a focus on questionnaire-based data and equipment usage measures. Meade et al. (in preparation) discuss operational performance with special emphasis on the potential impact on armor tactics, techniques, and procedures. The reader is encouraged to review all three reports for a complete account of the evaluation's findings and their implications.

To assess how well the Baseline and CVCC participants were matched in terms of basic qualifications, key data from the Biographical questionnaire were examined. Detailed profiles for each group appear in Appendix F. Rank as well as active duty experience levels (both armor and non-armor) were comparable for unit and vehicle commanders. However, active duty experience was significantly greater for Baseline gunners and drivers than for their CVCC counterparts. This difference in favor of the Baseline NCOs and enlisted personnel extended to military schooling, including Basic/Advanced NCO Course attendance. The difference might have influenced target engagement and navigation performance, possibly conferring a relative advantage on the Baseline battalions. At the same time, crews were generally not used to working together, and the training which they received during the test week should have been a levelling factor, to some degree. Given the evaluation's focus on C3 processes and the central role of the unit and vehicle commanders, the experience differences between the Baseline and CVCC gunners and drivers are not considered a major factor.

The measures of performance supporting this evaluation have been listed in the earlier Performance Measures subsection of this report. O'Brien et al. (1992a) defined the basic set cf measures, but several definitions have changed since the battalion TOC evaluation and a number of new measures have been developed. Appendix B presents the definitions for the modified and new measures, along with selected measures chosen to provide an across-the-board sampling by BOS.

Circumstances in executing the evaluation occasionally led to missing data. Two Baseline battalions and one CVCC battalion completed only part of Stage 3 of the test scenario, eliminating many of the Stage 3 measures for those units. The CVCC battalion missing the S3 crew generated data for only seven of the eight planned crews. During the Baseline week when the S3 crew operated with no gunner, target acquisition and engagement measures for that crew were excluded from the analyses. Occasional equipment difficulties also led to dropping impacted measures from the database. In addition, some measures were defined around events which could occur with variable frequency. Consequently, sample sizes in data tables vary, sometimes substantially.

In interpreting the results presented in this report, the reader should keep in mind the evaluation's limitations. Some of these limitations (e.g., closed-hatch operations only) stemmed from the simulation technology constraints in effect during the evaluation. Other limitations resulted from the evaluation's design, such as allocating crews to positions no lower than company XOs. The implications of the major methodological limitations have been discussed at the end of this report's Method section.

The outcomes of statistical analyses (ANOVAs, *t*-tests, Mann-Whitney tests, etc.) are presented strictly in summary form in this section. A probability level of .05 or less (one-tailed for *t*-tests and Mann-Whitney tests) is required before an effect is considered statistically significant. Appearing in Appendix C are tables completely characterizing the distributions of data. ANOVA summary tables (SPSS output) appear in Appendix D.

The presentation of performance data which follows is organized according to the research issues outlined in this report's Method section (Performance Measures subsection). The sequence within each issue's subsection follows the hypotheses supporting that research issue. Each subsection concludes with a summary of key findings.

Maneuver BOS

Issue 1: Does the CVCC system enhance the Maneuver BOS?

Given the CVCC system's automated navigation and CITV capabilities, the expected impacts on maneuvering and engaging the enemy on the battlefield were extensive. Several hypotheses organize the data related to the Maneuver BOS, according to the following BOS-based functions: (a) Move on Surface, (b) Navigate, (c) Process Direct Fire Targets, (d) Engage Direct Fire Targets, and (e) Control Terrain. The Performance Measures subsection of this report lists the measures used to quantify performance under these functions.

The results for several measures developed under the Maneuver BOS are not presented, due to the fact that the measures produced nearly all zeros. These measures include mean time out of sector/axis, mean time misoriented, number of fratricide hits by manned vehicles, and number of fratricide kills by manned vehicles.

Move on Surface

Hypothesis 1.1: The CVCC units' ability to move on the surface of the battlefield was expected to be significantly better than the Baseline units'.

Summary data (means and standard deviations) for the measures supporting this hypothesis appear in Table 8. The results for each measure are discussed in sequence, then key data are summarized at the end of the subsection.

Distance between BLUFOR and OPFOR center of mass (CoM). Designed for the defensive missions (Stages 1 and 3), this measure was defined to quantify the battalion's success in preventing the enemy force from closing on them as they delayed back. The ability to control the battalion's movement so as to maintain contact yet limit exposure to enemy fire was central to executing the delay missions in accordance with the brigade commander's intent. Subsequently the measure was extended to the offensive mission (Stage 2), since that mission ended with a defense of the newly occupied objectives. Akin to stand-off distance, the key to this measure was the separation between adjoining BLUFOR and OPFOR company-sized units upon completion of the mission. The distance between each BLUFOR non-reserve

Table 8

Mean Performance Data for Move on Surface Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Distance between BLUFOR and OPFOR CoM (meters)	5207.3 (844.3) n=6	3234.8 (607.4) n=6	2553.0 (659.9) n=6	2349.2 (316.9) n=6	3043.0 (1090.3) n=5	2768.5 (845.4) n=4
Range to OPFOR at displacement (meters)	2836.5 (564.4) n=6	2607.2 (392.6) n=5	NA	NA	2369.8 (404.9) n=5	2251.0 (451.9) n=4
Time to reach LD (minutes)	NA	NA	19.43 (4.56) n=6	24.84 (5.79) n=6	NA	NA
Time to reach objectives (minutes)	NA	NA	29.42 (4.53) n=6	36.35 (5.71) n=6	NA	NA
Exposure Index						
Bn Echelon	9.06 (11.0) n=11	15.10 (12.6) n=12	6.60 (4.7) n=11	6.41 (4.2) n=12	14.57 (11.5) n=9	10.11 (10.2) n=8
Co Echelon	4.12 (6.5) n=36	4.60 (5.9) n=35	4.02 (3.0) n=34	4.57 (2.8) n=31	9.17 (10.8) n=30	8.26 (10.9) n=23

Note. Standard deviations appear in parentheses below the means. NA = Not applicable.

company's CoM and the CoM of its nearest OPFOR company was computed at the point when the last OPFOR firing occurred. CoM was defined as the arithmetic mean of the company vehicles' x-y plots, including dead vehicles, within 500 m. The average of the three non-reserve companies' values was computed to yield a battalion-level measure. Larger values signified better unit performance, with the CVCC capabilities expected to enable the battalion to better control its movement in relation to the enemy forces while delaying.

From Table 8, means for this measure are displayed graphically in Figure 10. In all three stages, the average end-of-engagement distance separating BLUFOR and OPFOR companies was greater in the CVCC condition than in the Baseline condition. The effect of condition was significant ($F(1, 27) = 11.17$, $p=.002$), as was the effect of stage ($F(2, 27) = 18.19$, $p<.001$). The condition by stage interaction was also significant ($F(2, 27) = 5.19$, $p=.012$). Differences between stages (greater distances in Stage 1 and smaller in Stage 2, compared to Stage 3) most

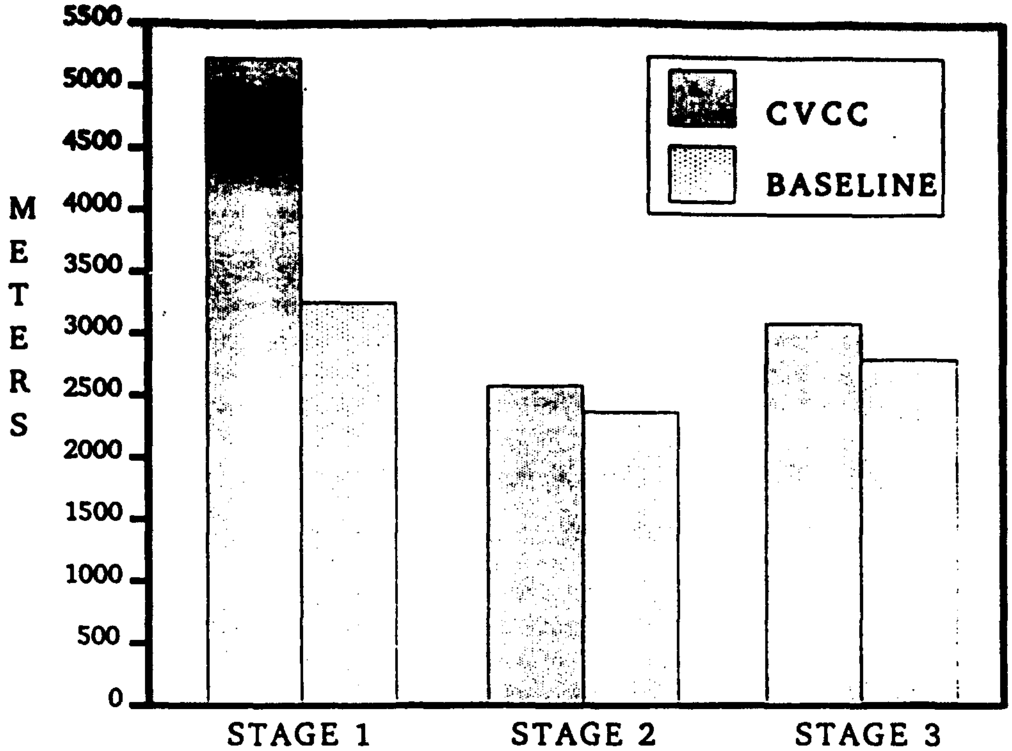

Figure 10. Mean end-of-stage distance between BLUFOR and OPFOR center of mass.

likely resulted from the tactical differences built into the test scenario, including the offensive nature of Stage 2. The condition by stage interaction (due mainly to the more substantial difference between conditions in Stage 1) can be explained by the fact that the CVCC commanders generally chose to pull back further in completing their delay, perhaps indicating greater confidence in their abilities to navigate and "see" the battlefield.

These results show that the CVCC-equipped battalions did a better job of controlling their movement while delaying, thus resulting in less risk of receiving hostile fire. This was a major factor in meeting the brigade commander's intent, as expressed in the OPORD for the test scenario. In the counterattack mission, the CVCC battalions were able to keep the enemy force at a greater stand-off distance, again reducing the risk of attrition due to enemy fire.

<u>Range to OPFOR at displacement (Stages 1 and 3 only)</u>. The unit and vehicle commanders were given standard instructions, representing the commander's intent, to displace during delay missions when a company-sized OPFOR element approached within 2000 m of a BLUFOR company's position. The reason for this was to avoid becoming decisively engaged. This measure was designed to quantify how well the company commanders were able to apply

this criterion in requesting/executing their unit displacement. The linear distance between each BLUFOR non-reserve company's CoM and its nearest OPFOR company's CoM was computed at the time the battalion displacement began, then was averaged across companies. Appendix B presents the definition of this measure. For the conditions of this evaluation, longer distances generally corresponded to better performance.

In both delay stages, as seen in Table 8, the average displacement ranges were greater for CVCC-equipped companies. However, this trend was not significant. The effect of stage was not significant, nor was the condition by stage interaction. Because of the attrition of two Baseline units in Stage 3, the data for Stage 1 alone were analyzed using a *t*-test; again the difference between conditions was not significant.

The lack of significant differences between conditions contrasts with the results of earlier research at the company level (Leibrecht et al., 1992). In that study, the advantage of the CVCC-equipped units was significant. The measure used in the company evaluation was based on the closest friendly and enemy vehicles, whereas the measure in this evaluation was based on the closest companies' CoMs. This measurement difference may account for the discrepancy in findings between the two company and battalion evaluations.

Time to reach line of departure (Stage 2 only). During the counterattack mission (Stage 2), the battalion was given a target time to arrive at the LD (15 minutes following issue of the FRAGO). To ensure synchronization of all BLUFOR companies, the ideal was to reach the LD precisely at the designated time. This measure was computed as the time elapsed from REDCON-1 to the point when the first BLUFOR vehicle crossed the LD.

The data (see Table 8) show that CVCC battalions were more successful in reaching the LD at the designated time. For the CVCC condition, elapsed times ranged from 13.3 to 24.0 minutes with a mean of 19.43 minutes (standard deviation (*SD*) = 4.56 minutes). Among Baseline battalions, elapsed times ranged from 16.4 to 31.6 minutes, averaging 24.84 minutes (*SD* = 5.79 minutes). A *t*-test revealed the difference between conditions was not significant. However, an important aspect of these data is the fact that CVCC units, overall, were closer to the target time and more consistent in their performance, arriving between 1.7 minutes early and 9 minutes late. In contrast, Baseline units were always late, ranging from 1.4 to 16.6 minutes later than the designated time and showing greater variability of performance.

The better performance of the CVCC units on this measure most likely relates to the CVCC's POSNAV and automated navigation capabilities, designed to enhance maneuver during execution. It also appears related to the *ad hoc* finding that those units reached REDCON-1 more quickly than their Baseline cohorts. Among CVCC battalions, time to report REDCON-1 averaged 7.82 minutes

(*SD* = 5.28, range 3.1-12.5 minutes). In the Baseline condition, the corresponding parameter averaged 17.28 minutes (*SD* = 9.61, range 13.5-23.9). The difference between conditions was significant ($t(7) = 2.36$, $p<.05$). The CVCC units' faster establishment of readiness to execute the mission was no doubt the result of more rapid transmission of the FRAGO and greater clarity, discussed later in the Command and Control BOS subsection.

Time for companies to reach objectives (Stage 2 only). Used for the offensive stage only, this measure captured the time taken to accomplish the primary portion of the battalion's mission in the counterattack. In addition to transit time, the measure included the time required to organize the unit on the objective and report "set." It was computed as an average across the three non-reserve BLUFOR companies. As a reflection of speed in executing the counterattack, shorter times defined better performance.

Mean time to reach the company objectives was shorter in the CVCC condition, as can be seen in Table 8. On the average, CVCC-equipped battalions completed the primary mission in 29.42 minutes (*SD* = 4.53, range 23.9-36.4 minutes), compared to an average of 36.35 minutes for the Baseline condition (*SD* = 5.71, range 29.8-45.1 minutes). The difference between conditions was significant ($t(10) = 2.12$, $p<.05$). In addition, the smaller standard deviation for the CVCC condition indicated greater consistency of performance. The better performance of the CVCC units is consistent with data for the preceding measure and is largely attributable to better maneuver control afforded by the mutual POSNAV and automated navigation capabilities.

Exposure index. As a vehicle is exposed to more enemy vehicles, the risk of being engaged rises. By using maneuver principles based on knowledge of enemy positions, a key to survival is to reduce the direct exposure (i.e., intervisibility) to enemy vehicles capable of delivering hostile fire. The exposure index was developed to quantify a vehicle's risk of enemy-initiated engagement. The definition of this measure appears in Appendix B. Following initial intervisibility with an enemy vehicle, a count of all intervisible enemy vehicles was obtained for each manned vehicle every 30 s until the first main gun firing by the company or command group. All counts from the sample period were averaged to yield a single value per manned vehicle. For this measure, smaller values were desirable.

As Table 8 shows, there were no consistent differences between the CVCC and Baseline conditions. The effect of condition was not significant. The most striking feature of these data was the consistently higher mean exposure index for battalion echelon vehicles, seen in both conditions. The echelon effect was significant ($F(1, 240) = 17.36$, $p<.001$), as was the effect of stage ($F(2, 240) = 8.09$, $p<.001$). None of the two-way interactions was significant, nor was the three-way interaction.

The higher mean exposure index for battalion echelon vehicles was unexpected, because it was assumed the battalion commander and S3 would generally position themselves to the rear of the companies, exposing them to fewer enemy vehicles. However, the battalion commander and S3 were frequently seen in the midst of company formations, and may have been more inclined to position themselves with companies in contact. Further, they may have begun firing later than the company commanders and XOs. These factors would have elevated their exposure index counts. These issues warrant future investigation, as increased exposure of battalion echelon vehicles would be of tactical concern.

The significant effect of stage reflected largely a lower exposure index in the counterattack mission. This most likely resulted from the lower density of enemy vehicles during the bulk of Stage 2.

Summary of key data. The data supported the hypothesis that the CVCC capabilities would enhance the battalion's ability to move on the surface. CVCC-equipped units ended each stage at greater distances from the enemy, better meeting the brigade commander's intent. The end-of-stage stand-off data indicated the CVCC battalions were better able to control their movement during delay operations and to keep the enemy at safer ranges. Greater control of movement among CVCC units was reflected in more consistent timing of key battle milestones, particularly the time taken to reach the LD and the objectives in Stage 2.

Navigate

Hypothesis 1.2: The CVCC unit's ability to navigate on the battlefield was expected to be significantly better than the Baseline units.

Table 9 presents the summary data--means and standard deviations--associated with this hypothesis.

Distance travelled. Because of the CVCC's POSNAV and automated navigation capabilities, it was anticipated that CVCC-equipped battalions would be able to navigate more accurately and avoid being lost or misoriented. Accordingly, crews in the CVCC condition were expected to travel less distance, overall, in accomplishing the mission. See Appendix B for the definition of this measure.

Table 9 displays the mean data for distance travelled. The reduction expected for CVCC units materialized only in Stage 2 (counterattack). The condition effect was not significant, nor was the echelon effect. At the same time, the effect of stage was significant ($F(2, 255) = 32.31$, $p<.001$), due apparently to scripted tactical differences between stages. Although the patterns in Stages 1 and 3--generally greater distances for CVCC battalions--differed from Stage 2, the condition by stage interaction was not significant, nor were the other interactions. Analysis of Stage 2 data alone still revealed no significant

Table 9

Mean Performance Data for Navigate Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Distance travelled (meters)						
Bn Echelon	13517.8 (7352.1) n=11	13512.3 (8171.9) n=12	7455.6 (3341.9) n=11	8509.5 (3114.2) n=12	8006.0 (2585.3) n=10	6550.5 (2394.8) n=8
Co Echelon	13378.9 (5083.2) n=36	11270.2 (4062.7) n=36	9597.2 (2521.8) n=35	10044.0 (2823.8) n=36	9037.3 (3242.2) n=30	7525.5 (2514.2) n=23
Fuel used (gallons)						
Bn Echelon	20.74 (8.23) n=11	22.91 (10.90) n=12	12.63 (3.78) n=11	16.29 (4.74) n=12	14.87 (3.09) n=10	12.64 (3.11) n=8
Co Echelon	20.22 (6.89) n=36	18.99 (5.77) n=36	17.53 (8.92) n=35	16.18 (4.84) n=36	15.04 (5.09) n=30	12.29 (3.68) n=23
Time to complete stage (minutes)	67.52 (4.34) n=6	73.95 (7.11) n=6	41.46 (3.95) n=6	52.40 (9.72) n=6	**	**

Note. Standard deviations appear in parentheses below the means.

Double asterisks (**) indicate data are excluded because of bias introduced by attrition of Baseline units.

difference between conditions, although the effect of echelon was significant ($F(1, 90) = 7.31$, $p=.008$). The condition by echelon interaction was not significant.

Several factors are important in comparing the CVCC and Baseline conditions with respect to these data. CVCC-equipped battalions frequently chose to withdraw farther back in executing both delay missions (Stages 1 and 3) than did their Baseline counterparts. This may have reflected greater confidence in their navigation abilities and in their information regarding the battle status. On a related count, CVCC commanders were often observed moving from one location to another for direct observation, presumably capitalizing on the CVCC system's superior navigation capabilities. Such movement occurred much less frequently among Baseline units. Finally, the unit commanders and XOs participating in the Baseline condition may have relied substantially on unmanned BLUFOR vehicles to navigate, particularly in Stages 1 and 3. This would have artificially lowered their total distance travelled by reducing unnecessary or wasted movement, since BLUFOR elements generally were programmed for the most direct route.

Fuel used. As a result of the expectation that the CVCC capabilities would reduce overall distance travelled, it was anticipated that fuel consumption would also decline. Appendix B contains the definition followed in computing this measure.

Mean fuel consumption data are found in Table 9. Although fuel consumption among CVCC units was modestly lower in Stage 2 (counterattack), the condition effect was not significant. Neither was the echelon effect significant. The significant effect of stage ($F(2, 255) = 25.06$, $p<.001$) reflected mainly the higher values in Stage 1, where proportionally greater distance was travelled because of the greater distances to subsequent battle positions scripted. None of the interactions was significant.

The same factors discussed for distance travelled are relevant when interpreting the data for fuel used.

Time to complete stage. The time required to fully execute each stage was defined as the elapsed time from the initial REDCON-1 to the completion of the last scripted event (submission of a SITREP). Given the CVCC's automated C3 capabilities, CVCC-equipped battalions were expected to perform each mission more quickly than Baseline battalions.

A confounding factor made it difficult to interpret the Stage 3 completion times. The two Baseline battalions failing to complete Stage 3 fell short because they ran out of the time allotted for completing all three stages of the scenario. These two slower Baseline units yielded indeterminate values for completing Stage 3. In contrast, the one CVCC battalion failing to complete Stage 3 was terminated for administrative reasons: a higher priority requirement necessitated relinquishing the network, even though there was a sufficient amount of the allotted time left for the battalion to complete the stage. The net effect was a bias in favor of the Baseline units because, in essence, the slower units were weeded out. Consequently, Stage 3 data were excluded from this analysis.

The means for Stages 1 and 2 appear in Table 9 and are presented for graphic comparison in Figure 11. The battalions using the CVCC system took less time to complete both stages. The effect of condition was significant ($F(1, 20) = 10.10$, $p=.005$), as was the effect of stage ($F(1, 20) = 75.83$, $p<.001$). The condition by stage interaction was not significant. The differences between stages were undoubtedly due to variations in tactical events built into the test scenario.

The faster completion times for CVCC-equipped battalions are congruent with the data for time to reach LD and time to reach the objectives (discussed earlier under the Move on Surface

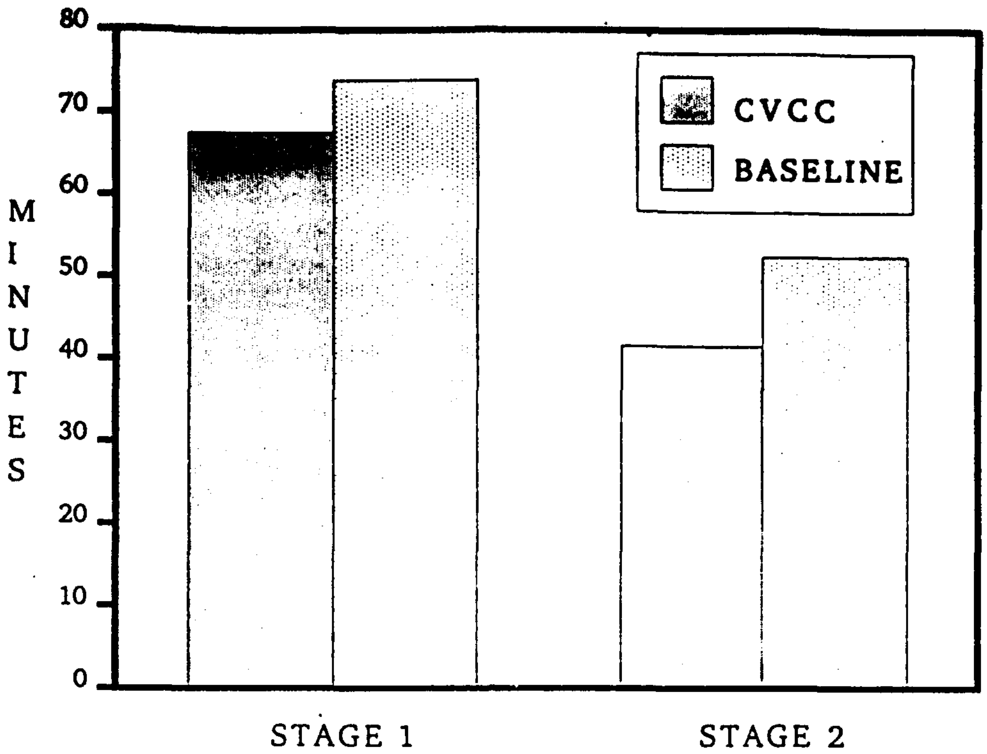

Figure 11. Mean time to complete Stages 1 and 2.

hypothesis). This trend replicates previous findings reported by Leibrecht et al. (1992) at the company level.

<u>Summary of key data</u>. The results provided modest support of the hypothesis that navigation in battalion operations would benefit from the CVCC system's capabilities. Battle Master observations indicated that CVCC crews moved much more frequently to a new position on the battlefield, apparently to secure a new or better vantage point. This suggests that the CVCC equipment gave commanders greater freedom of tactical movement in executing their command and control duties. Reinforcing this observation was the fact that CVCC participants, especially drivers, commented overwhelmingly that the automated navigation aids were a great advantage. One CVCC battalion commander observed that reduced fear of getting lost was a great operational advantage.

The significantly reduced time to complete Stages 1 and 2 reflected favorably on the navigation features of the CVCC system. Greater confidence resulting from the automated navigation capabilities apparently enabled CVCC units to move more expeditiously in executing the mission. At the same time, other factors most likely contributed to faster mission completion, including more rapid dissemination of orders and combat reports and shorter decision cycles.

Significant savings of distance travelled and fuel consumed have been reported previously among CVCC-equipped platoons and companies (Du Bois & Smith, 1989, 1991; Leibrecht et al., 1992). The absence of comparable effects in this evaluation almost certainly reflects the higher levels at which the crews operated. Battalion command and company command personnel are accustomed to trailing subordinate units, and Baseline personnel undoubtedly did so in the test scenario. In this case, the subordinate units were SAFOR elements programmed for direct routes. At the same time, CVCC-equipped personnel used their POSNAV and automated navigation aids to exercise greater freedom of movement, increasing their comparative travel distances and fuel consumption.

Process Direct Fire Targets

Hypothesis 1.3: The CVCC units' ability to process direct fire targets on the battlefield was expected to be significantly better than the Baseline units'.

The measures addressing the processing of direct fire targets focused on crew lasing activities as indicators of target acquisition behaviors. Summary data for these measures appear in Table 10.

Key limitations of the MWTB simulation methodology impact the interpretation of data related to target acquisition. These limitations include limited visual fidelity of vision block and gunner's sight imagery, and reduction of the vehicle commander's vision block coverage to a 60 degree view of the battlefield instead of 360 degrees. In addition, the use of crews without loaders in this evaluation reduced each crew's capability to search for targets on the battlefield. As discussed earlier at the end of the Method section, these limitations mean that this evaluation's target acquisition data are not representative of actual tank battalion performance. Rather, the data in this subsection, especially time to acquire targets, provide relative benchmarks only.

Maximum lase range. This measure was designed to quantify the outer edge of the range envelope for detecting potential targets. It was defined as the maximum distance a manned vehicle lased to a potential target, excluding lasing to non-vehicles. In the CVCC condition, both GPS and CITV lase events were eligible. Given the CITV capabilities to enhance battlefield surveillance and target acquisition, CVCC-equipped vehicles were expected to generate greater maximum lase ranges.

Means for the maximum lase ranges, found in Table 10, are displayed graphically in Figure 12. Overall, the mean ranges for CVCC-equipped vehicles exceeded those for Baseline vehicles. The condition effect was significant ($F(1, 240) = 5.50$, $p=.02$). In addition, the effect of stage was significant ($F(2, 240) = 18.56$, $p<.001$), as was the condition by stage interaction ($F(2, 240) = 3.53$, $p=.031$). The effect of echelon was not significant. The

Table 10

Mean Performance Data for Process Direct Fire Targets Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Maximum lase range (meters)						
Bn Echelon	2983.0 (445.1) n=11	3046.6 (343.0) n=11	2516.2 (873.4) n=10	2491.6 (600.7) n=10	2848.1 (575.0) n=11	2263.9 (499.4) n=8
Co Echelon	3130.7 (245.2) n=35	3010.2 (468.1) n=33	2599.6 (627.1) n=31	2602.9 (611.4) n=30	2775.2 (652.0) n=35	2341.7 (907.1) n=27
Time to acquire targets[a] (minutes)						
Bn Echelon	2.43 (.77) n=10	2.87 (.88) n=11	2.69 (1.14) n=7	2.33 (1.07) n=7	1.61 (.91) n=11	1.64 (1.22) n=6
Co Echelon	2.13 (.79) n=36	2.43 (1.02) n=33	1.97 (.84) n=30	2.94 (1.57) n=30	1.78 (1.30) n=34	2.36 (1.42) n=23
Time between lases to different targets (minutes)						
Bn Echelon	.51 (.32) n=11	.68 (.34) n=11	.88 (.63) n=8	.67 (.56) n=9	.60 (.39) n=10	.89 (.58) n=8
Co Echelon	.56 (.28) n=35	.52 (.25) n=32	.86 (.70) n=34	.69 (.64) n=26	.58 (.35) n=34	.49 (.34) n=24
Time from first lase to first fire (minutes)						
Bn Echelon	.33 (.30) n=8	.27 (.26) n=10	.49 (.71) n=5	.20 (.21) n=5	.71 (.83) n=8	.10 (.05) n=7
Co Echelon	.48 (.45) n=35	.31 (.32) n=30	.20 (.15) n=23	.38 (.82) n=25	.26 (.43) n=30	.18 (.33) n=23

Note. Standard deviations appear in parentheses below the means.

[a]MWTB simulation data for target acquisition provide relative values only, due to simulation limitations.

significant stage effect reflected primarily the greater ranges occurring in Stage 1, which most likely resulted from the stage's longer line-of-sight conditions. The CVCC vehicles enjoyed a greater advantage in Stage 3 than in Stages 1 or 2. The reason

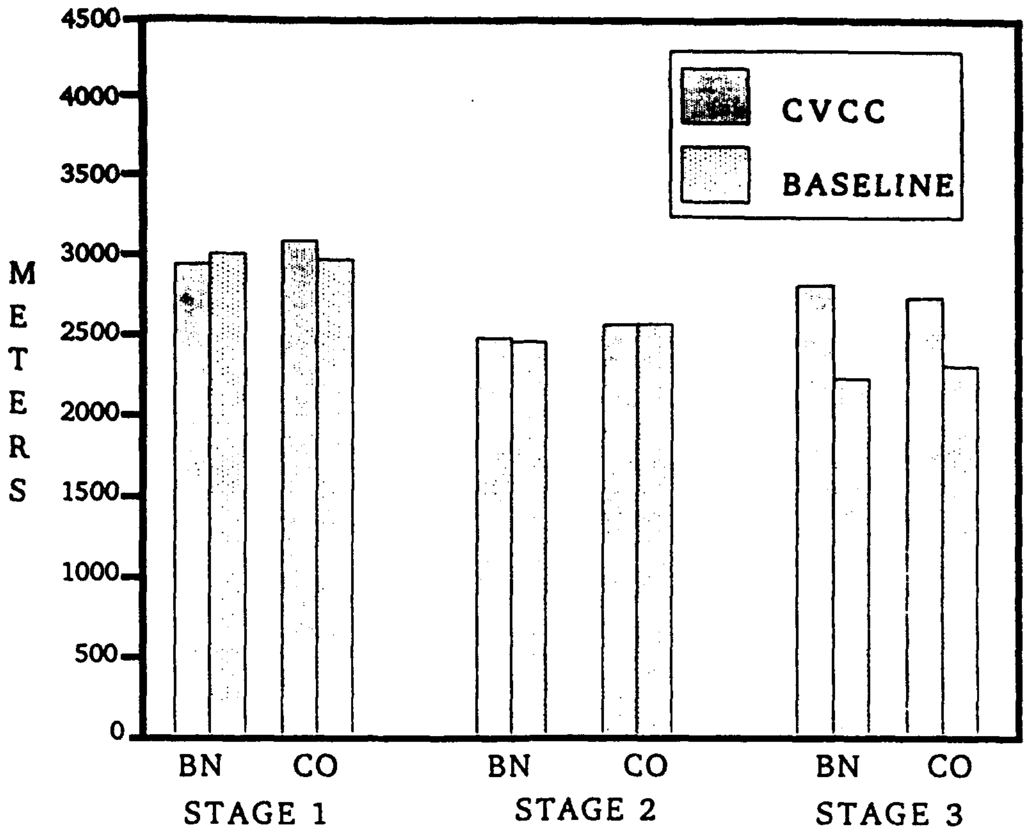

Figure 12. Maximum lase range means.

for this is not clear, but it may be that Baseline vehicles were not as successful in selecting positions with good fields of fire in Stage 3.

<u>Time to acquire targets</u>. Target acquisition time was quantified by measuring, for each manned vehicle, the elapsed time between initial visibility of an enemy vehicle and the first lase to the same vehicle. For CVCC-equipped vehicles, lases from the GPS and CITV were compared to select the shorter interval. For each stage the average target acquisition time per vehicle was computed. The definition of this measure appears in Appendix B. Because of the CVCC's independent thermal viewing capabilities for unit and vehicle commanders, crews were expected to acquire targets more quickly in the CVCC condition.

From Table 10, mean data for this measure are displayed for graphic comparison in Figure 13. The expected advantage of the CVCC-equipped vehicles was confirmed--across the board, Baseline vehicles took more than half a minute longer to respond to the first potential target by lasing. The effect of condition was significant ($F(1, 226) = 11.44$, $p=.001$), along with the effect of stage ($F(2, 226) = 3.84$, $p=.023$). The echelon effect and the interaction effects were all nonsignificant. The reader is reminded that, due to limitations of the simulation methodology,

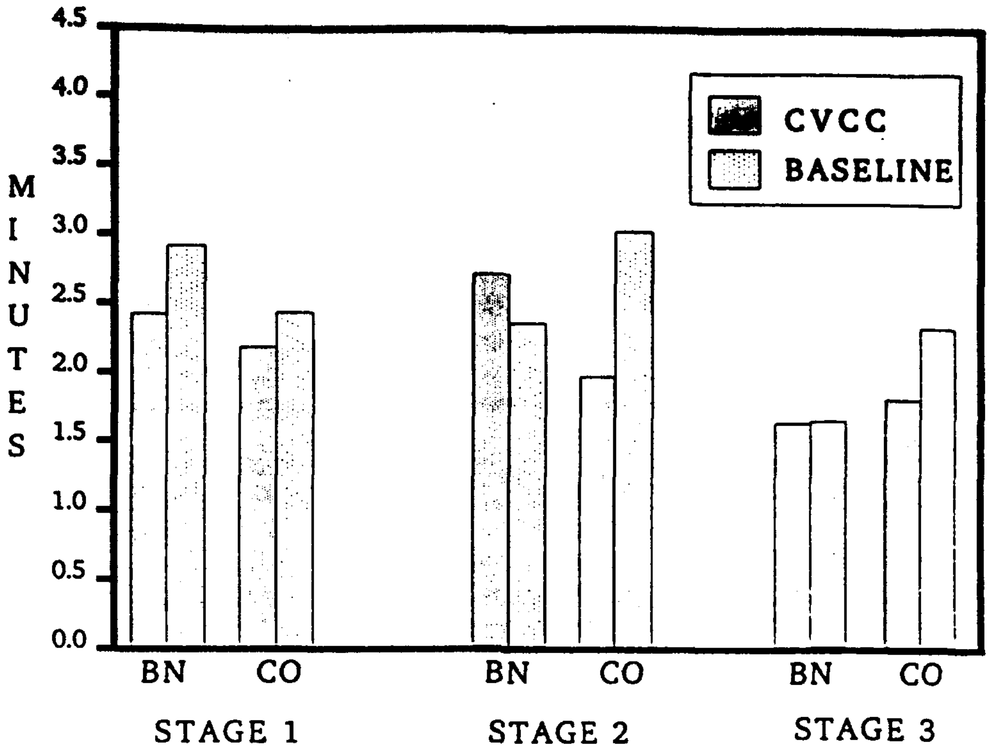

Figure 13. Mean time to acquire targets.

these data represent performance on a relative--not absolute--scale.

The variation in target acquisition time across stages appears related to two factors. The longer times in Stage 2 undoubtedly stemmed from the on-the-move nature of the counterattack mission, with enemy vehicles stationary throughout the primary portion of the stage. These conditions made it more difficult for crewmembers to detect distant vehicles. On the other hand, the shorter times in Stage 3 are more challenging to explain, especially considering its tactical similarity to Stage 1. It is possible the terrain conditions in Stage 1 resulted in more targets being visible at one time, so that it took a relatively long time to service some of the targets.

<u>Time between lases to different targets</u>. As an index of speed in acquiring sequential targets, this measure quantified the time interval separating successive lases to different enemy vehicles (see Appendix B for the definition of this measure). The computational procedure measured the elapsed time from a manned vehicle's last lase at an OPFOR vehicle to its first lase at the next OPFOR vehicle. For CVCC-equipped vehicles, lases from the GPS and CITV were compared to select the shorter interval. The advantage of sighting/lasing systems for both the commander and gunner (the "hunter-killer" capability) led to the expectation of shorter values for this measure among CVCC-equipped vehicles.

Table 10 summarizes the data for this measure. The mean values did not vary greatly across conditions, stages, or echelons, ranging generally from half a minute to nearly one minute. Only the effect of stage was significant ($F(2, 230) = 5.52$, $p = .005$), reflecting the longer times occurring in Stage 2. This undoubtedly resulted from the on-the-move nature of the counterattack mission and the lower density of enemy vehicles during Stage 2. The inclusion of GPS-to-GPS lases in computing this measure for CVCC-equipped battalions may have obscured the expected advantage of the "hunter-killer" capability.

