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... Operational Effectiveness Of An Armor Battalion

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Leibrecht, Bruce C.; Meade, Glen. A.; Schmidt, J. H.; and Doherty, W. J.

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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 four days of training and testing culminating in a simulated combat test scenario. One of a series, this report documents improvements in the performance of unit and vehicle commanders, 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, training requirements, and operational effectiveness parameters for future automated C3 systems supporting mounted warfare.

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

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

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Field Unit at Fort Knox, Kentucky
Barbara A. Black, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
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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 to conduct a battalion-level evaluation of the CVCC capabilities.

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; Director, Directorate of Combat Developments, U.S. Army Armor School; and Director, Mounted Warfighting Battlespace Lab.

EDGAR M. JOHNSON
Technical Director

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The following members of ARI's Fort Knox Field Unit provided invaluable input to this evaluation: Dr. Barbara Black, Field Unit Chief; Dr. Kathleen Quinkert, Leader of the Future Battlefield Conditions (FBC) Team; Dr. Carl Lickteig and Mr. Gary Elliott, FBC Team members; and MAJ James Whitehead, the Field Unit's Research and Development Coordinator.

In addition to the authors, the BDM Federal, Inc. research staff included Dr. Nancy Atwood, Dr. Beverly Winsch, Dr. Laura Ford, Ms. Alicia Sawyer, Ms. Frances Ainslie, Mr. Paul Smith, 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.

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

EXECUTIVE SUMMARY

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 dissemination of orders and more complete dissemination of INTELLIGENCE reports, while reducing substantially the volume of voice radio traffic. The overall volume of usable information contained in CONTACT,

CFF (Call for Fire), SHELL, AND SPOT 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 POSNAV capabilities, CVCC-equipped battalions reached 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. The advantage afforded by earlier target acquisition appeared to enable CVCC crews to select ammunition more effectively. The use of CVCC equipment did not distract crews from participating in the battle.

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

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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 (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 (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 which are to be 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; 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., in preparation). 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, more effective C3, meeting critical challenges of a rapid-pace, high-mobility, wide-dispersion battlefield.

The Future Battlefield Conditions 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., 1992). 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.

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, & Smith, in preparation) analyzes combat performance in the context of armor doctrine and tactics, including unit standing operating procedures. A third report (Atwood, Winsch, Sawyer, & Meade, 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 (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 (Department of the Army, 1991b), in which one of seven Battlefield Operating Systems deals entirely with command and control. Indeed, Burkett (1990) argues that C3 is the crucial key to winning on the battlefield. 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., Department of the Army, 1993). All have a common thread in terms of purpose and outcome of the C3 system: "... to assist the commander in making reasoned decisions and executing them in a manner to accomplish his mission" (Knudson, 1990, p. 19). 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 (Department of the Army, 1985).

More recent observations of combat operations during Desert Storm support the 1985 NTC conclusions. In the Defense Department's final report to Congress on the Persian Gulf War (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 represents a pioneering effort in automated C3. 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 (see Table 1). 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.

International efforts addressing automation of C3 functions are paralleling those in the U.S. Army. The German efforts under the bilateral CVCC program led to a joint demonstration in late 1992 (Hewish, 1993). The British Army is developing a Battlefield Artillery Target Engagement System using digital technology (Tusa, 1993). Similarly, the French Army is working on an artillery-oriented system to accommodate expected improvements in targeting capabilities (Tusa, 1993). Both the British and French efforts are aimed in large part at processing and disseminating the expanded quantities of targeting data generated by unmanned aerial vehicles.

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" (Department of the Army, 1992a, 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 (Department of the Army, 1992b). 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.

Digitization of the Battlefield

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, not long ago the standard among combat units.

Digital technology has given rise to the term "electronic battlefield" (e.g., Payne, 1992; Robinson, 1991). This technology provides powerful capabilities to acquire, process, integrate, correlate, display, disseminate, and manage large quantities of battlefield information. The speed and reliability with which these functions can be accomplished offer great potential in a rapid-paced, highly fluid combat environment. Other advantages include greater accuracy of input information, automatic posting to digital map displays, and automatic reporting of selected data (e.g., ammunition and fuel status). On balance, digital technology can enable the commander to "see the battlefield" more comprehensively and accurately, with updates occurring more quickly. The importance of capitalizing on digital capabilities is reflected in current-generation Army Field Manuals (e.g., Department of the Army, 1993) and in the lessons learned from Desert Storm (Robinson, 1991).

With the advent of powerful, miniaturized, ruggedized computers, the Army has made great strides to incorporate digital technology in combat systems. 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). The MCS supports exchange of information among armor, infantry, aviation, engineer, signal, chemical, and military police units. This system was used by some divisions during Desert Storm operations (Robinson, 1991). TACFIRE is a well-known system enabling fire support personnel to coordinate indirect fires by digitally exchanging reports, messages, and some graphics (Department of the Army, 1991a). This system links tactical fire support elements across the battlefield: forward observers, maneuver fire support teams, fire support officers, and indirect fire units communicate and coordinate using a network of digital C3 nodes.

Providing a digital network among Army aviation elements is the Airborne Target Handover System (ATHS). This system integrates aviation and indirect fire systems by means of call-for-fire protocols compatible with TACFIRE, thus facilitating indirect fire targeting from airborne forward observers (Department of the Army, 1990). With the exception of the TACFIRE linkage, the ATHS relies on voice radio communications to interface with other battlefield systems, such as the MCS and IVIS.

The planned replacement for TACFIRE is the Advanced Field Artillery Tactical Data System (AFATDS). Part of the ATCCS family, this system is designed to integrate fire support command and control throughout the combined arms and joint battlefield (Association of the U.S. Army, 1992). Digital communications will link mortar, field artillery, and aviation units with close air support and naval gunfire elements, as well as with offensive electronic warfare systems. Not only will AFATDS support multi-service operations, it is to be interoperable with German and British automated fire support systems.

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 Position Navigation (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 of its own tank and 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, including advanced capabilities, have been integrated in the experimental CVCC system (Leibrecht et al., in preparation).

Another navigation aid is the Global Positioning System (GPS), capitalizing on orbiting satellite technology. Designed for a broad range of applications, the GPS can display the user's location with a horizontal error of only 5-10 m (Robinson, 1991). A family of vehicle-mounted and man-portable receivers is being fielded, including hand-held units. GPS units were in great demand in Desert Storm, where they were a critical factor in combat success on the relatively featureless desert terrain (Robinson, 1991). In addition to both mounted and dismounted ground operations, the system was used successfully in combat aircraft, both rotary- and fixed-wing.

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, with a C3 support role among combat support and combat service support units at the division and corps levels. 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 exhange of information) among diverse collaborating units. Acknowledging this, the Army Command and Control Master Plan calls for separate automated C3 systems (for example, the MCS and AFATDS) 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. As Robinson (1991) notes, electronic battlefield capabilities such as the MCS and GPS provide the technological basis for enhancing the synergism of air and ground forces.