Time from first lase to first fire. This measure was designed to provide an index of a crew's speed in responding to enemy targets with direct fire. Conceptually the process included application of IFF procedures. In practice, elapsed time was computed from a manned vehicle's first lase at an enemy vehicle to the firing of the first round directed at the same vehicle (see Appendix B for the definition). Given the enhanced situational awareness expected to result from CVCC capabilities (e.g., greater awareness of friendly and enemy positions), shorter lase-to-fire times were anticipated for CVCC-equipped vehicles.

Summary data for this measure can be found in Table 10. In spite of an apparent advantage for the Baseline vehicles, the condition effect was not significant. Likewise, the effects of echelon and stage were nonsignificant, as were all interactions.

Summary of key data. Two measures clearly demonstrated the contributions of the CVCC system to the acquisition of targets for direct fire engagement. The maximum range at which lasing to an enemy vehicle occurred was significantly greater in the CVCC condition for all stages. In addition, target acquisition time was significantly shorter for CVCC crews. These results are attributed to the enhanced sensing capability provided by the CITV.

Engage Direct Fire Targets

Hypothesis 1.4: The CVCC units' ability to engage direct fire targets on the battlefield was expected to be significantly better than the Baseline units'.

This hypothesis must be tempered to account for the fact that crews participating in the evaluation were assigned roles at the company XO level and higher. There were no crews operating at the wingman or platoon leader level. Thus, engagement of the enemy was largely executed by SAFOR vehicles. While the SAFOR elements were under the direct control of unit commanders, the SAFOR algorithms determining target engagement were the same in both conditions. With CVCC equipment in the hands of crews whose primary responsibilities centered on command and control, the opportunities to assess the direct influence of CVCC capabilities on engaging the enemy were somewhat limited by the design of the evaluation.

Many of the measures under this hypothesis share certain common fundamentals. Kills of vehicles (both enemy and friendly) include both catastrophic and firepower kills (as determined on-line by the vehicle's computer), but not mobility kills. Kills due to both direct and indirect fire are counted, unless otherwise noted. Finally, friendly damages and casualties include those resulting from friendly fire (i.e., fratricide), unless indicated differently.

Table 11 contains summary data (means and standard deviations) for the measures supporting this hypothesis.

Table 11

Mean Performance Data for Engage Direct Fire Targets Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Percent OPFOR killed	87.1 (8.7) n=6	88.2 (8.6) n=6	98.1 (1.6) n=6	91.1 (13.4) n=6	71.9 (21.8) n=5	87.2 (17.9) n=4
Percent BLUFOR killed	22.1 (10.0) n=6	26.0 (10.7) n=6	4.4 (2.3) n=6	9.4 (6.0) n=6	26.6 (9.7) n=5	22.3 (10.7) n=4
Losses/kill ratio	.16 (.08) n=6	.19 (.10) n=6	.05 (.02) n=6	.12 (.09) n=6	.28 (.13) n=5	.18 (.11) n=4
Percent OPFOR vehicles killed by manned vehicles	10.1 (6.5) n=6	10.4 (3.7) n=6	6.6 (2.9) n=6	3.8 (2.7) n=6	14.0 (6.5) n=5	12.6 (7.1) n=4
Number rounds fired by manned vehicles						
Bn Echelon	11.6 (10.3) n=11	10.0 (6.5) n=12	4.1 (5.9) n=11	5.2 (6.8) n=12	6.5 (7.2) n=10	8.8 (10.5) n=8
Co Echelon	15.4 (7.5) n=36	15.1 (10.8) n=36	8.0 (9.0) n=36	8.1 (8.6) n=36	10.5 (6.6) n=30	12.1 (8.8) n=24
Number manned vehicles sustaining a killing hit	2.17 (1.94) n=6	2.33 (.82) n=6	.67 (.82) n=6	.83 (.98) n=6	2.40 (1.52) n=5	3.25 (1.89) n=4

(table continues)

(Table 11 continued)

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Mean target hit range (meters)						
Bn Echelon	2487.8 (357.5) $n=7$	2151.3 (426.4) $n=9$	2018.3 (1074.6) $n=3$	1896.0 (925.5) $n=5$	2106.9 (731.8) $n=5$	1649.1 (365.9) $n=4$
Co Echelon	2312.2 (304.8) $n=24$	2214.9 (365.9) $n=28$	1770.4 (734.1) $n=21$	1889.5 (528.4) $n=20$	1970.1 (561.4) $n=25$	2012.1 (515.4) $n=17$
Mean target kill range						
Bn Echelon	2440.8 (504.0) $n=6$	2105.0 (530.5) $n=7$	2664.5 -- $n=1$	1402.3 (1162.2) $n=3$	2369.4 (695.5) $n=3$	1498.2 (239.6) $n=3$
Co Echelon	2288.5 (318.1) $n=20$	2243.6 (390.7) $n=23$	1762.5 (768.4) $n=15$	1773.1 (608.9) $n=16$	1910.0 (553.1) $n=21$	1916.8 (587.3) $n=11$
Hits/round ratio, manned vehicles						
Bn Echelon	.20 (.18) $n=10$	.40 (.18) $n=10$	.17 (.17) $n=5$	.35 (.37) $n=6$	.23 (.25) $n=8$	.26 (.28) $n=8$
Co Echelon	.17 (.16) $n=35$	.24 (.15) $n=31$	.31 (.32) $n=28$	.28 (.26) $n=27$	.27 (.24) $n=28$	.21 (.23) $n=24$
Kills/hit ratio, manned vehicles						
Bn Echelon	.47 (.41) $n=7$	.29 (.31) $n=9$	.22 (.38) $n=3$	0 (0) $n=5$	.20 (.19) $n=5$	.19 (.24) $n=4$
Co Echelon	.36 (.30) $n=24$	.31 (.23) $n=28$	.31 (.36) $n=21$	.22 (.37) $n=20$	.48 (.38) $n=25$	.35 (.40) $n=17$
Kills/round ratio, manned vehicles						
Bn Echelon	.08 (.08) $n=10$	.11 (.11) $n=10$	.02 (.05) $n=5$	0 (0) $n=6$	.06 (.08) $n=8$	.05 (.10) $n=8$
Co Echelon	.07 (.10) $n=35$	.09 (.09) $n=31$	.10 (.20) $n=28$	.03 (.05) $n=27$	.13 (.15) $n=28$	.06 (.12) $n=24$

Note. Standard deviations appear in parentheses below the means.

Percent of OPFOR killed by end of stage. This primary indicator of engagement outcome quantified the battalion's success in destroying the enemy forces. Examination of the data (summarized in Table 11) revealed no consistent mean differences between CVCC-equipped and Baseline units. The effect of condition was not significant, nor was the condition by stage interaction. Analysis by *t*-test of Stage 2 alone, where performance data were most consistent, still failed to reveal a significant difference between conditions. The lack of significant differences between conditions is consistent with results reported by Leibrecht et al. (1992). A significant stage effect ($F(2, 27) = 3.84$, $p=.034$) reflected largely a lower proportion of OPFOR killed in Stage 3 than in the other two stages. This probably resulted from the scripted OPFOR attack routes in Stage 3, which were slightly more likely to avoid contact with friendly elements during the later portion of the stage.

Percent of BLUFOR killed by end of stage. Another primary index of engagement outcome, this measure indicated how successfully the battalion conserved its own forces during the exchange with the enemy. The entire BLUFOR (manned and unmanned) was represented. As seen in Table 11, on the average about one-quarter of the battalion was lost during delay missions (Stages 1 and 3) and less than one-tenth during the counterattack mission (Stage 2). There was no significant effect of condition, but the effect of stage was significant ($F(2, 27) = 15.78$, $p<.001$). The latter trend (fewer losses in the counterattack) was undoubtedly due to the lower density of OPFOR in Stage 2, with the force ratio more in favor of the BLUFOR. The condition by stage interaction was not significant. A post hoc analysis indicated that the difference between conditions in Stage 2 was significant ($t(10) = 1.91$, $p<.05$). Thus, during the counterattack mission the CVCC capabilities significantly enhanced the battalion's ability to protect its forces from attrition.

Losses/kill ratio. A simple loss-exchange ratio, this measure expressed the cost of kills inflicted on the enemy in terms of friendly vehicles lost in the exchange. As explained in Appendix B, the ratio was calculated by dividing the total number of BLUFOR losses (excluding fratricide) by the total number of OPFOR losses. The lower the ratio, the better the combat effectiveness of the battalion.

Summary data for this measure appear in Table 11. As can be seen, mean performance did not vary systematically between the Baseline and CVCC conditions. The condition effect and the condition by stage interaction were both nonsignificant. The effect of stage was significant ($F(2, 27) = 7.61$, $p=.002$). This is in line with the lower ratios during Stage 2, which apparently reflected the numerical superiority of the BLUFOR in the offensively oriented counterattack. Because of the differing trends seen in Stage 2, the counterattack data were analyzed alone using a *t*-test. The Stage 2 difference between conditions was significant ($t(10) = 1.85$, $p=.047$). This latter finding indicated that during the counterattack mission the CVCC capabilities conferred a reliable advantage, consistent with the BLUFOR attrition findings presented in the preceding subsection.

Percent of OPFOR vehicles killed by all manned vehicles. This measure was designed to indicate the extent to which crewed tanks contributed to attritting the enemy. Since the CCD might divert a unit/vehicle commander's attention from the immediate battle, it was possible that CVCC-equipped crews might participate less fully than Baseline crews, thereby killing proportionally fewer enemy vehicles. The data (summarized in Table 11) reveal equivalent mean performance by CVCC and Baseline units. The condition effect was not significant, nor was the condition by stage interaction. A significant stage effect ($F(2, 28) = 8.17$, $p=.002$) reflected mainly lower proportions in Stage 2, likely the result of unit and vehicle commanders trailing somewhat behind their companies during the on-the-move counterattack. As with other measures in this target engagement category, the data for Stage 2 were analyzed alone using a t-test. The Stage 2 difference between conditions was not significant.

Number of rounds fired by manned vehicles. As a basic index of firing activity by crews in manned simulators, this measure captured the cumulative number of SABOT and HEAT rounds fired by each crew during each stage. Similar to the immediately preceding measure, this index provided a more general indicator of the extent to which crewed tanks participated in the actual fighting of the battle. Mean number of rounds fired (see Table 11) did not differ consistently between the CVCC and Baseline conditions, as shown by a nonsignificant effect of condition. The effect of echelon was significant ($F(1, 250) = 9.85$, $p =.002$), with company echelon crews firing substantially more rounds than battalion echelon crews. This is understandable, given the broader command and control responsibilities of the battalion commander and his S3, as well as their general positioning somewhat to the rear.

A significant stage effect ($F(2, 250) = 15.72$, $p<.001$) resulted principally from more rounds being fired in Stage 1 compared to the other two stages. The lower numbers in Stage 2 were predictable, due to the lower OPFOR density scripted in the counterattack mission. The modest difference between the two delay stages (means for Stage 1 being higher than for Stage 3) most likely reflect scripted differences in terrain line-of-sight conditions and OPFOR routes. None of the interactions for this measure was significant.

Overall, these results show a logical pattern of participation in the battle that was not modified by the use of CVCC equipment. This further dispels the suspicion that the task demands of the CCD might distract unit leaders from fighting the battle.

Number of manned vehicles sustaining a killing hit. Even though manned simulators were programmed to override the damaging effects of direct fire or indirect fire hits, the host computer classified hits in terms of damages sustained. The number of vehicles sustaining at least one killing hit was tallied during each stage, with fratricide kills included. This measure provided a rough indicator of exposure to lethal enemy fire.

The data for this measure appear in Table 11. Although consistently fewer manned tanks in the CVCC condition sustained killing hits, the mean difference was modest and the effect of condition was not significant. A significant stage effect ($F(2, 27) = 6.58$, $p=.005$) reflected principally lower means during Stage 2, consistent with the lower density of OPFOR in the counterattack mission. The condition by stage interaction was nonsignificant.

These data indicate that the CVCC equipment did not influence the proportion of manned vehicles taking lethal enemy fire. On one hand, this finding suggests that the CVCC capabilities (e.g., navigation aids, CITV) did not enhance vehicle survivability. On the other hand, it suggests that risk-taking behavior among unit and vehicle commanders was equivalent across the CVCC and Baseline conditions.

Mean target hit range. This measure was designed to capture the typical distance at which crews firing their main guns scored hits against enemy targets. Applying to manned vehicles only, the measure was computed as the distance (in meters) from a firing vehicle to the OPFOR vehicle hit by the round fired. The range values for all hits scored by a given crew were averaged to produce a single value for each stage. Given the hunter-killer advantage of the CITV, including the IFF feature, the CVCC-equipped battalions were expected, on the average, to hit targets at greater ranges.

Table 11 summarizes the data for this measure. Inspection of the means reveals no systematic difference between the CVCC and Baseline conditions, confirmed by the lack of a significant condition effect. The echelon effect was also nonsignificant, but the effect of stage was significant ($F(2, 156) = 9.84$, $p<.001$). None of the interactions was significant. The stage effect reflected primarily longer hit ranges in Stage 1, similar to the longer maximum lase ranges in Stage 1 discussed earlier. As in that case, the longer line-of-sight terrain conditions in Stage 1 were presumably a key factor.

The lack of a significant CVCC advantage for this measure appears inconsistent with the significant CVCC advantage for maximum lase range discussed earlier. Although CVCC-equipped crews first lased to targets at greater ranges, their decisions to fire came at ranges comparable to the Baseline crews. The CVCC commander could not fire with his CITV active, leaving the firing process typically in the hands of the gunner. The CITV's IFF function had a substantial inherent error rate, generally leading crews to comment that they relied on conventional IFF means (GPS and vision blocks). Thus, crews in both conditions apparently exercised comparable processes in deciding when to fire at targets.

Mean target kill range. This measure was defined and computed very similarly to the preceding measure (see Appendix B for the definition of mean target kill range). Paradoxically, mean target kill range can exceed mean target hit range when shorter-range hits failing to kill the target leave longer-range kills predominant.

The data for the measure, summarized in Table 11, paralleled very closely those for mean target hit range, including the ANOVA outcomes. The condition and echelon effects were nonsignificant, while the effect of stage was significant ($F(2, 117) = 10.11$, $p<.001$). The condition by echelon interaction was significant ($F(1, 117) = 5.42$, $p = .022$), but the other interaction terms were nonsignificant. The significant condition by echelon interaction reflects the better performance of CVCC participants primarily at the battalion echelon, as seen with mean target hit range data. Basically the same factors discussed earlier to explain the pattern of results for mean target hit range apply to the findings for mean target kill range.

Hits/round ratio, for manned vehicles. As an index of basic firing accuracy (marksmanship), the proportion of rounds hitting an OPFOR vehicle was computed for each crewed tank. Higher ratios indicate better performance. The data for this measure are summarized in Table 11. None of the main effects (condition, echelon, stage) was significant, nor was any of the interactions. These findings indicate that the CVCC's capabilities did not impact main gun firing accuracy. The limitations of the distributed simulation environment in terms of ballistic algorithms, probabilities of hits and kills, and implementation of target lead should be kept in mind. These limitations were discussed at the end of the Method section.

Kills/round ratio, for manned vehicles. An indicator of the effectiveness of main gun firings, this measure compared the number of enemy vehicles killed to the number of rounds fired by each crewed tank. Higher ratios represent better performance. Table 11 presents summary data for this measure. There were no significant main effects or interactions, indicating that this measure was not a discriminator for any of the variables of interest in this evaluation.

Kills/hit ratio, for manned vehicles. Providing an index of the effectiveness of rounds that hit enemy targets, this measure calculated the proportion of hits scored by each crewed tank which resulted in destruction (mobility kills excluded) of the target. Higher ratios indicate better performance. Mean ratios appear in Table 11, where an overall difference in favor of CVCC-equipped vehicles can be seen. The effect of condition was significant ($F(1, 156) = 3.94$, $p=.049$), while the effects of

echelon and stage were nonsignificant. None of the interaction terms was significant.

The advantage observed for crews using the CVCC equipment may be attributable to better round selection for the types of targets and ranges encountered within the simulation environment. The factors that determine a kill, given a hit, include the point of impact and angle of attack along with the type of munition. As discussed in a subsequent subsection on the Intelligence BOS, CVCC participants more accurately reported the type of OPFOR vehicles in their transmitted CONTACT and SPOT reports. Given improved target identification, CVCC crews would have been more likely to select the optimal round for the target.

Number of OPFOR vehicles killed south of designated PL (Stages 1 and 3 only). For each of the two delay stages, lethality in the primary engagement areas was quantified. For each stage, this was accomplished by determining the cumulative number of OPFOR vehicles killed by the battalion south of two successive PLs during the course of the stage. In general, the earlier the enemy is attritted the better, other factors (such as friendly losses) being equal. These measures were originally developed as input to a composite measure quantifying the extent to which the battalion met the brigade commander's intent. The data for the separate measures, however, are presented here for the sake of completeness.

The summary data for these measures appear in Table 12. The Baseline battalions consistently killed more of the enemy in the

Table 12

Mean Enemy Kills in Primary Engagement Areas, by Condition

Measures	CVCC	Baseline
Number OPFOR vehicles killed south of PL Jack (Stage 1)	64.7 (22.7) n=6	81.7 (14.3) n=6
Number OPFOR vehicles killed south of PL Club (Stage 1)	84.8 (11.8) n=6	89.8 (9.1) n=6
Number OPFOR vehicles killed south of PL Ace (Stage 3)	38.6 (22.1) n=5	54.5 (33.3) n=4
Number OPFOR vehicles killed south of PL Queen (Stage 3)	67.2 (21.8) n=5	83.8 (17.2) n=4

Note. Standard deviations appear in parentheses below the means

Summary of key data. Several of the measures for this function supported the hypothesis that the CVCC capabilities would benefit the direct fire engagement of enemy targets. The prevention of BLUFOR losses and the losses/kill ratio were enhanced during the counterattack mission, indicating that CVCC-equipped battalions were better able to protect themselves from lethal fire. The kills/hit ratio was significantly higher for CVCC-equipped vehicles, suggesting greater effectiveness for those rounds hitting targets. A clear explanation for this finding is not apparent. CVCC crews may have been able to exercise more deliberate round selection and aiming, given the earlier target acquisition performance discussed in the preceding subsection. However, no data were collected on type of round selected or aiming accuracy. The possibility of unidentified artifactual factors, including statistical artifact, cannot be ruled out.

The advantages of the CVCC system were achieved in spite of the fact that the CVCC battalions tended to maintain greater primary engagement areas in both delay stages, although the differences between conditions were not significant. This pattern is consistent with the results discussed for the Control Terrain hypothesis in the following subsection, and probably relates to the greater stand-off distance which CVCC units tended to maintain (see earlier Move on Surface subsection). stand-off distance from the enemy, as discussed earlier in this section. Maintaining contact while conserving combat strength was an important component of the commander's intent in the delay missions. The CVCC capabilities apparently enabled battalions to more successfully meet this part of the commander's intent without sacrificing their effectiveness in destroying the enemy.

The equivalence of firing activity between manned vehicles in the CVCC and Baseline conditions indicated that the presence of the CVCC equipment did not by itself distract the crews from processing and engaging direct fire targets.

Control Terrain

Hypothesis 1.5: The CVCC units' ability to control terrain on the battlefield was expected to be significantly better than the Baseline units'.

Was the battalion bypassed by the OPFOR? The Battle Master determined whether more than four OPFOR platoons penetrated to the rear of the front-line BLUFOR companies. Virtually all of the Baseline and CVCC battalions completed Stage 1 without being bypassed by the enemy, and all battalions completing Stage 3 did so without the enemy bypassing them. A chi-square test confirmed there was no significant difference between the two conditions. The maximum performance in both conditions may have resulted from scripted information reaching the company commanders from the SAFOR operators (role-playing platoon leaders) in the Baseline condition, enabling the unit leaders to stay sufficiently abreast of the battle to avoid being bypassed.

Number of OPFOR vehicles penetrating designated line. For each stage, a control line was defined to determine undesirable enemy penetration by the end of the stage. These control lines were based on mission training plans and represented defensive boundaries which the battalion should have defended to deny enemy penetration. In Stage 1, the CVCC-equipped battalions allowed an average of 4.17 enemy vehicles ($\underline{SD}$ = 6.46) to penetrate the control line. In Stage 2, one CVCC battalion permitted two enemy vehicles to penetrate, and another CVCC battalion allowed one enemy vehicle. In Stage 3, one CVCC battalion completed the mission with ten enemy vehicles penetrating the control line. This contrasts with performance of the Baseline battalions, none of which permitted any enemy vehicles to penetrate the designated control line in any of the three stages. Because of the exclusive occurrence of zero values for Baseline units, no ANOVAs were performed on any of these measures.

For the delay missions (Stages 1 and 3), the curious performance of the CVCC battalions probably relates to their tendency to begin their displacement earlier and end their missions with greater stand-off distance than did the Baseline battalions. These trends were discussed in the subsection addressing the Move on Surface hypothesis. No explanation for the CVCC units' performance in Stage 2 is readily evident.

Summary of key data. The data for the primary measures supporting this function did not support the hypothesis that CVCC equipment would enhance control of terrain. The mission in the two delay stages was to maintain contact and continue to attrit the enemy, and this may have led commanders to try to inflict maximum losses on the enemy early in the battle. The battalions in both conditions appeared to pursue preventing enemy penetration quite aggressively. In addition, the means available for controlling terrain in the simulation environment of this evaluation may have constrained the outcome. Combat engineer support was not modelled, and SAFOR vehicles/units did not alter their behavior in response to artillery fire. This left direct fire as the primary means for controlling terrain, and the preceding subsection documented that CVCC and Baseline units performed similarly on many engagement measures.

Summary of Findings

The measures analyzed under this BOS yielded support for the expected beneficial impact of the CVCC system on battlefield maneuver functions. As summarized in Table 13, there was clear evidence in four of the five functions that CVCC capabilities enhanced the battalion's performance in the areas of tactical movement, target acquisition, and target engagement.

Greater control of movement among CVCC units was reflected in more rapid movement to objectives in the counterattack, in more consistent timing of key battle milestones, and in better end-of-stage stand-off distances. These findings undoubtedly resulted from the automated navigation capabilities, which

Table 13

Summary of Major Maneuver BOS Findings

Function	CVCC Advantages
Move on Surface	- Safer end-of-mission stand-off ranges in all stages - REDCON-1 reached more quickly in Stage 2 - Faster movement to objectives in Stage 2 - More consistent timing of movement-dependent milestones in Stage 2
Navigate	- Faster completion of mission in Stages 1 and 2 - Greater apparent freedom of movement for unit and vehicle commanders
Process Direct Fire Targets	- Greater maximum target detection range in all stages - Faster target acquisition in all stages
Engage Direct Fire Targets	- Fewer friendly losses in Stage 2 - Improved losses/kill ratios in Stage 2 - Enhanced kills/hit ratios in all stages

apparently gave the crews more confidence in their navigation abilities. The latter probably accounted for the greater apparent freedom of movement in evidence on the part of CVCC unit and vehicle commanders. As reported in previous research (Du Bois & Smith, 1989, 1991; Leibrecht et al., 1992) the CVCC units completed the combat missions more quickly than Baseline units. The ability to monitor the unit's position on the tactical map in real time apparently enabled CVCC units to move more expeditiously in executing the mission. At the same time, other factors most likely contributed to faster mission completion, including more rapid dissemination of orders and combat reports and shorter decision cycles.

The CVCC-equipped crews were able to detect their first targets at a greater range than did crews using conventional equipment. In addition, CVCC crews acquired targets more quickly once they became visible. These findings reflect the hunter-killer advantages of the CITV and are consistent with results from company-level research (Leibrecht et al., 1992). However, they differ from Quinkert's (1990) crew-level finding that the principal advantage of the CITV occurred after acquisition of the initial target. This difference most likely relates to the current focus on battalion performance compared to the earlier assessment of crew performance.

The improved performance in engaging the enemy--reduced attrition of friendly forces and more favorable losses per kill during the counterattack, and higher kills/hit ratios in all stages--for CVCC-equipped crews have not been reported in earlier research. The enhancements in preventing friendly attrition when counterattacking most likely resulted from the CVCC's automated positioning and navigation aids and the digital dissemination of precise information about enemy locations. The higher kills/hit ratios are difficult to explain, and experimental or statistical artifacts cannot be ruled out.

The CVCC crews engaged in firing activity as frequently as Baseline crews, and the two groups were equivalent in the proportion of the enemy which they killed. These results are important because they indicate that, at the company and battalion echelons, the presence of the CVCC equipment did not by itself distract the crews from processing and engaging direct fire targets. This reinforces similar results reported by Leibrecht et al. (1992).

The equivalence of CVCC and Baseline performance on many of the measures in this BOS may be largely a result of the experimental design. With participants/crews allocated no lower than company XO duty positions, SAFOR vehicles/units predominated in executing maneuver functions. The SAFOR reporting procedures in the Baseline condition relied on the SAFOR operator relaying messages which appeared on the control screen. As a result, the volume and quality of information reaching company commanders and XOs may have been similar for Baseline and CVCC conditions. Further, Baseline crews could follow SAFOR elements instead of navigating on their own. These factors would have impacted positioning and navigation as well as certain decision processes (e.g., the decision to displace), masking legitimate effects of the CVCC system. In addition, the predominant involvement of SAFOR elements in target acquisition and engagement may well have led crews in both conditions to downplay their emphasis on acquiring and engaging targets. In short, experimental design-related factors may have levelled out differences which might have appeared if wingman or platoon leader vehicles had been manned.

Previous researchers have reported significant savings of distance and fuel among CVCC-equipped platoons and companies (Du Bois & Smith, 1989, 1991; Leibrecht et al., 1992). The absence of a comparable effect at the battalion level undoubtedly reflects the roles assigned to participating crews and the ease of following SAFOR vehicles. Vehicle commanders at the company XO level and higher are accustomed to trailing subordinate units and often stated they did so in the test scenario. This circumstance would largely explain the rare misorientation and straying out-of-sector which occurred in this evaluation.

The results discussed in this subsection documented the beneficial contributions of the CVCC capabilities to the battalion's accomplishment of battlefield maneuver functions.

The following subsection presents the results addressing the processing of indirect fire targets.

Fire Support BOS

Issue 2: Does the CVCC system enhance the Fire Support BOS?

The CVCC's impact on the accuracy of designating enemy targets for engagement with indirect fire is discussed in this subsection. Organizing the presentation of data is a single hypothesis, based on the Process Ground Targets component of the Fire Support BOS. The quantitative focus in addressing this issue is the accuracy of CFF reports, reflecting the precision with which battalion elements were able determine and communicate the locations of enemy targets selected to receive indirect fire.

Process Ground Targets

Hypothesis 2.1: The CVCC units' ability to process ground targets for indirect fire on the battlefield was expected to be significantly better than the Baseline units'.

Mean accuracy of CFF locations. Accuracy of requests for indirect fire was quantified by comparing the enemy location specified in each CFF to the actual location of the nearest enemy unit at the time the CFF was transmitted. Only CFFs with valid grid locations were analyzed. In practice, the CoM of the three enemy vehicles (regardless of type) nearest the reported location defined the location of the nearest enemy unit. Only those unit and vehicle commanders transmitting scorable CFFs contributed values for this measure. Appendix B presents the definition of this measure, including an explanation of scorable CFFs. The computational process yielded distance measurements of the discrepancies between actual and reported locations. The smaller the discrepancy, the better the accuracy.

Because of the small sample size for the Baseline condition in Stage 3 ($n = 3$), only the data from Stages 1 and 2 were analyzed. Descriptive data for these two stages appear in Table 14. As seen in Figure 14, during both stages the CVCC participants submitted substantially more accurate CFFs than those submitted by Baseline participants. This was a reliable advantage, as shown by a significant effect of condition ($F(1, 52) = 9.96$, $p=.003$). The effect of stage was not significant, nor was the condition by stage interaction.

The standard deviations for these data are smaller in Stages 1 and 2 for the CVCC-equipped battalions than for the Baseline battalions. This indicates more consistent performance when using CVCC equipment, a distinct benefit on a fast-paced, highly fluid battlefield.

Of the CFF requests transmitted by Baseline participants, many were not scorable because they lacked adequate information on location. Baseline unit and vehicle commanders submitted an

Table 14

Mean Performance Data for Process Ground Targets Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline
CFF location accuracy (deviation, in meters)	526.8 (475.6) n=25	4087.2 (8022.2) n=9	679.2 (897.0) n=15	2981.3 (1621.2) n=7
Percent CFFs with correct type	90.6 (17.7) n=25	73.3 (25.5) n=9	87.5 (28.9) n=16	66.7 (23.6) n=7

Note. Standard deviations appear in parentheses below the means.

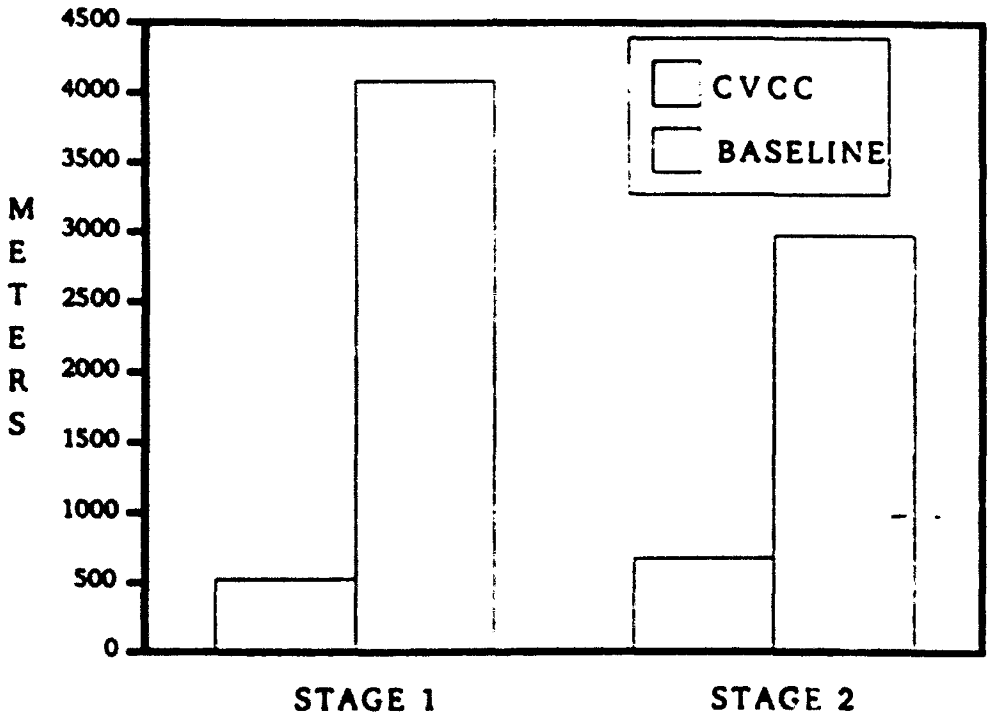

Figure 14. Mean accuracy scores for enemy locations contained in CFF (Call for Fire) reports.

average of 52 CFF reports per stage, of which 34.3 (66 percent) were missing target locations. In each stage the CVCC commanders transmitted substantially more scorable CFF reports than their Baseline counterparts, as indicated by the cell sample sizes (see

Table 14). Thus, a much greater quantity of usable targeting information reached the FSO when the CVCC equipment was used.

These data show that the CVCC capabilities increased both accuracy and consistency of performance in reporting enemy locations in CFF reports. The data further reveal that substantially more usable information was transmitted by unit and vehicle commanders in the CVCC condition, highlighting the value of the CVCC system's precise location reporting capabilities.

<u>Percent of CFFs with correct type</u>. This measure quantified the accuracy of unit and vehicle commanders' identification of type of enemy vehicle in their requests for fire support. Scoring was accomplished by comparing the reported vehicle type with the actual types of enemy vehicles visible to the reporting vehicle at the time the CFF was transmitted. Only reports containing a valid grid location and valid type of enemy vehicle (tank, helicopter, or personnel carrier) were scored. If one or more enemy vehicles of the type reported were visible, the CFF was scored "correct." For each commander sending scorable CFFs, the proportion scored "correct" was calculated.

As with the preceding measure, only data from Stages 1 and 2 were analyzed because of the small Stage 3 sample size for the

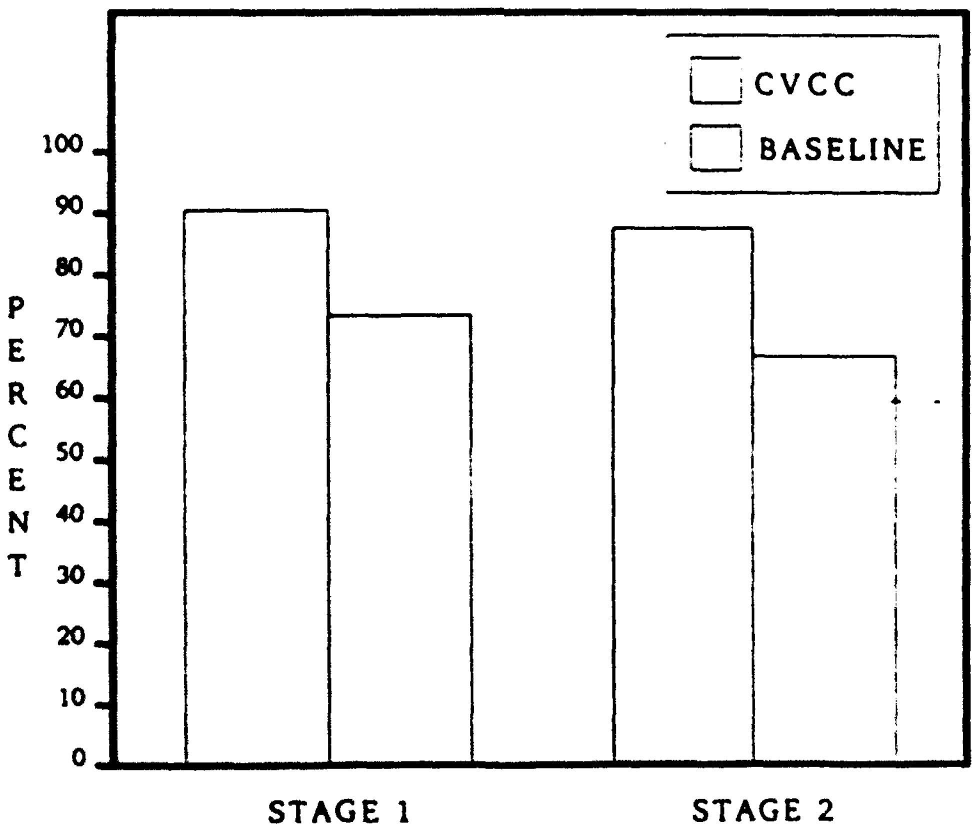

Figure 15. Mean percentage of CFF (Call for Fire) reports correctly identifying vehicle type.

Baseline condition. Table 14 presents descriptive data for this measure. Figure 15 displays the means, showing a consistently greater proportion of CFFs containing correct enemy vehicle types in the CVCC condition. The performance advantage of the CVCC system was significant, as evidenced by the significant effect of condition ($F(1, 53) = 7.50$, $p=.008$). Neither the effect of stage nor the condition by stage interaction was significant. These data establish that the CVCC capabilities increased the overall accuracy of reporting the type of enemy vehicle in CFF reports.

Summary of Findings

Table 15 summarizes the findings pertaining to the processing of ground targets under the Fire Support BOS. The data clearly document that the CVCC capabilities enhance both location and identification accuracy in the process of requesting fire missions from mortar and artillery elements. In turn, this can be expected to improve the accuracy of indirect fires delivered on enemy targets, contributing to more effective massing of friendly fires. At the same time, the data suggest that location accuracy suffers during engagements where the friendly force is on the move. As a general principle, offensive maneuvers may degrade certainty of position information and demand more attention for navigation and target acquisition than defensive maneuvers, leading to less accurate CFF reports. However, the CVCC capabilities clearly are effective in limiting the degradation during on-the-move engagements.

Table 15

Summary of Major Fire Support BOS Findings

Measure	CVCC Advantages
Accuracy of CFF locations	- CFF report location accuracy better in Stages 1 and 2
% CFFs with correct type	- CFF report vehicle identification accuracy better in Stages 1 and 2
# CFFs with complete information	- Greater volume of usable information in Stages 1 and 2

The superior location accuracy afforded by the CVCC system is undoubtedly due largely to the ability to input precise locations to CFFs by lasing or by touching the map screen. The CVCC's advantage in terms of target identification accuracy most likely results from the CITV's surveillance capabilities as well as the digital exchange of information about enemy elements, including display of report-based icons on the tactical map.