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 on 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

Overlapping all three thrusts just discussed--automated C3, digitization of the battlefield, and horizontal integration--is 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; Quinkert, 1990). The program has aggressively pursued innovative applications of advanced technology to meet the harsh C3 challenges of the future battlefield. Indeed, the CVCC technology provided the foundation for the distributed simulation demonstration of 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 (Table 1) include digital reporting capabilities, digital tactical map and overlay functions, automated positioning and navigation features, independent thermal viewing for the vehicle commander, and automated planning and control for the battalion staff. At the heart of the system, the CCD integrates digital reporting and map 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 information in graphic or pictorial form makes it easier for users at all levels to assimilate. Exchange of information 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.

Table 1

Major C3 Features of the CVCC System

Digital reporting
- Precise location input
- Graphic display of key information
- Automatic logistics reporting
Digital tactical map with graphic overlays
Automated navigation
- Graphic routes
- Driver's steering display
- Graphic display of friendly vehicle locations
Independent thermal viewing for vehicle commander
Automated battalion staff planning and control
Secure digital burst transmission

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[1] is a pioneering battlefield simulation environment supporting Army research and development efforts. For example, combat, training, and materiel developers can put their ideas on trial in the MWTB environment before locking in concepts or system designs. More specifically, the MWTB is designed to provide low-cost, unit-level, full mission simulation using extended local and long-haul networking and families of simulators supported by site-specific microprocessors (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 conduct combat simulations to assess the battlefield contributions of experimental configurations and training approaches before final design, production, and field implementation.

The MWTB represents distributed networking architecture that can be modified to accommodate a broad range of soldier performance research and development (R&D). The evolution of the MWTB began with 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 (Alluisi, 1991). SIMNET-T (Training) was developed to support operational training of troop units. SIMNET-D (Developmental) was established to apply SIMNET technology to developing and testing warfighting concepts, battlefield doctrine, combat materiel, training approaches, and organizational concepts. The MWTB, originally the SIMNET-D facility (and, until recently, called the Close Combat Test Bed--CCTB), now supports a variety of initiatives sponsored by DARPA (now known as the Advanced Research Projects Agency), ARI, the Mounted Warfighting Battlespace Lab and the Combat Developments community at Fort Knox, and others.

The SIMNET architecture was designed specifically to accommodate the introduction of newer and more powerful equipment as it became available. A huge increase in both simulators and simulation technology occurred in the late 1980's; however, much was developed for specific purposes and was often unique and/or proprietary. In 1989, DARPA and the U.S. Army Simulation, Training, and Instrumentation Command (then Project Manager, Training Devices) initiated a project to establish industry standards for the SIMNET protocols, called Distributed Interactive Simulation (DIS). The DIS architecture provides the structure through which "... independently developed systems may interact with each other in a well managed and validated combat simulation environment..." (Loral Systems Company, 1992). The MWTB is today closely involved with the development of and compliance with those DIS standards.

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[1]An asset of the U.S. Army Armor Center, the MWTB was formerly known as the Close Combat Test Bed, and prior to that, SIMNET-D.

The MWTB's automated C3 capabilities (including the CVCC technologies) are characterized by selective fidelity of components, collective training, and an iterative approach to system design. Selective fidelity enables system performance to be sufficiently emulated to elicit the required levels of perceptual realism among users (Chung, Dickens, O'Toole, & Chiang, 1988). This "psychological fidelity" enables the battlefield-oriented perceptual cues within the test bed to be exploited without having to employ more expensive operational technology.

MWTB Capabilities

The MWTB's research capabilities are thoroughly described by Atwood et al. (in preparation). 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 et al., 1988). 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 2 summarizes these capabilities, and Figure 1 shows a schematic of the basic system architecture.

MWTB Advantages

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 (O'Brien et al., 1992), including its:

1. Flexibility in allowing crews to perform a broad range of missions.

2. Versatility in providing realistic engagement interaction in a variety of simulated battlefield settings.

3. Capability to present tank crews and units with operationally realistic task and mission loading levels.

4. Fidelity of tactical communications.

5. Adaptability in ensuring standardization of experimental procedures.

6. Value in identifying training requirements.

7. Relatively low cost in evaluating experimental configurations of C3 and related systems.

8. Automated capability to capture and analyze objective performance data.

Table 2

The MWTB'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 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 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.

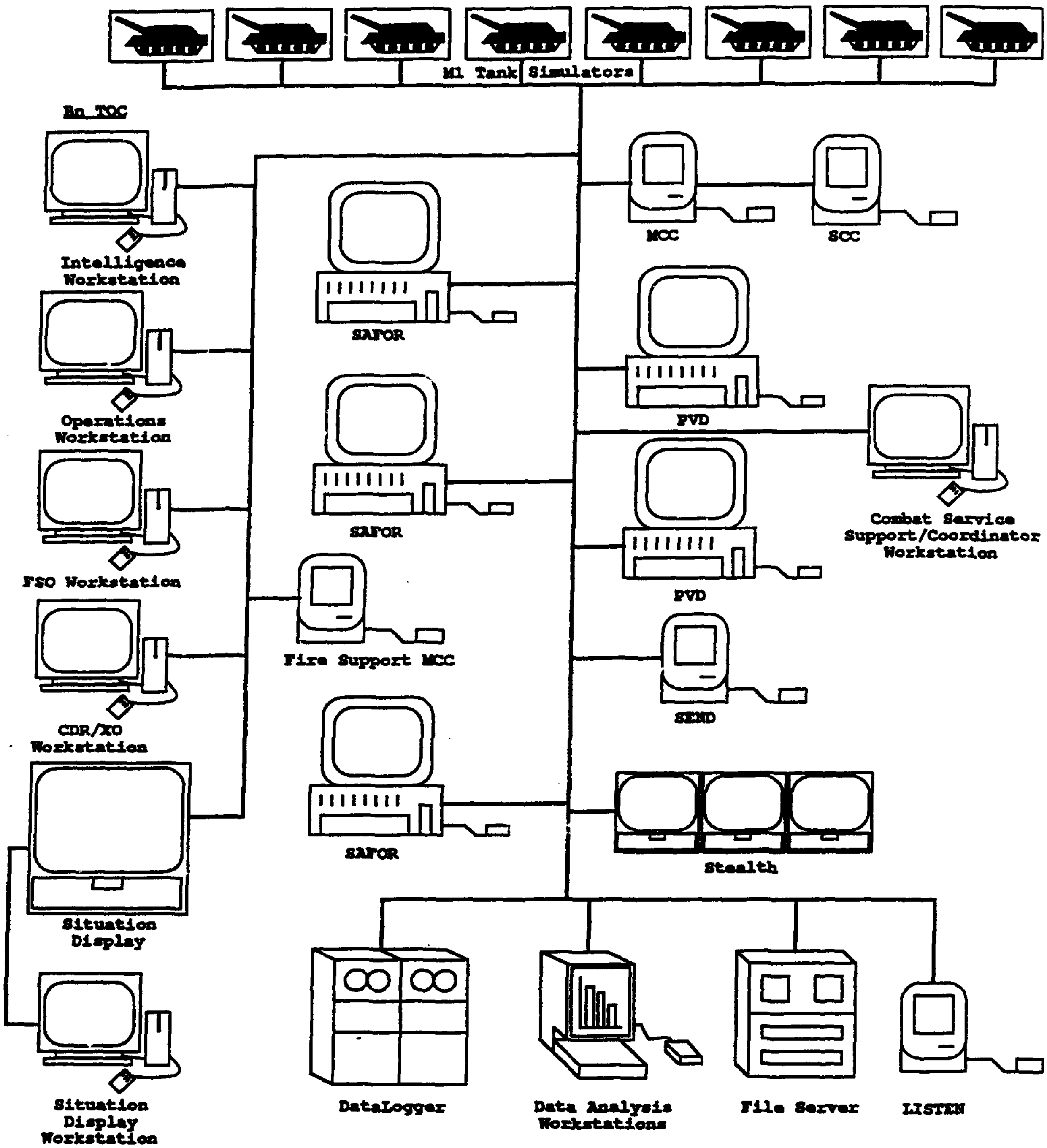

Figure 1. Schematic of the basic distributed simulation networking environment in the Mounted Warfare Test Bed. Tank simulators and battalion TOC workstations represent the battlefield environment. MCC (Management, Command, and Control), SAFOR (semiautomated forces), and PVD (Plan View Display) elements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