Two of every three Baseline CFFs were missing target locations. This is a high rate of missing information and is an important shortcoming, given the requirements for accurate delivery of indirect fires. The CVCC capabilities, particularly the CCD's prompts for location information and the ease of obtaining precise locations of enemy targets, are especially valuable in ensuring that complete and accurate locations are submitted with CFF reports.

The results presented in this subsection indicate how CVCC capabilities can help unit and vehicle commanders generate accurate fire support requests to increase the effectiveness of their surface attacks. The following subsection discusses the CVCC's impact on the accomplishment of command and control activities.

Command and Control BOS

Issue 3: Does the CVCC system enhance the Command and Control BOS?

This subsection is organized around the six command and control functions identified earlier in this report: (a) Receive and Transmit the Mission, (b) Receive and Transmit Enemy Information, (c) Receive and Transmit Friendly Troop Information, (d) Manage Means of Communicating Information, (e) Direct and Lead Subordinate Forces, and (f) Assess the Battlefield Situation. The subsection concludes with a summary of findings.

Certain measures took on fixed values for the CVCC condition, due to limitations in the simulation model. In particular, simulated CVCC transmission time was on the order of milliseconds, appearing instantaneous to the user. Digital report transmission times, therefore, were not measured and for purposes of the evaluation were assumed to be zero. Definitive digital transmission time data for fielded C3 systems are not available, but digital burst transmission times for standard combat reports are estimated in milliseconds. Complex transmissions, such as operational overlays, may require several minutes until more powerful compression techniques are implemented. In a parallel vein, unit and vehicle commanders could edit only their own digital reports, not reports originated by others. Consequently, consistency of relayed digital reports was ensured and quantitative measures of consistency were assumed to be 100 percent.

Two measures are not presented, because the number of observations in the Baseline condition was too small to support meaningful analysis of data. The deviation of the BLUFOR location reported in a SITREP from the actual BLUFOR location required two FLOT (forward line of own troops) endpoints to enable computation, and nearly all Baseline SITREPs reported own unit location as a single center-of-mass grid. The elapsed time for the companies to respond to a request for a fuel/ammunition report was captured only infrequently.

Receive and Transmit the Mission

Hypothesis 3.1: The CVCC units' ability to receive and transmit the mission on the battlefield was expected to be significantly better than the Baseline units'.

The measures supporting this function captured the duration of FRAGO transmissions, the number and duration of transmissions clarifying the FRAGO, and the consistency of FRAGOs relayed on the company command nets. The performance data are summarized in Table 16. These data were collected only for Stages 2 and 3, when the battalion FRAGOs were issued and executed.

Table 16

Mean Performance Data for Receive and Transmit the Mission Hypothesis Measures, by Stage and Condition

Measures	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Elapsed time from Bn transmission of FRAGO to receipt by co cdr/XO (minutes)	0[a] 0 n=6	18.65 (6.14) n=6	.09[a] (.08) n=6	15.65 (8.40) n=5
Number requests by co cdrs/XOs to clarify FRAGO/overlay	0 0 n=36	.33 (.53) n=36	.08 (.28) n=36	.53 (.97) n=30
Duration of requests to clarify FRAGO/overlay (minutes)				
Company commanders	-.- -.- n=0	.43 (.07) n=5	.26 -.- n=2	.43 (.23) n=12
Company XOs	-.- -.- n=0	.60 (.46) n=7	-.- -.- n=0	.58 (.55) n=3
Consistency of FRAGO received (percent)	100[a]	18.94 (12.41) n=17	100[a]	35.27 (17.21) n=15

Note. Standard deviations appear in parentheses below the means.

No battalion FRAGO was published during Stage 1.

[a]The CVCC model ensured nearly instantaneous, error-free transmission of FRAGOs.

Elapsed time from battalion transmission of FRAGO to receipt by company commander/XO. As explained in Appendix B, this measure was defined as the total elapsed-time from the start of the TOC's transmission of a FRAGO to the point when the last company commander finished relaying the FRAGO to his XO, including any transmissions clarifying the order. In the CVCC condition, values for this measure were assumed to be zero when no requests for clarification occurred. Mean transmission times in the Baseline condition (see Table 16) were nearly 16 minutes or greater. The maximum value for CVCC battalions was .35 minutes--the time spent by a company commander seeking clarification. The time saved by the digital capabilities enabled the CVCC battalions to begin planning and executing the mission earlier. Because of the fixed values for the CVCC condition, nonparametric analyses of differences between conditions were performed using Mann-Whitney tests. The difference between Baseline and CVCC conditions was significant in Stage 2 ($U(6, 6) = 0$, $p = .001$) and in Stage 3 ($U(5, 6) = 0$, $p < .004$).

Number of requests by company commander/XO to clarify FRAGO/overlay. This measure captured the frequency with which company commanders and XOs requested clarification of FRAGOs transmitted to them, including the digital overlays transmitted in the CVCC condition. Unique requests (generally individual transmissions) were tallied from voice radio playback logs, with requests for restatement of information counted as unique transmissions. The definition of this measure appears in Appendix B. Summary data are presented in Table 16. CVCC participants rarely requested clarification of FRAGOs, whereas Baseline participants fairly frequently sought clarification, some individuals issuing up to four requests in one stage. Because of the predominance of zero values in these data, they were analyzed with Mann-Whitney tests. The analyses revealed significant differences between Baseline and CVCC conditions in Stage 2 ($U(36, 36) = 450$, $p < .001$) and Stage 3 ($U(30, 36) = 400.5$, $p < .01$). Thus, the CVCC's digital FRAGOs with graphic overlays provided greater apparent clarity of information than the Baseline condition's voice-transmitted FRAGOs.

Duration of requests by company commanders/XOs to clarify FRAGO/overlay. This measure quantified the actual voice transmission time spent by company commanders and XOs clarifying the FRAGOs (see Appendix B for the definition). It should be noted that clarification times also are incorporated in the FRAGO transmission times discussed in an earlier subsection. As seen in Table 16, in the CVCC condition the two requests for clarification which occurred across both stages averaged one-quarter minute. By contrast, Baseline clarification requests averaged around one-half minute. Due to the infrequent observations for the CVCC battalions, no ANOVAs were performed on these data.

When these data are combined with the data for number of clarification requests, the difference between the two conditions is dramatic. In the CVCC condition, the FRAGO's graphic overlay and embedded text were apparently so self-explanatory that unit and vehicle commanders spent almost no time seeking clarification. In contrast, Baseline commanders altogether spent over six minutes on the radio obtaining clarification of FRAGOs during each stage.

Consistency of FRAGO received. FRAGO consistency was quantified by comparing the contents of the FRAGO received by the company XO to a template of key information from the scripted FRAGO. The process yielded a percentage score (0-100%), with higher values representing better consistency. Scores for the CVCC condition were set at 100%, since the evaluation's CVCC model ensured consistency of transmitted information. For the Baseline condition, the mean percentage of information relayed correctly (see Table 16) was 19% in Stage 2 and 35% in Stage 3. Because of the fixed values (100%) for the CVCC condition, statistical analysis was performed using the Mann-Whitney test. The difference between the two conditions was significant in Stage 2 ($U(17, 18) = 0$, $p<.001$) and in Stage 3 ($U(15, 18) = 0$, $p<.001$). The contrast between the two conditions was dramatic, indicating a substantial loss or distortion of information when using voice communications.

In general, the information lost as Baseline participants relayed FRAGOs included friendly situation information, especially that pertaining to other companies; enemy situation information; detailed map information, such as grid specifications for phase lines, axes and boundaries; and coordination information such as the requirement to report when set.

To determine if less consistent Baseline FRAGOs generated more clarification activity, Pearson product-moment correlations were computed between FRAGO consistency scores and time spent clarifying FRAGOs. The resulting correlation coefficients for Stages 2 and 3 were .13 and -.23, respectively. These values indicate no strong relationship between FRAGO consistency and clarification requests.

Summary of key data. The data for this function convincingly documented performance advantages of the CVCC system. Both speed and consistency in transmitting FRAGOs were significantly better among CVCC-equipped units. The evaluation's CVCC model provided nearly instantaneous FRAGO transmission and freedom from errors upon relay, ensuring immediate dissemination of orders containing complete, undistorted information. Further, digital FRAGOs apparently conveyed mission information more clearly, rarely generating requests for clarification. In contrast, Baseline commanders sacrificed an average of 15 minutes or more of mission execution time relaying and clarifying mission information, and they correctly relayed only one-third or less of the FRAGO information to their subordinates. In a nutshell, the CVCC system substantially enhanced the battalion's ability to disseminate mission information. An important qualification here is the limited CVCC model of digital transmission, which did not reflect the delays and degradation encountered with an actual SINCGARS system.

The data from this evaluation represent only part of the process involved in disseminating FRAGOs throughout a fully manned battalion. In reality, unit leaders at all levels would have to relay FRAGOs to completely disseminate them, adding time to the communications chain. The ease of relaying digital FRAGOs would be expected to speed the process of passing orders down the complete command chain.

Receive and Transmit Enemy Information

Hypothesis 3.2: The CVCC units' ability to receive and transmit enemy information on the battlefield was expected to be significantly better than the Baseline units'.

The measures used to evaluate this hypothesis quantified three aspects of INTEL report transmissions: speed of fully disseminating scripted reports, clarifications requested, and information loss or distortion resulting from the dissemination process. Table 17 summarizes the performance data supporting this hypothesis.

Table 17

Mean Performance Data for Receive and Transmit Enemy Information Hypothesis Measures, by Stage and Condition

Measures	Stage 1		Stage 2		Stage 3	
	CVCC	Baseline	CVCC	Baseline	CVCC	Baseline
Time to transmit INTEL reports full net (minutes)	0[a]	1.65 (.96) n = 10	0[a]	1.58 (1.03) n = 3	0[a]	.82 -.- n = 1
Number requests to clarify INTELs						
Bn Echelon	0 0 n = 11	.09 (.30) n = 11	0 0 n = 11	.08 (.29) n = 12	.09 (.30) n = 11	.13 (.35) n = 8
Co Echelon	0 0 n = 36	.06 (.23) n = 36	0 0 n = 36	.06 (.24) n = 35	0 0 n = 36	0 0 n = 25
Consistency of INTEL received (percent)	100[a]	60.32 (39.95) n = 6	100[a]	100.00 -.- n = 1	100[a]	25.00 -.- n = 1

Note. Standard deviations appear in parentheses below the means.

[a]The CVCC model ensured nearly instantaneous, error-free transmission of INTEL reports.

Time to transmit INTEL reports full net. An index of transmission speed, this measure was defined as the elapsed time from the start of an INTEL transmission by the TOC until the message was received by the last manned vehicle. Reception was signalled by verbal acknowledgment in the Baseline condition, and by the transmission event itself in the CVCC condition. For CVCC units, basic transmission values were set at zero because all manned elements were on a common digital net (battalion command net) and digital transmission was nearly instantaneous, so all unit and vehicle commanders received the INTEL at the same time. For Baseline units, the INTEL was transmitted by TOC personnel on the battalion O&I net and was then relayed by the company XO to the company commander. The time consumed by clarification queries was included in Baseline transmission times. Only INTELS relayed by company XOs were included in the analysis.

As Table 17 shows, Baseline transmission times averaged more than 1.5 minutes in Stages 1 and 2. Due to the fixed zero values for the CVCC condition, the nonparametric Mann-Whitney test was used for inferential analysis. Because of the small sample sizes in Stages 2 and 3, only data from Stage 1 were analyzed. The difference between Baseline and CVCC conditions in Stage 1 was significant ($U(10, 18) = 0$, $p < .001$).

Overall, Baseline commanders relayed approximately 10% of the INTELs scripted for the scenario. The following numbers of scripted reports drove the opportunities to relay INTELs: fifteen in Stage 1, five in Stage 2, and nine in Stage 3. In the CVCC condition, all unit and vehicle commanders received INTEL reports simultaneously on the battalion's digital net, so there was no need to relay them. Although these data do not lend themselves to statistical analysis, the advantages of the CVCC system were clear and dramatic. Every CVCC commander received all INTEL reports with no delay and with 100% consistency. Thus the CVCC digital capabilities saved valuable time and ensured maximum distribution of information at the echelons implemented in this evaluation.

Two possibilities could explain the low number of reports relayed in the Baseline condition. The first is a matter of relevance. Company XOs might not have relayed INTEL reports which they considered of no interest to their commander or subordinates. The second is a matter of priority. When the company was in contact, INTELs that did not bear on the immediate situation might not have been relayed, in deference to more pressing operational requirements.

Number of requests to clarify INTELs. This measure quantified the frequency with which unit and vehicle commanders requested clarification of INTEL reports they received by voice or digital transmission. Unique requests (generally individual transmissions) were tallied from voice radio playback logs, with requests for restatement of information counted as unique transmissions (see Appendix B for the definition of this measure). Table 17 presents summary data for the battalion and company command echelons. Only one request for clarification of an INTEL ever occurred in the CVCC condition. Baseline participants issued three requests for clarification in Stage 1, three in Stage 2, and one in Stage 3. Mann-Whitney tests indicated there were no significant differences between the two conditions for any of the stages or echelons.

Consistency of INTEL received. This measure was designed to capture the distortion or loss of intelligence information resulting from the process of disseminating INTEL reports. Comparing the contents of INTEL reports received by company commanders to a template corresponding to the scripted report, consistency was defined as the percentage of elements accurately transmitted, with higher values constituting better performance. As with FRAGOs, the evaluation's CVCC model ensured consistency of transmitted information, so CVCC scores were set at 100%. Among Baseline units, only eight relayed INTEL reports were scorable (see Appendix B for criteria). Only in Stage 1 was more than one INTEL report scorable; during that stage consistency scores averaged 60%. These data were analyzed by means of the Mann-Whitney test, due to the fixed values for the CVCC condition. Only data from Stage 1 were analyzed, because of the extremely small Baseline sample sizes in Stages 2 and 3. The difference between Baseline and CVCC conditions in Stage 1 was significant ($U(6, 18) = 8.5$, $p<.001$).

These observations indicate substantial loss or distortion of information occurred when INTEL reports were relayed by voice radio. Among the information commonly lost was number of enemy vehicles, type of activity, and heading.

Summary of key data. The transmission of INTEL reports was significantly faster and more error-free in the CVCC condition. The rapid, highly consistent dissemination of digitally transmitted INTEL reports afforded distinct advantages to unit and vehicle commanders using CVCC equipment. These advantages ensured wide distribution of intelligence information without degradation of quality or currency. In contrast, Baseline INTEL reports were seldom relayed, and those that were relayed suffered loss or distortion of information. Clearly the CVCC capabilities enhanced the battalion's distribution of up-to-date information about enemy activities. At the same time, it should be remembered that the CVCC model of digital transmission did not reflect the delays and degradation encountered with an actual SINCGARS system.

This evaluation quantified only part of the process involved in disseminating INTEL reports throughout a battalion. In reality, unit leaders across all echelons could choose to relay INTELs, adding time to the distribution process as well as additional opportunities for loss and distortion of information. The ease of relaying digital reports would be expected to speed the process of fully disseminating enemy information.

Receive and Transmit Friendly Troop Information

Hypothesis 3.3: The CVCC units' ability to receive and transmit friendly troop information on the battlefield was expected to be significantly better than the Baseline units'.

The measures supporting this function focused on the time spent communicating about the unit's activities and status, and on the timeliness of reporting key battle milestones. Table 18 provides summary data for this hypothesis.

Table 18

Mean Performance Data for Receive and Transmit Friendly Troop Information Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Mean time to transmit SITREP full net (minutes)	NA	3.05 (2.84) n=52	NA	2.61 (2.16) n=32	NA	2.24 (1.72) n=25
Number of voice transmissions from Bn cdr/S3 to TOC	5.17 (5.56) n=6	13.50 (10.67) n=6	1.83 (1.83) n=6	9.50 (7.59) n=6	**	**
Mean duration of commo between TOC and Bn cdr/S3 (minutes)	.56 (.58) n=42	.51 (.57) n=142	.52 (.47) n=20	.45 (.37) n=88	**	**
Delay between observed event and report to TOC (minutes)						
PL/LD crossing	.91 (1.59) n=10	1.13 (1.46) n=12	1.28 (1.04) n=12	.73 (.72) n=6	.43 (.30) n=4	– n=0
BP arrival	1.36 (1.58) n=11	3.29 (3.83) n=12	1.79 (.15) n=3	2.26 (3.93) n=5	5.43 (3.90) n=4	2.57 (3.53) n=3

Note. Standard deviations appear in parentheses below the means.

NA indicates the measure, as defined, did not apply to the CVCC condition.

Double asterisks (**) indicate data are excluded because of unique Stage 3 features.

Mean time to transmit SITREP full net. This measure was designed to quantify speed of throughput transmission of friendly unit information as represented in the SITREP. It was defined as the elapsed time from a platoon leader's (role played by support staff member) transmission of a SITREP on a company net until reception of the company SITREP was acknowledged by the TOC (see Appendix B for the complete definition of this measure). The primary processing time involved was the platoon leader's transmission time and the company XO's relay time. Only SITREPs which were originated at the platoon level and relayed to the TOC were analyzed. CVCC XOs were instructed to compose integrated company-level SITREPs, rather than relay SITREPs received from subordinates. As a result, this measure was not well suited to characterizing CVCC performance, and data for the CVCC units were excluded from the analysis.

Table 18 summarizes mean Baseline data for this measure. On average, Baseline participants took more than two minutes to transmit SITREPs full net.

Number of voice transmissions between battalion commander/S3 and TOC. This index quantified the volume of voice radio coordination occurring among the battalion commander and his primary staff, excluding orders and reports. Transmissions of interest here included coordination, analysis, and general information-sharing exchanges between the commander, S3, and TOC personnel. Named reports (CONTACT, CFF, ADJUST FIRE, SHELL, SPOT, SITREP, FUEL, AMMO, INTEL, NBC) and FRAGOs were excluded. From playback-based transcriptions of message contents, the number of qualifying transmissions was tallied (see Appendix B for the complete operational definition). This measure applied only to Stages 1 and 2, because there was no scripted brigade FRAGO in Stage 3 to drive planning and coordination. It should be noted that this measure differs from the total number of voice radio transmissions discussed later in this section, where transmissions were based on keying the radio, rather than playback of report contents.

Summary data for this measure appear in Table 18. Baseline battalion command group members exchanged substantially more voice radio transmissions with TOC staff than their CVCC counterparts, outnumbering the CVCC participants as much as five-fold. The effect of condition was significant ($F(1,20) = 7.30$, $p = .014$), while the effect of stage and the condition by stage interaction were nonsignificant. The lower number of coordination exchanges among CVCC-equipped command groups indicates the digital exchange of FRAGOs, overlays, and related information reduced the need to coordinate by voice radio means.

Mean duration of voice radio transmissions between battalion commander/S3 and TOC. This measure was designed to characterize the typical time that members of the battalion command group spent coordinating with each other by voice radio. As with the preceding measure, named reports and FRAGOs were excluded. For Stages 1 and 2 only, the total elapsed time required to complete each exchange was computed from playback information. In general, shorter transmission times were desirable. This measure differs from the average length of voice radio transmissions discussed later in this section; transmission length was computed from radio keying events.

The mean durations (see Table 18) were quite comparable between the Baseline and CVCC conditions. The effects of condition and stage were both nonsignificant, as was the condition by stage interaction. In other words, the length of individual voice exchanges was comparable across conditions. However, when the data for this measure were combined with the frequency data from the preceding measure, the CVCC system reduced the total volume of voice radio traffic in this category by nearly 50 minutes on the battalion command and battalion O&I nets in Stage 1, and by almost 30 minutes in Stage 2. This is a striking effect of the CVCC's digital capabilities.

Delay between observed PL/LD crossing and reported crossing. Linked to key tactical milestones, this measure was designed to index the timeliness with which the battalion's companies reported crossing a designated control line. Elapsed time was calculated between the observed crossing and the company's corresponding report to the TOC. Cases where a unit failed to report crossing the PL/LD were ignored. Smaller values (shorter delays) corresponded to better performance. The data for this measure (see Table 18) did not yield any significant main effects or interactions. However, it is important to note that it was not essential for CVCC commanders to report crossing PLs and LDs because the mutual POSNAV feature gave the battalion commander and his staff the ability to monitor companies' locations in real time.

Delay between observed arrival and reporting set at BP. Similar to the preceding measure, this index quantified the timeliness of the battalion's reporting of its updated status at the end of a tactical movement phase. The measure was computed as the elapsed time from a unit's observed arrival in a battle position to the point when that company reported "set" in the BP on the battalion command net. In the counterattack stage, the objectives were treated as BPs. Cases where a company failed to report being set were ignored. Smaller values (shorter delays) indicated better performance.

The data for this measure (see Table 18) showed a sizable advantage for the CVCC condition in Stages 1 and 2. Neither of the main effects nor the interaction was significant, even when the data were reanalyzed excluding Stage 3. However, practical consideration of the trends illustrates the advantage of the CVCC capabilities. In the Baseline condition, the battalion commander relied on voice radio traffic to monitor the flow of the battle. Overall, Baseline commanders received information indicating readiness to continue the mission that averaged up to 5.4 minutes old, and was nearly 13 minutes old on occasion. Moreover, those reports represented only periodic updates. These findings translated into substantial delays in achieving readiness to continue the mission. In the CVCC condition, the digital system provided the battalion commander and TOC staff with continuous information on the location and status of the entire force. Therefore, reporting being set in a new BP was marginally necessary, at best.

Summary of key data. In spite of the difficulties in testing statistical significance for this hypothesis, the data firmly illustrated the beneficial contributions of the CVCC system. It is noteworthy that, in principle, the CVCC capabilities reduced the need for reporting a unit's status and location. This advantage should be especially important when a unit is conducting continuous flow operations. Unfortunately, the three-stage structure of the test scenario, with breaks and reconstitution between stages, may not have fully capitalized on the CVCC's capabilities.

The mutual POSNAV feature and the automated logistics reporting capabilities provided a readily-accessible, up-to-date profile of unit status. A recurring comment among CVCC participants during debriefings was the observation that they had an excellent picture of the unit's status throughout the battle. By contrast, Baseline commanders frequently commented that they had difficulty keeping track of the friendly unit situation, probably due in part to the time it took subordinates to provide updated information on their status. The receipt of dated information led to delays in Baseline units' readiness to continue the mission. Also noteworthy was the reduced need for members of the CVCC-equipped command group to coordinate by voice radio. This was most likely the result of exchanging orders, overlays, and related information in digital form. All in all, the CVCC system clearly enhanced the dissemination of friendly unit information.

Manage Means of Communicating Information

Hypothesis 3.4: The CVCC units' ability to manage means of communicating information on the battlefield was expected to be significantly better than the Baseline units'.

Data for this function derive from four measures: the average length of voice transmissions, the number of voice transmissions, transmission time on voice nets, and the number of named voice reports. Summary performance data are presented in Table 19.

Average length of voice radio transmissions. This measure was designed to provide a useful indicator of the average voice transmission duration. As explained in Appendix B, a transmission was defined as the uninterrupted keying of a microphone on a radio network. Durations of less than one second and greater than 30 seconds were excluded, to eliminate both isolated key clicks and "hot mike" malfunctions. It was expected that voice transmissions of CVCC unit and vehicle commanders would tend to be shorter, given that much of their tactical information was communicated digitally.

Generally averaging between three and five seconds, the duration of voice transmissions (see Table 19) did not differ significantly as a function of conditions, stages, or their interaction, except for the C Company command net, where the

Table 19

Mean Performance Data for Manage Means of Communicating Information Hypothesis Measures, by Stage, Condition, and Network

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Average voice transmission duration (seconds)						
Bn cmd net	4.30 (.54) n=6	4.40 (.68) n=6	4.21 (.60) n=6	4.53 (.50) n=6	3.93 (.30) n=6	4.14 (.46) n=5
Bn O&I net	3.58 (.35) n=6	3.80 (.41) n=6	3.23 (.55) n=6	3.56 (.55) n=6	3.19 (.33) n=6	3.40 (.32) n=5
A Co cmd net	3.83 (.58) n=6	3.82 (.52) n=6	4.06 (.88) n=6	3.94 (.51) n=6	4.05 (.45) n=6	4.25 (.62) n=5
B Co cmd net	3.65 (.56) n=6	4.02 (.87) n=6	3.58 (.37) n=6	3.97 (.59) n=6	3.59 (.49) n=6	3.78 (.63) n=5
C Co cmd net	3.20 (.19) n=6	4.09 (.53) n=6	3.42 (.20) n=6	4.13 (.41) n=6	3.28 (.19) n=6	4.20 (.27) n=5
Total number of voice radio transmissions						
Bn Cmd net	281.17 (48.39) n=6	501.00 (120.80) n=6	169.00 (48.03) n=6	341.17 (93.06) n=6	**	**
Bn O&I net	89.33 (34.64) n=6	278.50 (69.19) n=6	50.83 (35.27) n=6	172.17 (60.18) n=6	**	**
A Co cmd net	154.00 (66.88) n=6	249.00 (66.87) n=6	81.33 (38.05) n=6	162.00 (27.06) n=6	**	**
B Co cmd net	152.50 (25.59) n=6	225.50 (57.61) n=6	97.33 (21.64) n=6	170.50 (42.83) n=6	**	**
C Co cmd net	89.50 (24.92) n=6	231.00 (50.22) n=6	83.17 (14.52) n=6	177.83 (46.90) n=6	**	**

(*table continues*)

(Table 19 continued)

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Total time on voice radio net (minutes)						
Bn Cmd net	20.34 (5.55) n=6	35.98 (6.11) n=6	12.08 (4.62) n=6	25.56 (7.26) n=6	**	**
Bn O&I net	5.25 (1.95) n=6	17.52 (4.18) n=6	2.86 (2.30) n=6	10.12 (3.38) n=6	**	**
A Co cmd net	9.86 (4.30) n=6	16.04 (5.32) n=6	5.82 (3.57) n=6	10.68 (2.30) n=6	**	**
B Co cmd net	9.10 (.86) n=6	14.51 (1.31) n=6	5.81 (1.36) n=6	11.01 (1.69) n=6	**	**
C Co cmd net	4.72 (1.15) n=6	15.51 (2.61) n=6	4.75 (.91) n=6	12.29 (3.81) n=6	**	**
Total number of named voice reports						
Bn Echelon	1.45 (1.69) n=11	2.67 (2.71) n=12	.64 (1.03) n=11	.92 (1.00) n=12	**	**
Co Echelon	3.33 (2.34) n=36	16.67 (5.94) n=36	1.47 (1.63) n=36	7.92 (4.71) n=36	**	**

Note. Standard deviations appear in parentheses below the means.

Double asterisks (**) indicate data are excluded because of unique Stage 3 features.

effect of condition was significant ($F(1, 29) = 57.24$, $p<.001$). There is no apparent explanation for the significantly longer Baseline durations on the C Company net. In essence, the patterns were very similar across the various radio nets implemented in the evaluation. These findings suggest that the availability of digital communications did not directly influence voice transmission duration.

Soldiers are trained to use short voice transmissions in order to reduce the likelihood of being located by enemy direction finding equipment. When a longer message must be transmitted, radio operators break the message into shorter transmissions. The data for this measure do not reflect the number of transmissions required to pass complete messages. A second reason to break up transmissions in this manner is to allow access to the network for higher priority traffic. These data show that soldiers maintained radio transmission discipline in accordance with Army SOP and training, regardless of the experimental condition. This was consistent with the battalion SOP provided to all unit and vehicle commanders participating in the evaluation.

Total number of voice radio transmissions. This measure quantified the overall volume of voice radio activity. As with the preceding measure, a transmission was defined by the keying of a microphone, with events less than one second and greater than 30 seconds being ignored. By no means was a transmission synonymous with a complete message or report (see Appendix B for the definition of this measure). Because a great deal of tactical information was communicated digitally in the CVCC condition, it was expected that CVCC participants would generate fewer voice transmissions. Due mainly to the lack of a scripted brigade FRAGO in Stage 3, this measure was applied to only Stages 1 and 2.

The data for this measure appear in Table 19, organized by radio net. The means for the CVCC units were consistently lower than those for the Baseline condition, with a significant effect of condition for every network (e.g., for battalion command net, $F(1, 20) = 33.05, p<.001$). In addition, a significant stage effect was found for all nets except C Company command (e.g., for battalion command net, $F(1, 20) = 15.91, p<.001$). The condition by stage interaction was nonsignificant for all of the networks. Appendix C includes a complete account of ANOVA summaries.

The digital communication capabilities of the CVCC system substantially reduced voice radio traffic at battalion and company echelons (see Figures 16 and 17). Across all networks the reduction factors ranged from 20% to 70%, with the largest reductions appearing on the battalion O&I network.

The differences between stages can be explained by a variety of factors, including the differing nature of the missions and variable stage lengths. Actual mission execution times varied between stages, with execution times being longer in Stage 1.

Total time on voice radio network. This measure provided a more complete picture of voice communication activities. As explained in Appendix B, it was computed by multiplying the total number of voice transmissions by the average length. This yielded a value reflecting the total "air time" for each net, excluding microphone keying events less than one second and greater than 30 seconds. Due to the Baseline participants' total reliance on voice communications, it was expected that they would spend more total time on the voice radio nets. As was the case with number of voice transmissions, this measure applied to only Stages 1 and 2.

The data for this measure appear in Table 19, organized by radio net. The means for the CVCC units were consistently lower

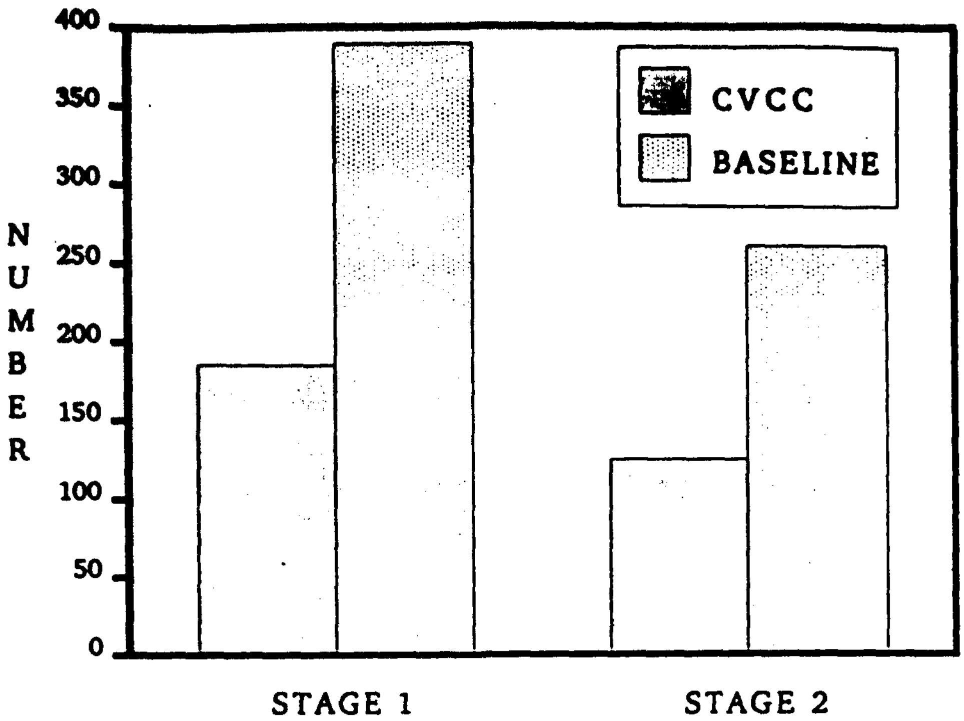

Figure 16. Volume of voice radio transmissions on battalion nets (average per net).

than those for the Baseline condition, with a significant effect of condition for every network (e.g., for battalion command net, $F(1, 20) = 35.76$, $p<.001$). In addition, a significant stage effect was found for all nets except C Company command (e.g., for battalion command net, $F(1, 20) = 14.71$, $p<.001$). The condition by stage interaction was not significant for any of the nets. Appendix C includes a complete account of ANOVA summaries.

The digital communication capabilities of the CVCC system significantly reduced the total time on voice radio nets at battalion and company echelons. Across all networks the reduction factors ranged from 37% to 72%, with the largest reductions generally occurring on the battalion O&I network. This consistent pattern constitutes a considerable battlefield advantage, favorably impacting network accessibility for critical C3 traffic, time required to disseminate combat information, and susceptibility to electronic detection and electronic countermeasures.

<u>Number of named voice reports</u>. An important aspect of voice radio communications was the total number of named voice reports transmitted by each unit and vehicle commander. Named reports included CONTACT, SPOT, SHELL, INTEL, SITREP, CFF, ADJUST FIRE, FUEL, AMMO, and NBC reports. From playback-based transcriptions of message contents, the number of qualifying reports was tallied

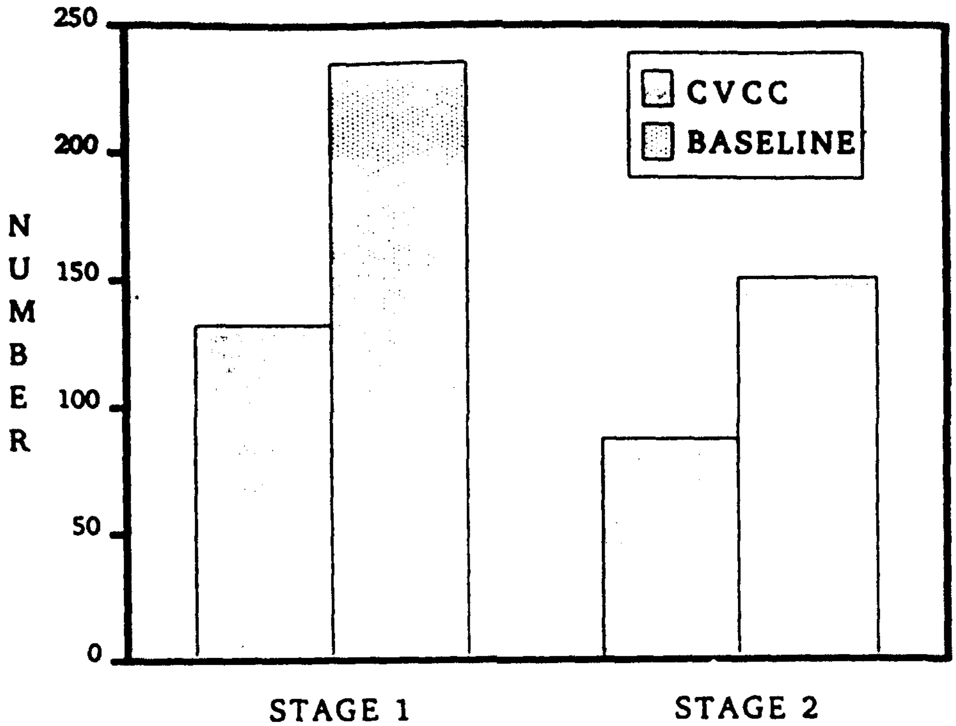

Figure 17. Volume of voice radio transmissions on company nets (average per net).

across all report types. The definition of this measure appears in Appendix B. For the CVCC condition, this measure is a reflection of practical decisions to transmit messages such as CONTACT reports by voice, when they could have been prepared and transmitted digitally. As with the two preceding measures, only data from Stages 1 and 2 were analyzed.

Summary data for this measure appear in Table 19. The CVCC unit and vehicle commanders transmitted substantially fewer named voice reports than their Baseline counterparts, especially at the company echelon. At the battalion echelon the reduction averaged over 40%, while at the company echelon it averaged 80%. The effect of condition was significant ($F(1, 182) = 209.78$, $p<.001$), as were the echelon effect ($F(1, 182) = 96.53$, $p<.001$) and the stage effect ($F(1, 182) = 66.95$, $p<.001$). These results establish that, at a global level, the CVCC's digital reporting capabilities significantly reduced the voice reporting load. The higher frequency of reports at the company echelon reflected the fact that most of the reporting to the TOC was accomplished by company commanders and XOs. The differences between Stages 1 and 2 undoubtedly resulted from the scripted differences between the delay and counterattack missions.

Among Baseline unit and vehicle commanders, the most frequently transmitted report types were SITREP, SPOT, CONTACT, and CFF reports, accounting for 21%, 20%, 14%, and 13% of the company echelon total in Stage 1, respectively. In the CVCC condition, CONTACTs, SPOTs, and SITREPs accounted for most of the company echelon reports transmitted by voice, with 32%, 27%, and 25% of the Stage 1 total, respectively. It appeared that CVCC commanders opted to send voice reports when urgency or tone of the communication was a key factor. When they did opt for voice transmission, they retained the option to obtain precise location information by visually extracting a lase-based map grid from a digital report field.

For the CVCC condition, a complete picture of reporting activity requires an accounting of digital reports. In Stage 1, CVCC participants at the battalion level originated an average of 3.33 digital reports, while those at the company level originated an average of 10.50. Comparable figures for Stage 2 were 2.86 and 7.03 at the battalion and company echelons, respectively. A more detailed discussion of digital reporting can be found in Atwood et al. (in preparation). When these figures are combined with the data from Table 19, they reveal that 76% of the total reports sent by CVCC battalion commanders and S3s were transmitted digitally; the comparable proportion for company commanders and XOs was 80%. Thus, by far the bulk of the reporting in the CVCC condition was accomplished digitally. Overall, CVCC battalion commanders and S3s sent more reports than their Baseline counterparts, whereas company commanders and XOs in both conditions sent about the same volume of reports.

Summary of key data. Taken together, these results document the value of the CVCC's digital communications capabilities. When the data for total time on voice nets are considered, the operational impact becomes especially important. In Stage 1, for example, Baseline commanders used the battalion level radio nets for an average of 53.5 minutes, compared to 25.6 minutes of voice traffic in CVCC units. Besides enhanced operational security attributed to the reduced voice radio signature, the accessibility of command networks was notable. Frequently during scenario debriefings, Baseline unit commanders expressed frustration at being unable to enter the battalion command network to report critical events. By contrast, CVCC unit commanders often expressed wonder that the command net seemed so quiet, yet they didn't perceive any lack of tactical information.

Direct and Lead Subordinate Forces

Hypothesis 3.5: The CVCC units' ability to direct and lead subordinate forces on the battlefield was expected to be significantly better than the Baseline units'.

The data for this function captured whether the battalion prevented decisive engagement in delay situations, whether it withdrew intact from initial delay positions, whether it massed fires on the OPFOR in the counterattack, and whether the battalion met the brigade commander's intent. Three of these measures used criteria from applicable mission training plans to arrive at a binary (yes/no) determination, as explained in the discussion that follows. A composite measure integrating the component measures provided an overall index of the battalion's command effectiveness.

Did the task force prevent decisive engagement? This evaluative question was answered (yes or no) by the Battle Master during the execution of both delay stages (Stages 1 and 3). The Battle Master assessed the commanders' reaction time to the order to displace, the proportion of battalion vehicles successfully displacing, and the influence of friendly SAFOR controllers' response time. He also determined the number of BLUFOR vehicles lost (see Appendix B for the definition of this measure). The data from this measure showed no consistent trends. In Stage 1, all CVCC battalions prevented decisive engagement, while four of six Baseline battalions did so. In Stage 3, four of four Baseline battalions prevented decisive engagement, but only four of six CVCC battalions did likewise. Chi-square tests revealed that the differences between conditions were not significant for either stage.

Did the battalion withdraw intact? Near the end of each delay stage (Stages 1 and 3) the Battle Master answered this question with a yes or no determination. The battalion was considered intact if 70% of the unit survived by the end of the withdrawal. Performance trends for this measure slightly favored CVCC units. During Stage 1, five of six CVCC units and four of six Baseline units withdrew intact. In Stage 3, four of six CVCC units and two of four Baseline units met the criterion. The differences between conditions were not significant, as shown by chi-square tests.

Number of counterattacking companies engaging OPFOR. This measure quantified the extent to which the battalion massed fires on the OPFOR in the counterattack stage (Stage 2). The Battle Master observed the number of BLUFOR companies that engaged (exchanged fire with) the OPFOR main body and recorded the number on his log. Five CVCC battalions engaged the OPFOR with two companies and one battalion engaged with three companies. In the Baseline condition, one battalion engaged the OPFOR with one company, four battalions engaged with two companies, and one battalion engaged with three companies. Thus, all of the CVCC-equipped battalions successfully massed fires and all but one Baseline battalion did likewise. The difference between conditions was not significant, as revealed by a chi-square test.

To what extent did the battalion meet the brigade commander's intent? This measure used a percentage summed across component variables to express the overall performance of units in each stage, as compared to the brigade commander's intent (see Meade et. al., in preparation) and mission training plan standards (Department of the Army, 1988). In delay stages (Stages 1 and 3), component variables included the percentage of BLUFOR losses, the number of OPFOR vehicles killed on the enemy side of selected PLs, and the number of OPFOR vehicles penetrating a given line by the end of the stage. In the counterattack stage (Stage 2), the component variables included the percentage of BLUFOR and OPFOR losses and the number of OPFOR vehicles that penetrated a given line by the end of the stage.

The means for this measure (see Appendix C, Table C-10) showed a trend in favor of Baseline units in Stages 1 and 3, but the condition effect was not significant. The degree to which this measure relied on OPFOR losses and terrain control measures might explain the observed trends. Baseline battalions tended to fight longer from initial delay positions, and in so doing, inflicted heavier losses on the OPFOR early in the battle. At the same time, Baseline units took heavier losses in those initial positions, at least in Stage 1. By contrast, CVCC battalions tended to withdraw from initial positions earlier, in accordance with the concept of the operation. Since OPFOR losses contributed more heavily to the overall score, this measure appears to have favored Baseline units somewhat.

The results for this measure contrast with the findings discussed earlier for end-of-stage stand-off range, which indicated the CVCC-equipped battalions more successfully met the brigade commander's intent for maintaining contact while limiting the risk of attrition. In maintaining greater stand-off ranges, the CVCC battalions appear to have compromised somewhat their ability to destroy the enemy and stop his momentum.

Battalion command effectiveness composite index. This composite measure provided an overall index of the effectiveness of the battalion's command procedures. The index integrated the information contained in the four separate measures supporting this hypothesis. Computations transformed the original score for each of the input measures to a standard distribution ranging from zero to one hundred. Then the transformed scores were averaged to yield a composite index for each battalion in each stage. The complete operational definition of this measure appears in Appendix B. As shown in Appendix C, Table C-10, the composite scores ranged from 29.45 to 98.17 for the CVCC battalions, and from 62.39 to 97.59 for the Baseline battalions. The effect of condition was not significant, nor was the stage effect or the condition by stage interaction. In a word, no consistent performance trends were revealed by the composite index.

Summary of key data. No significant differences between CVCC and Baseline conditions were found in any of the measures supporting this function. Thus, the data did not support the hypothesis that CVCC-equipped units would direct and lead subordinate forces more effectively than Baseline units.

Assess the Battlefield Situation

Hypothesis SA1: The CVCC unit leaders' assessment of the battlefield situation was expected to be significantly better than the Baseline units'.

Vehicle and unit commanders completed a Situational Assessment questionnaire at the end of Stage 3, estimating enemy and friendly losses and rating their confidence in their responses. Each participant was asked to report only for his own unit (i.e., battalion commander and S3 reported for the battalion, company commanders and XOs reported only for their respective companies). Their estimation responses were compared with actual data from that stage to determine how accurately they interpreted the tactical situation. Ratings of confidence were made using a five-point scale, with 1 anchored as "not at all confident" and 5 as "completely confident." A sample copy of the questionnaire can be found in Appendix A. Table 20 summarizes situational assessment data.

The Situational Assessment questionnaire was designed for administration immediately following the final stage of the test scenario. One Baseline battalion ended tactical execution with Stage 2, and a second Baseline scenario was terminated before OPFOR contact in Stage 3. Both of those units therefore reported on Stage 2, rather than Stage 3. The last two items reported in

Table 20

Mean Performance Data for Assess Situation Hypothesis Measures, by Condition

Measures	CVCC	Baseline
Number of vehicles destroyed (percent correct)		
OPFOR tanks		
Bn Echelon	50.09 (32.55) $n = 11$	40.17 (26.52) $n = 12$
Co Echelon	27.57 (23.19) $n = 35$	44.17 (34.19) $n = 36$
OPFOR BMPs		
Bn Echelon	48.09 (33.51) $n = 11$	39.11 (33.10) $n = 12$
Co Echelon	46.03 (29.64) $n = 35$	37.31 (30.91) $n = 36$
Own tanks		
Bn Echelon	38.09 (25.61) $n = 11$	27.83 (12.66) $n = 12$
Co Echelon	48.20 (34.94) $n = 35$	49.11 (43.31) $n = 36$

(table continues)

(Table 20 continued)

Measures	CVCC	Baseline
Determination whether own unit destroyed any OPFOR during delay (percent correct)		
Bn Echelon	90.91 n=11	75.00 n=8
Co Echelon	63.89 n=36	69.57 n=23
Distance from initial to subsequent BPs (deviation in kilometers)		
Bn Echelon	1.02 (1.09) n=11	2.64 (3.77) n=8
Co Echelon	1.21 (1.52) n=35	1.53 (1.51) n=24
Composite situational assessment index		
Bn Echelon	33.18 (11.97) n=11	30.98 (14.10) n=8
Co Echelon	21.65 (12.59) n=36	24.41 (12.31) n=23

Note. Standard deviations appear in parentheses below the means.

Table 20 were not appropriate for units that did not complete Stage 3; therefore, no data were collected from those two Baseline units for those items.

Percentage of OPFOR tanks correctly identified. Participants were asked how many OPFOR tanks (T-72s) their unit destroyed during the stage. As explained in Appendix B, their numerical responses were compared to the actual number of OPFOR tank losses obtained from the automated database. A value of 100% represented a perfect estimate. Estimated values greater or less than the actual number of kills were decremented; for example, when responses of 9 or 11 kills were compared to an actual value of 10, both received a value of 90%.

The performance scores were modest in both conditions (see Table 20). Neither the condition effect nor the echelon effect was significant, nor was the condition by echelon interaction. CVCC battalion commanders and S3s more accurately assessed OPFOR tank losses than did Baseline battalion command groups, but at the company level, Baseline units were more accurate.

Mean confidence ratings for this item appear in Appendix C, Table C-12. Overall, Baseline participants reported significantly higher confidence in their responses than CVCC groups ($F(1, 90) = 5.70$, $p=.019$). Neither the echelon effect nor the condition by echelon interaction was significant.

Percentage of BMPs correctly identified. Participants estimated how many BMPs their unit destroyed during the stage. This item differed from the preceding one only in the type of OPFOR vehicle. The scoring was accomplished in the same manner. At both echelons, CVCC unit and vehicle commanders assessed the number of OPFOR BMPs killed more accurately than did Baseline participants. However, the condition effect was not significant.

As seen in Appendix C, Table C-12, confidence ratings for these responses differed only slightly between conditions. Company-level Baseline participants registered more confidence in their responses, but no significant effect of condition was found. Neither the echelon effect nor the condition by echelon interaction was significant.

Percentage of own vehicles destroyed. Participants reported the number of tanks lost from their own unit during the stage. Scoring was accomplished in the same manner as with the two preceding items.

Overall, CVCC participants were slightly more accurate in their assessment of their own losses. Also, company commanders and XOs in both conditions made notably more accurate estimates of their vehicle losses than did battalion command group members. However, neither the condition nor the echelon effect was significant.

Mean confidence ratings reported in conjunction with this item can be found in Appendix C, Table C-12. Ratings were significantly higher among Baseline participants than CVCC ($F(1, 90) = 4.62$, $p=.034$), and significantly higher among company commanders and XOs than among battalion commanders and S3s ($F(1, 90) = 38.46$, $p<.001$). The condition by echelon interaction was not significant.

Destruction of OPFOR vehicles after the order to delay. This item asked the respondents whether their unit destroyed any OPFOR vehicles after they were ordered to displace. At the battalion echelon, CVCC participants were more frequently correct (91% correct) than Baseline participants (75% correct), but the reverse was evident at the company echelon (64% correct in CVCC, 70% in Baseline). Chi-square tests showed there was no significant difference between condition at either echelon.

Mean confidence ratings were very similar between conditions at the battalion level (CVCC mean = 4.00, Baseline mean = 4.12) and the company level (CVCC mean = 4.06, Baseline mean = 3.65). There were no significant differences between conditions or echelons.

Deviation between true and reported distance. The Stage 3 FRAGO specified initial and subsequent BPs for each company. Respondents were asked to estimate the distance between positions for their unit. Responses were compared with standard, measured values for each company, based on the master FRAGO. For the battalion echelon, the average for A, B, and C Companies was used.

As can be seen in Table 20, CVCC participants estimated the distance more accurately than did Baseline participants. However, the effect of condition was not significant. Neither was the echelon effect nor the condition by echelon interaction significant.

As seen in Appendix C, Table C-12, mean confidence ratings for this item were nearly identical for the two conditions. The ratings did not differ significantly as a function of condition or echelon. Likewise, the condition by echelon interaction was not significant.

Composite situational assessment index. To provide an overall indicator of situational assessment performance, the scores for the individual items from the Situational Assessment questionnaire were combined to form a composite index. Data from the two Baseline battalions failing to complete Stage 3 were excluded, as were data from unit and vehicle commanders who did not answer all five questions. Computational procedures were established to transform the original score for each of the input items to a standard distribution ranging from zero to one hundred. The transformed scores were then averaged to yield a composite index for each unit/vehicle commander in each stage. The complete operational definition of this measure appears in Appendix B. Higher scores represent better performance, up to the maximum score of 100.

Table 20 contains the summary data for this composite measure. There was no notable difference between the Baseline and CVCC conditions, and the effect of condition was not significant. However, the higher performance scores at the battalion level represented a significant echelon effect ($F(1, 74) = 8.16$, $p=.006$). The better performance among battalion commanders and S3s may well be the result of their greater levels of experience. The condition by echelon interaction was not significant.

Summary of key data. The analysis of data supporting the Assess Situation hypothesis yielded mixed trends, with no significant differences between conditions. Thus, the expected advantage for the CVCC condition was not demonstrated. The two cases where Baseline confidence ratings were significantly higher were not associated with higher performance scores. This suggests that Baseline participants may have overestimated their understanding of the battlefield situation. It may well be that the greater volume and wider dissemination of combat information in the CVCC condition gave CVCC participants a more realistic comprehension of their own situational assessment.

It should be noted that the situational assessment instrument was based on the assumption that short term memory realistically reflects situational awareness. However, the instrument was only administered once per test group, at the end of the last stage. By that point, the battalion typically had developed a working concept of the OPFOR formation's size, and an estimate of its current strength. Also, by virtue of relatively recent SITREPs from subordinates, Baseline participants should have had a fairly accurate snapshot of their own unit situation immediately preceding the end of the exercise. It is possible that awareness peaked at this point, regardless of condition. Unfortunately, the situational assessment methodology did not capture the participants' ongoing assessment of the tactical situation throughout the scenario. Therefore, if the CVCC system enabled commanders to maintain a more accurate assessment throughout the scenario, as their debriefing comments suggested, the "peaking" effect near the end of the exercise may have reduced the likelihood that such an affect would be demonstrated.

Summary of Findings

The CVCC capabilities enhanced the performance of battalions in four of the six functions under the Command and Control BOS. Table 21 summarizes the major findings for this BOS. Overall, the data firmly exemplified the beneficial CVCC contributions to the accomplishment of C3 functions in both defensive and offensive operations. Several of the key findings resulted from comparing empirical Baseline values to fixed CVCC values, the latter driven by functional characteristics of the CVCC system.

The CVCC's digital transmission capabilities enabled more rapid dissemination of FRAGOs, resulting in substantial savings of time. The same capabilities produced maximum dissemination of INTEL reports, a dramatic improvement over the Baseline condition. The CVCC system's enhanced communications features ensured that all unit and vehicle commanders received combat-critical information at the same time, a benefit achieved without imposing additional task demands on the participants. In a fully manned battalion, unit leaders would have to relay FRAGOs and INTEL reports to accomplish complete dissemination. But the ease of relaying digital items should speed the process of passing orders and reports down the command chain, when compared with conventional voice dissemination.

The completeness and consistency of the digital FRAGOs and INTEL reports were powerful features of the CVCC system as modeled in this evaluation. Undoubtedly these advantages contributed heavily to the dramatic reduction in time spent clarifying FRAGOs, a finding also reported by Leibrecht et al. (1992). At the same time, some participants wanted the ability to edit FRAGOs and overlays to tailor them to subordinate unit requirements. This suggests a trade-off between rigid

Table 21

Summary of Major Command and Control BOS Findings

Function	CVCC Advantages
Receive and transmit mission	- More rapid dissemination of FRAGOs - Greater consistency and completeness of information received - Fewer requests to clarify FRAGOs - Much less time spent clarifying FRAGOs
Receive and transmit enemy information	- More rapid dissemination of INTEL reports - Maximum dissemination of INTEL info - Greater consistency and completeness of information received
Receive and transmit friendly troop information	- Fewer voice transmissions among command group for coordination - Reduced need to report unit location and status
Manage means of communicating information	- Fewer total voice radio transmissions - Reduced volume of named voice reports - Reduced time on voice radio networks - Better accessibility on command networks

consistency and the ability to modify transmissions generated elsewhere, a fruitful topic for future research on automated C3.

The CVCC's digital capabilities, including the automated reporting of logistics status, reduced the voice radio coordination demands on members of the command group. In addition, the mutual POSNAV function and automated logistics reporting feature reduced the need for vehicle and unit commanders to report their location and fuel/ammunition status. This would appear to reduce task demands on unit and vehicle commanders, while greatly increasing the volume and timeliness of information regarding the status of friendly forces.

The reduction of voice radio traffic which occurred in the CVCC condition would have at least two important benefits in actual combat operations. First, it would lessen the unit's electronic signature, thereby decreasing susceptibility to detection by the enemy and to electronic countermeasure intervention. Second, it would make the radio networks more accessible for critical command and control voice transmissions. Participants in this evaluation commented very favorably about the ease of access to voice networks.

The results showing no consistent impact of the CVCC capabilities on situational awareness are similar to findings reported by Leibrecht et al. (1992). However, the lack of quantitative trends is somewhat inconsistent with the CVCC participants' comments that they had a better picture of the battle. It may well be that the instrument used to quantify situational assessment was not sufficiently sensitive to detect CVCC effects, especially considering the instrument's reliance on participants' memory of events. It is also possible that not all aspects of assessing the battlefield situation are likely to benefit from use of the CVCC system.

The data for this BOS document relatively robust advantages of the CVCC capabilities in accomplishing command and control functions. The next subsection addresses the results bearing on the contributions of the CVCC system to the execution of intelligence functions.

Intelligence BOS

Issue 4: Does the CVCC system enhance the Intelligence BOS?

This subsection examines the effect of CVCC capabilities on collecting intelligence information. One hypothesis, based on the Collect Threat Information component of the Intelligence BOS, organizes data presentation.

Collect Threat Information

Hypothesis 4.1: The CVCC units' ability to collect threat information on the battlefield was expected to be significantly better than the Baseline units'.

The measures supporting this analysis focused on the accuracy of obtaining and reporting enemy location information, as reflected in CONTACT, SPOT, and SHELL reports, and on the descriptive accuracy of the target identification process reflected in CONTACT and SPOT reports. Participants prepared CONTACT, SPOT, and SHELL reports based on their direct observations of the battlefield and on input from their subordinates. Among company commanders and XOs, input from subordinates came from BLUFOR operators' voice reports in the Baseline condition, and primarily from SAFOR-generated reports in the CVCC condition. In preparing digital reports, CVCC participants could use their LRFs to obtain precise locations. Table 22 summarizes the data for this hypothesis.

Accuracy of CONTACT reports. Two measures quantified CONTACT report accuracy--one representing the precision of reported enemy locations, and another reflecting the correctness of the reported target identification.

Accuracy of CONTACT report locations. CONTACT report location accuracy determined how close the reported enemy location was to actual enemy locations. The measure was computed

Table 22

Mean Performance Data for Collect Threat Information Hypothesis Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
CONTACT report accuracy						
Location accuracy (deviation, in meters)	538.3 (681.3) n=30	881.1 (1022.4) n=16	600.4 (840.1) n=23	988.9 (1471.4) n=10	355.7 (497.3) n=19	1043.3 (1762.5) n=7
Percent reports with correct type	84.72 (29.20) n=30	59.38 (31.01) n=16	88.70 (26.25) n=18	50.71 (32.14) n=14	84.47 (30.32) n=19	46.43 (30.37) n=7
SPOT report accuracy						
Observed locations (deviation, in meters)	436.7 (470.4) n=34	1993.3 (2774.2) n=23	369.4 (433.8) n=25	1331.2 (1490.2) n=13	375.7 (588.2) n=18	884.5 -- n=2
Destroyed locations (deviation, in meters)	394.4 (423.2) n=32	1430.1 (2382.0) n=22	363.0 (396.4) n=25	1041.0 (1392.9) n=11	328.6 (532.1) n=17	884.5 -- n=2
Correctness of number and type observed (percent)	81.86 (27.29) n=34	83.82 (25.12) n=23	95.16 (11.88) n=25	94.29 (17.90) n=14	81.47 (30.45) n=19	100.00 -- n=2
Correctness of number and type destroyed (percent)	78.99 (27.44) n=33	54.55 (40.31) n=23	88.58 (17.13) n=25	68.94 (32.53) n=12	73.52 (32.08) n=18	73.08 -- n=2
SHELL report location accuracy (deviation, in meters)	2034.3 (1033.4) n=22	1648.1 (595.5) n=15	1662.8 (578.0) n=15	1333.2 (429.2) n=5	1888.2 (645.2) n=25	1783.7 (751.3) n=7

Note. Standard deviations appear in parentheses below the means.

as the distance, in meters, from the reported location to the nearest OPFOR vehicle at the time the report was sent. Only reports containing valid locations were scored to yield an average for each vehicle sending CONTACT reports. Smaller distance values represented better performance. The mean deviations for this measure can be found in Table 22. Location accuracy was significantly better among CVCC units than among Baseline units ($F(1, 99) = 4.84$, $p=.030$). The largest difference between conditions occurred in Stage 1 (see Figure 18), with Baseline units' deviations averaging more than six times those of CVCC units. Neither the stage effect nor the condition by stage interaction was significant.

In all three stages, the standard deviations for the CVCC battalions were substantially smaller than those for the Baseline

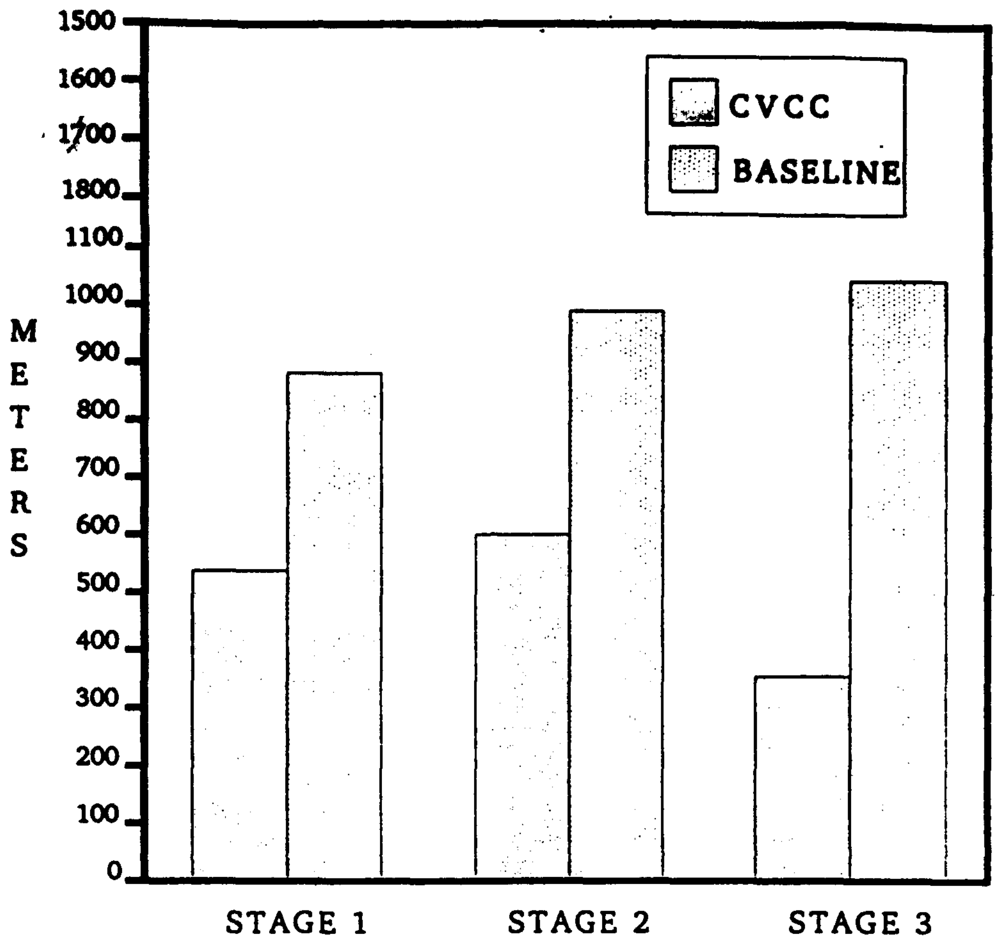

Figure 18. Mean deviation (in meters) of enemy vehicle locations reported in CONTACT reports.

battalions. As discussed earlier in this report, the more consistent performance of the CVCC units is a distinct advantage.

Twenty-nine percent of all Baseline CONTACT reports (38.3 out of 133.7 per stage, on the average) could not be scored for accuracy due to lack of valid locations (e.g., "Tanks, south"). Although armor SOPs call for only cardinal direction in CONTACT reports, participants in this evaluation were instructed to specify grid location(s) of enemy vehicles in their CONTACT reports. This procedure acknowledged that valuable intelligence information can be gained when precise enemy locations are specified as early as possible. Inspection of the cell sample sizes for CONTACT report accuracy (see Table 22) revealed that CVCC commanders sent substantially more CONTACT reports containing locations. Thus, the CVCC capabilities enabled participants to provide a greater quantity of fully usable enemy information to the TOC staff.

Percent CONTACT reports with correct type. This measure was designed to quantify the accuracy with which unit and vehicle commanders identified the type of enemy vehicle in their CONTACT reports. If there were enemy vehicles of the type reported actually visible to the reporting tank at the time of report transmission, the report was scored as correct. For each vehicle sending CONTACT reports, the proportion of correct reports in each stage was computed. For this measure of descriptive accuracy, larger percentages represented better performance.

Across the three stages, the proportion of correct CONTACT reports among CVCC units averaged better than 84% (see Figure 19), while Baseline units' proportions averaged less than 60%. The effect of condition was significant ($F(1, 98) = 27.85$, $p<.001$), but neither the stage effect nor the condition by stage interaction was significant.

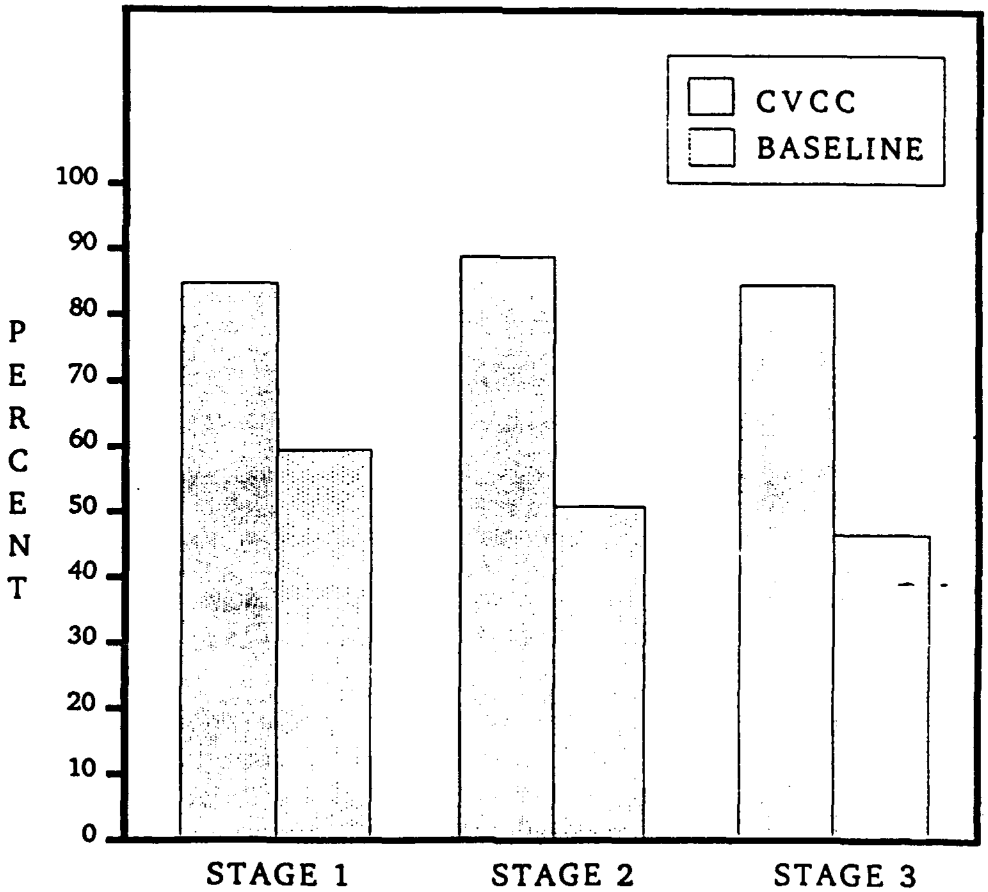

Figure 19. Mean percent of CONTACT reports with correct vehicle type.

<u>Accuracy of SPOT reports</u>. Two measures furnished information about SPOT report accuracy--one quantifying the precision of reported enemy locations, and another reflecting the correctness of the reported target type and number.

<u>Accuracy of SPOT report locations</u>. As with CONTACT report location accuracy, this measure quantified the distance deviation between reported and actual enemy locations. The same procedures used to compute accuracy of locations specified in CONTACT reports were used for locations in SPOT reports (see Appendix B for the definition of this measure). Only reports containing valid locations were analyzed. All participants were instructed to report OPFOR vehicles observed and destroyed. The accuracy of reported locations was computed for each type of information, yielding two submeasures. Better performance was indicated by smaller distance values.

Table 22 presents the mean distance deviations for both the observed and destroyed components of this measure. Only data for Stages 1 and 2 were analyzed, due to the very small Baseline sample size ($n = 2$) in Stage 3. CVCC units' location accuracy was significantly better for enemy observed ($F(1, 91) = 17.21$, $p<.001$) and enemy destroyed ($F(1, 86) = 9.82$, $p=.002$). The Baseline units' deviations averaged up to four-and-a-half times those of CVCC units. Neither the stage effect nor the condition by stage interaction was significant for either component of this measure.

In Stages 1 and 2, the standard deviations for the CVCC battalions were substantially smaller than those for the Baseline battalions. The greater consistency of the CVCC units' performance is a distinct advantage.

An average of 124.3 unique SPOT reports per stage were sent by Baseline unit and vehicle commanders. Of those reports, an average of 36.3 (29.2 percent) did not contain valid locations and were therefore excluded from the analysis of accuracy. This shows a large proportion of flawed SPOT reports for the Baseline condition. Overall, the CVCC unit and vehicle commanders sent substantially more scorable SPOT reports than did their Baseline counterparts, reflected in the larger sample sizes for this measure (see Table 22). In other words, the CVCC's capabilities resulted in a larger quantity of usable enemy information reaching the TOC.

<u>Correctness of SPOT report number and type</u>. The accuracy of the identification process associated with generating SPOT reports was assessed by comparing the number of enemy vehicles reported to the number of same-type vehicles actually visible to the reporting vehicle at the time the report was sent. As explained in Appendix B, this measure was computed separately for the observed and destroyed components of the SPOT report to yield an average per vehicle. The computations yielded percentage scores ranging from 0 to 100%, with higher scores representing greater accuracy.

Mean correctness scores for both the observed and destroyed components of this measure appear in Table 22. Only data for Stages 1 and 2 were analyzed, due to the very small Baseline sample size ($n = 2$) in Stage 3. CVCC units' accuracy was significantly better for number and type of enemy destroyed ($F(1, 89) = 12.59$, $p=.001$) but not for number and type of enemy observed. This suggests that the CVCC equipment provided an advantage only when participants identified and counted enemy vehicles destroyed, perhaps due to the thermal capability of the CITV. The effect of stage was significant for the enemy observed component ($F(1, 92) = 6.91$, $p=.01$), reflecting higher scores in Stage 2, but it was not significant for the enemy destroyed component. The condition by stage interaction was not significant for either component.

In the case of the enemy destroyed component of this measure, the standard deviations for the Baseline battalions were substantially larger than those for the CVCC battalions. This parallels the findings for the location accuracy of SPOT reports discussed earlier and represents a combat performance advantage.

<u>Accuracy of SHELL report locations</u>. SHELL report location accuracy was quantified as the deviation, in meters, between the reported and actual locations of OPFOR artillery impacts. For each report with a valid location, the reported location was compared to the actual location of the nearest OPFOR artillery impact at the time of report transmission. An average was then computed for each vehicle. Smaller distance values for this measure constitute better accuracy.

As seen in Table 22, the mean performance for Baseline units tended to be better than for CVCC units, with the most notable difference occurring in Stage 1. However, the condition effect was not significant, nor was the effect of stage. The condition by stage interaction was also nonsignificant.

Among the CVCC participants, accuracy scores for SHELL reports were substantially worse than they were for CONTACT and SPOT reports. A possible explanation for this may lie in the use of the LRFs to input report locations. In most cases the LRFs will obtain a reliable distance reading from a solid target, and therefore provide relatively accurate input to the CCD for tactical reports. In the case of artillery impacts, however, participants may either have input the attack location by hand using the CCD touchscreen, or lased to a point on the ground near the artillery bursts. Either of these options would have yielded relatively inaccurate locations.

An average of 41.3 SHELL reports per stage were transmitted by Baseline unit and vehicle commanders. Of these, an average of 12 per stage (29.1 percent) were not scorable due to missing locations. As with CONTACT and SPOT reports, this is a relatively high rate of missing information and would hamper the TOC in constructing a realistic picture of the battle. As can be seen from the cell sizes in Table 22, CVCC participants sent substantially more SHELL reports than did their Baseline counterparts. Even though the accuracy of SHELL report locations did not benefit from the CVCC capabilities, the higher volume of usable location information resulting from digital reporting was a definite advantage.

Summary of Findings

Table 23 summarizes the findings for the Intelligence BOS. CVCC units rendered SPOT and CONTACT reports that were significantly more accurate than Baseline units' reports, in terms of both enemy location and vehicle identification. In earlier research at the company level, Leibrecht et al. (1992) reported only CONTACT reports being more accurate. With respect to SHELL report location accuracy, the lack of differences between conditions echoed a finding from company-level research (Leibrecht et al., 1992). On balance, the data clearly show that the CVCC units' ability to collect threat information on the battlefield was significantly better than the Baseline units'. In short, the CVCC system enhanced the Intelligence BOS.

Table 23

Summary of Major Intelligence BOS Findings

Measure	CVCC Advantages
Accuracy of CONTACT reports	- More accurate reporting of enemy locations in all stages - More accurate identification of enemy vehicle types in all stages - More consistent reporting of locations and types of vehicles in all stages
Accuracy of SPOT reports	- More accurate reporting of enemy locations in Stages 1 and 2 - More accurate determination of enemy vehicle numbers and types in Stages 1 and 2 - More consistent reporting of locations, numbers, and types of vehicles destroyed in Stages 1 and 2
# reports with complete info	- Greater volume of usable info for CONTACT, SPOT, and SHELL reports

The data for the measures which were based on grid locations show that, in those cases where the digital system could capitalize on reliable range returns from the LRFs, accuracy was significantly better among CVCC units than among Baseline units. This finding is consistent with the CFF report accuracy data from the Fire Support BOS, discussed earlier in this section, where similar procedures were used to quantify location accuracy.

The finding that CVCC-equipped commanders sent substantially more CONTACT, SPOT, and SHELL reports containing valid locations has considerable operational significance. Valuable intelligence information is lost when enemy location is not specified. Baseline CONTACT, SPOT, and SHELL reports were frequently missing location information, which forced the TOC staff to query the sender or to proceed without the information. The ease of obtaining locations by lasing or touching the touchscreen most likely accounted for the greater volume of complete reports in the CVCC condition. On the bottom line, the CVCC capabilities enabled participants to provide a larger quantity of enemy information with overall higher quality (accuracy) to the TOC staff. This has important implications for assessing and controlling the battle, ensuring responsiveness of combat support and combat service support elements, projecting and planning future operations, and coordinating with adjacent units.

The conclusions based on the findings documented in this section are presented in the report's final section--Conclusions and Recommendations. The results discussed in this report are only part of the findings obtained in the CVCC battalion evaluation. For a full account of the evaluation's findings, the reader is again encouraged to review the companion reports by Atwood et al. (in preparation) and Meade et al. (in preparation). The latter report includes a valuable discussion of battlefield integration implications, based on current Army combat doctrine, which transcend individual BOSs. The following section discusses major lessons learned during the course of the evaluation, addressing both operational and methodological implications.

Lessons Learned

The purpose of this section is to document practical lessons learned during the course of this evaluation so that they can be used by combat developers and investigators concerned with automated C3 systems and simulation-based assessments. By and large the lessons learned stem from participant feedback, discussions among the research staff, integrated observations during execution of scenarios, and extrapolations from performance data. This section first discusses lessons learned dealing with operational effectiveness issues--command and control, navigation and maneuver, destroying the enemy, and gathering intelligence information. The discussion next addresses methodological issues, providing observations of value in designing future evaluations. Lessons learned in the context of armor TTPs are reported by Meade et al. (in preparation). Similar observations about SMI issues, especially regarding design of automated C3 user interfaces, are presented in Atwood et al. (in preparation).