9. Unique analysis capabilities afforded by playback.

MWTB Constraints

As with any large-scale simulation, the MWTB has several constraints in its representation of operational combat settings. These limitations, many of which have been addressed by Du Bois and Smith (1989), include the following:

1. Limited visual fidelity of the computer-generated imagery, which limits depth perception, battlefield orientation, long-range target identification, and certain tactical maneuvers.

2. Maximum simulated viewing distance of 3500 meters, resulting in a potentially misrepresented horizon.

3. Loss of vision block imagery, especially for the driver, when the computer image generator is overloaded.

4. Inability to conduct open hatch operations, which, together with a limited number of cupola vision blocks, constrains the vehicle commander's view of the battlefield and complicates navigation.

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

6. Potential for vehicle commanders to follow semiautomated vehicles instead of navigating on their own.

7. Absence of machine guns and smoke grenades.

8. Problematic performance of the sighting and fire control systems, such as difficulty in maintaining proper bore sight and unrealistic implementation of target lead functionality.

9. Simplistic implementation of fire support (mortars and howitzers), combat support (e.g., combat engineering), and combat service support (e.g., resupply).

10. Unrealistic behavior of semiautomated vehicles, including perfect identification of targets, unrealistic fire control and distribution, and failure to use cover and concealment when moving.

11. Lack of vehicle identification plates, resulting in problematic identification of friendly vehicles.

12. Lack of the gunner's auxiliary sight (GAS), constraining the use of terrain for protective positioning.

It is important to note that these constraints applied at the time the CVCC battalion evaluation was being planned and implemented. Ongoing technical efforts continue to improve the simulation technology, especially in the areas of semiautomated forces and combat support capabilities.

Several special features help offset the MWTB constraints. For example, a grid azimuth indicator and a turret-to-hull reference display (provided in each simulator) help compensate for the closed hatch constraint, providing cues that are critical for positioning, maneuvering, and navigation. To counter the limited visual fidelity, crews can be provided with special topographic paper maps which represent buildings, rivers, roads, etc. as they appear on the simulated battlefield. Also, special tactical guidelines have been developed to mitigate the limited viewing distance, along with navigation training.

ARI-Fort Knox CVCC Research Program

The ARI-Fort Knox Future Battlefield Conditions Team has pioneered and sustained the use of the MWTB's capabilities to evaluate emerging armor concepts. Early work with promising components led to progressive evaluations of the fully integrated CVCC system. An iterative design-evaluate approach has ensured the systematic evolution of the CVCC system, based on input from armor subject matter experts 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 an automated POSNAV system configured in either grid or terrain map format. The performance of armor crews using these formats was compared with that of crews using conventional navigational techniques. By using POSNAV, crews were able to navigate more accurately and efficiently than crews using conventional means in virtually all battlefield situations. For example, both POSNAV groups performed road marches significantly better than the control group.

Relative to the control group, POSNAV crews were better able to determine own-tank location, maintain own-tank orientation, determine locations of other battlefield elements, perform map terrain association, navigate point to point, bypass obstacles, and react to enemy fire. Differences between POSNAV and control conditions in their questionnaire responses were statistically significant for 32 of the 36 measures analyzed. The research clearly suggests that POSNAV systems can be expected to significantly improve the performance of tank crews and platoons on the battlefield.

In a similar effort, Du Bois and Smith (1991) evaluated the IVIS, an automated C3 display, using the MWTB. IVIS is a distributed information management system designed to provide improved capabilities to assess both friendly and threat battlefield situations. Findings of the IVIS study indicated that tank crews and platoons equipped with IVIS performed significantly better than conventionally-equipped control crews and platoons in virtually every capacity. Specifically, IVIS significantly improved unit performance in mission execution time and success, report times and accuracy, fragmentary order (FRAGO) execution, battle position occupation, and obstacle bypass efficiency. IVIS crews not only performed better overall than control crews, but perhaps more importantly, they also performed more consistently as indicated by smaller standard deviations for all measures. Significant differences in favor of IVIS-equipped crews were also found for a number of process measures, including fuel use and mean velocity. The benefits of IVIS were attributed almost solely to the system's POSNAV capabilities, as opposed to the automated report functions. This may have resulted, at least in part, because the platoon level used in the evaluation was not high enough 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.

Results of the CITV assessment (Quinkert, 1990) indicated that the CITV's principal advantage is for those targets that are acquired and engaged after the initial target. This advantage was represented by an increase in the number of detections and subsequent kills accomplished at a significantly faster pace. Accuracy, as defined by gunners' aiming error, was not improved by using the CITV. Gunners did not feel it necessary to take more time to engage the targets, even though the shorter vehicle commander search times nominally gave them more time. This reflected their high level of confidence in their gunnery skills.

Recommended improvements to the CITV included a directional orientation capability for the own-vehicle icon, shorter fire control commands, and ergonomic enhancements in the palm and designate switches on the control handle. It was also suggested that emphasis should be placed on training to improve the coordination between the vehicle commander and gunner for tasks involving the CITV.

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 of the CVCC experimental configuration enabled companies to complete both defensive and offensive missions in significantly less time. As a result, every CVCC company was able to complete all missions, whereas only 25% of the Baseline companies were able to complete offensive missions and 50% were able to complete defensive missions. The POSNAV capabilities led to CVCC companies traveling significantly less distance and consuming significantly less fuel in executing both defensive and offensive missions.

The CCD's automated reporting functions significantly improved both accuracy and timeliness of FRAGOs and CONTACT reports. Especially useful was the ability to input locations to digital reports by lasing to a target or by touching the digital map display. Digital transmission improved the clarity of FRAGOs and INTELLIGENCE reports. At the same time, the net-wide routing of digitally transmitted reports and the absence of confirmation of reception by the addressee resulted in numerous duplicate reports. Directly related to this, soldier-participants frequently complained about receiving excessive numbers of reports. This pointed to the need to reduce redundant reports (e.g., filtering based on report identifiers) and to provide verification of report reception. CVCC vehicle commanders frequently transmitted voice radio messages (e.g., brief orders or queries) that did not fit the established report formats, indicating a need to provide free text capabilities on the CCD.