Operational Effectiveness

Command and Control

Automated C3 systems such as the CVCC do not eliminate the need for voice radio communications, nor were they intended to. Rather, digital reports and voice messages should complement one another. Even with digital reporting available, voice radio transmissions exchange a great deal of important combat information, and much of it is not appropriate for the report formats supported by the digital system. In the current evaluation, many participants felt that it was preferable to transmit certain reports--especially CONTACT and NBC reports--by voice means rather than via the CCD.

By reducing the overall volume of voice radio traffic, digital reporting helps free voice networks for critical C3 communications. Commanders see this as a distinct advantage, allowing them more timely access for verbal transmissions. This underscores the complementary relationship between digital and voice communications. From a tactical perspective, the reduced radio signature is important in decreasing the unit's nerability to electronic detection and electronic rmeasures, although digital transmissions would somewhat the reduction of voice transmissions.

Digital transmissions in the battalion evaluation could not be modified as they were relayed. This characteristic ensured completeness and consistency in the process of disseminating information, both upward and downward. Participants accepted the lack of editing capability well, except in the case of orders (FRAGOs) and the accompanying overlays. Unit leaders frequently requested the ability to modify FRAGOs and overlays so they could tailor them to the tactical level of their subordinate units. Investigators will likely find themselves confronting this issue in future research efforts.

Automated reporting of vehicle/unit logistics status is an excellent example of a totally automated function which was very well received by commanders and XOs in the battalion evaluation. This function automatically reported the current status of personnel, ammunition, fuel, and equipment. It reduced the burden in terms of requirements to transmit specific information about logistics status. Together with the ready display of friendly vehicle locations provided by mutual POSNAV, the automated logistics reporting substantially reduced the need to submit SITREPs. This development raises the prospect that unit SOPs might need to redefine requirements for routine submission of SITREPs--either their format or frequency of submission might be altered, or perhaps both. Significantly, the combination of mutual POSNAV, digital map overlays, and automated logistics reporting may nearly eliminate the need for voice communications prior to engaging the enemy.

As implemented in the CVCC system, routing of reports was based on network-wide broadcast; all vehicles on a given digital network received all transmissions sent on that network. Many participants firmly requested discrete addressing--the ability to direct messages to a specific receiver. This reflected their belief that many messages are not needed by everyone on the network, that selectivity in disseminating information can be an advantage in combat. However, there are potential disadvantages with discrete addressing, such as inadvertent omission of an addressee and inability to eavesdrop on important combat information.

Digital transmission capabilities can lead to individual users receiving large numbers of reports, FRAGOs, overlays, etc. (Atwood et al., in preparation; Ainslie et al., 1991). Users' concerns about being deluged by a tidal wave of reports are nearly universal, and tools for managing the volume of information take on considerable importance. In the current evaluation, tools for reducing the volume of reports included automatic rejection of redundant reports (those received previously), icons on the electronic map signalling report location and type, aggregation of same-type reports meeting certain criteria, and the ability to delete reports individually and in blocks. Such tools and many others, such as discrete addressing (discussed in the previous paragraph) and filtering out unwanted reports, could be adapted or developed for future research.

Automated C3 systems can successfully integrate information for users. In the current evaluation, for example, friendly vehicle icons could be selected to represent units instead of individual vehicles, and automated logistics information could be aggregated to unit levels. In addition to information integration, the integration of originally separate components can yield considerable payoff. System integration examples from the current evaluation include the functional integration of the CCD and POSNAV components to facilitate navigation and monitoring of unit locations; the capability to input location information from the CITV's LRF into CCD reports; and integration of M1 tank components with the CCD to support automated logistics reporting (O'Brien et al., 1992a; Smith & Heiden, in preparation). Consigning the integration of information to a machine is a challenging enterprise not without risks, but it can bring high payoff if the process facilitates the user's information processing and decision making. This is a relatively new area in which much work remains to be done.

Navigation and Maneuver

Automated navigation systems such as the CVCC's have been found to have dramatic effects on tactical movement and maneuver (Du Bois & Smith, 1989, 1991; Leibrecht et al., 1992; O'Brien et al., 1992b), and soldiers are almost unanimous in praising their capabilities. The positive effects have been measured up to the battalion level and may vary according to echelon. For example, crews may be less likely to become lost or misoriented, while a task force may be more likely to fully complete assigned combat missions. Thus, a useful lesson is that performance of navigation and maneuver tasks offers an established anchor for quantification in future research efforts.

Automated navigation systems give unit leaders a substantial sense of confidence in their unit's ability to avoid getting lost. This tends to produce increased freedom of movement, which can lead to greater dispersion of forces for enhanced survivability.

Providing automated information to vehicle drivers, especially in graphic form, lessens the burden on unit leaders. As drivers assume greater responsibility for navigating, unit leaders are able to spend more of their time commanding and directing their unit's combat activities. This illustrates the relationship between enhancement of navigation functions and the accomplishment of command and control.

Destroying the Enemy

Vehicle commanders operating at higher echelons (company command, battalion command) are primarily responsible for directing the combat activities of their units. Therefore, the attention they pay to engaging the enemy could be less than it would be at lower echelons. Consequently, the effects of advanced systems on target acquisition and engagement may vary according to echelon.

The use of automated C3 equipment in this evaluation did not distract crews from fighting the battle and engaging the enemy. This indicates that unit and vehicle commanders can integrate advanced systems into their combat performance without modifying their tank's target acquisition and engagement effectiveness.

Automated IFF functions tend to be ignored or discounted if they frequently produce erroneous determinations. Participants in the current evaluation often reported they did not trust the IFF function. This may have countered the potential benefits of the IFF capability, slowing crews' responsiveness in acquiring and processing targets. Accordingly, future IFF implementations should model greater reliability.

Intelligence Gathering

As implemented in this evaluation, automated C3 capabilities substantially enhanced performance related to gathering intelligence information. The CVCC system's greater accuracy in reporting enemy locations resulted from inputting precise location information to reports, which was possible because of the integration of LRF and touch screen inputs to the CCD. In addition, the digital communications capabilities increased the volume of usable information--there were more reports containing valid locations.

The greater accuracy in reporting enemy locations will result in higher quality intelligence information reaching the TOC, the battalion command group, and higher echelons. Coupled with the enhanced volume of usable information, this can be expected to yield a more accurate picture of enemy formations and activities, enabling the mounted force to more effectively control the battle and plan future missions.

The sensitivity of intelligence gathering and processing to automated C3 effects makes this an important area for assessment in future research efforts.

General Considerations

Qualified crewmembers utilizing experimental equipment sometimes discover unexpected ways to use the advanced capabilities. For example, in the current evaluation some participants used the CITV to establish fields of fire and target reference points. Such outcomes, including equipment usage patterns and innovations, yield important information for training developers (Atwood et al., in preparation) and TTP developers (Meade et al., in preparation). This underscores the value of the soldier-in-the-loop approach in conducting simulation evaluations.

Evaluation Methods

Task Organization

MWTB capabilities provide wide flexibility in configuring test units. By combining qualified crews with computer generated elements, a host of unit "slices"--allocations of actual crews--can be designed to meet different research objectives. For example, the battalion slice used for primary data collection in this evaluation was relatively shallow, spanning only the battalion and company echelons. However, the battalion slice used for the evaluation's DCEs extended from the battalion command echelon down to the wingman's level (Lickteig et. al., 1992). The MWTB's capabilities extend to large-scale operations using long-haul networking and "seamless" interaction with actual vehicles in the field.

The task organization of the test unit can be effectively manipulated by a combination of crewed simulators, SAFOR elements, and MCC-controlled elements. At the same time, the validity of the task organization can be influenced by the balance between the manned, computer-generated, and notional elements. The composition of the test unit, including the manned slice, must be chosen carefully to meet the objectives of the evaluation.

Given current Army doctrine's emphasis on combined arms operations, the tank-pure battalion structure used in this evaluation can be modified to accommodate appropriate combined arms force structures. For example, mechanized infantry platoons could be cross-attached to form company teams, using SAFOR units or a combination of crewed and SAFOR vehicles.

At the battalion level, practical implementation of the test unit configuration relies heavily on SAFOR operators role-playing key positions (e.g., platoon leaders, scout section leaders). The more roles each operator is responsible for playing, the greater the workload. Care should be taken to avoid overloading SAFOR operators with an excessive span of control. The penalty for violating this principle is reduced responsiveness and realism among the SAFOR components of the test unit. Simple steps can be taken to control SAFOR operator workload, such as using radio operators to assist in handling voice communications.

Communications

The MWTB provides good flexibility for examining future communication networks, such as those that may be required by automated C3 systems. Networks supporting automated C3 evaluations should be realistic, in accordance with Army doctrine, but tempered with future-oriented input from combat developers. Limited simulation equipment will typically force trade-off decisions and compromises in configuring the working radio networks. This, in turn, can affect task load on selected participants and constrain ready access to combat-critical information. Where network structure varies from established Army doctrine, the impact on operational dynamics and user credibility should be carefully assessed.

Ideally, in research efforts the structure of communication networks should be comparable between baseline and experimental conditions. In the current evaluation, the network structure for routing digital reports between the TOC and company XOs differed from the voice network structure. This led to differences in procedures for computing certain report transmission measures. In future research efforts, where experimental design considerations lead to network differences between test conditions, the impact on quantitative measures should be determined at the outset and the evaluation structured to examine the trade-offs involved.

Realistic communications (both voice and digital) between the test unit and its parent headquarters are desirable. In the current evaluation, the absence of a brigade-level digital network led to brigade-level digital messages being transmitted on the battalion digital network. Thus, where a relay action should have been required to provide those reports to company commanders and XOs, no actual relay was necessary.

Realistic voice and digital communications between unit commanders and their subordinate SAFOR elements are also desirable. The absence of a downward digital link from the company echelon to the SAFOR operators limited realism in the battalion evaluation. Given a digital battalion FRAGO, the company commander had to provide the SAFOR operator more verbal information than he would have if the SAFOR operator had had the capability to receive digital FRAGOs and routes.

Combat Scenarios

Effective training and test scenarios require certain elements: training objectives for training scenarios, operational briefing, mission planning and preparation, operational checks in simulators, mission execution, and debriefing. The testing schedule for simulation evaluations is often constrained, with limited time available for each test scenario. A challenge for the scenario developer is to craft scenarios which both experimental and baseline units have a reasonable chance of completing in the time available. Standardized OPORDs and overlays can be provided to reduce planning time requirements. Construction of scenarios which are realistic in terms of feasible execution time is a highly desirable goal.

The realism of the planning and preparation phase can sometimes be enhanced by using available simulation tools (Atwood, Winsch, Quinkert, & Heiden, in preparation). For example, in the current evaluation SAFOR capabilities were used to conduct leaders reconnaissance at the Stealth station following the operational briefing. Such techniques can enhance the scenario's overall credibility and foster a sound role-playing attitude on the part of the participants.

When mission changes occur, comparability of graphics between experimental and baseline conditions can be enhanced by capitalizing on existing graphics. In the current evaluation, Baseline participants frequently complained that new graphics were issued with FRAGOs, with wholesale changes in operational control measures which were judged unnecessary. When new missions involve basically the same sector, reliance on existing graphics may be preferable. Alternatively, new missions could be constructed in such a way that old graphics would be clearly inappropriate.

Scenarios requiring numbers of SAFOR vehicles exceeding the capacity of the SAFOR system--approximately 60 vehicles per station--risk interruptions during execution. Overtaxing the SAFOR system results in slow responsiveness and greater danger of system crashes. It is important to understand the practical limitations of the SAFOR system and structure the scenarios accordingly. This may lead to trade-off decisions in configuring BLUFOR and OPFOR forces. It is also important to provide adequate, realistic training to SAFOR operators.

Simulation Capabilities

In terms of simulator capabilities, the MWTB's M1 simulators were not designed to support gunnery training. The simulators use an automatic lead solution that does not accurately represent the actual M1 tank, making gunnery difficult with moving targets.

In addition, the simulators do not accommodate boresighting by individual gunners. Consequently, gunners frequently complain that the system is not working properly. It is important to explain to crewmembers that gunnery functions differ in the MWTB simulation environment.

Equipment failures are common in the distributed interactive simulation environment. Such failures often interrupt test scenario execution, potentially impacting measures of performance and breaking up the flow of the battle for the participants. Equipment failures occurring during training exercises and scenarios can degrade the quality and effectiveness of the training program, which in turn can hurt the quality of the data collected during testing. Ensuring smooth execution of training and testing events requires reliable operation of equipment. The planning of evaluations should ensure adequate preventive maintenance, including protection of time blocks for maintenance and availability of sufficient spare parts. In some cases (see following paragraph) hardware upgrades are required to reduce equipment failures. Wherever possible, back-up vehicle simulators are desirable to avoid loss of crews and concomitant loss of data.

To support future research, a number of improvements to distributed interactive simulation capabilities are highly desirable. Vehicle simulators should be outfitted with the means to signal clearly to the crew that their simulator has sustained a killing hit, short of taking the entire simulator down. Expanding the processing capacity of the CIGs to eliminate loss of vision block imagery would reduce frustration on the part of crewmembers and enhance the credibility of the basic simulation model. Improved SAFOR capabilities are needed to upgrade processing capacity, ease of controlling SAFOR actions, realism of SAFOR behavior, and system response speed. Indeed, efforts are in progress to develop enhanced SAFOR systems. Better technician-level mechanisms to simplify and facilitate the process of initializing simulation components are highly desirable. Expanded tools for monitoring the status of simulation components (e.g., SINCGARs simulators) and diagnosing equipment malfunctions are required. Finally, human factors enhancements to the control equipment user interfaces (e.g., MCC terminal, FSE terminal, PVD) would improve operational reliability and reduce the time required to train control staff. It is worth noting that the Army is pursuing distributed interactive simulation upgrades in its Close Combat Tactical Trainer (CCTT) program, including enhanced computer image generation capabilities.

Experimental Procedures

Of fundamental importance to an effective evaluation of automated C3 capabilities is the selection of participants. Obtaining crewmembers qualified for their intended test positions is imperative. For most experimental applications, configuring a crew with crewmembers who normally work together is preferred.

For some applications it would be desirable to form a given test unit using crews which normally work together as a unit.

The allocation of crews within the test unit configuration can strongly influence C3 dynamics as well as the measurement process. In designing evaluations, investigators should carefully weigh the feasible alternatives against the evaluation's objectives. The credibility of the design, the interaction among crews/echelons, the desired C3 environment, and the impact on performance measures are all important considerations in determining duty assignments for participating crews. It is sometimes possible to implement different crew allocations in separate phases of testing. In the current evaluation, a relatively horizontal battalion slice was used for primary data collection, whereas a vertical slice was used for DCEs.

In preparing for an evaluation, two steps are critical to ensure readiness to begin actual testing. The first is a thorough functional test of the hardware and software, subjecting the complete set of functionalities to rigorous testing with a fully loaded network. Careful planning, preparation, and coordination should precede the conduct of functional testing, as in the CVCC battalion evaluation (Heiden, Smith, & Schmidt, in preparation). The second step is a full-scale pilot test with crews in all vehicle simulators. This determines if there are problems with software, training materials and procedures, scenario materials and procedures, and scheduling which may require modifications. Following both of these steps, adequate time should be scheduled to permit necessary corrections to be implemented.

Adequate training of participants at the individual, crew, and unit levels is an essential element, even when participants have SIMNET experience or when intact crews are involved. In addition, adequate training of the support staff is necessary, covering all aspects of the evaluation from operating specific items of equipment to executing SAFOR procedures and collecting data. Implementation of a thorough training program helps ensure a viable test of the conditions of interest and helps protect the quality of the database.

Soldiers using new equipment for the first time often exhibit reluctance or resistance to accepting the new technology. However, as they work with the equipment their attitude typically becomes more positive. In an evaluation, the investigators must explain and demonstrate how the new equipment can help the users do their jobs and increase the unit's combat effectiveness. Lessons learned across successive CVCC evaluations led to more emphasis on hands-on training and more effective utilization of equipment. At the same time, as lessons were learned care was taken to avoid procedural changes during an ongoing evaluation. Critical to standardization in the CVCC battalion evaluation was the detailed set of materials for training and testing contained in the support package (Sawyer et al., in preparation).

Kill suppress is a useful mechanism to maintain consistency of scenario execution and prevent loss of valuable opportunities to collect data. Participants in CVCC research have accepted this provision quite well. However, this mechanism does compromise realism of the test conditions somewhat. It is difficult to adjust measures of performance to account for ostensible attrition of vehicles protected by kill suppress, but quantitative information about notional kills sustained can be obtained easily to help explain performance data.

When lower echelon vehicles within the unit are SAFOR vehicles, crews may choose to follow them rather than navigate for themselves. This can mask advantages of automated navigation systems. At the same time, it can leave crews susceptible to becoming lost or disoriented if they become separated from SAFOR elements. Procedures could be developed to make SAFOR navigation subject to errors, thereby reducing participants' level of trust.

Factors such as kill suppress and the ability to follow SAFOR vehicles can threaten the realistic role-playing atmosphere desired. These factors can be countered by providing timely guidance and feedback to participants (consistent with each participant's privacy rights) and by relying on peer pressure and the participants' typical desire to cooperate. More aggressive techniques include penalties for repeated incidents of unwanted behavior and asking the ranking participant to intervene.

Automated navigation systems can fail during combat, and the affected crew must be able to continue performing its warfighting tasks. A crew must maintain proficiency in manual navigation techniques in order to cope with failure modes. Modelling equipment failure contingencies in simulation evaluations is worth consideration, as is incorporating procedures to assess a crew's readiness to navigate without automated assistance.

To help compensate for equipment failures, tardy participants, and related problems, it is helpful to program make-up time in the training and testing schedule. It is also important to establish priorities for deleting scheduled events, in case unavoidable loss of time is substantial. In the current evaluation, standard contingency rules and staff operating procedures (Meade et al., in preparation) were followed to resolve problems, with emphasis on protecting the integrity of training and the quality of data collected.

Participants in the CVCC battalion evaluation routinely requested feedback on their performance. Feedback was provided in the post-scenario debriefing, without making evaluative comments about "good" versus "bad." Performance feedback can enhance the training benefit received by the participants, but in a research effort inappropriate feedback could contaminate the data. In particular, care should be exercised to avoid providing comments or information reflecting experimenter bias or comparing the current group's performance to previous groups.

Data Collection and Analysis

The Situational Assessment instrument used in this evaluation was based on the participant's ability to recall geographic and quantitative features from the just-completed mission. For this and perhaps other reasons, the instrument did not prove very sensitive to contributions of the CVCC system. Given the importance of situational awareness in combat operations, especially related to fratricide, it would seem worthwhile to develop reliable techniques to assess this aspect of mounted warfighting. Useful background information about situational awareness can be found in Sarter and Woods (1991).

Determining reliable effects of automated C3 equipment relies on statistically significant findings. Given the performance variability typically encountered in this research area, achieving acceptable statistical power may require a dozen or more groups in each test condition. However, obtaining groups to participate in evaluations is difficult, especially at the battalion level. Investigators must often settle for smaller samples, and getting the most out of the available groups is imperative. Techniques for enhancing statistical power include: (a) using a within-subjects or matched groups design; (b) obtaining the largest number of groups practical; (c) designing test sessions to enable more data collection opportunities; (d) pooling observations to increase reliability of measures; and (e) eliminating unwanted sources of variability by means of experimental control and standardization. Bessemer and Boldovici (in preparation) discuss measurement and analysis issues in the distributed interactive simulation environment.

Manual collection of data during test scenarios, including the flagging and recording of events at a PVD terminal, can place heavy demands on support staff members. Competing tasks, distractions, and difficulty in interpreting on-line tactical events can result in lost and unusable data elements. Methods and procedures to protect data collectors from distractions and competing demands would help. It might be worthwhile to explore the use of an electronic clipboard using codes or keys designed to simplify recording. Alternatively, it may be possible to develop procedures for obtaining log-based data elements from DataLogger recordings, and efforts in this direction have been initiated at MWTB. Where data collection logs are necessary, they should be designed to facilitate on-line activities of the data collector, and completed logs should be checked daily.

As part of data collection and analysis planning, it is important to identify data elements required to support measures of performance/effectiveness early. This is especially true for those elements relying on instrumentation software which may have to be developed in parallel with basic system functionality. Involving the data analyst from the start is highly desirable. Implementation of measures in the form of computational algorithms should begin early, and the algorithms should be verified and validated at the earliest opportunity, preferably during pilot testing. There is a need for more effective techniques to verify and validate algorithms. In addition, it is important to maintain a complete archival catalog of performance measures and computational algorithms in the MWTB technical library.

Manual reduction of battalion evaluation data was complicated in some cases by the difficulty in converting DataLogger time to real time. A recently developed MWTB capability to record real clock time as part of the data stream during recording of test events should resolve this problem in future research efforts.

Quality control (QC) checking of the evaluation's database is indispensable. This is true for both automated and manual data, but it is particularly demanding for automated data because comprehensive QC checking must be conducted iteratively across multiple reduction phases. QC activities are performed largely by manual means. Therefore, it is critical to program sufficient calendar time and resources to accomplish QC requirements satisfactorily. In the long run, development of automated routines and other means to facilitate QC checking would be a great advantage.

Many measures relating to communications effectiveness required transcription of voice radio transmissions during off-line exercise playbacks. This process proved to be very time-consuming. System upgrades to facilitate the playback process and prevent frequent failures would significantly reduce the time required for transcription playbacks. In the long run, perhaps voice recognition technology could be adapted to automate the process of converting spoken transmissions to a paper record.

Reduction of large DCA data sets, such as those resulting from this evaluation's test scenario, requires most of the DCA computer's disk memory for a single scenario. This means that only data from one test scenario can be processed at a time, and returning later to that same scenario requires reloading the tapes into memory. The DCA hardware should be upgraded to permit simultaneous storage of the complete database from all test scenarios or removable disk storage of each scenario. This would greatly facilitate the reduction of automated data.

Conclusions and Recommendations

Conclusions

The major findings presented in the Results and Discussion section were based principally on statistically significant trends. Occasional nonsignificant trends were highlighted when considered operationally meaningful. Table 24 organizes the primary conclusions by research issue and tactical BOS. Overall findings establish a solid empirical foundation regarding the operational effectiveness of automated C3 systems such as CVCC.

Table 24

Conclusions of the Evaluation

Issue 1: Does the CVCC system enhance the Maneuver BOS?

+ CVCC battalions completed combat missions more quickly.

+ During counterattack, CVCC battalions timed their movement-dependent milestones more consistently and reached their objectives more quickly.

+ CVCC unit and vehicle commanders showed greater apparent freedom of movement in monitoring and directing their units.

+ CVCC battalions maintained safer end-of-stage stand-off ranges, enhancing compliance with brigade commander's intent.

+ CVCC crews acquired targets faster and at greater maximum ranges.

+ CVCC battalions completed counterattack missions with fewer friendly losses and fewer losses per enemy kill.

+ CVCC crews were not distracted from processing and engaging direct fire targets.

Issue 2: Does the CVCC system enhance the Fire Support BOS?

+ Digital CFF reports contained substantially more accurate information on location and type of enemy vehicles.

+ CVCC units provided a greater volume of fully usable information for targeting of indirect fires.

Issue 3: Does the CVCC system enhance the Command and Control BOS?

+ CVCC commanders disseminated orders more quickly.

+ Digital transmission resulted in more rapid and more thorough dissemination of INTEL reports.

+ Digital FRAGOs and INTEL reports were substantially more consistent and more complete, with requests to clarify FRAGOs greatly reduced.

+ CVCC capabilities greatly reduced the need for company commanders and XOs to report unit location and status.

+ CVCC unit and vehicle commanders spent substantially less time on voice radio networks.

(table continues)

(Table 24 continued)

Issue 4: Does the CVCC system enhance the Intelligence BOS?

- **+ Digital CONTACT and SPOT reports contained substantially more accurate information on location and type of enemy vehicles.**

- **+ CVCC unit and vehicle commanders distributed a decidedly greater volume of fully usable information in their CONTACT, SHELL, and SPOT reports.**

The reader should bear in mind that these conclusions are based on the performance of tank battalions operating in the interactive simulation environment. Inherent in the experimental design and methodology were a number of limitations (discussed earlier in this report) which form an important part of the context for the evaluation's conclusions.

Recommendations for Future Research

The future of C3 on the combined arms battlefield will rely heavily on automation and digital technologies. Major research initiatives directed at horizontal integration and combined arms command and control are poised to establish the technology and knowledge base required to support materiel, training, doctrine, and force structure requirements. As a prime example, the Army plans to integrate battlefield digitization and distributed simulation in large-scale training exercises known as Louisiana Maneuvers (e.g., Ross, 1993). The simulation building blocks used in the CVCC program (e.g., CCD, POSNAV, CITV, automated TOC workstations) form a high technology foundation for future research and development. At the same time, steady improvements in distributed interactive simulation capabilities (e.g., enhanced SAFOR programs) are expanding the basic research potential of test beds such as the MWTB. These improvements are being driven by the Army's research initiatives, including large-scale training applications such as Louisiana Maneuvers.

Playing a central role in the Army's combined arms research initiatives are the recently established Battle Labs. The U.S. Army Training and Doctrine Command (TRADOC) has organized a network of Battle Labs to develop new warfighting concepts and capabilities. The Battle Labs serve as focal points for examining the latest concepts for battlefield organization, doctrine, tactics, and technology-based capabilities. The network addresses early entry, depth and simultaneous attack, mounted and dismounted battlespace, battle command, and combat service support. A focus of the Battle Lab missions is to capitalize on distributed interactive simulation to advance ideas and evaluate them. The Mounted Warfighting Battlespace Lab at Fort Knox, Kentucky, plays a major role in the Army's horizontal integration research initiative.

The experience and lessons learned from the CVCC research program furnish valuable pointers to research issues which will be important as the Army pushes automated C3 capabilities into the high technology future. Based largely on the observations accumulated during the battalion evaluation, the following issues loom as key questions to be answered in future research and development efforts.

1. What are the functional requirements and constraints encountered when applying automated C3 tools in the combined arms, mounted warfighting environment?

2. What training approaches are required to support fielding of automated C3 systems among disparate elements of combined arms forces, so as to optimize combat effectiveness? What is the optimal mix of live and simulation training?

3. What task-based requirements should drive future training developments for automated C3 systems? A thorough analysis of tasks and skills from a component and system perspective is highly desirable.

4. How can training be conducted to maximize retention and transfer of training?

5. How can allocation of attention be influenced to minimize information overload and optimize performance?

6. What steps will ensure that manual (back-up) skills are maintained in case automated systems fail?

7. How do automated C3 tools impact operational effectiveness of the combined arms force? What new capabilities, including staff planning and coordination, are required to optimize the impact?

8. How does echelon influence the design and utilization of combined arms C3 systems?

9. What modifications to combined arms TTPs will be necessary to optimize effectiveness of automated C3 systems?

10. What user interface considerations (e.g., design and format) are important to ensure smooth linkage both horizontally and vertically?

11. How will new research capabilities, especially distributed simulation tools, enhance the research and development efforts directed at automating C3 processes in the combined arms environment?

12. What is the validity of interactive simulation models of automated C3 systems, and how can the validity be improved?

In addition to these questions, practical challenges and issues posed by battlefield integration considerations are discussed by Meade et al. (in preparation). Among these are the integration of advanced systems with conventional technologies, problems stemming from non-compatible technologies, and allocation of advanced systems when equipping complete units is not feasible.

The answers to these and related questions will have a fundamental influence on future directions for the digitized battlefield. An empirical, soldier-in-the-loop foundation to guide the automation of C3 for the combined arms environment is a key to meeting the difficult challenges in synchronizing combat activities. The achievable advancements in horizontal integration will boost force effectiveness under a broad array of force projection contingencies. The ultimate, tangible payoff of new C3 tools will be a dramatic improvement in the Army's readiness to meet unpredictable challenges to national interests.

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Appendix A

Sample Data Collection Instruments

Contents of Appendix A:

NOTE: Data collection logs were developed using nomenclature slightly different from that used in this report. "Defensive Scenario" refers to the Test Scenario. "Defensive Stage 1" refers to the first delay stage (Stage 1). "Defensive Stage 2" refers to the counterattack stage (Stage 2). "Defensive Stage 3" refers to the second delay stage (Stage 3).

Only Stage 1 of the RA Log is presented in this appendix. The Stage 1 sample is representative of Stages 2 and 3.

January 25, 1994

BATTLEMASTER LOG

DEFENSIVE SCENARIO

Formative Bn Evaluation

Date:____________________ File: BFE_D_ _ _ _ _

BattleMaster:____

Assistant BattleMaster:__________________________________

Position	Sim*	Call Sign	Vehicle ID*
Bn Cmdr	3B	Y06	__________
S3	2B	Y03	__________
A Co Cmdr	4A	A06	__________
A Co XO	4B	A05	__________
B Co Cmdr	2D	B06	__________
B Co XO	2C	B05	__________
C Co Cmdr	4C	C06	__________
C Co XO	3C	C05	__________

* Be sure to note changes in Sim and Vehicle ID if there is a change in simulator(s) assignment.

DCA Notified to Turn DataLogger ON: ____:____:____ (Time) ________ (Flag)

TURN VIDEO CAMERAS ON

Stage 1:

________ **Bn Cdr calls in RedCon 1: Time:** ________

OPFOR BEGINS MOVEMENT

________ **Bde TOC requests SitRep**

________ **Bn TOC sends SitRep to Bde**

________ **Bde issues Intel: "All source INTEL reports sighting of 2nd Ech MRB/1st Ech Regt, ES9756, moving N."**

OPFOR ARTILLERY BARRAGE ON BPs 10, 20, 30

________ On Bde Net: 1-92 Mech Cdr reports initiating delay to PL Club.

________ If A Co has not requested to delay, Bde sends to Bn: "To prevent 1-92 Mech from becoming decisively engaged, all Bns delay to Phase II BPs."

DATA ELEMENT: Did Task Force prevent a decisive engagement?

YES ________ NO ________

1. How long did it take Co Cdrs to delay after order to do so?

____

2. Did at least 50% of front line vehicles successfully displace?

____

3. How quickly did Blufor controller react to delay order?

____

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times);-Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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BattleMaster Log - Defensive Scenario

Stage 1

_______ BDE: "DIVARTY Acquisition radar reports 144th RAG vic ES910725.

_______ Bde issues Warning Order: "Suspected 2nd echelon of MRB of 144th moving NW in W sector of 1-10 AR AO....

_______ Bde Cdr to Bn Cdr: "Concerned about enemy's direction of attack, which is more westerly than expected....

_______ S11 reports SET screen line 1

_______ FRAGO issued to Bn TOC

_______ BDE requests FUEL report

_______ Bn Toc reports crossing of PL JACK

_______ Bn Toc reports crossing of PL CLUB

_______ Bn Toc reports SET in BPs 11, 24, 34, CATK in progress

_______ BDE requests AMMO report

_______ S11 reports SET screen line 2

_______ BDE requests SITREP

_______ Bn TOC sends SitRep to Bde

_______ TOC notifies BDE that FRAGO is complete OR BDE notifies TOC that prep time "is up." (Indicate which)

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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BattleMaster Log - Defensive Scenario

Stage 1

DATA ELEMENT: Was Bn Bypassed by enemy?

YES ________ NO ________________

Did 13 or more enemy vehicles penetrate North of forward Cos?

____

_______ BREAK (End of Stage: Participants out of sims)

DATA ELEMENT: Measure distance between each company COM and scripted endpoint (use PVD ruler):

A Co:_____ B Co: _____ C Co: _____ D Co: _____

Reason(s) for distance from endpoints:___________________________

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DO THE VCRS AND DATALOGGER NEED TO BE TURNED OFF?

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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Stage 2:

_______ Bn Cdr calls in STARTEX: Time: ___________

_______ TOC directed to issue FRAGO Time: ___________

_______ Bn Cdr reports RedCon 1: Time: ___________

_______ Bde issues Intel: Division All source reports elements of 146th MRR vic ES9063, moving North."

_______ Bde issues Warning Order: "1-10 AR and 1-92 Mech be prepared to resume defensive after 1-10 AR counterattack."

_______ BDE requests FUEL report

_______ Bn TOC reports crossing LD: Time: ___________

_______ Bde issues FRAGO 2 to Bn TOC

_______ BDE requests AMMO report

LEAD ELEMENTS OF 2ND ECHELON MRB REACH VIC ES863815 (forward of Obj FOG)

OPFOR ARTILLERY ON A AND B COMPANIES

2ND ECHELON MRC+ REACHES OBJ SNOW

DATA ELEMENT: How many companies engaged the OPFOR main baody in the CATK? ___________

_______ Bde requests SitRep

_______ Bn TOC sends SitRep to Bde

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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Stage 2

______ **TOC notifies BDE that FRAGO is complete OR BDE notifies TOC that prep time "is up." (Indicate which)**

______ **BREAK (End of Stage: Participants remain in sims)**

DATA ELEMENT: Measure distance between each company COM and scripted endpoint (use PVD ruler):

A Co:______ B Co: ______ C Co: ______ D Co: ______

Reason(s) for distance from endpoints:______________________________
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DO THE VCRS AND DATALOGGER NEED TO BE TURNED OFF?

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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Stage 3:

_______ Bn Cdr calls in STARTEX: Time: __________

_______ TOC directed to issue FRAGO Time: __________

_______ Bn Cdr reports RedCon 1: Time: __________

<u>DATA ELEMENT</u>: Time unit was told to be in BPs Time: __________

_______ Send flag at time units SHOULD be in BPs (from above)

_______ Time Bn reports SET in BPs

OPFOR BEGINS MOVEMENT

_______ Bn TOC sends SitRep to Bde

OPFOR artillery barrage along PL ACE (on BPs 25, 45, &35)

_______ On Bde Net: 1-92 Cdr reports facing elements of 79th GTR.

PLATOON CONTROLLER FOR A CO REPORTS GAS TO A CO CDR

PLATOON CONTROLLER FOR C CO REPORTS GAS TO C CO CDR

_______ Bn TOC sends NBC warning (GAS) to Bde

_______ Bn TOC sends NBC report to Bde

_______ Bde issues Intel: "2nd echelon MRB+ sighted vicinity ES8673, moving North."

_______ Bde orders 1-10 AR to delay to PL Queen (if request has not yet been made)

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times);-Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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BattleMaster Log - Defensive Scenario

Stage 3

DATA ELEMENT: Did Task Force prevent a decisive engagement?

YES _________ **NO** _________________

1. How long did it take Co Cdrs to delay after order to do so?

____

2. Did at least 50% of front line vehicles successfully displace?

____

3. How quickly did Blufor controller react to delay order?

____

________ BDE requests AMMO report

________ BDE requests FUEL report

________ Bn TOC reports all companies SET on BPs

________ Bde requests SitRep

________ Bn TOC sends SitRep to Bde

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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Stage 3

DATA ELEMENT: **Was Bn Bypassed by enemy?**

YES __________ NO __________________

Did 13 or more enemy vehicles penetrate North of forward Cos?

____

________ **END OF EXERCISE** (Participants out of sims for SITUATIONAL ASSESSMENT)

DATA ELEMENT: Measure distance between each company COM and scripted endpoint (use PVD ruler):

A Co:______ B Co: ______ C Co: ______ D Co: ______

Reason(s) for distance from endpoints:__________________________

____

____

____

____

CALL COMPUTER ROOM TO STOP TAPE

STOP VIDEO CAMERAS

Send Flags and Record: Breakdowns (who, what, start and stop times); Halt in Exercise (why, start and stop times); Equipment Problems; Anything Noteworthy or Out of the Ordinary.

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January 25, 1994

TOC LOG
DEFENSIVE SCENARIO

Date:_______________ Monitor: _________

Stage 1:

________ First CONTACT report from simulators
05 F Specify sender: ______________________

________ First SPOT Report from simulators
06 F Specify sender: ______________________

________ First CFF from simulators
07 F Specify sender: ______________________

________ A Co requests permission to delay to BP 13
08 F

________ Bn Cdr orders Bn to delay to BPs
09 F

________ Bn Cdr orders D Co to execute CATK
10 F

________ TOC requests FUEL report
11 F

________ TOC requests AMMO report
12 F

BREAK (End of Stage 1: Participants out of simulators)

Additional Notes/Flags:

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H = Help **F = Flag** **C = Comment**

Stage 2:

________ **LD reported**
13 F

________ **First CONTACT report from simulators**
05 F **Specify sender: ____________________**

________ First SPOT Report from simulators
06 F Specify sender: ____________________

________ First CFF from simulators
07 F Specify sender: ____________________

________ TOC requests FUEL report
11 F

________ TOC requests AMMO report
12 F

<u>BREAK</u> (End of Stage 2: Participants remain in simulators)

Additional Notes/Flags:

H = Help **F = Flag** **C = Comment**

Stage 3:

_______ **First CONTACT report from simulators**
05 F **Specify sender:** ____________________

_______ First SPOT Report from simulators
06 F Specify sender: ____________________

_______ First CFF from simulators
07 F Specify sender: ____________________

_______ NBC warning sent to TOC
14 F

_______ NBC report sent to TOC
15 F

_______ Permission to delay is requested
16 F Specify requester: ____________________

_______ Bn Cdr orders Bn to delay
09 F

_______ TOC requests AMMO report
11 F

_______ TOC requests FUEL report
12 F

<u>END OF EXERCISE</u> (Participants out of simulators: Administer SITUATIONAL ASSESSMENT)

Additional Notes/Flags:

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H = Help **F = Flag** **C = Comment**

RA DEFENSIVE LOG
Formative Bn Evaluation - CVCC

Date:_____________ **RA:** ____________ **Sim Duty Position:** ____________

Stage 1: Delay.

As the stage begins, 2 OPFOR recon Plts are advancing to establish the initial defensive positions. The BLUFOR along PL KING receive a 10 min OPFOR artillery barrage. A friendly tank company from the 1-52 Mech is continuing its movement rearward (N) past the D Co position. The OPFOR recon Plts establish contact with A and C Co's. Subsequently, the OPFOR attacks with 2 MRBs in the 1st echelon of the 144th MRR and 1 MRB in its 2nd echelon. Each MRB has 2 MRC+ in its 1st echelon and a 3rd MRC+ in its 2nd echelon.

As the battle progresses A Co is forced to delay due to OPFOR pressure and because the 1-92 Mech on the W (right) of 1-10 AR is being forced to delay. The Bn Cdr has the Bn delay to subsequent BPs. After movement to subsequent BPs is initiated, the Bde issues FRAGO 1 to 1-10 AR, a counterattack to the SW to destroy the 2nd echelon of the 144th MRR as it passes through the A Co sector. The Bn Cdr sends a Warning Order.

As C Co delays back toward PL JACK, contact is broken with the OPFOR. Shortly thereafter, B Co reports contact with OPFOR is broken and indicates the direction of OPFOR movement is towards BP 11. A Co continues in contact as it delays to BP 11. D Co displaces to BP 42. As this stage ends, the 1st echelon MRBs of the 144th MRR have either been eliminated or move out of the 1-10 AR sector to the NW. A, B, C, and D Cos are set in BPs 12, 24, 34, and 11, respectively, and are preparing to counterattack.

Stage 2: Counterattack.

As this stage begins, Bn FRAGO 1 is issued. D Co remains in defensive position in BP 11. A Co attacks along AXIS BETTY on the right flank (W) to secure Obj RAIN; B Co attacks along AXIS PAM in the center to secure Obj SNOW; and C Co attacks along AXIS LIZ on the left (E) flank to secure Obj FOG. After the Cos cross the LD, Bde issues FRAGO 2 to 1-10 AR, to resume delay after completion of the counterattack. The Bn Cdr sends a Warning Order. As A Co is reaching Obj RAIN, it makes contact with the 2nd echelon MRB of the 144th MRR. The battle is joined; the OPFOR turns to meet the BLUFOR attack. As this stage ends, the OPFOR has been eliminated and A, B, C, and D Cos are in the vicinity of Obj RAIN, SNOW, FOG, and BP 11, respectively.

Stage 3: Delay.

As this stage begins, FRAGO 2 is issued. The FRAGO 2 overlay establishes new BPs 25 (W sector), 45 (center sector), and 35 (E sector), along new PL ACE. FRAGO 2 also establishes BPs 46 (center sector) and 36 (E sector), along PL QUEEN. A, B, and C Cos move to establish defensive positions in BPs 25, 45, and 35, respectively. D Co moves to BP 46 and becomes the reserve. The OPFOR has element of the 2nd echelon of the 39th GMRD moving forward (N). The OPFOR in the 1-10 AR sector is the 146th MRR which has 2 MRBs forming the 1st echelon of the regiment. Each of the MRBs attack with 2 MRC+s in its 1st echelon and 1 MRC+ in its 2nd echelon. The battle is joined. After a period of fighting, the OPFOR deploys chemical munitions. 1-10 AR delays to subsequent BPs along PL QUEEN. As the stage ends, the Cos are set in position, have submitted SitReps, and are prepared to continue the delay mission.

Stage 1 (Def):

STARTING SITUATION: The Bn is set in BPs along PL KING; A Co is in BP 10, B Co is in BP 20, C Co is in BP 30. D Co is in reserve along PL CLUB in BP 40. The simulation is initiated by OPFOR movement.

Bde Net: "All Source Intel reports sighting of MRB, possibly 2nd echelon of MRR, moving ES940650."

OPFOR artillery barrage on BPs 10, 20, 30

Bde Net: 1-92 Mech Bn Cdr reports to Bde Cdr heavy contact along PL KING

S11 reports consolidated at CP10, moving to screen line 1.

Bde issues Intel: "210 ACR reports only light contact in their sector."

Bde issues Warning Order: "1-10 AR be prepared to counter attack to SW from vicinity PL Spade; 1-91 Mech be prepared to establish hasty defense along PL Club."

1-92 Mech Cdr requests permission to delay to PL Club.

Bde sends to Bn, "To prevent 1-92 Mech from becoming decisively engaged, all Bns delay to Phase II BPs." (if request to delay has not been made)

DIVARTY reports 144thRAG vic ES 910725.

Bde issues Warning Order: "Suspected 2nd echelon of MRB of 144th moving NW in W sector of 1-10 AR AO. 1-10 AR be prepared to establish hasty defense along PL CLUB.

Bde Cdr to Bn Cdr: "Concerned about enemy's direction of attack, which is more westerly than expected. Ensure that your eastern flank companies do not get bypassed.

A Co reports SET at BP 11; B Co reports SET at BP 24; C Co reports SET at BP 34; D Co reports SET at BP 42

Report	Tally
Adjust Fire	
Ammo	
Call for Fire	
Contact	
Shell	
SitRep	
Spot	
Intel	
FRAGO	
NBC	
OTHER	

Stage 1 (Def):

Record:
Coordination between TC and crew
Problems with the Equipment
Novel uses of the Equipment
Questions that the TC asked you
Anything Noteworthy or Out of the Ordinary.

____

____

____

____

BREAK (End of Stage 1: Participants out of simulators)

Did crewmember express dissatisfaction with the equipment? What was it?

____

____

____

What percentages of firings was done by TC? ____________

Use of Maps:

Tactical Map (CCD) _____ + Lap Map _____ = 100%

Use of Visual Devices:

VBs_______ + GPSE_______ + CITV_______ + CCD_______ = 100%

Additional Notes:

____

____

____

____

EXAMPLES OF COORDINATION BETWEEN TC AND OTHER CREW MEMBERS

Designate was NOT clearly signalled to gunner.

Gunner tells TC to let go of palm switch--after designating a target.

TC asks gunner to input grids to reports.

TC forgets to switch to GPS mode so gunner can input grids to reports.

Driver requests next waypoint.

Driver requests clarification of waypoint(s).

SITUATIONAL ASSESSMENT QUESTIONNAIRE - Test Scenario

CO CDRS & XOS — SIM ____________

RA ________________________________ DATE ____________

CONDITION ____________ WEEK ____________

Please answer each question and rate your confidence in your answer using the scale below. Place the number from the scale in the space preceding each question.

1	2	3	4	5
Not at all Confident	Somewhat Confident	Moderately Confident	Very Confident	Completely Confident

Confidence Rating

_______ 1. During the last stage, how many enemy tanks did your company destroy?

Number of enemy tanks destroyed: _______

_______ 2. During the last stage, how many BMPs did your company destroy?

Number of BMPs destroyed: _______

_______ 3. During the last stage, did your company destroy any enemy vehicles after the order to delay was given?

Yes _______ No _______

_______ 4. During the last stage, how many tanks in your company were destroyed?

Number of company tanks destroyed: _______

_______ 5. How far (in km) was your initial BP from your subsequent BP (as established in the last FRAGO)?

Distance (km): _______

Appendix B

Selected Performance Measure Definitions

SELECTED PERFORMANCE MEASURE DEFINITIONS

This appendix contains the definitions of selected measures and includes collection, reduction and analysis summaries. The selected definitions provide examples for each BOS function addressed in this evaluation. The basic set of measures was developed during the battalion TOC evaluation and has been defined by O'Brien et al. (1992). Several measures have changed since that report, and a number of new measures have been developed. All modified and new measures are included in this appendix with an asterisk (*) identifying modified measures and a double asterisk (**) marking new measures. In addition, occasional unchanged measures are included to provide a sampling for each BOS function evaluated.

The term "Standard DCA Output" refers to measures for which DCA routines exist as part of the standard MWTB library. Documentation for these routines can be obtained from the senior MWTB analyst.

Measures Terminology

The following definitions provide a ready reference for terms used in this appendix.

BLUFOR	The entire friendly force; comprised of friendly SAFOR vehicles and manned simulators.
Kill	Unless otherwise stated, refers to firepower and catastrophic kills; excludes mobility kills.
Lase	Use of an LRF device to a target which returns a valid number not greater than 3500 m.
OPFOR	The entire enemy force; comprised of enemy SAFOR vehicles.
Relay	The transmission of a report by someone other than the sender and on a net other than the net on which it was received.
Send	The transmission of a report by the originator.
Stage	The test scenario consists of three stages, each analyzed separately. Stages are defined from REDCON1 to completion of the last scripted event, minus any periods of breakdown.

Transmission	The sending of a report. For voice reports refers to "appearance" of the sender on the radio net. For digital reports refers to pressing of the CCD SEND button.

Move on Surface

1.1.3*: Exposure Index

Operational Definition: The number of non-dead OPFOR vehicles to which each manned vehicle is exposed during a defined exposure period. For each manned vehicle, the exposure period begins when initial intervisibility with a non-dead OPFOR vehicle is established and lasts until the first direct firing from that manned vehicle's company or command group.

Collection & Reduction Summary: DCA routine determines, for each manned vehicle, initial intervisibility with a non-dead OPFOR vehicle. The time from initial intervisibility to first main gun round fired from that vehicle's company (or command group) is recorded.

ANOVA Summary: Condition X Echelon

Expected N (per cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

1.1.4*: Range to OPFOR at displacement (Stages 1 and 3)

Operational Definition: The distance, in meters, between each non-reserve company's CoM and the nearest OPFOR company's CoM at the time that either (a) the Bn Cdr orders the Bn to displace or (b) the first BLUFOR vehicle moves out; averaged across companies, excluding companies from 2nd battalion; CoM may include dead vehicles (BLUFOR or OPFOR) but excludes vehicles more than 500 m from computed CoM.

Collection & Reduction Summary: Assistant S3 flags and records order to displace; flag and flag time are entered into database. DCA is provided with database input and CoMs are computed. If displacement occurs in the absence of an order, displacement will be noted at a PVD during playback sessions.

ANOVA Summary: Condition

Expected N (per Cell): 1/stage/week

Navigate

1.2.1: Distance travelled

Operational Definition: Cumulative distance (in meters) driven by each manned vehicle during a stage; based on vehicle odometer reading.

Collection & Reduction Summary: Standard DCA routine

ANOVA Summary: Condition X Echelon

Expected N (per cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

1.2.2: Fuel used

Operational Definition: Total amount of fuel (in gallons) consumed by each manned vehicle in executing the mission.

Collection & Reduction Summary: Standard DCA routine

ANOVA Summary: Condition X Echelon

Expected N (per cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

Process Direct Fire Targets

1.3.1*: Time to acquire targets, by a) CITV laser; b) GPS laser; and c) shortest interval from either laser system

Operational Definition: Average elapsed time, in minutes, from when a non-dead OPFOR vehicle becomes visible (for at least 6 consecutive seconds) to a manned vehicle, until that manned vehicle lases to the non-dead OPFOR vehicle. May include periods of intermittent intervisibility lasting 3 seconds or less; periods lasting more than 7 minutes will not be included.

Collection & Reduction Summary: DCA routine determines intervisibility as defined above; computes interval between start of intervisibility period and first lase with a given laser system to a target. Compute average per vehicle, excluding periods lasting more than 7 minutes.

CVCC data are provided in three sub-measure categories: a) CITV laser only; b) GPS laser only; and c) shortest interval between intervisiblity and first lase from either CITV or GPS laser; the first two provide diagnostic information, the third will be used for comparison with the Baseline condition. Baseline data are provided for GPS laser only.

ANOVA Summary: Condition X Echelon

Expected N (per Cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

1.3.2*: Time between lases to different targets, by a) *CITV* laser; b) GPS laser; and c) shortest interval from either laser system

Operational Definition: Average elapsed time, in minutes, from the last lase on an OPFOR vehicle, by a manned vehicle, until the first lase by the same manned vehicle on a different OPFOR vehicle. Durations exceeding 5 minutes are excluded.

Collection & Reduction Summary: Intended target algorithm determines lases to OPFOR vehicles and time of lase; computes interval between last lase on one OPFOR vehicle to first lase on a different OPFOR vehicle; excludes times between lases greater than 5 minutes in duration. Compute average per vehicle.

CVCC data are provided in three sub-measure categories: a) CITV laser only; b) GPS laser only; and c) shortest interval between lases from either CITV or GPS laser; the first two provide diagnostic information, the third will be used for comparison with the Baseline condition. Note that for the "c" submeasure (both CITV and GPS laser) the interval may be computed between last CITV lase on OPFOR target and first GPS lase on different target (and vice versa). Baseline data are provided for GPS laser only.

ANOVA Summary: Condition X Echelon

Expected N (per Cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

1.3.3*: Time from first lase to first fire

Operational Definition: Elapsed time, in minutes, from when a manned vehicle first lases to an OPFOR vehicle until that manned vehicle first fires on that OPFOR vehicle; average per vehicle. Includes lases and firings from gunner (CVCC and Baseline conditions) and vehicle commander (CVCC only); includes hits and misses. Excludes lases beyond 3500 meters. Excludes durations greater than 5 minutes and excludes zero values in calculation of means.

Collection & Reduction Summary: Standard DCA routine, except times greater than 5 minutes and zero values are not included.

ANOVA Summary: Condition X Echelon

Expected N (per Cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

Engage Direct Fire Targets

1.4.3: Losses/kill ratio

Operational Definition: Total number of OPFOR kills (firepower and catastrophic) by BLUFOR compared to total number of losses (firepower and catastrophic) taken by BLUFOR. Includes direct and indirect fire losses.

Collection & Reduction Summary: Standard DCA routine

ANOVA Summary: Condition

Expected N (per cell): 1/stage/week

1.4.5: Mean target kill range

Operational Definition: Distance (in meters) from a firing manned vehicle to the OPFOR vehicle killed (catastrophic and firepower) by the round fired; average per vehicle; kills classified by the computer.

Collection & Reduction Summary: Standard DCA routine

ANOVA Summary: Condition X Echelon

Expected N (per cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

Control Terrain

1.5.1: Number of OPFOR vehicles penetrating designated line. (Stage 2)

Operational Definition: Cumulative number of OPFOR vehicles that crossed the designated line (line is based on MTP criteria for a successful counterattack).

Collection & Reduction Summary: Determine, by DCA routine, the number of OPFOR vehicles that penetrate north of a line from ES82008300 to ES85008339 to ES85408570 to ES87008570 to ES91008400 by the end of the stage.

ANOVA Summary: Condition

Expected N (per Cell): 1/stage/week

Fire Support BOS

Process Ground Targets

2.1.1 Mean accuracy of CFF locations

Operational Definition: Deviation, in meters, of nearest three OPFOR vehicles to reported OPFOR location. For descriptive purposes a tally of the number of CFFs which could not be scored (due to missing locations) will be kept. Only CFFs with grid locations will be analyzed; objectives, pre-planned fires, and final protective fires will not be included.

Collection/Reduction Summary: Baseline: Record CFF sender, send time, and contents from playback tapes, enter into database for input to DCA table. CVCC: Essential report elements are input directly to DCA table.

For each report location, determine the OPFOR vehicles (of any type) intervisible for at least 6 seconds. Determine the three closet OPFOR vehicles to the CFF sender. Calculate the CoM of the three OPFOR vehicles, then determine direct distance from that CoM to the reported location.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

Command and Control BOS

Receive and Transmit Mission

3.1.1: Elapsed time from Bn transmission of FRAGO to receipt by Co Cdr/XO (Stages 2 and 3)

Operational Definition: The total elapsed time between TOC initiation of FRAGO transmission to the time the last Co XO receives the FRAGO; includes time for clarification, if any.

Collection/Reduction Summary: Baseline: Record sender, send time (start of transmission), receive time (end of transmission), from audio playback of Bn Cmd/Bn O&I nets, enter into database for input to DCA table. For each FRAGO, compute elapsed time from initiation at TOC until completion of transmission by the last company commander, including time for clarification.

CVCC: Set value at zero.

Analysis Summary: Condition (Nonparametric)

Expected N (per Cell): 1/stage/week

3.1.2: Duration of requests by Co Cdr/XO to clarify FRAGO/overlay

Operational Definition: The average length of the Co Cdr/XO request(s) for clarification of FRAGO and/or the accompanying overlay.

Collection/Reduction Summary: Record from audio playback of Bn Cmd/Bn O&I net: requestor, start and end of each request made by each Co Cdr/XO. Compute duration times; enter into database.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

3.1.4:** Number of requests by company commander/XO to clarify FRAGO/overlay (Stages 2 and 3 only)

Operational Definition: The total number of Co Cdr/XO's unique request(s) for clarification of FRAGO and/or the accompanying overlay. A unique request is generally defined as a single question, raised by a given participant, in a single transmission. For example, if A06 asks, "Where is BP 45," receives an answer, then asks, "Where is BP 35," that constitutes two unique requests. By contrast, if he had asked, "Where are BPs 35 and 45" in the original transmission, that would be only one unique request.

Collection/Reduction Summary: From data reduction log for measure 3.1.2 (Duration of requests to clarify FRAGO/overlay), tally number of unique requests made by each Co Cdr and XO, by stage (Stages 2 and 3 only). Include zero values. Enter into database.

Analysis Summary: Condition (Nonparametric)

Expected N (per Cell): 6/stage/week (Stages 2 and 3 only)

Receive and Transmit Enemy Information

3.2.1: Time to transmit INTEL reports full net: Bn TOC to lowest manned net

Operational Definition: The elapsed time, in minutes, between the time the Bn TOC initiates transmission of the INTEL report to the time the last company commander receives the INTEL (reception completed includes time to last clarification, if any).

Collection/Reduction Summary: Baseline: Record INTEL sender, send times (start of transmission), receive times (end of transmission), and contents from audio playback of Bn Cmd/Bn O&I nets, enter into database for input to DCA table. For each report, compute elapsed time from initiation at TOC until acknowledgement by the last company commander, including time for clarification (if any).

CVCC: Set value at zero.

Analysis Summary: Condition (Nonparametric)

Expected N (per Cell): Occurrence dependent

3.2.2*: Consistency of INTEL received

Operational Definition: The consistency of INTEL report contents, comparing received INTEL to scripted INTEL; expressed as a percentage of scripted elements correctly received.

Collection/Reduction Summary: Baseline INTELs are recorded from all nets during playback of tapes. Contents are compared to original text. No data are computed for CVCC condition, as original and relayed digital INTELs are identical.

Elements from INTELs (see examples below) are scored as follows:

Y = Yes - the item was included either verbatim, or repeated in recognizable form.
N = No - the item was not repeated, or it was repeated inaccurately.

Divide total "Y" ratings by total number of items scored, multiply by 100. If scorer is unsure of the appropriate rating, the item will be reviewed by an SME to determine the appropriate Y or N rating.

Scoring templates for example INTEL reports:

Script Time	Content	Rating	
T+16:00	What: MRB (of 1st Ech MRR)	Y	N
	Where: ES9756	Y	N
	Activity: Moving	Y	N
	Heading: North	Y	N
T+96:00	What: Heavy vehicle movement, estimated regimental formations	Y	N
	#: 2	Y	N
	Where: ES8165, ES9071	Y	N
	Activity: Moving	Y	N
	Heading: North	Y	N

Analysis Summary: Descriptive summary for Baseline condition

3.2.3: Number of requests to clarify INTELs**

Operational Definition: The total number of vehicle commander's unique requests for clarification of INTEL messages. A unique request is generally defined as a single question, raised by a given participant, in a single transmission. For example, if C05 requests the location of the lead echelon battalions in and OPFOR second echelon regiment identified in the most recent INTEL report, that represents a unique request.

Collection/Reduction Summary: From data reduction logs for measure 3.2.1 (Time to transmit INTEL reports full net: Bn TOC to lowest manned net), tally the number of unique requests to clarify INTEL reports by each vehicle commander, by stage. Include zero values. Enter into database.

Analysis Summary: Condition (Nonparametric)

Expected N (per Cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

Receive and Transmit Friendly Troop Information

3.3.1*: Mean time to transmit SITREP full net: lowest net to Bn TOC (Baseline only)

Operational Definition: The elapsed time, in minutes, from the lowest net transmission of a SITREP to the time the Bn TOC receives the company SITREP. Computed for Baseline only.

Collection/Reduction Summary: Baseline: Record SITREP sender, send times (start of transmission), receive times (end of transmission), and contents from audio playback of Bn Cmd/Bn O&I/Co nets, enter into database for input to DCA table. CVCC: Essential report elements are input directly to DCA table.

For each report, compute transmission time for each net: From initiation on company net until company report received by the TOC; cumulate across nets. Compute transmission times from start of transmission (first Plt Ldr to report) to acknowledgement on the receiving net.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

3.3.3: Deviation of BLUFOR location reported in SITREP from actual location

Operational Definition: Deviation, in meters, of reported FLOT from actual FLOT (of reporting company).

Collection & Reduction Summary: Baseline: Record SITREP sender, send time and contents from playback tapes, enter into database for input to DCA table. CVCC: Essential report elements are input directly to DCA table via computer routines.

For each reported FLOT, at report send time or AS OF time (whichever is applicable), determine the actual FLOT of the reporting company by identifying the most forward vehicle on either edge of the company formation (DCA routine). The midpoint between the two locations so defined is compared to the midpoint between the two FLOT locations in the SITREP to yield a direct-line distance.

ANOVA Summary: Condition

Expected N (per Cell): 1/stage/week

3.3.7:** Number of voice transmissions between Bn Cdr/S3 and TOC (Stages 1 and 2 only)

Operational Definition: The total number of voice radio transmissions from the S3 or Bn Cdr to the Bn TOC. Includes unscripted TOC transmissions, such as requests for guidance, and Bn Cdr/S3 responses to questions from the TOC. Excludes named reports and verification that FRAGOs or named reports have been received. For example, coordination between the Bn Cdr and XO regarding a Bde FRAGO or the emplacement of a FASCAM minefield would be included whether initiated by the TOC or the commander. Likewise, a recommendation from the TOC that a unit begin movement to meet an LD time would be included. By contrast, TOC-initiated updates on either the friendly or the enemy situation would not be included.

Collection/Reduction Summary: From playback-based data reduction logs for measure 3.3.2 (mean duration of voice radio transmissions between Bn TOC and Bn Cdr/S3, excluding named reports), tally the number of transmissions, by stage (Stages 1 and 2 only). Include zero values. Enter into database.

ANOVA Summary: Condition

Expected N (per Cell): 1/stage/week

Manage Means of Communicating Information

3.4.1: **Average length of voice radio transmissions, by network**

Operational Definition: **The average duration of voice radio transmissions, as defined by keying the radio; computed for each radio network. Transmissions shorter than 1 second or greater than 30 seconds are eliminated.**

Collection/Reduction Summary: DCA routine determines duration of radio transmissions between radio keying events; excludes transmissions shorter than 1 second or greater than 30 seconds. Compute average per network.

ANOVA Summary: Condition

Expected N (per Cell): 1/network/stage/week

3.4.2:** Total number of voice radio transmissions, by network

Operational Definition: The total number of discrete voice radio transmissions from manned simulators, as defined by keying the radio; computed for each radio network. Excludes transmissions shorter than 1 second and longer than 30 seconds.

Collection/Reduction Summary: A *single transmission* is defined as the keying of a radio for at least 1 second. Continuous transmissions greater than 30 seconds are excluded to eliminate "hot mike" events. DCA tallies total number of transmissions per network, inputs to RS/1 table.

ANOVA Summary: Condition

Expected N (per Cell): 1/network/stage/week

3.4.3:** Total time on voice radio network (Stages 1 and 2 only)

Operational Definition: The total time that participants spent on each voice radio network, by stage and condition. Excludes transmissions of less than one second (i.e., "clicking" events) and greater than 30 seconds (i.e., "hot mike" events). Computed for Stages 1 and 2 only.

Collection/Reduction Summary: For each network, multiply the number of voice radio transmissions (3.4.2) by the average duration of voice radio transmissions (3.4.1) to determine the total time on each network. Enter result into database.

ANOVA Summary: Condition

Expected N (per cell): 1/network/stage/week

3.4.4: Number of named voice reports**

Operational Definition: The total number of named voice reports sent from each simulator, by stage and condition.

Collection/Reduction Summary: From data reduction logs for voice reports, tally the number of named reports (CONTACT, SPOT, SHELL, INTEL, SITREP, CFF, ADJUST, FUEL, AMMO, NBC) for each stage. Include zero values.

ANOVA Summary: Condition X echelon

Expected N (per Cell): Bn echelon: 2/stage/week
Co echelon: 6/stage/week

<u>Direct and Lead Subordinate Forces</u>

3.5.1: Did Task Force prevent decisive engagement? (Stages 1 and 3)

Operational Definition: Determination (yes/no) whether the TF prevented a decisive engagement during stages 1 and 3. Based on Battle Master's assessment of reaction time of Co Cdrs and Bn Cdr, the proportion of Bn vehicles successfully displacing, and a consideration of BLUFOR SAFOR controllers' response time.

Collection & Reduction Summary: Battle Master monitors engagement, assessing (a) reaction time of Co Cdrs (requesting permission to displace) and Bn Cdr (ordering displacement), (b) proportion of Bn vehicles successfully displacing (more than 50% of front-line elements = acceptable), and (c) BLUFOR SAFOR controllers' response time; records whether TF prevented a decisive engagement (Y/N); input to database.

Analysis Summary: Condition (X^2 for each stage)

Expected N (per Cell): 1/stage/week

3.5.5:** Battalion command effectiveness composite index

Operational Definition: A composite index of command group effectiveness based on the "Direct and Lead Subordinate Forces" function. For Stages 1 and 3, combines data from measures 3.5.1 (Did Task Force prevent decisive engagement?), 3.5.2 (Did the Bn withdraw intact?) and 3.5.4 (To what extent did the Bn meet the Bde Cdr's intent?). For Stage 2, combines data from measures 3.5.3 (Number of counterattacking companies engaging OPFOR) and 3.5.4.

Collection/Reduction Summary:

For Stages 1 and 3, for each battalion:

a. Determine whether the unit prevented decisive engagement (measure 3.5.1). If no, score = 0, if yes, score = 100.
b. Obtain the percent of BLUFOR intact at end-stage (feeder data for measure 3.5.2).
c. Multiply the "met commander's intent score" (percent) (measure 3.5.4) by four, to weight each component of the commander's intent score equally with the data from steps a and b, above.
d. Sum the values from steps a thru c.
e. Divide the sum (step d) by 6 to obtain a value from 0 to 100.
f. Enter the value into a dBASE file.

For Stage 2, for each battalion:

a. Multiply the number of companies engaging the OPFOR (measure 3.5.3) by 33 1/3 to obtain a value between 0 and 100.
b. Multiply the "met commander's intent score" (percent) (measure 3.5.4) by three, to weight each component of the commander's intent score equally with the data from step a, above.
c. Sum the values from steps a and b.
d. Divide the sum (step c) by 4 to obtain a value from 0 to 100.
e. Enter the resulting value into a dBASE file.

ANOVA Summary: Condition

Expected N (per Cell): 1/stage/week

Collect Threat Information

4.1.1: Accuracy of SPOT report locations

Operational Definition: Deviation, in meters, of nearest OPFOR vehicle to reported OPFOR location. Any report containing more than one location is treated as separate reports. The "observed" and "destroyed" elements of the SPOT report are scored independently. For descriptive purposes a tally is kept of voice reports which could not be scored (due to missing locations).

Collection/Reduction Summary: Baseline: Record SPOT sender, send time and contents from playback tapes, enter into database for input to DCA table. CVCC: Essential report elements are input to DCA table via computer routines.

To score the "SPOT-Observed" element:

For each report location, at report create time (or AS OF time, whichever is applicable), determine the most recent intervisibility lasting at least 6 seconds with OPFOR vehicles (regardless of type). If this is not the first SPOT report for the original reporting vehicle (do not score relays), the search backward extends to the previous SPOT. If this is the first SPOT, the search backward extends to the start of the stage.

Determine distance from reported location to location of the OPFOR vehicle closest to that reported location.

To score the "SPOT-Damaged" element:

For each report location, at report create time (or AS OF time, whichever is applicable), determine the most recent intervisibility lasting at least 6 seconds with OPFOR vehicles (regardless of type). If this is not the first SPOT report for the original reporting vehicle (do not score relays), the search backward extends to the previous SPOT. If this is the first SPOT, the search backward extends to the start of the stage.

From the candidate pool of OPFOR vehicles, determine those which have suffered catastrophic kills; of those, determine distance from reported location to location of dead OPFOR vehicle closest to that reported location.

ANOVA Summary (for each SPOT report element): Condition

Expected N (per cell): Occurrence dependent

4.1.2: Correctness of SPOT report number and type

Operational Definition: For each scorable SPOT report, the percentage of reported vehicles, of the reported type, which were found to be visible to the reporting vehicle. Any report containing more than one location is treated as separate reports. The "observed" and "destroyed" elements of the SPOT report are scored independently. Scorable reports are those which contain location, number, and type.

Collection/Reduction Summary: Baseline: Record SPOT sender, send time and contents from playback tapes, enter into database for input to DCA table. CVCC: Essential report elements are input directly to DCA table via computer routines.

For each reported location, determine the number and type of OPFOR vehicles with which the original reporting vehicle (do not score relays) had intervisibility lasting at least 6 seconds. If this is not the first SPOT for the reporting vehicle, the search backward extends to the previous SPOT. If this is the first SPOT, the search backward extends to stage start.

Compare the number of same-type visible vehicles (regardless of location) with the reported vehicles (for the SPOT-damaged element, compare only vehicles which have suffered a catastrophic kill). If there are at least as many vehicles as reported, of the reported type, score the report 100%. If there are fewer vehicles than reported, of the reported type, divide the number of intervisible, same-type vehicles by the number of reported vehicles.

ANOVA Summary (for each SPOT report element): Condition

Expected N (per cell): Occurrence dependent

Assess Situation

SA1.1: Situational Assessment Question 1: During the last stage, how many OPFOR tanks did your company (Co Cdrs & XOs) or battalion (Bn Cdr & S3) destroy? (Stage 3)

Operational Definition: Total number of T72s destroyed (catastrophic kills only) by A, B, and C companies and by the Bn as a whole. Score is expressed by the percentage of T72s correctly reported.

Collection & Reduction Summary: DCA constructs a killer-victim-kill table by BLUFOR unit and victim type (include totals). Divide questionnaire response by table entry; convert to a percentage; record; enter into database.

ANOVA Summary: Condition X Echelon

Expected N (per Cell): Bn echelon: 2/week
Co echelon: 6/week

SA1.6: Composite situational assessment index**

Operational Definition: A composite index of participants' situational assessment scores (SA1.1 - SA1.5), by echelon and condition. Excludes data from units that did not complete Stage 3 (i.e., prepared their situational assessment based on Stage 2 performance), and responses from vehicle commanders that did not answer all five items.

Collection/Reduction Summary:

From previous (processed) database:
Exclude questionnaire data from Stage 2, and data from participants that did not complete all five situational assessment items.

For each qualifying respondent, by week:

a. Average the reported values for measures SA1.1 (% correct: OPFOR tanks destroyed) and SA1.2 (% correct: OPFOR BMPs destroyed), to arrive at a single value (range 0-100).
b. Determine whether vehicle commander responded correctly on item SA1.3 (whether his unit destroyed any enemy vehicles after receiving the order to delay). If incorrect, score = 0, if correct, score = 100.
c. Determine the score for item SA1.4 (% correct: own tanks destroyed).
d. Obtain the score for item SA1.5 (difference between actual and reported distance from initial to subsequent BP).
   (1) If the deviation is 0, score = 100. Go to step e.
   (2) If the deviation is greater than 4, score = 0. Go to step e.
   (3) If the deviation is between 0 and 4, divide the deviation by 4 to obtain a value between 0 and 1.
   (4) Multiply the quotient from step (3) by 100 to convert it to a percentage.
   (5) Subtract the product from step (4) from 100 to obtain a score between 0 and 100.
e. Average the scores from steps a thru d, and enter the result into the database.

ANOVA Summary: Condition X Echelon

Expected N (per Cell): Bn echelon: 2/week
Co echelon: 6/week

Appendix C

Descriptive Data Tables for Performance Measures

Table C-1

Descriptive Data for Move on Surface Hypothesis (Maneuver BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Distance Between BLUFOR and OPFOR Center-of-Mass (in meters)	5207.33 (844.26) 4400.00 6386.00 n=6	3234.83 (607.42) 2377.00 4027.00 n=6	2553.00 (659.90) 1812.00 3609.00 n=6	2349.17 (316.95) 1932.00 2678.00 n=6	3043.00 (1090.34) 1857.00 4120.00 n=5	2768.50 (845.45) 1999.00 3854.00 n=4
Time to Reach LD (in minutes)	NA	NA	19.43 (4.56) 13.30 24.00 n=6	24.84 (5.79) 16.37 31.60 n=6	NA	NA
Exposure Index						
Bn Echelon	9.06 (11.00) 0.00 28.57 n=11	15.10 (12.56) 0.00 29.44 n=12	6.60 (4.74) 1.00 15.12 n=11	6.41 (4.17) 2.33 18.76 n=12	14.57 (11.46) 0.00 29.77 n=9	10.11 (10.21) 0.00 29.45 n=8
Company Echelon	4.12 (6.49) 0.00 28.00 n=36	4.60 (5.88) 0.00 29.53 n=35	4.02 (2.99) 0.00 12.00 n=34	4.57 (2.76) 0.00 11.00 n=31	9.17 (10.83) 0.00 34.71 n=30	8.26 (10.87) 0.00 41.00 n=23
Range to OPFOR at Displacement (in meters)	2836.50 (564.38) 2243.00 3559.00 n=6	2607.20 (392.64) 2273.00 3150.00 n=5	NA	NA	2369.80 (404.88) 1655.00 2645.00 n=5	2251.00 (451.94) 1858.00 2898.00 n=4
Time for Companies to Reach Objectives (in minutes)	NA	NA	29.42 (4.53) 23.87 36.38 n=6	36.35 (5.71) 29.82 45.09 n=6	NA	NA

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Some measures were not applicable (NA) in certain stages.

Table C-2

Descriptive Data for Navigate Hypothesis (Maneuver BOS) Measures, by Stage and Condition

Measures	Stage 1		Stage 2		Stage 3	
	CVCC	Baseline	CVCC	Baseline	CVCC	Baseline
Distance Travelled (in meters)						
Bn Echelon	13517.85	13512.32	7455.64	8509.48	8005.98	6550.48
	(7352.13)	(8171.88)	(3341.92)	(3114.25)	(2585.29)	(2394.84)
	5405.37	5961.81	1326.22	6146.34	5477.71	3330.48
	30823.92	31002.81	13467.45	17470.88	13381.97	11310.58
	n=11	n=12	n=11	n=12	n=10	n=8
Company Echelon	13378.94	11270.19	9597.20	10043.98	9037.29	7525.50
	(5083.24)	(4062.69)	(2521.80)	(2823.81)	(3242.25)	(2514.20)
	6013.09	3150.75	4721.14	5678.78	3782.19	3437.48
	21889.76	20350.78	15093.33	15467.29	16127.39	12732.51
	n=36	n=36	n=35	n=36	n=30	n=23
Fuel Used (in gallons)						
Bn Echelon	20.74	22.91	12.63	16.29	14.87	12.64
	(8.23)	(10.90)	(3.78)	(4.74)	(3.09)	(3.11)
	11.18	13.96	9.41	12.07	11.65	9.09
	37.31	47.41	18.66	27.80	21.48	19.51
	n=11	n=12	n=11	n=12	n=10	n=8
Company Echelon	20.22	18.99	17.53	16.18	15.04	12.29
	(6.89)	(5.77)	(8.92)	(4.84)	(5.09)	(3.68)
	10.63	7.74	9.18	9.03	8.08	6.49
	38.04	33.22	72.32	28.36	26.71	19.87
	n=36	n=36	n=35	n=36	n=30	n=23
Time to Complete Stage (in minutes)	67.52	73.95	41.46	52.40	a	a
	(4.34)	(7.11)	(3.95)	(9.72)		
	63.38	66.72	36.81	41.97		
	75.47	87.28	48.68	67.15		
	n=6	n=6	n=6	n=6		

Note. Each data cell includes the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (_n_).

[a]Stage 3 data are excluded because of bias introduced by attrition of Baseline units.