The CVCC capabilities enhanced target engagement performance, extending maximum lasing range as well as ranges for hitting and killing targets. These improvements were significant only during defensive missions. Further, more timely unit displacement during the delay mission was observed. The CCD-related C3 demands on CVCC leaders did not decrease their vehicles' participation in firing activities.

The battalion TOC evaluation (O'Brien et al., 1992) 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. Participants indicated they received too many reports and that creating and reading reports consumed too much time, particularly during engagements. Questionnaire responses indicated the CVCC significantly reduced some of the workload on unit commanders, especially for determining battlefield locations, monitoring and directing navigation, and monitoring the unit's position. 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. Preliminary data from a subset of the database have been reported by Leibrecht et al. (in preparation). This report and its companion reports (Meade et al., in preparation; Atwood 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., 1992) and contemporary developments in armor doctrine (e.g., Faulconbridge, 1992) 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 (Department of the Army, 1991b) 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 SMI factors critically affect utilization of the CVCC configuration, and how do they impact CVCC design?

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

Hypotheses for each of the BOS-based 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, and their rationales are discussed by Meade et al. (in preparation).

Approach

Both Baseline and CVCC conditions (conventional C3 means versus automated C3 tools) were simulated to enable realistic quantification of CVCC contributions to unit leader performance. 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 optimize scenario consistency, manned simulators were not permitted to be killed. Multiple stages within the scenario enabled repeated observations of performance.

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 semiautomated forces (SAFOR) under the control of the battalion commander or company commanders. Progressive training incorporated classroom, supervised hands-on, and crew and unit practice exercises.

Test support personnel role-played other battalion personnel, generally corresponding to key TOC staff and SAFOR vehicle commanders. The TOC staff, which included military subject matter experts (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.

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 (for which data were analyzed separately, but for which no statistical comparisons were planned), 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, due to the dissimilar performance requirements resulting primarily from widely varying enemy force structures between the delay and counterattack stages, direct comparison of the stages was not a focus of interest.

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 participants, facilities, materials, and procedures supporting the evaluation. In addition, descriptions of the performance measures, support staff, and methodological limitations are presented.

Test Battalions

Participants

A total of 282 U.S. Army personnel and one U.S. Marine participated in the twelve test weeks (six Baseline and six CVCC groups). 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 (AOCs) 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 roles of battalion S3 (one), company commander (three), or company XO (three). 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, B, and C companies. The battalion's remaining combat vehicles (i.e., the tank platoons, all of D Company, and the scout platoon) were represented by SAFOR elements controlled by unit commanders and operated by role-playing test personnel. Blue Forces (BLUFOR) were comprised of all non-manned SAFOR vehicles. BLUFOR and manned vehicles collectively can be referred to as Friendly forces. The OPFOR (Opposing Forces) consisted of SAFOR only. Figure 2 illustrates the battalion (BLUFOR) configuration (minus the scout platoon and the battalion TOC), differentiating between the manned simulators and SAFOR.

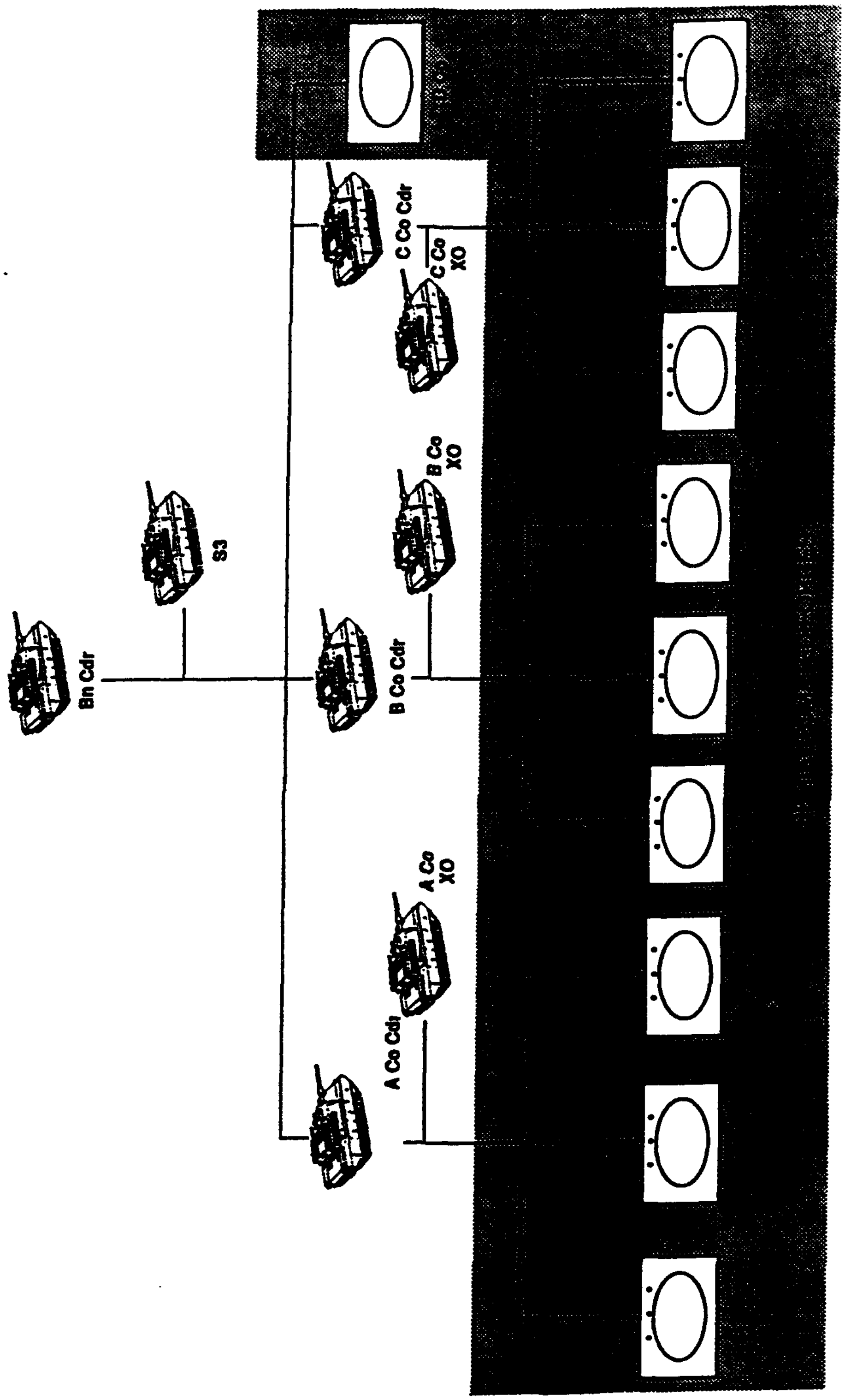

Figure 2. Illustration of the battalion configuration (minus the Tactical Operations Center and scout platoon).

Battalion TOC Staff

Four test personnel (contract employees) staffed the battalion TOC, emulating the functions of a battalion main command post. These personnel, 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 Atwood et al. (in preparation).

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 (Figure 3) included a classroom, eight vehicle simulators, the TOC, the Exercise Control Room (ECR), 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. (1992). Details on these components are presented in the following paragraphs.

Baseline M1 simulators

Eight M1 tank simulators were used in the evaluation. As depicted in Figure 4, the M1 simulator consists of two major sections: a driver's compartment and a turret crew compartment. The turret crew compartment has stations for the vehicle commander, gunner, and loader. More detailed descriptions of the basic simulator components and operation may be found in the <u>M1 SIMNET Operator's Guide</u> (Department of the Army, 1987) while CVCC simulator documentation may be found in the <u>SIMNET Users' Guide</u> (Department of the Army, 1989), and in the <u>SIMNET Combat Vehicle Command and Control (CVC2) System User's Guide</u> (Smith, 1990).

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 (what views to display), to the sound system (what sounds to transmit), and to the IDC boards (current status of crew controls). Messages about the current vehicle status are transmitted over the simulation Ethernet to other simulators and exercise control systems.

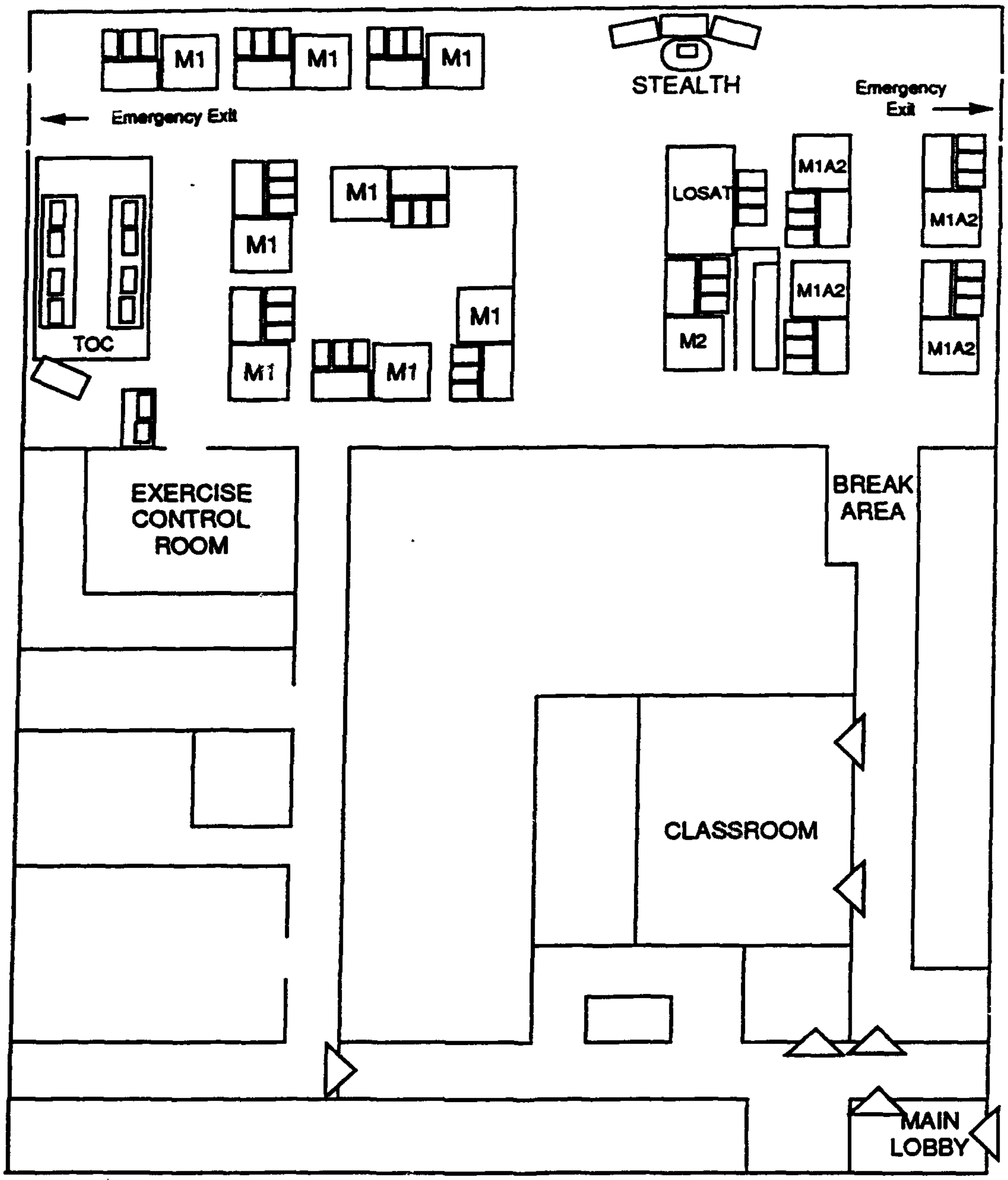

Figure 3. Floor plan of the Mounted Warfare Test Bed.

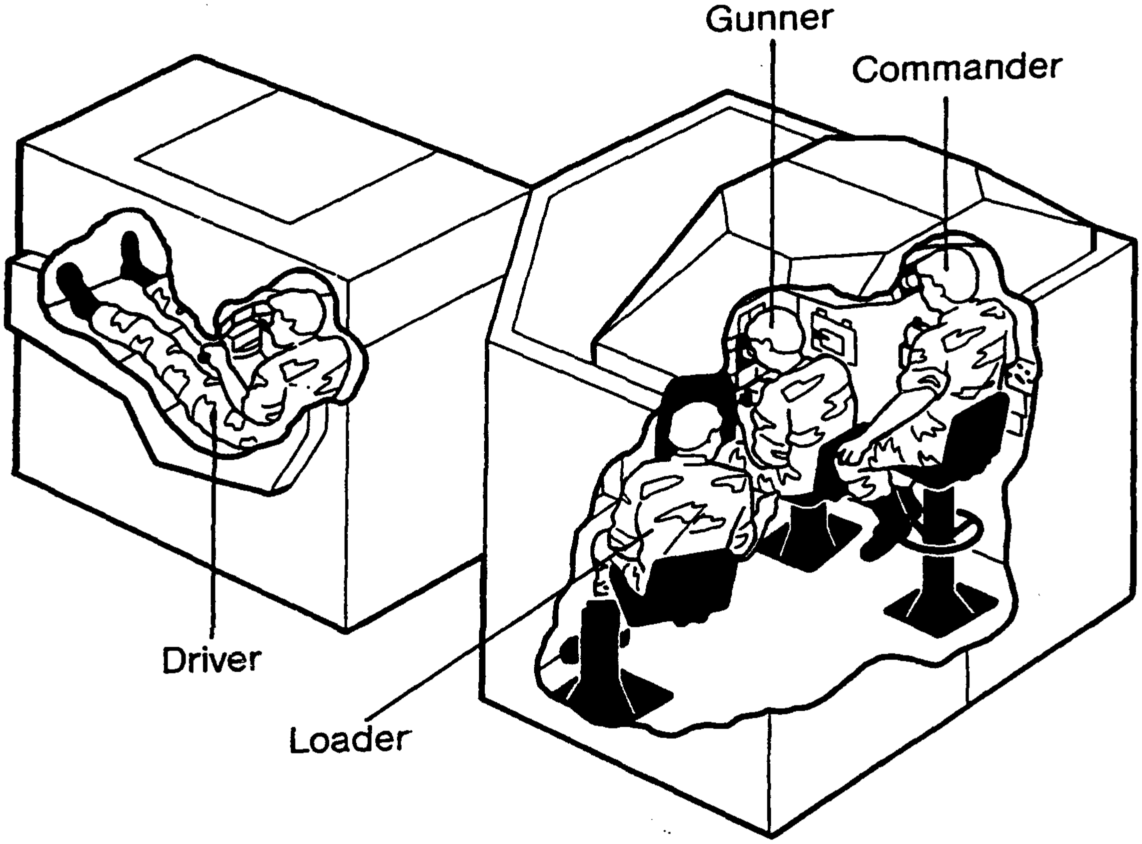

Figure 4. Basic M1 simulator used in the evaluation, showing the turret crew compartment and driver's compartment. Because the autoloading simulator required no crewmember/loader, the loader's position was occupied by a research staff member (trainer/observer).