Table C-3

Descriptive Data for Process Direct Fire Targets Hypothesis (Maneuver BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Time to Acquire Targets (in minutes)						
Bn Echelon	2.43	2.87	2.69	2.33	1.61	1.64
	(0.77)	(0.88)	(1.14)	(1.07)	(0.91)	(1.22)
	1.26	1.72	1.24	0.87	0.29	0.36
	4.03	5.00	4.91	3.81	3.53	3.64
	n=10	n=11	n=7	n=7	n=11	n=6
Company Echelon	2.13	2.43	1.97	2.94	1.78	2.36
	(0.79)	(1.02)	(0.84)	(1.57)	(1.30)	(1.42)
	0.55	0.65	0.61	1.05	0.25	0.36
	4.38	5.65	3.83	6.81	4.61	5.00
	n=36	n=33	n=30	n=30	n=34	n=23
Time Between Lases to Different Targets (in minutes)						
Bn Echelon	0.51	0.68	0.88	0.67	0.60	0.89
	(0.32)	(0.34)	(0.63)	(0.56)	(0.39)	(0.58)
	0.12	0.22	0.12	0.16	0.13	0.23
	1.14	1.40	2.25	2.00	1.26	1.79
	n=11	n=11	n=8	n=9	n=10	n=8
Company Echelon	0.56	0.52	0.86	0.69	0.58	0.49
	(0.28)	(0.25)	(0.70)	(0.64)	(0.35)	(0.34)
	0.05	0.20	0.00	0.08	0.15	0.15
	1.39	1.23	3.50	3.01	1.37	1.53
	n=35	n=32	n=34	n=26	n=34	n=24
Time from Lase to First Fire (in minutes)						
Bn Echelon	0.33	0.27	0.49	0.20	0.71	0.10
	(0.30)	(0.26)	(0.71)	(0.21)	(0.83)	(0.05)
	0.09	0.06	0.06	0.07	0.05	0.05
	0.87	0.68	1.75	0.56	2.22	0.20
	n=8	n=10	n=5	n=5	n=8	n=7
Company Echelon	0.48	0.31	0.20	0.38	0.26	0.18
	(0.45)	(0.32)	(0.15)	(0.82)	(0.43)	(0.33)
	0.05	0.04	0.04	0.04	0.03	0.05
	1.61	1.60	0.53	4.05	2.42	1.65
	n=35	n=30	n=23	n=25	n=30	n=23
Maximum Lase Range (in meters)						
Bn Echelon	2983.00	3046.64	2516.20	2491.60	2848.09	2263.88
	(445.06)	(342.96)	(873.42)	(600.72)	(575.04)	(499.45)
	2065.00	2400.00	700.00	1537.00	1512.00	1519.00
	3402.00	3493.00	3393.00	3463.00	3436.00	2953.00
	n=11	n=11	n=10	n=10	n=11	n=8
Company Echelon	3130.66	3010.15	2599.55	2602.87	2775.17	2341.70
	(245.18)	(468.06)	(627.06)	(611.38)	(652.01)	(907.08)
	2461.00	1175.00	759.00	593.00	306.00	352.00
	3472.00	3464.00	3352.00	3337.00	3469.00	3480.00
	n=35	n=33	n=31	n=30	n=35	n=27

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Table C-4

Descriptive Data for Engage Direct Fire Targets Hypothesis (Maneuver BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Percent of OPFOR Killed by End of Stage	87.09	88.24	98.12	91.13	71.88	87.24
	(8.67)	(8.55)	(1.59)	(13.41)	(21.76)	(17.93)
	74.51	71.57	96.77	64.52	46.88	60.42
	96.08	95.10	100.00	98.39	97.92	97.92
	n=6	n=6	n=6	n=6	n=5	n=4
Percent of BLUFOR Killed by End of Stage	22.14	26.04	4.43	9.38	26.56	22.27
	(9.95)	(10.72)	(2.30)	(6.01)	(9.70)	(10.70)
	9.38	14.06	1.56	1.56	14.06	12.50
	37.50	40.63	7.81	15.63	40.63	34.38
	n=6	n=6	n=6	n=6	n=5	n=4
Losses/Kill Ratio	0.16	0.19	0.05	0.12	0.28	0.18
	(0.08)	(0.10)	(0.02)	(0.09)	(0.13)	(0.11)
	0.06	0.10	0.02	0.02	0.10	0.09
	0.29	0.36	0.08	0.25	0.41	0.31
	n=6	n=6	n=6	n=6	n=5	n=4
Mean Target Hit Range (in meters)						
Bn Echelon	2487.83	2151.31	2018.27	1896.05	2106.86	1649.13
	(357.54)	(426.37)	(1074.59)	(925.48)	(731.85)	(365.87)
	2040.54	1444.79	777.92	428.31	1458.82	1237.58
	3156.40	2687.36	2668.18	2785.10	2956.77	1977.11
	n=7	n=7	n=3	n=5	n=5	n=4
Company Echelon	2312.15	2214.90	1770.40	1889.50	1970.14	2012.07
	(304.77)	(365.92)	(734.06)	(528.41)	(561.39)	(515.39)
	1681.22	1526.73	378.37	984.51	928.72	726.56
	2751.91	2913.76	3064.64	2788.03	2796.89	2753.70
	n=24	n=28	n=21	n=20	n=25	n=17
Mean Target Kill Range (in meters)						
Bn Echelon	2440.85	2104.98	--	1402.32	2369.39	1498.20
	(503.98)	(500.46)	--	(1162.20)	(695.50)	(239.65)
	1657.80	1422.27	2664.47	428.55	1601.24	1252.70
	3156.40	2687.36	2664.47	2688.92	2956.41	1731.54
	n=6	n=7	n=1	n=3	n=3	n=3
Company Echelon	2288.54	2243.64	1762.48	1773.10	1910.05	1916.85
	(318.11)	(390.72)	(768.45)	(608.94)	(553.10)	(587.29)
	1562.12	1508.19	557.71	767.31	977.24	726.56
	2729.17	3069.15	3064.64	2788.03	2796.89	2812.14
	n=20	n=23	n=15	n=16	n=21	n=11
Percent of OPFOR Vehicles Killed by Manned Vehicles	10.13	10.36	6.62	3.81	14.04	12.60
	(6.54)	(3.71)	(2.92)	(2.73)	(6.53)	(7.10)
	5.15	7.14	3.23	0.00	5.81	6.45
	22.35	16.67	11.29	7.50	23.64	19.64
	n=6	n=6	n=6	n=6	n=5	n=4

(table continues)

(Table C-4 continued)

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Hits/Round Ratio, Manned Vehicles						
Bn Echelon	0.20 (0.18) 0.00 0.47 n=10	0.40 (0.18) 0.00 0.62 n=10	0.17 (0.17) 0.00 0.40 n=5	0.35 (0.37) 0.00 1.00 n=6	0.23 (0.25) 0.00 0.67 n=8	0.26 (0.28) 0.00 0.55 n=8
Company Echelon	0.17 (0.16) 0.00 0.50 n=35	0.24 (0.15) 0.00 0.60 n=31	0.31 (0.32) 0.00 1.00 n=28	0.28 (0.26) 0.00 1.00 n=27	0.27 (0.24) 0.00 1.00 n=29	0.21 (0.23) 0.00 0.91 n=24
Kills/Hit Ratio, Manned Vehicles						
Bn Echelon	0.47 (0.41) 0.00 1.00 n=7	0.29 (0.31) 0.00 1.00 n=9	0.22 (0.38) 0.00 0.67 n=3	0.00 (0.00) 0.00 0.00 n=5	0.20 (0.19) 0.00 0.40 n=5	0.19 (0.24) 0.00 0.50 n=4
Company Echelon	0.36 (0.30) 0.00 1.00 n=24	0.31 (0.23) 0.00 0.67 n=28	0.31 (0.36) 0.00 1.00 n=21	0.22 (0.37) 0.00 1.00 n=20	0.48 (0.38) 0.00 1.00 n=25	0.35 (0.40) 0.00 1.00 n=17
Kills/Round Ratio, Manned Vehicles						
Bn Echelon	0.08 (0.08) 0.00 0.22 n=10	0.11 (0.11) 0.00 0.33 n=10	0.02 (0.05) 0.00 0.12 n=5	0.00 (0.00) 0.00 0.00 n=6	0.02 (0.05) 0.00 0.12 n=5	0.00 (0.00) 0.00 0.00 n=6
Company Echelon	0.07 (0.10) 0.00 0.41 n=35	0.09 (0.09) 0.00 0.40 n=31	0.10 (0.20) 0.00 1.00 n=28	0.03 (0.05) 0.00 0.14 n=27	0.13 (0.15) 0.00 0.55 n=28	0.08 (0.12) 0.00 0.33 n=24
Number of Manned Vehicles Sustaining a Killing Hit	2.17 (1.94) 0.00 5.00 n=6	2.33 (0.82) 1.00 3.00 n=6	0.67 (0.82) 0.00 2.00 n=6	0.83 (0.98) 0.00 2.00 n=6	2.40 (1.52) 1.00 4.00 n=5	3.25 (1.89) 2.00 6.00 n=4

(table continues)

(Table C-4 continued)

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Number of Rounds Fired by Manned Vehicles						
Bn Echelon	11.64 (10.26) 0.00 31.00 *n*=11	10.00 (6.47) 0.00 21.00 *n*=12	4.09 (5.89) 0.00 17.00 *n*=11	5.25 (6.82) 0.00 20.00 *n*=12	6.50 (7.17) 0.00 23.00 *n*=10	8.75 (10.53) 1.00 30.00 *n*=8
Company Echelon	15.36 (7.51) 0.00 31.00 *n*=36	15.06 (10.80) 0.00 40.00 *n*=36	7.97 (8.95) 0.00 29.00 *n*=36	8.08 (8.58) 0.00 29.00 *n*=36	10.53 (6.62) 0.00 23.00 *n*=30	12.08 (8.79) 1.00 30.00 *n*=24
Number of OPFOR Vehicles Killed South of PL JACK (Stage 1 only)	64.67 (22.70) 31.00 93.00 *n*=6	81.67 (14.28) 58.00 93.00 *n*=6	NA	NA	NA	NA
Number of OPFOR Vehicles Killed South of PL CLUB (Stage 1 only)	84.83 (11.79) 64.00 98.00 *n*=6	89.83 (9.11) 72.00 97.00 *n*=6	NA	NA	NA	NA
Number of OPFOR Vehicles Killed South of PL QUEEN (Stage 3 only)	NA	NA	NA	NA	67.20 (21.80) 45.00 94.00 *n*=5	83.75 (17.21) 58.00 94.00 *n*=4
Number of OPFOR Vehicles Killed South of PL ACE (Stage 3 only)	NA	NA	NA	NA	38.60 (22.07) 18.00 73.00 *n*=5	54.50 (33.29) 13.00 94.00 *n*=4

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (*n*).

Some measures were not applicable (NA) in certain stages.

Table C-5

Descriptive Data for Process Ground Targets Hypothesis (Fire Support BOS) Measures, by Stage and Condition

Measures	Stage 1		Stage 2		Stage 3	
	CVCC	Baseline	CVCC	Baseline	CVCC	Baseline
Accuracy of CFF Report Locations (observed; in meters)	526.75	4087.15	679.17	2981.29	391.79	115.33
	(475.64)	(8022.25)	(896.97)	(1621.19)	(501.39)	(52.37)
	20.00	162.00	41.50	52.00	36.00	77.00
	1846.00	24462.33	3050.00	4378.00	2295.00	175.00
	n=25	n=9	n=15	n=7	n=22	n=3
Percent of CFF Reports with Correct Type (observed)	90.57	73.33	87.50	66.67	91.53	83.33
	(17.70)	(25.50)	(28.87)	(23.57)	(24.15)	(28.87)
	50.00	50.00	0.00	50.00	0.00	50.00
	100.00	100.00	100.00	100.00	100.00	100.00
	n=25	n=9	n=16	n=7	n=22	n=3

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Table C-6

Descriptive Data for Receive and Transmit Mission Hypothesis (Command and Control BOS) Measures, by Stage and Condition

Measures	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Elapsed Time from Bn Transmission of FRAGO to Reception by Co Cdr/XO (in minutes)	0.00[a] (0.00) 0.00 0.00 n=6	18.66 (6.14) 9.50 27.22 n=6	0.09[a] (0.08) 0.00 0.35 n=6	15.65 (8.40) 6.18 26.05 n=5
Duration of Request to Clarify FRAGO/Overlay (in minutes)				
Company Cdr	-- -- -- -- n=0	0.43 (0.07) 0.32 0.50 n=5	0.26 (--) 0.16 0.35 n=2	0.43 (0.23) 0.15 0.95 n=12
Company XO	-- -- -- -- n=0	0.60 (0.46) 0.17 1.50 n=3	-- -- -- -- n=0	0.58 (0.55) 0.27 1.22 n=3
Consistency of FRAGO (percent of elements correctly received)	100.00[a]	18.97 (12.41) 0.00 50.00 n=17	100.00[a]	35.27 (17.21) 9.09 72.72 n=15
Number of Requests by Company Commanders/XOs to Clarify FRAGO/Overlay	0.00 (0.00) 0.00 0.00 n=36	0.33 (0.53) 0.00 2.00 n=36	0.08 (0.28) 0.00 1.00 n=36	0.53 (0.97) 0.00 4.00 n=30

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

FRAGOs were transmitted in Stages 2 and 3 only.

[a]The CVCC model ensured nearly instantaneous, error-free transmission of FRAGOs (overlays and text). Maximum FRAGO consistency values were assumed.

Table C-7

Descriptive Data from Receive and Transmit Enemy Information Hypothesis (Command and Control BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Time to Transmit INTEL from Bn TOC to Co Cdr (in minutes)	0.00[a]	1.65	0.00[a]	1.58	0.00[a]	--
		(0.96)		(1.03)		--
		0.73		0.56		0.82
		3.63		2.63		0.82
		_n_=10		_n_=3		_n_=1
Consistency of INTEL Reports (percent of elements correctly received)	100.00[a]	60.32	100.00[a]	--	100.00[a]	--
		(39.95)		--		--
		0.00		100.00		25.00
		100.00		100.00		[illegible].00
		_n_=6		_n_=1		_n_=1
Number of Requests to Clarify INTEL Reports						
Bn Echelon	0.00	0.09	0.00	0.08	0.09	0.13
	(0.00)	(0.30)	(0.00)	(0.29)	(0.30)	(0.35)
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	1.00	0.00	1.00	1.00	1.00
	_n_=11	_n_=11	_n_=11	_n_=12	_n_=11	_n_=8
Company Echelon	0.00	0.06	0.00	0.06	0.00	0.00
	(0.00)	(0.23)	(0.00)	(0.24)	(0.00)	(0.00)
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	1.00	0.00	1.00	0.00	0.00
	_n_=36	_n_=36	_n_=36	_n_=35	_n_=36	_n_=25

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (_n_).

[a]The CVCC model ensured the nearly instantaneous, error-free transmission of INTEL reports. Zero transmission times and maximum consistency values were assumed.

Table C-8

Descriptive Data for Receive and Transmit Friendly Troop Information Hypothesis (Command and Control BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Time to Transmit SITREP from Lowest Net to Bn TOC (in minutes)	NA[a]	3.05 (2.84) 0.08 10.45 n=52	NA[a]	2.61 (2.16) 0.30 8.63 n=32	NA[a]	2.24 (1.72) 0.11 6.78 n=25
Mean Duration of Voice Transmissions Between Bn Cdr/S3 and TOC (in minutes)	0.56 (0.58) 0.17 2.58 n=42	0.51 (0.57) 0.01 4.23 n=142	0.52 (0.47) 0.03 1.67 n=20	0.45 (0.37) 0.03 1.83 n=88	b	b
Difference Between Observed and Reported PL/LD Crossing (in minutes)	0.91 (1.59) 0.02 5.26 n=10	1.13 (1.46) 0.08 4.25 n=12	1.28 (1.04) 0.18 3.35 n=12	0.73 (0.72) 0.03 1.95 n=6	0.43 (0.30) 0.67 0.80 n=4	-- -- -- -- n=0
Difference Between Observed BP Arrival and Reporting SET (in minutes)	1.36 (1.58) 0.05 4.60 n=11	3.29 (3.83) 0.05 12.88 n=12	1.79 (0.15) 1.65 1.95 n=3	2.26 (3.93) 0.05 9.21 n=5	5.43 (3.90) 0.08 8.91 n=4	2.57 (3.53) 0.05 6.60 n=3
Number of Voice Transmissions Between Bn Cdr/S3 and TOC	5.17 (5.56) 1.00 16.00 n=6	13.50 (10.67) 1.00 32.00 n=6	1.83 (1.83) 0.00 4.00 n=6	9.50 (7.89) 3.00 24.00 n=6	b	b

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

[a]SITREP transmission time did not apply to the CVCC condition.

[b]Stage 3 data are excluded because of the absence of a scripted brigade FRAGO in that stage.

Table C-9

Descriptive Data for Manage Means of Communicating Information Hypothesis (Command and Control BOS) Measures, by Stage and Condition

	Stage 1		Stage 2		Stage 3	
Measures	CVCC n=6	Baseline n=6	CVCC n=6	Baseline n=6	CVCC n=6	Baseline n=5
Average Length of Voice Transmissions (in minutes)						
Bn Command Net	4.30	4.40	4.21	4.53	3.93	4.14
	(0.54)	(0.68)	(0.60)	(0.50)	(0.30)	(0.46)
	3.64	3.51	3.36	3.99	3.46	3.58
	4.88	5.22	4.95	5.11	4.24	4.64
Bn O&I Net	3.58	3.80	3.23	3.56	3.19	3.40
	(0.35)	(0.41)	(0.55)	(0.55)	(0.33)	(0.32)
	3.29	3.36	2.51	3.19	2.58	3.15
	4.15	4.35	3.95	4.68	3.48	3.94
A Company Net	3.83	3.82	4.06	3.94	4.05	4.25
	(0.58)	(0.52)	(0.88)	(0.51)	(0.45)	(0.62)
	3.40	2.97	3.34	3.21	3.50	3.61
	4.84	4.46	5.26	4.47	4.56	5.10
B Company Net	3.65	4.02	3.58	3.97	3.59	3.78
	(0.56)	(0.87)	(0.37)	(0.59)	(0.49)	(0.63)
	3.08	3.08	3.17	3.15	3.16	3.02
	4.65	5.53	4.07	4.83	4.43	4.74
C Company Net	3.20	4.09	3.42	4.13	3.28	4.20
	(0.19)	(0.53)	(0.20)	(0.41)	(0.19)	(0.27)
	2.98	3.48	3.13	3.59	3.05	3.87
	3.44	4.71	3.66	4.74	3.52	4.57

(table continues)

(Table C-9 continued)

Measures	Stage 1 CVCC n=6	Stage 1 Baseline n=6	Stage 2 CVCC n=6	Stage 2 Baseline n=6	Stage 3 CVCC n=6	Stage 3 Baseline n=5
Total Number of Voice Radio Transmissions						
Bn Command Net	281.17	501.00	169.00	341.17	a	a
	(48.39)	(120.80)	(48.03)	(93.06)		
	247.00	339.00	133.00	225.00		
	378.00	681.00	260.00	481.00		
Bn O&I Net	89.33	278.50	50.83	172.17	a	a
	(34.64)	(69.19)	(35.27)	(60.18)		
	28.00	219.00	23.00	110.00		
	131.00	363.00	113.00	272.00		
A Company Net	154.00	249.00	81.33	162.00	a	a
	(66.88)	(66.87)	(38.05)	(27.06)		
	83.00	163.00	30.00	127.00		
	266.00	350.00	127.00	208.00		
B Company Net	152.50	225.50	97.33	170.50	a	a
	(25.59)	(57.61)	(21.64)	(42.83)		
	107.00	160.00	68.00	131.00		
	173.00	328.00	129.00	240.00		
C Company Net	89.50	231.00	83.17	177.83	a	a
	(24.92)	(50.22)	(14.52)	(46.90)		
	53.00	165.00	56.00	91.00		
	118.00	295.00	98.00	227.00		

(table continues)

(<u>Table C-9 continued</u>)

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Total Time on Voice Radio Net (in minutes)						
Bn Command Net	20.34 (5.55) 15.54 30.76 n=6	35.98 (6.11) 24.91 42.93 n=6	12.08 (4.62) 7.74 20.11 n=6	25.56 (7.26) 18.40 39.14 n=6	a	a
Bn O&I Net	5.25 (1.95) 1.80 7.53 n=6	17.52 (4.18) 12.25 24.04 n=6	2.86 (2.30) 0.96 7.20 n=6	10.12 (3.38) 5.84 15.43 n=6	a	a
A Company Net	9.86 (4.30) 4.71 16.32 n=6	16.04 (5.32) 9.75 21.98 n=6	5.82 (3.57) 1.75 10.75 n=6	10.68 (2.30) 6.80 12.57 n=6	a	a
B Company Net	9.10 (0.86) 8.30 10.65 n=6	14.51 (1.31) 13.15 16.84 n=6	5.81 (1.36) 3.89 7.13 n=6	11.01 (1.69) 8.54 12.72 n=6	a	a
C Company Net	4.72 (1.15) 2.88 5.86 n=6	15.51 (2.61) 12.08 18.24 n=6	4.75 (0.91) 3.10 5.88 n=6	12.29 (3.81) 6.48 16.52 n=6	a	a
Total Number of Named Voice Reports						
Bn Echelon	1.45 (1.69) 0.00 5.00 n=11	2.67 (2.71) 0.00 7.00 n=12	0.64 (1.03) 0.00 3.00 n=11	0.92 (1.00) 0.00 3.00 n=12	a	a
C Company Net	3.33 (2.34) 0.00 9.00 n=36	16.67 (5.94) 5.00 29.00 n=36	1.47 (1.63) 0.00 7.00 n=36	7.92 (4.71) 1.00 23.00 n=36	a	a

<u>Note</u>. Each data cell (from top to bottom) includes the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

[a] Stage 3 data are excluded because of the absence of a scripted brigade FRAGO in that stage.

Table C-10

Descriptive Data for Direct and Lead Subordinate Forces Hypothesis (Command and Control BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Percentage Score for Meeting Brigade Commander's Intent	81.93	89.97	94.35	94.35	66.21	84.11
	(19.14)	(6.70)	(9.29)	(9.55	(26.21)	(19.89)
	53.13	80.86	77.70	77.63	19.02	55.78
	100.00	97.46	99.90	99.90	97.46	98.44
	n=6	n=6	n=6	n=5	n=6	n=4
Battalion Command Effectiveness Composite Index	82.85	82.68	66.11	83.61	84.12	84.50
	(15.94)	(11.48)	(20.93)	(5.64)	(13.18)	(16.02)
	57.26	69.10	29.45	74.09	66.67	62.39
	98.17	97.59	89.76	89.76	96.77	96.63
	n=6	n=6	n=6	n=6	n=6	n=4

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Table C-11

Descriptive Data for Collect Threat Information Hypothesis (Intelligence BOS) Measures, by Stage and Condition

Measures	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Accuracy of SPOT Report Locations (observed; in meters)	436.70	1993.28	369.39	1331.22	375.74	884.50
	(470.39)	(2774.19)	(433.76)	(1490.23)	(588.19)	(--)
	1.00	41.00	2.00	31.00	0.00	862.00
	1700.00	10527.00	1735.50	4469.50	2188.00	907.00
	n=34	n=23	n=25	n=13	n=18	n=2
Accuracy of SPOT Report Locations (destroyed; in meters)	394.44	1430.09	362.96	1040.97	328.65	884.50
	(423.19)	(2381.98)	(396.43)	(1392.92)	(532.14)	(--)
	1.00	14.00	0.67	18.00	0.00	862.00
	1700.00	9103.50	1229.00	3994.00	1724.00	907.00
	n=32	n=22	n=25	n=11	n=17	n=2
Correctness of SPOT Report Number and Type (observed; percentage)	81.86	83.82	95.16	94.29	81.47	100.00
	(27.29)	(25.12)	(11.88)	(17.90)	(30.45)	(--)
	0.00	20.00	50.00	33.33	0.00	100.00
	100.00	100.00	100.00	100.00	100.00	100.00
	n=34	n=23	n=25	n=25	n=19	n=2
Correctness of SPOT Report Number and Type (destroyed; percentage)	78.99	54.55	88.58	68.94	73.52	73.08
	(27.44)	(40.31)	(17.13)	(32.53)	(32.08)	(--)
	0.00	0.00	50.00	0.00	0.00	46.15
	100.00	100.00	100.00	100.00	100.00	100.00
	n=33	n=23	n=25	n=12	n=18	n=2
Accuracy of SHELL Report Locations (in meters)	2034.27	1648.10	1662.83	1333.20	1888.25	1783.67
	(1033.36)	(595.52)	(577.95)	(429.22)	(645.23)	(751.28)
	327.00	740.50	747.00	984.00	891.00	802.00
	4195.00	2476.00	2430.00	2068.00	3236.00	2793.00
	n=22	n=15	n=15	n=5	n=25	n=7
Accuracy of CONTACT Report Locations (in meters)	538.27	881.13	600.37	988.88	355.67	1043.29
	(681.31)	(1022.42)	(840.10)	(1471.44)	(497.26)	(1762.46)
	3.00	124.33	7.00	41.50	1.00	32.00
	2698.00	3512.00	3037.00	4087.00	1742.00	4828.50
	n=30	n=16	n=23	n=10	n=19	n=7
Percent CONTACT Reports with Correct Type	84.72	59.38	88.70	50.71	84.47	46.43
	(29.20)	(31.01)	(26.25)	(32.14)	(30.32)	(30.37)
	0.00	0.00	0.00	0.00	0.00	0.00
	100.00	100.00	100.00	100.00	100.00	100.00
	n=30	n=16	n=18	n=14	n=19	n=7

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Table C-12

Descriptive Data for Situational Assessment Hypothesis (Command and Control BOS) Measures, by Condition

	Percent Correctly Identified		Confidence Rating	
Measures	CVCC	Baseline	CVCC	Baseline
Number of OPFOR Tanks Destroyed (percent correct)				
Bn Echelon	50.09	40.17	2.45	3.08
	(32.55)	(26.52)	(1.29)	(0.79)
	0.00	0.00	1.00	2.00
	100.00	77.00	5.00	5.00
	n=11	n=12	n=11	n=12
Company Echelon	27.57	44.17	2.89	3.39
	(23.19)	(34.19)	(0.96)	(1.20)
	0.00	0.00	1.00	0.00
	100.00	100.00	5.00	6.00
	n=35	n=36	n=35	n=36
Number of OPFOR BMPs Destroyed (percent correct)				
Bn Echelon	48.09	39.11	3.00	3.00
	(33.51)	(33.10)	(1.18)	(1.13)
	0.00	0.00	1.00	1.00
	90.00	91.00	5.00	5.00
	n=11	n=12	n=11	n=12
Company Echelon	46.03	37.31	2.80	3.33
	(29.64)	(30.91)	(1.08)	(1.29)
	0.00	0.00	1.00	1.00
	100.00	100.00	5.00	5.00
	n=35	n=36	n=35	n=36
Number in Your Unit Destroyed (percent correct)				
Bn Echelon	38.09	27.83	2.82	3.25
	(25.61)	(12.66)	(1.08)	(0.97)
	0.00	0.00	1.00	2.00
	83.00	50.00	4.00	5.00
	n=11	n=12	n=11	n=12
Company Echelon	48.20	49.11	4.17	4.56
	(34.94)	(43.31)	(1.01)	(0.65)
	0.00	0.00	2.00	3.00
	100.00	100.00	5.00	5.00
	n=35	n=36	n=35	n=36

(table continues)

(Table C-12 continued)

Measures	Deviation Between Actual and Reported Distance (in meters) CVCC	Baseline	Confidence Rating CVCC	Baseline
Distance from Initial BP to Later BP (deviation in kilometers)				
Bn Echelon	1.02 (1.09) 0.23 3.77 n=11	2.64 (3.77) 0.23 11.77 n=8	3.45 (0.82) 2.00 5.00 n=11	3.50 (0.76) 2.00 4.00 n=8
Company Echelon	1.21 (1.52) 0.00 6.90 n=35	1.53 (1.51) 0.00 5.40 n=24	3.57 (0.95) 1.00 5.00 n=35	3.54 (0.88) 1.00 5.00 n=24
Composite Situational Assessment Index				
Bn Echelon	33.18 (11.97) 1.75 46.25 n=11	30.98 (14.10) 8.00 45.63 n=8	--	--
Company Echelon	21.65 (12.59) 0.25 36.13 n=36	24.41 (12.31) 1.75 42.25 n=23	--	--

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parentheses), minimum, maximum, and number of observations (n).

Appendix D

Analysis of Variance Summary Tables

Table D-1

ANOVA Summaries for Measures Supporting Move on Surface Hypothesis (Maneuver BOS)

Distance Between BLUFOR and OPFOR Center-of-Mass (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	26123628.668	3	8707876.223	15.687	.000
COND	6198484.986	1	6198484.986	11.166	.002
STAGE	20199037.844	2	10099518.922	18.194	.000
2-way Interactions	5765872.847	2	2882936.423	5.193	.012
COND STAGE	5765872.847	2	2882936.423	5.193	.012
Explained	31889501.515	5	6377900.303	11.489	.000
Residual	14988056.000	27	555113.185		
Total	46877557.515	32	1464923.672		

Exposure Index

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1978.074	4	494.518	8.293	.000
COND	6.095	1	6.095	.102	.749
ECHELON	1034.949	1	1034.949	17.356	.000
STAGE	964.910	2	482.455	8.091	.000
2-way Interactions	429.983	5	85.997	1.442	.210
COND ECHELON	7.897	1	7.897	.132	.716
COND STAGE	130.755	2	65.377	1.096	.336
ECHELON STAGE	283.171	2	141.586	2.374	.095
3-way Interactions	168.820	2	84.410	1.416	.245
COND ECHELON STAGE	168.820	2	84.410	1.416	.245
Explained	2576.877	11	234.262	3.929	.000
Residual	14311.137	240	59.630		
Total	16888.014	251	67.283		

Range to OPFOR at Displacement (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1013442.373	2	506721.187	2.331	.129
COND	159807.755	1	159807.755	.735	.404
STAGE	861025.008	1	861025.008	3.961	.064
2-way Interactions	14951.327	1	14951.327	.069	.796
COND STAGE	14951.327	1	14951.327	.069	.796
Explained	1028393.700	3	342797.900	1.577	.234
Residual	3477743.100	16	217358.944		
Total	4506136.800	19	237165.095		

Table D-2

ANOVA Summaries for Measures Supporting Navigate Hypothesis (Maneuver BOS)

Distance Travelled (in meters)

Source of Variation	Squares	DF	Square	F	of F
Main Effects	1068242373.41	4	267060593.35	16.410	.000
COND	27231266.541	1	27231266.541	1.673	.197
ECHELON	7006204.897	1	7006204.897	.431	.512
STAGE	1051631208.77	2	525815604.39	32.309	.000
2-way Interactions	146831295.955	5	29366259.191	1.804	.112
COND ECHELON	7096431.591	1	7096431.591	.436	.510
COND STAGE	59959502.660	2	29979751.330	1.842	.161
ECHELON STAGE	81423590.419	2	40711795.209	2.502	.084
3-way Interactions	15534581.908	2	7767290.954	.477	.621
COND ECHELON STAGE	15534581.908	2	7767290.954	.477	.621
Explained	1230608251.27	11	111873477.39	6.874	.000
Residual	4149976231.67	255	16274416.595		
Total	5380584482.94	266	20227761.214		

Fuel Used (in gallons)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	2024.095	4	506.024	12.562	.000
COND	29.918	1	29.918	.743	.390
ECHELON	1.453	1	1.453	.036	.850
STAGE	2019.217	2	1009.608	25.063	.000
2-way Interactions	315.125	5	63.025	1.565	.171
COND ECHELON	99.471	1	99.471	2.469	.117
COND STAGE	29.827	2	14.913	.370	.691
ECHELON STAGE	192.101	2	96.051	2.384	.094
3-way Interactions	60.502	2	30.251	.751	.473
COND ECHELON STAGE	60.502	2	30.251	.751	.473
Explained	2399.721	11	218.156	5.416	.000
Residual	10272.070	255	40.283		
Total	12671.791	266	47.638		

Time to Complete Stage (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3852.992	2	1926.496	42.966	.000
COND	452.922	1	452.922	10.101	.005
STAGE	3400.071	1	3400.071	75.831	.000
2-way Interactions	30.510	1	30.510	.680	.419
COND STAGE	30.510	1	30.510	.680	.419
Explained	3883.502	3	1294.501	28.871	.000
Residual	896.752	20	44.838		
Total	4780.254	23	207.837		

Table D-3

ANOVA Summaries for Measures Supporting Process Direct Fire Targets Hypothesis (Maneuver BOS)

Time to Acquire Targets (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	27.152	4	6.788	5.280	.000
COND	14.709	1	14.709	11.442	.001
ECHELON	.066	1	.066	.051	.821
STAGE	9.887	2	4.943	3.845	.023
2-way Interactions	7.864	5	1.573	1.223	.299
COND ECHELON	2.392	1	2.392	1.861	.174
COND STAGE	1.438	2	.719	.559	.572
ECHELON STAGE	4.707	2	2.353	1.831	.163
3-way Interactions	3.662	2	1.811	1.409	.247
COND ECHELON STAGE	3.662	2	1.811	1.409	.247
Explained	38.638	11	3.513	2.732	.002
Residual	290.539	226	1.286		
Total	329.177	237	1.389		

Time Between Lases to Different Targets (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	2.732	4	.683	3.178	.014
COND	.156	1	.156	.726	.395
ECHELON	.245	1	.245	1.138	.287
STAGE	2.374	2	1.187	5.525	.005
2-way Interactions	1.119	5	.224	1.042	.394
COND ECHELON	.383	1	.383	1.783	.183
COND STAGE	.436	2	.218	1.014	.365
ECHELON STAGE	.287	2	.144	.668	.514
3-way Interactions	.300	2	.150	.697	.499
COND ECHELON STAGE	.300	2	.150	.697	.499
Explained	4.151	11	.377	1.756	.063
Residual	49.425	230	.215		
Total	53.575	241	.222		

Time from Lase to First Fire (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.037	4	.259	1.202	.311
COND	.498	1	.498	2.309	.130
ECHELON	.062	1	.062	.286	.593
STAGE	.511	2	.256	1.186	.308
2-way Interactions	1.917	5	.383	1.778	.119
COND ECHELON	.548	1	.548	2.540	.113
COND STAGE	.727	2	.363	1.686	.188
ECHELON STAGE	.494	2	.247	1.145	.320
3-way Interactions	.779	2	.389	1.806	.167
COND ECHELON STAGE	.779	2	.389	1.806	.167
Explained	3.732	11	.339	1.574	.109
Residual	42.477	197	.216		
Total	46.209	208	.222		

(table continues)

(Table D-3 continued)

Maximum Lase Range (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	15108043.947	4	3777010.987	10.558	.000
COND	1969187.894	1	1969187.894	5.504	.020
ECHELON	101137.126	1	101137.126	.283	.595
STAGE	13283321.925	2	6641660.963	18.565	.000
2-way Interactions	2621446.538	5	524289.308	1.466	.202
COND ECHELON	1350.023	1	1350.023	.004	.951
COND STAGE	2528456.218	2	1264228.109	3.534	.031
ECHELON STAGE	85761.608	2	42880.804	.120	.887
3-way Interactions	223185.832	2	111592.916	.312	.732
COND ECHELON STAGE	223185.832	2	111592.916	.312	.732
Explained	17952676.317	11	1632061.483	4.562	.000
Residual	85860320.203	240	357751.334		
Total	103812996.520	251	413597.596		

Table D-4

ANOVA Summaries for Measures Supporting Engage Direct Fire Targets Hypothesis (Maneuver BOS)

Percent of OPFOR Killed by End of Stage

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1337.118	3	445.706	2.668	.068
COND	33.543	1	33.543	.201	.658
STAGE	1282.946	2	641.473	3.839	.034
2-way Interactions	641.532	2	320.766	1.920	.166
COND STAGE	641.532	2	320.766	1.920	.166
Explained	1978.649	5	395.730	2.369	.066
Residual	4511.165	27	167.080		
Total	6489.814	32	202.807		

Percent of BLUFOR Killed by End of Stage

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	2356.626	3	785.542	10.624	.000
COND	35.206	1	35.206	.476	.496
STAGE	2333.909	2	1166.954	15.782	.000
2-way Interactions	125.045	2	62.523	.846	.440
COND STAGE	125.045	2	62.523	.846	.440
Explained	2481.671	5	496.334	6.712	.000
Residual	1996.460	27	73.943		
Total	4478.131	32	139.942		

Losses/Kill Ratio

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.129	3	.043	5.080	.006
COND	.001	1	.001	.101	.754
STAGE	.129	2	.065	7.606	.002
2-way Interactions	.034	2	.017	2.004	.154
COND STAGE	.034	2	.017	2.004	.154
Explained	.164	5	.033	3.850	.009
Residual	.229	27	.008		
Total	.393	32	.012		