The MWTB simulators were developed using a selective fidelity approach. That is, the simulators do not include all functions and controls found in an actual M1 tank--only those necessary to fight. 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 ammo 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 contain several modifications not found in other MWTB M1 simulator configurations. The gunner's sight is equipped with a Thermal Imaging System (TIS) which can be toggled for the normal daylight view. The simulator also includes a simulated autoloader. The full cycle time to reload a round after firing is approximately eight seconds. During the first three and one-half seconds, the system waits for the gunner to select the desired ammunition type. In the remaining four and one-half seconds, the system opens the breech and the ammo doors, loads a round of the selected type, and closes the breech and ammo doors. The autoloader is also capable of unloading a round when the gunner changes the ammo select switch before firing.

Each simulator is also equipped with two simulated SINCGARS radios. These radios replace the CB radios found in other MWTB simulators. The radios convert voice transmissions into digital signals, which are broadcast over the simulation Ethernet. This capability also allows voice transmissions to be captured with simulation data broadcast over the Ethernet.

CVCC M1 simulators

In addition to the basic M1 simulator hardware and software described in the previous paragraphs, the simulators used in the CVCC condition include several other major capabilities. Table 3 summarizes the key differences between the M1 simulators used in the Baseline and CVCC conditions. The major components distinguishing the CVCC M1 from the Baseline M1 are the CCD, POSNAV, and CITV. These components make up the CVCC integrated crewstation area, illustrated in Figure 5.

Table 3

Comparison of Baseline and CVCC M1 Simulator Capabilities

	Baseline	CVCC
<u>Navigation</u>		
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
<u>Target acquisition and engagement</u>		
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
CITV (with LRF, 3 scan modes, magnification, polarity)		X
CITV target designate		X
<u>Communications</u>		
Radio intercom (communication with crew)	X	X
SINCGARS radios (voice communication)	X	X
SINCGARS radio interface unit (data communication)		X
Digital combat report communication		X
Digital tactical overlay communication		X
Digital navigation route communication		X

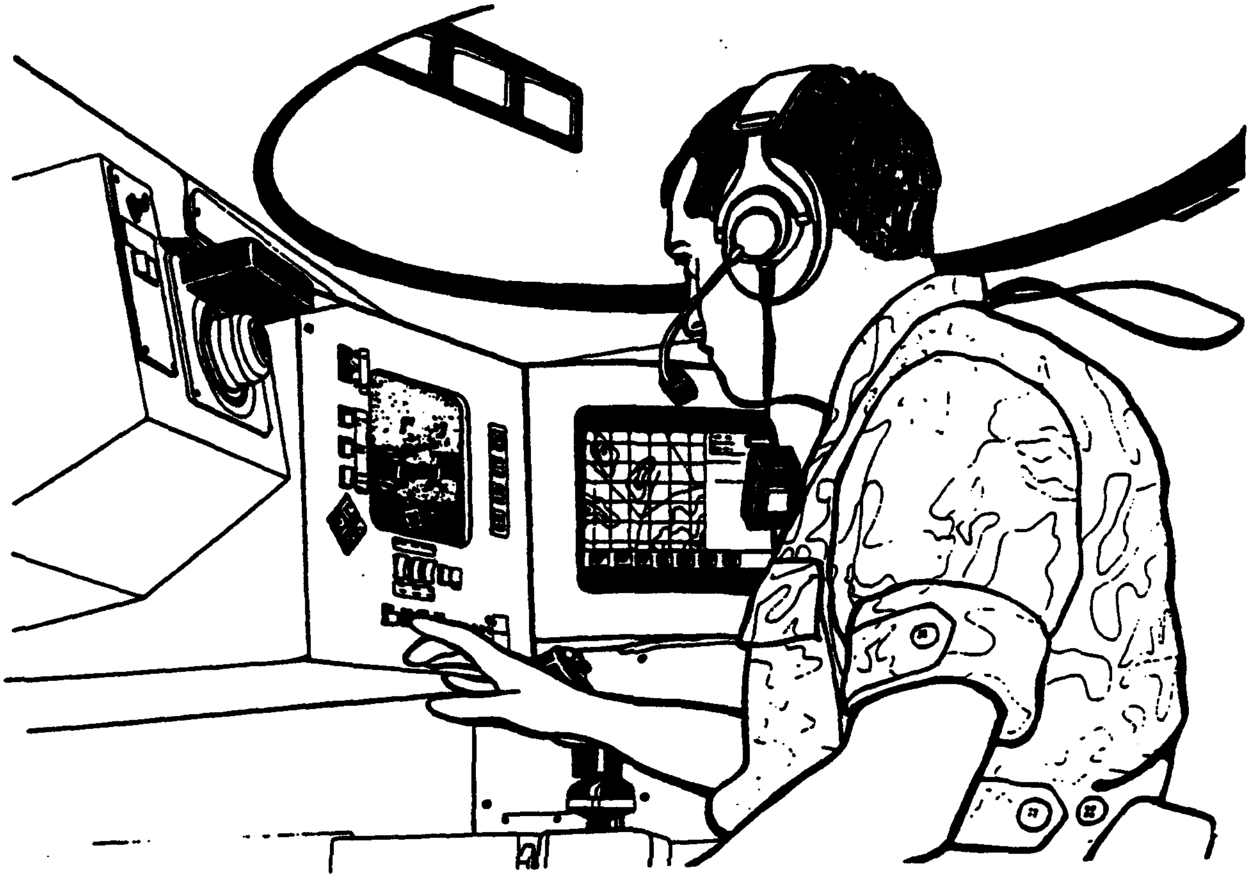

Figure 5. Vehicle commander's crewstation as seen in the CVCC condition.

Table 4 lists the basic capabilities of the CCD and POSNAV systems. A guide to the functionality and operation of these systems has been prepared in the form of a job aid (BDM Federal, Inc., in preparation). A detailed description of functional capabilities can be found in Atwood et al. (in preparation). A brief overview of the CCD and POSNAV systems follows.

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 configuration used in this experiment (SIMNET Version 7) has been upgraded from previous versions evaluated in the battalion TOC evaluation (O'Brien et al., 1992), the company evaluation (Leibrecht et. al, 1992), and the platoon evaluation (Du Bois & Smith, 1991). Since the battalion TOC evaluation, the CCD hardware platform has also been upgraded from Masscomps with approximately 16-20 megabytes of memory to SPARCstation IPXs with 48 megabytes of memory. The new platforms and increased memory have greatly enhanced the processing speed for the CCD and POSNAV components. At the same time, functionality modifications have been made to capitalize on findings and lessons learned from iterative CVCC research. Atwood et al. (in preparation) describe the recent changes in the CCD and POSNAV functionalities.

Table 4

C3 Capabilities of the CCD and POSNAV 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 and storage/retrieval
- Navigation waypoint autoadvance
- Driver's display (with steer-to-indicator)

<u>Digital Communication</u>

- Combat report preparation
- Laser range finder location input to combat reports
- Send/receive/relay combat reports (including report icons)
- Receive/relay tactical overlays
- Send/receive/relay navigation routes
- Friendly vehicle locations (mutual POSNAV)
- Automated logistics reports, with autorouting

<u>General Characteristics</u>

- Thumb (cursor) control
- Touchscreen input

<u>CCD interface overview</u>. A 10.5-inch diagonal SPARC cathode ray tube (CRT) mounted to the right of the vehicle commander houses the CCD display. The interface display encompasses only a 7 by 5.75 inch rectangular working area of the CRT. Figure shows the display with its CCD and POSNAV components. 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 (e.g., the Map menu) and the submenus (e.g., the Map Features submenu) when primary keys (e.g., MAP) and secondary keys (e.g., Exit, Back, and Cancel) 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.

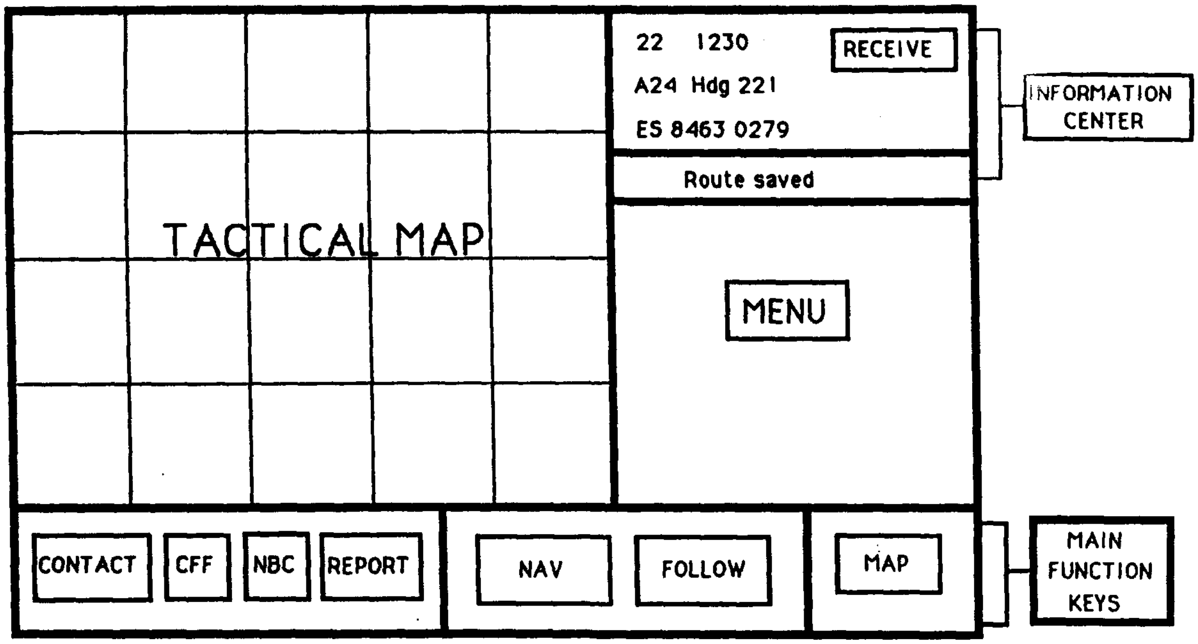

Figure 6. Command and Control Display (CCD) interface. See text for description.

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 vehicle commanders with automated, accurate updates of critical positioning and navigation information, such as own-vehicle and other friendly vehicle locations on a tailorable, digital map as well as grid locations and vehicle headings. POSNAV also provides the means to create routes and to send navigational information to the driver. The driver uses this information to steer to the next control point. The POSNAV configuration used in this experiment has been upgraded from previous versions evaluated in the battalion TOC evaluation (O'Brien et al., 1992), the company evaluation (Leibrecht et. al, 1992), the platoon evaluation (Du Bois & Smith, 1991), and the crew evaluation (Du Bois & Smith, 1989).

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

Commander's Independent Thermal Viewer. The CITV affords the vehicle commander an independent battlefield viewing capability and an independent laser range finder (LRF). The CITV's capabilities assist in the performance of navigation, battlefield surveillance, target acquisition (including identification), and fire control tasks. Table 5 lists the functional capabilities of the CITV configuration, described by Quinkert (1988). 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.

Table 5

Capabilities of the CITV Configuration

- Independent thermal search
  - 3X and 10X magnification
  - White-hot and black-hot polarity
  - Gun Line of Sight (GLOS) lock-on
  - Manual search
  - Autoscan
- Independent LRF
- Identification Friend or Foe (IFF)
- Target Designate
- Own-vehicle icon (directional, all parts moving)

Mounted directly in front of the vehicle commander, the CITV display includes control switches around three sides of a central display screen (Figure 7). The commander controls operation of the CITV via inputs from the functional switches and control handle buttons. The control handle is also used to manually control movement of the CITV sensor. The interface components consist of: (a) rectangular (6.5 X 5.88 inches) monochrome CRT display screen with own-vehicle icon and sighting reticle; (b) three-position toggle switch for power (OFF, STANDBY, and ON); (c) push-button selector switch for basic mode (CITV, GPS); (d) push-button selector switches for operational mode (AUTOSCAN, MANUAL SEARCH, GLOS [Gun Line of Sight]); (e) two-position push-button switch for polarity (WHITE-HOT, BLACK-HOT); (f) Autoscan control switches for setting sector limits and adjusting scan rate; (g) control handle push buttons for switching magnification (3X, 10X), operating the laser, and designating targets; (h) control knobs for adjusting brightness and contrast. The interface also includes several target stack push-buttons along the bottom. As in the battalion TOC evaluation (O'Brien et al., 1992), the target stack function was inoperative in this evaluation.