Mean Target Hit Range (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	5703054.039	4	1425763.510	5.038	.001
COND	109430.196	1	109430.196	.387	.535
ECHELON	18057.882	1	18057.882	.064	.801
STAGE	5567064.595	2	2783532.297	9.836	.000
2-way Interactions	1169466.511	5	233893.302	.826	.533
COND ECHELON	631954.805	1	631954.805	2.233	.137
COND STAGE	309357.871	2	154678.935	.547	.580
ECHELON STAGE	207992.283	2	103996.142	.367	.693
3-way Interactions	88035.253	2	44017.626	.156	.856
COND ECHELON STAGE	88035.253	2	44017.626	.156	.856
Explained	6960555.803	11	632777.800	2.236	.015
Residual	44148227.311	156	283001.457		
Total	51108783.114	167	306040.617		

(table continues)

(Table D-4 continued)

Mean Target Kill Range (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	6493170.123	4	1623292.531	5.390	.001
COND	437786.594	1	437786.594	1.454	.230
ECHELON	351.511	1	351.511	.001	.973
STAGE	6086845.183	2	3043422.591	10.106	.000
2-way Interactions	1651302.890	5	330260.578	1.097	.366
COND ECHELON	1632996.541	1	1632996.541	5.423	.022
COND STAGE	40009.666	2	20004.833	.066	.936
ECHELON STAGE	23240.454	2	11620.227	.039	.962
3-way Interactions	642087.325	2	321043.662	1.066	.348
COND ECHELON STAGE	642087.325	2	321043.662	1.066	.348
Explained	8786560.337	11	798778.212	2.652	.005
Residual	35234404.961	117	301148.760		
Total	44020965.298	128	343913.791		

Percent OPFOR Vehicles Killed by Manned Vehicles

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	376.750	3	125.583	4.956	.007
COND	14.548	1	14.548	.574	.455
STAGE	356.252	2	178.126	7.030	.003
2-way Interactions	13.811	2	6.906	.273	.764
COND STAGE	13.811	2	6.906	.273	.764
Explained	390.561	5	78.112	3.083	.025
Residual	684.132	27	25.338		
Total	1074.693	32	33.584		

Hits/Round Ratio, Manned Vehicles

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.253	4	.063	1.184	.319
COND	.046	1	.046	.869	.352
ECHELON	.042	1	.042	.793	.374
STAGE	.168	2	.084	1.577	.209
2-way Interactions	.477	5	.095	1.788	.117
COND ECHELON	.178	1	.178	3.326	.070
COND STAGE	.178	2	.089	1.669	.191
ECHELON STAGE	.116	2	.058	1.086	.340
3-way Interactions	.020	2	.010	.185	.831
COND ECHELON STAGE	.020	2	.010	.185	.831
Explained	.750	11	.068	1.277	.240
Residual	11.106	208	.053		
Total	11.856	219	.054		

(table continues)

(Table D-4 continued)

Kills/Hit Ratio, Manned Vehicles

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.300	4	.325	2.996	.020
COND	.427	1	.427	3.940	.049
ECHELON	.216	1	.216	1.988	.161
STAGE	.606	2	.303	2.793	.064
2-way Interactions	.400	5	.080	.738	.596
COND ECHELON	.020	1	.020	.183	.670
COND STAGE	.011	2	.006	.052	.949
ECHELON STAGE	.376	2	.188	1.736	.180
3-way Interactions	.088	2	.044	.406	.667
COND ECHELON STAGE	.088	2	.044	.406	.667
Explained	1.788	11	.163	1.499	.137
Residual	16.915	156	.108		
Total	18.703	167	.112		

Kills/Round Ratio, Manned Vehicles

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.111	4	.028	1.903	.111
COND	.028	1	.028	1.894	.170
ECHELON	.020	1	.020	1.406	.237
STAGE	.064	2	.032	2.194	.114
2-way Interactions	.120	5	.024	1.650	.148
COND ECHELON	.008	1	.008	.585	.445
COND STAGE	.069	2	.034	2.374	.096
ECHELON STAGE	.037	2	.019	1.277	.281
3-way Interactions	.002	2	.001	.084	.920
COND ECHELON STAGE	.002	2	.001	.084	.920
Explained	0233	11	.021	1.457	.150
Residual	3.021	208	.015		
Total	3.254	219	.015		

Number of Manned Vehicles Sustaining a Killing Hit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	25.202	3	8.401	4.511	.011
COND	1.015	1	1.015	.545	.467
STAGE	24.489	2	12.244	6.575	.005
2-way Interactions	.757	2	.379	.203	.817
COND STAGE	.757	2	.379	.203	.817
Explained	25.959	5	5.192	2.788	.037
Residual	50.283	27	1.862		
Total	76.242	32	2.383		

(table continues)

(Table D-4 continued)

Number of Rounds fired by Manned Vehicles

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3000.143	4	750.036	10.357	.000
COND	9.119	1	9.119	.126	.723
ECHELON	713.401	1	713.401	9.851	.002
STAGE	2277.652	2	1138.826	15.725	.000
2-way Interactions	67.040	5	13.408	.185	.968
COND ECHELON	.101	1	.101	.001	.970
COND STAGE	56.211	2	28.106	.388	.679
ECHELON STAGE	10.263	2	5.131	.071	.932
3-way Interactions	14.019	2	7.009	.097	.908
COND ECHELON STAGE	14.019	2	7.009	.097	.908
Explained	3081.201	11	280.109	3.868	.000
Residual	18104.921	250	72.420		
Total	21186.122	261	81.173		

Table D-5

ANOVA Summaries for Measures Supporting Process Ground Targets Hypothesis (Fire Support BOS)

Accuracy of CFF Report Locations (observed; in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	104836436.722	2	52418218.361	4.980	.010
COND	104792198.243	1	104792198.24	9.956	.003
STAGE	642866.493	1	642866.493	.061	.806
2-way Interactions	4390214.387	1	4390214.387	.417	.521
COND STAGE	4390214.387	1	4390214.387	.417	.521
Explained	109226651.109	3	36408883.703	3.459	.023
Residual	547314957.465	52	10525287.644		
Total	656541608.573	55	11937120.156		

Percent of CFF Reports with Correct Type (observed)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	4364.641	2	2182.321	4.051	.023
COND	4042.530	1	4042.530	7.504	.008
STAGE	230.394	1	230.394	.428	.516
2-way Interactions	36.357	1	36.357	.067	.796
COND STAGE	36.357	1	36.357	.067	.796
Explained	4400.998	3	1466.999	2.723	.053
Residual	28551.000	53	538.698		
Total	32951.998	56	588.429		

Table D-6

ANOVA Summaries for Measures Supporting Receive and Transmit Friendly Troop Information Hypothesis (Command and Control BOS)

Mean Duration of Voice Transmissions Between Bn Cdr/S3 and TOC (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.371	2	.185	.701	.497
COND	.147	1	.147	.558	.456
STAGE	.205	1	.205	.774	.380
2-way Interactions	.003	1	.003	.011	.918
COND STAGE	.003	1	.003	.011	.918
Explained	.373	3	.124	.471	.703
Residual	76.098	288	.264		
Total	76.472	291	.263		

Difference Between Observed and Reported PL/LD Crossing (in minutes)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.594	3	.531	.341	.796
COND	.103	1	.103	.066	.798
STAGE	1.594	2	.797	.511	.604
2-way Interactions	1.384	1	1.384	.888	.352
COND STAGE	1.384	1	1.384	.888	.352
Explained	2.978	4	.745	.478	.752
Residual	60.766	39	1.558		
Total	63.744	43	1.482		

Difference Between Observed BP Arrival and Reporting SET (in minutes)

Stages 1-3

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	26.625	3	8.875	.892	.456
COND	5.280	1	5.280	.530	.472
STAGE	23.387	2	11.694	1.175	.322
2-way Interactions	30.526	2	15.263	1.533	.231
COND STAGE	30.526	2	15.263	1.533	.231
Explained	57.151	5	11.430	1.148	.356
Residual	318.540	32	9.954		
Total	375.691	37	10.154		

Stages 1 and 2 only

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	19.161	2	9.581	1.043	.366
COND	18.699	1	18.699	2.036	.165
STAGE	1.144	1	1.144	.125	.727
2-way Interactions	3.019	1	3.019	.329	.571
COND STAGE	3.019	1	3.019	.329	.571
Explained	22.180	3	7.393	.805	.502
Residual	247.932	27	9.183		
Total	270.112	30	9.004		

(table continues)

(Table D-6 continued)

Number of Voice Transmissions Between Bn Cdr/S3 and TOC (Stages 1 and 2 only)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	464.667	2	232.333	4.414	.026
COND	384.000	1	384.000	7.296	.014
STAGE	80.667	1	80.667	1.533	.230
2-way Interactions	.667	1	.667	.013	.912
COND STAGE	.667	1	.667	.013	.912
Explained	465.333	3	155.111	2.947	.058
Residual	1052.667	20	52.633		
Total	1518.000	23	66.000		

Table D-7

ANOVA Summaries for Measures Supporting Manage Means of Communicating Information Hypothesis (Command and Control BOS)

Average Length of Voice Transmissions (in minutes)

Bn Command Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.225	3	.408	1.455	.247
COND	.376	1	.376	1.339	.257
STAGE	.800	2	.400	1.426	.257
2-way Interactions	.070	2	.035	.124	.884
COND STAGE	.070	2	.035	.124	.884
Explained	1.294	5	.259	.923	.481
Residual	8.138	29	.281		
Total	9.432	34	.277		

Bn O&I Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.561	3	.520	2.767	.060
COND	.558	1	.558	2.966	.096
STAGE	.959	2	.480	2.550	.095
2-way Interactions	.023	2	.011	.060	.941
COND STAGE	.023	2	.011	.060	.941
Explained	1.584	5	.317	1.684	.170
Residual	5.454	29	.188		
Total	7.038	34	.207		

A Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.566	3	.189	.511	.678
COND	.004	1	.004	.012	.915
STAGE	.565	2	.282	.764	.475
2-way Interactions	.146	2	.073	.197	.822
COND STAGE	.146	2	.073	.197	.822
Explained	.712	5	.142	.385	.855
Residual	10.716	29	.370		
Total	11.428	34	.336		

B Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1.047	3	.349	.966	.422
COND	.900	1	.900	2.493	.125
STAGE	.120	2	.060	.166	.848
2-way Interactions	.062	2	.031	.086	.918
COND STAGE	.062	2	.031	.086	.918
Explained	1.109	5	.222	.614	.690
Residual	10.474	29	.361		
Total	11.583	34	.341		

(table continues)

(Table D-7 continued)

C Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	6.216	3	2.072	19.415	.000
COND	6.109	1	6.109	57.238	.000
STAGE	.111	2	.056	.521	.600
2-way Interactions	.077	2	.038	.359	.701
COND STAGE	.077	2	.038	.359	.701
Explained	6.293	5	1.259	11.793	.000
Residual	3.095	29	.107		
Total	9.388	34	.276		

Number of Voice Radio Transmissions

Bn Command Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	341472.000	2	170736.000	24.478	.000
COND	230496.000	1	230496.000	33.046	.000
STAGE	110976.000	1	110976.000	15.911	.001
2-way Interactions	3408.167	1	3408.167	.489	.493
COND STAGE	3408.167	1	3408.167	.489	.493
Explained	344880.167	3	114960.056	16.482	.000
Residual	139499.667	20	6974.983		
Total	484379.833	23	21059.993		

Bn O&I Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	176080.417	2	88040.208	32.449	.000
COND	144615.375	1	144615.375	53.300	.000
STAGE	31465.042	1	31465.042	11.597	.003
2-way Interactions	6902.042	1	6902.042	2.544	.126
COND STAGE	6902.042	1	6902.042	2.544	.126
Explained	182982.458	3	60994.153	22.480	.000
Residual	54264.500	20	2713.225		
Total	237246.958	23	10315.085		

A Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	84528.333	2	42264.167	15.196	.000
COND	46288.167	1	46288.167	16.643	.001
STAGE	38240.167	1	38240.167	13.749	.001
2-way Interactions	308.167	1	308.167	.111	.743
COND STAGE	308.167	1	308.167	.111	.743
Explained	84836.500	3	28278.833	10.168	.000
Residual	55625.333	20	2781.267		
Total	140461.833	23	6107.036		

(table continues)

(Table D-7 continued)

B Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	50252.083	2	25126.042	16.013	.000
COND	32047.042	1	32047.042	20.424	.000
STAGE	18205.042	1	18205.042	11.602	.003
2-way Interactions	.042	1	.042	.000	.996
COND STAGE	.042	1	.042	.000	.996
Explained	50252.125	3	16750.708	10.675	.000
Residual	31381.833	20	1569.092		
Total	81633.958	23	3549.303		

C Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	88972.417	2	44486.208	32.040	.000
COND	83662.042	1	83662.042	60.255	.000
STAGE	5310.375	1	5310.375	3.825	.065
2-way Interactions	3290.042	1	3290.042	2.370	.139
COND STAGE	3290.042	1	3290.042	2.370	.139
Explained	92262.458	3	30754.153	22.150	.000
Residual	27769.167	20	1388.458		
Total	120031.625	23	5218.766		

Total Time on Voice Radio Network (in minutes)

Bn Command Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1794.870	2	897.435	25.237	.000
COND	1271.697	1	1271.697	35.762	.000
STAGE	523.174	1	523.174	14.713	.001
2-way Interactions	6.985	1	6.985	.196	.662
COND STAGE	6.985	1	6.985	.196	.662
Explained	1801.856	3	600.619	16.890	.000
Residual	711.196	20	35.560		
Total	2513.052	23	109.263		

Bn O&I Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	715.664	2	357.832	37.681	.000
COND	572.166	1	572.166	60.250	.000
STAGE	143.499	1	143.499	15.111	.001
2-way Interactions	37.686	1	37.686	3.968	.060
COND STAGE	37.686	1	37.686	3.968	.060
Explained	753.351	3	251.117	26.443	.000
Residual	189.929	20	9.496		
Total	943.280	23	41.012		

(table continues)

(Table D-7 continued)

A Company Command Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	315.346	2	157.673	9.740	.001
COND	182.936	1	182.936	11.301	.003
STAGE	132.410	1	132.410	8.180	.010
2-way Interactions	2.658	1	2.658	.164	.690
COND STAGE	2.658	1	2.658	.164	.690
Explained	318.004	3	106.001	6.548	.003
Residual	323.757	20	16.188		
Total	641.761	23	27.903		

B Company Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	238.395	2	119.198	66.619	.000
COND	169.200	1	169.200	94.565	.000
STAGE	69.195	1	69.195	38.673	.000
2-way Interactions	.065	1	.065	.037	.850
COND STAGE	.065	1	.065	.037	.850
Explained	238.461	3	79.487	44.425	.000
Residual	35.785	20	1.789		
Total	274.246	23	11.924		

C Company Command Net

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	518.960	2	259.480	44.233	.000
COND	503.615	1	503.615	85.851	.000
STAGE	15.345	1	15.345	2.616	.121
2-way Interactions	15.845	1	15.845	2.701	.116
COND STAGE	15.845	1	15.845	2.701	.116
Explained	534.805	3	178.268	30.389	.000
Residual	117.323	20	5.866		
Total	652.128	23	28.353		

Total Number of Named Voice Reports

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	4911.439	3	1637.146	122.689	.000
STAGE	893.389	1	893.389	66.951	.000
COND	2799.340	1	2799.340	209.785	.000
ECHELON	1288.049	1	1288.049	96.528	.000
2-way Interactions	1219.423	3	406.474	30.462	.000
STAGE COND	352.390	1	352.390	26.408	.000
STAGE ECHELON	147.869	1	147.869	11.081	.001
COND ECHELON	727.496	1	727.496	54.519	.000
3-way Interactions	77.213	1	77.213	5.786	.017
STAGE COND ECHELON	77.213	1	77.213	5.786	.017
Explained	6208.074	7	886.868	66.463	.000
Residual	2428.578	182	13.344		
Total	8636.653	189	45.697		

Table D-8

ANOVA Summaries for Measures Supporting Direct and Lead Subordinate Forces Hypothesis (Command and Control BOS)

Percent Score for Meeting Commander's Intent

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1697.075	2	848.538	2.287	.130
COND	833.340	1	833.340	2.246	.151
STAGE	694.602	1	694.602	1.872	.188
2-way Interactions	129.630	1	129.630	.349	.562
COND STAGE	129.630	1	129.630	.349	.562
Explained	1826.705	3	608.902	1.641	.215
Residual	6678.265	18	371.015		
Total	8504.971	21	404.999		

Battalion Command Effectiveness Composite Index

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	918.141	3	306.047	1.448	.250
COND	333.269	1	333.269	1.577	.220
STAGE	634.012	2	317.006	1.500	.240
2-way Interactions	585.416	2	292.708	1.385	.267
COND STAGE	585.416	2	292.708	1.385	.267
Explained	1503.557	5	300.711	1.423	.247
Residual	5916.410	28	211.300		
Total	7419.967	33	224.847		

Table D-9

ANOVA Summaries for Measures Supporting Collect Threat Information Hypothesis (Intelligence BOS)

Accuracy of SPOT Report Locations (observed; in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	42349659.291	2	21174829.646	9.274	.000
COND	39289421.902	1	39289421.902	17.207	.000
STAGE	1842304.943	1	1842304.943	.807	.371
2-way Interactions	1863484.914	1	1863484.914	.816	.369
COND STAGE	1863484.914	1	1863484.914	.816	.369
Explained	44213144.205	3	14737714.735	6.455	.001
Residual	207781297.615	91	2283310.963		
Total	251994441.820	94	2680791.934		

Accuracy of SPOT Report Locations (destroyed; in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	18188210.223	2	9094105.112	5.289	.007
COND	16878497.467	1	16878497.467	9.816	.002
STAGE	508202.485	1	508202.485	.296	.588
2-way Interactions	616084.714	1	616084.714	.358	.551
COND STAGE	616084.714	1	616084.714	.358	.551
Explained	18804294.938	3	6268098.313	3.645	.016
Residual	147876150.291	86	1719490.120		
Total	166680445.229	89	1872813.991		

Correctness of SPOT Report Number and Type (observed; percentage)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3457.068	2	1728.534	3.457	.036
COND	15.961	1	15.961	.032	.859
STAGE	3455.233	1	3455.233	6.910	.010
2-way Interactions	43.332	1	43.332	.087	.769
COND STAGE	43.332	1	43.332	.087	.769
Explained	3500.400	3	1166.800	2.333	.079
Residual	46002.961	92	500.032		
Total	49503.361	95	521.088		

Correctness of SPOT Report Number and Type (destroyed; percentage)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	15022.069	2	7511.035	8.513	.000
COND	11106.217	1	11106.217	12.583	.001
STAGE	2823.857	1	2823.857	3.201	.077
2-way Interactions	116.999	1	116.999	.133	.717
COND STAGE	116.999	1	116.999	.133	.717
Explained	15139.068	3	5046.356	5.720	.001
Residual	78521.145	89	882.260		
Total	93660.213	92	1018.046		

(table continues)

(Table D-9 continued)

Accuracy of SHELL Report Locations (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	2841711.239	3	947237.080	1.702	.173
COND	1520955.637	1	1520955.637	2.734	.102
STAGE	1564396.931	2	782198.465	1.406	.251
2-way Interactions	276397.526	2	138198.763	.248	.781
COND STAGE	276397.526	2	138198.763	.248	.781
Explained	3118108.765	5	623621.753	1.121	.356
Residual	46181157.668	83	556399.490		
Total	49299266.433	88	560218.937		

Accuracy of CONTACT Report Locations (in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	4732345.120	3	1577448.373	1.790	.154
COND	4267207.220	1	4267207.220	4.842	.030
STAGE	386082.551	2	193041.275	.219	.804
2-way Interactions	430099.094	2	215049.547	.244	.784
COND STAGE	430099.094	2	215049.547	.244	.784
Explained	5162444.213	5	1032488.843	1.172	.329
Residual	87242658.793	99	881238.978		
Total	92405103.007	104	888510.606		

Percent CONTACT Reports with Correct Type

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	24821.387	3	8273.796	9.387	.000
COND	24545.425	1	24545.425	27.847	.000
STAGE	301.672	2	150.836	.171	.843
2-way Interactions	928.064	2	464.032	.526	.592
COND STAGE	928.064	2	464.032	.526	.592
Explained	25749.451	5	5149.890	5.843	.000
Residual	86381.719	98	881.446		
Total	112131.170	103	1088.652		

Table D-10

ANOVA Summaries for Measures Supporting the Situational Assessment Hypotheses

Number of OPFOR Tanks Destroyed (Percent Correctly Identified)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3787.223	2	1893.612	2.198	.117
COND	2402.759	1	2402.759	2.790	.098
ECH	1338.526	1	1338.526	1.554	.216
2-way Interactions	3049.906	1	3049.906	3.541	.063
COND ECH	3049.906	1	3049.906	3.541	.063
Explained	6837.129	3	2279.043	2.646	.054
Residual	77520.147	90	861.335		
Total	84357.277	93	907.067		

Number of OPFOR Tanks Destroyed (Confidence Rating)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	8.923	2	4.462	3.797	.026
COND	6.694	1	6.694	5.697	.019
ECH	2.328	1	2.328	1.981	.163
2-way Interactions	.068	1	.068	.058	.810
COND ECH	.068	1	.068	.058	.810
Explained	8.992	3	2.997	2.551	.061
Residual	105.742	90	1.175		
Total	114.734	93	1.234		

Number of OPFOR BMPs Destroyed (Percent Correctly Identified)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1869.333	2	934.666	.972	.382
COND	1813.127	1	1813.127	1.885	.173
ECH	64.556	1	64.556	.067	.796
2-way Interactions	.292	1	.292	.000	.986
COND ECH	.292	1	.292	.000	.986
Explained	1869.625	3	623.208	.648	.586
Residual	86587.269	90	962.081		
Total	88456.893	93	951.149		

Number of OPFOR BMPs Destroyed (Confidence Rating)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3.901	2	1.950	1.397	.253
COND	3.814	1	3.814	2.733	.102
ECH	.101	1	.101	.073	.788
2-way Interactions	1.234	1	1.234	.884	.350
COND ECH	1.234	1	1.234	.884	.350
Explained	5.134	3	1.711	1.226	.305
Residual	125.600	90	1.396		
Total	130.734	93	1.406		

(table continues)

(Table D-10 continued)

Number in Your Unit Destroyed (Percent Correctly Identified)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	4482.165	2	2241.083	1.747	.180
COND	77.636	1	77.636	.061	.806
ECH	4389.057	1	4389.057	3.421	.068
2-way Interactions	540.954	1	540.954	.422	.518
COND ECH	540.954	1	540.954	.422	.518
Explained	5023.120	3	1674.373	1.305	.278
Residual	115475.731	90	1283.064		
Total	120498.851	93	1295.687		

Number in Your Unit Destroyed (Confidence Rating)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	34.073	2	17.037	21.371	.000
COND	3.679	1	3.679	4.615	.034
ECH	30.657	1	30.657	38.457	.000
2-way Interactions	.010	1	.010	.012	.912
COND ECH	.010	1	.010	.012	.912
Explained	34.083	3	11.361	14.251	.000
Residual	71.747	90	.797		
Total	105.830	93	1.138		

Distance From Initial BP to Later BP (deviation, in meters)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	9.435	2	4.717	1.439	.244
COND	7.534	1	7.534	2.299	.134
ECH	1.807	1	1.807	.551	.460
2-way Interactions	5.878	1	5.878	1.793	.185
COND ECH	5.878	1	5.878	1.793	.185
Explained	15.313	3	5.104	1.557	.207
Residual	242.533	74	3.277		
Total	257.846	77	3.349		

Distance from Initial BP to Later BP (Confidence Rating).

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.108	2	.054	.067	.935
COND	.002	1	.002	.003	.956
ECH	.105	1	.105	.131	.718
2-way Interactions	.020	1	.020	.025	.876
COND ECH	.020	1	.020	.025	.876
Explained	.128	3	.043	.053	.984
Residual	59.257	74	.801		
Total	59.385	77	.771		

(table continues)

(Table D-10 continued)

Composite Situational Assessment Index

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	1348.346	2	674.173	4.261	.018
COND	43.699	1	43.699	.276	.601
ECH	1290.628	1	1290.628	8.158	.006
2-way Interactions	85.591	1	85.591	.541	.464
COND ECH	85.591	1	85.591	.541	.464
Explained	1433.937	3	477.979	3.021	.035
Residual	11707.417	74	158.208		
Total	13141.354	77	170.667		

Appendix E

Digital Report Formats

Digital Report Formats

Contact Report

Purpose: To report initial enemy contact.

Prepared/Relayed by: Co Cdr

Format:

```
WHAT[a]   WHERE[a]
[   ]     [          ]
[   ]     [          ]
```

Example:

```
FROM C21  ORIG C21/0905
WHAT      WHERE
Tank      ES782946
PC        ES784945
```

Spot Report

Purpose: To report results of enemy contacts, enemy activities, and friendly activities.

Prepared/Relayed by: Co Cdr

Format:

```
WHAT[a]   OBSERVED   DESTROYED
[   ]     [  ]          [  ]
[   ]     [  ]       [  ]
WHERE
HEADING
ENEMY ACTION
OWN ACTION
AS OF
```

Example:

```
FROM A06 ORIG A11/1021
WHAT    OBSERVED    DESTROYED
PC         5            6
Tank       0            7
WHERE ES784921
HEADING  30
ENEMY ACTION  Gnd Atk
FRIENDLY ACTION  Delay
AS OF 22 1856:42
```

[a]Icons depict locations on the map screen when the report is in the receive queue, open, or posted to the map.

Call For Fire

Purpose: **To initiate indirect fires on a grid location or preplanned target (see also, Adjust Fire).**

Prepared/Relayed by: **Co XO**

Format:	Example:
WHAT[a]	**FROM** B05 **ORIG** B05/0843
LOCATION[a]	**WHAT** PC
CONCENTRATION NUMBER[b]	**LOCATION** ES721934
OBSERVER-TARGET LINE[c]	**CONC NO** AB4008
	OTLINE 47

Adjust Fire

Purpose: To adjust artillery or mortar fires from the last round fired in an adjust fire sequence, to adjust from a known point, or to end a mission in progress.

Prepared/Relayed by: Co XO

Format:	Example:
TARGET[a]	**FROM** A05 **ORIG** A23/0859
DIRECTION	**TARGET** ES992734
L/R SHIFT	**DIRECTION**4800
A/D SHIFT	**L/R SHIFT**0
FFE [ ] **EOM** [ ]	**A/D SHIFT**A 50
	FFE [X] **EOM** [ ]

[a]Icons depict locations on the map screen when the report is in the receive queue, open, or posted to the map.

[b]A concentration number is automatically provided if the selected target location is within 50 m of an existing, preplanned target and the preplanned target is posted on the top overlay.

[c]The observer-target line is automatically provided when the target is designated.

Situation Report

Purpose: To report the unit's location, enemy activity, and commander's/leader's intent.

Prepared/Relayed by: Co XO

Format:	Example:
AS OF	FROM D05 ORIG D05/0906
FLOT[a] [ ]	AS OF 13 0901:21
[ ]	FLOT ES893903
ENEMY ACT [ ]	ES728873
[ ]	ENEMY ACT Attack
CRITICAL SHORTAGES:	Medium
Personnel [ ]	CRIT SHORT [ ]
Ammunition [ ]	CDR INTENT Delay
Fuel [ ]	
Equipment [ ]	
COMMANDER'S INTENT	

NBC Report

Purpose: To report enemy nuclear, biological and chemical operations, activities or attacks.

Prepared/Relayed by: Co XO

Format:	Example:
OBSERVER LOCATION	FROM S11 ORIG S11/2242
ATTACK LOCATION	OBS LOC ES987789
BURST TYPE	ATK LOC ES959800
ATTACK TYPE	BURST TYPE Air
FLASH/BANG TIME[d]	ATTACK TYPE Nuclear
NUMBER SHELLS	FLASH/BANG TIME 3
NUCLEAR CRATER DIAMETER (M)[d]	NO. SHELLS 1
NUCLEAR CLOUD WIDTH (DEG)[d]	NUC CRATER DIA (M)
NUCLEAR CLOUD HEIGHT (DEG)[d]	NUC W (DEG) 5
	NUC HT (DEG)

[a]Icons depict locations on the map screen when the report is in the receive queue, open, or posted to the map.

[d]These fields apply only to nuclear reports.

Shell Report

Purpose: To report enemy indirect fire activities and locations.

Prepared/Relayed by: Co XO

Format:	Example:
NUMBER **WHERE**[a] **AS OF**	**FROM** D05 **ORIG** D11/1128 **NUMBER** 24 **WHERE** ES895882 **AS OF** 09 1122:49

Intelligence Report

Purpose: To report enemy activities, friendly activities, and obstacle locations.

Sent by: Bn S2, relayed by Co XO.

Format:		Example:
ENEMY UNIT **UNIT** **WHAT**[a] **NUMBER** **WHERE**[a] **ACTIVITY** **HEADING** **OBSTACLES:** **WHAT**[a] **WHERE**[a] **WHERE**[a] **AS OF**	**FRIENDLY** **WHAT**[a] **NUMBER** **WHERE**[a] **ACTIVITY** **HEADING**	**FROM** Y02 **ORIG** H33/1015 **ENEMY** 20 PC ES787901 Gnd Atk Hdg 350 **FRIENDLY** 9 Tank ES790926 Delay Hdg 15 **OBSTACLES** Blown Bridge ES787918 **AS OF** 06 1000:37

[a]Icons depict locations on the map screen when the report is in receive the queue, open, or posted to the map.

Appendix F

Biographical Data Tables

Table F-1

Participants' Service Experience (in Years)

	Officers		NCO/Enlisted[a]	
	CVCC	Baseline	CVCC	Baseline
Active Duty	6.16 (4.41) n=47	6.63 (4.13) n=48	4.73 (3.84) n=92	7.06 (5.00) n=96
In Armor units	3.93 (2.58) n=47	4.49 (2.61) n=48	4.36 (3.24) n=92	6.06 (4.37) n=95
In M1 units	1.80 (1.15) n=37	2.03 (1.27) n=38	2.98 (1.86) n=91	3.79 (3.07) n=89
In M60 units	1.98 (2.66) n=26	2.45 (1.99) n=26	2.82 (3.23) n=35	4.56 (3.90) n=48

Note. Each data cell includes the mean, standard deviation (in parentheses) and number of respondents (*n*).

[a]Experience levels among Baseline NCOs/enlisted personnel were significantly higher than among CVCC NCOs.

Table F-2

Cumulative Participant Experience (Man-years), by Duty Position

Duty Position	CVCC	Baseline
Officers		
Battalion commander	-- n=0	-- n=0
Battalion XO	1.16 n=2	-- n=0
Battalion S3	9.8 n=10	4.52 n=4
Battalion S2	-- n=0	0.50 n=1
Other battalion staff	18.45 n=15	19.95 n=21
Company commander	20.02 n=14	20.96 n=16
Company XO	27.60 n=24	36.16 n=32
Platoon leader	64.24 n=44	51.25 n=41
NCO/Enlisted		
Platoon sergeant	7.02 n=6	30.42 n=18
Tank commander	53.97 n=21	173.8 n=44
Gunner	119.28 n=56	182.0 n=65
Driver	152.25 n=87	141.96 n=78

Note. Table includes multiple responses from individual respondents. For example, an officer with experience as a platoon leader, XO and company commander would have reported his tenure in each duty position.

Each data cell includes cumulative man-years and number of respondents experienced in that duty position (n).

Table F-3

Participants' Military Schooling Level (Courses Completed)

Military School	CVCC *f*	CVCC %	Baseline *f*	Baseline %
<u>Officers</u>				
Command & General Staff Officer Course (CGSOC)	3	6.4	3	6.3
Combined Arms and Services Staff School (CAS3)	6	12.8	14	29.2
Armor Officer Advance Course (AOAC)	22	46.8	27	56.3
Armor Officer Basic Course (AOBC)	46	97.9	48	100
<u>NCO/Enlisted</u>				
Advanced NCO Course (ANCOC)	3	3.3	17[a]	17.7
Basic NCO Course (BNCOC)	19	20.7	46[a]	47.9
Primary Leadership Development Course (PLDC)	38	41.3	59[a]	61.5

<u>Note</u>. Table includes multiple responses from individual respondents. For example, a CAS3 graduate would most likely have also graduated from AOAC and AOBC.

f = frequency, % = percentage.

[a]NCOs among the Baseline group completed a significantly greater number of advanced military courses than NCOs among the CVCC group.

Table F-4

Rank Distribution of Participants

Rank	CVCC *f*	CVCC %	Baseline *f*	Baseline %
Officers				
Major	7	14.9	6	12.5
Captain	18	38.3	21	43.8
First Lieutenant	15	31.9	15	31.2
Second Lieutenant	7	14.9	6	12.5
NCO/Enlisted				
Sergeant First Class	0	0	3	3.1
Staff Sergeant	6	6.5	25[a]	26.0
Sergeant	22	23.9	20	20.8
Corporal/Specialist	39	42.4	37	38.5
Private First Class/ Private	25	27.2	11	11.5

Note. *f* = frequency, % = percentage.

[a]The Baseline group included a significantly higher number of Staff Sergeants than did the CVCC group.

Appendix G

List of Acronyms and Abbreviations

LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	DEFINITION
AFATDS	Advanced Field Artillery Tactical Data System
ANOVA	Analysis of Variance
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ASCII	American Standard for Information Interchange
ATCCS	Army Tactical Command and Control System
ATHS	Airborne Target Handover System
BBN	Bolt Beranek and Newman Inc.
Bde	Brigade
BDM	BDM Federal, Inc.
BLUFOR	Blue (friendly) Forces
BMP	Soviet Armored Personnel Carrier
Bn	Battalion
BOS	Battlefield Operating System
BP	Battle Position
C2	Command and Control
C3	Command, Control, and Communications
CB	Citizens' Band
CCD	Command and Control Display
CCTT	Close Combat Tactical Trainer
Cdr	Commander
CECOM	U.S. Army Communications-Electronics Command
CFF	Call for Fire
CIG	Computer Image Generation
CITV	Commander's Independent Thermal Viewer
Cmd	Command
Co	Company
CO	Commanding Officer
CoM	Center of Mass
CSS	Combat Service Support
CVCC	Combat Vehicle Command and Control
DARPA	Defense Advanced Research Projects Agency
DBMS	Database Management System
DCA	Data Collection & Analysis System
DCD	Directorate of Combat Developments
DCE	Data Collection Exercise
Dvr	Driver
ECR	Exercise Control Room
FBC	Future Battlefield Conditions
FLOT	Forward Line of Own Troops
FRAGO	Fragmentary Order
FSO	Fire Support Officer
GAS	Gunner's Auxiliary Sight
GLOS	Gun Line of Sight
Gnr	Gunner
GPS	Gunner's Primary Sight

ACRONYM	DEFINITION
GPSE	Gunner's Primary Sight Extension
HEAT	High Explosive Anti-Tank
IDC	Interactive Device Controller
IFF	Identification Friend or Foe
INTEL	Intelligence Report
IVIS	Intervehicular Information System
LD	Line of Departure
LRF	Laser Range Finder
MCC	Management, Command and Control System
MCS	Maneuver Control System
MOS	Military Occupational Specialty
MOU	Memorandum of Understanding
MRS	Muzzle Reference System
MSE	Mobile Subscriber Equipment
MWTB	Mounted Warfare Test Bed
NBC	Nuclear, Biological, Chemical
NCO	Non-Commissioned Officer
NTC	National Training Center
O&I	Operations and Intelligence
OPFOR	Opposing Forces
OPORD	Operations Order
PL	Phase Line
Plt	Platoon
POSNAV	Position Navigation
Prep	Preparation
PVD	Plan View Display
QC	Quality Control
RA	Research Assistant
REDCON	Readiness Condition
RIU	Radio Interface Unit
S2	Intelligence Officer
S3	Operations Staff Officer
SA	Situational Assessment
SAFOR	Semiautomated Forces
SCC	SIMNET Control Console
SICPS	Standard Integrated Command Post System
SIMNET	Simulation Networking
SIMNET-D	Simulation Networking--Developmental
SIMNET-T	Simulation Networking--Training
SINCGARS	Single Channel Ground and Airborne Radio System
SitDisplay	Situation and Planning Display
SITREP	Situation Report
SME	Subject Matter Expert
SMI	Soldier-Machine Interface
SOP	Standing Operating Procedure
SPSS	Statistical Package for the Social Sciences
STX	Situational Training Exercise
TACFIRE	Tactical Fire Direction
TACOM	U.S. Army Tank-Automotive Command
TIS	Thermal Imaging System
TNG	Training

ACRONYM	DEFINITION
TOC	Tactical Operations Center
TRADOC	U.S. Army Training and Doctrine Command
TRP	Target Reference Point
TTPs	Tactics, Techniques, and Procedures
U-COFT	Unit-Conduct of Fire Trainer
USAARMC	U.S. Army Armor Center
VCR	Video Cassette Recorder
XO	Executive Officer