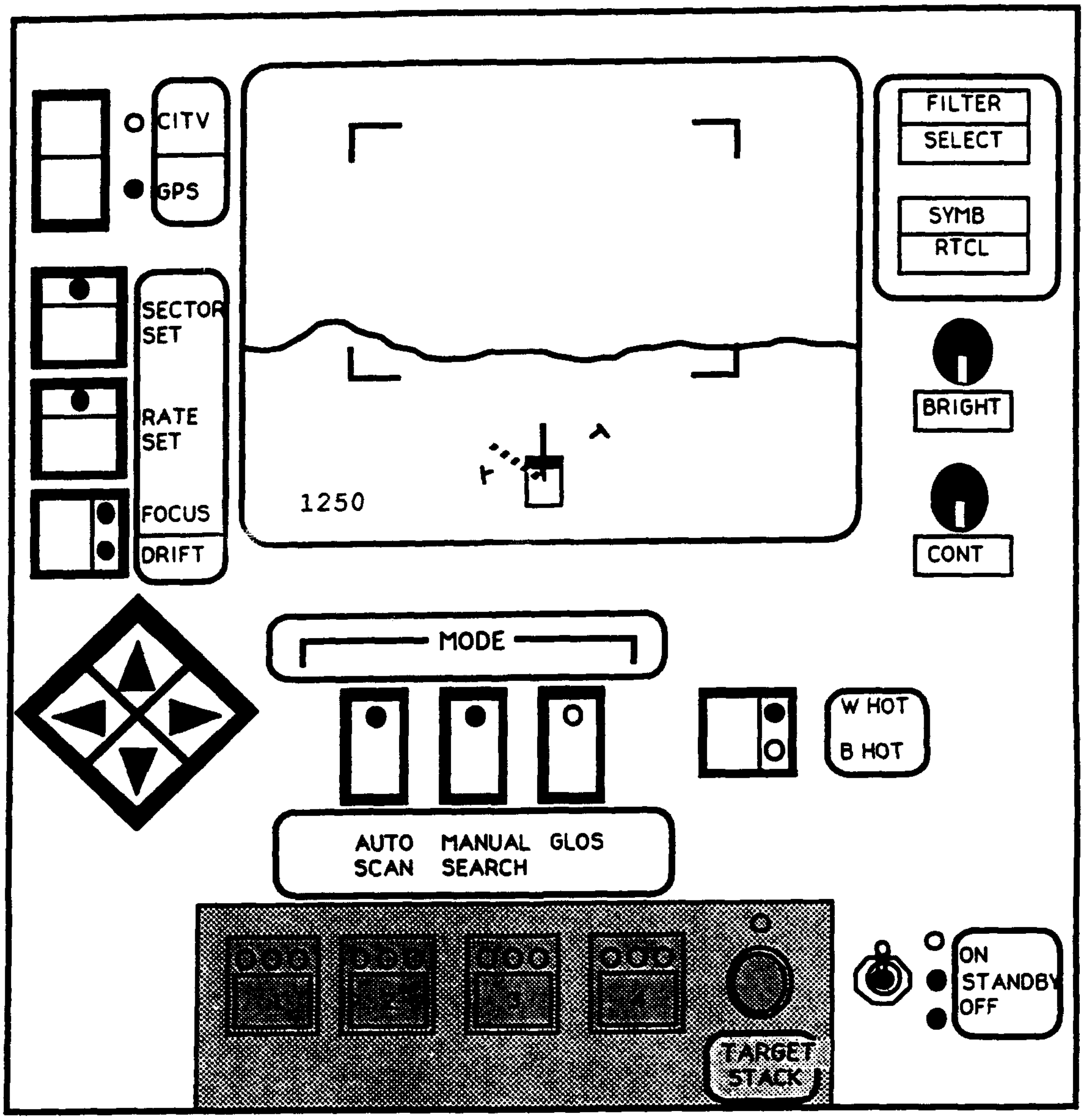

Figure 7. Commander's Independent Thermal Viewer (CITV) interface. See text for description. (Target stack functions, in the bottom shaded area, were inoperative.)

Tactical Operations Center

In addition to the vehicle simulators, a battalion TOC supported tactical operations in both the Baseline and CVCC conditions (see Figures 8 and 9). The battalion TOC was located in a Standard Integrated Command Post System (SICPS) tent, the same type used for a field-deployed TOC. The automated TOC (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 (Figure 8) 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 (Figure 9) 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, called the SitDisplay workstation, 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

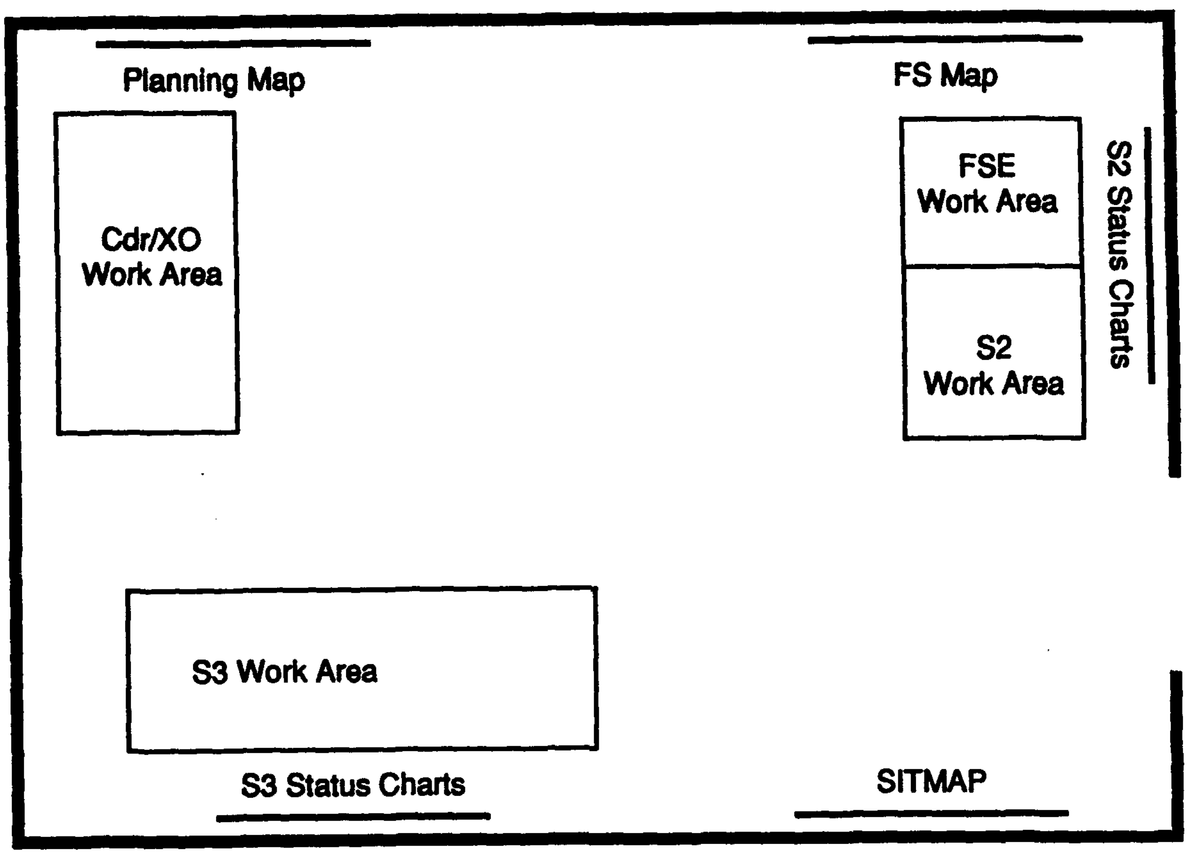

Figure 8. Floor plan of the battalion Tactical Operations Center used in the Baseline condition.

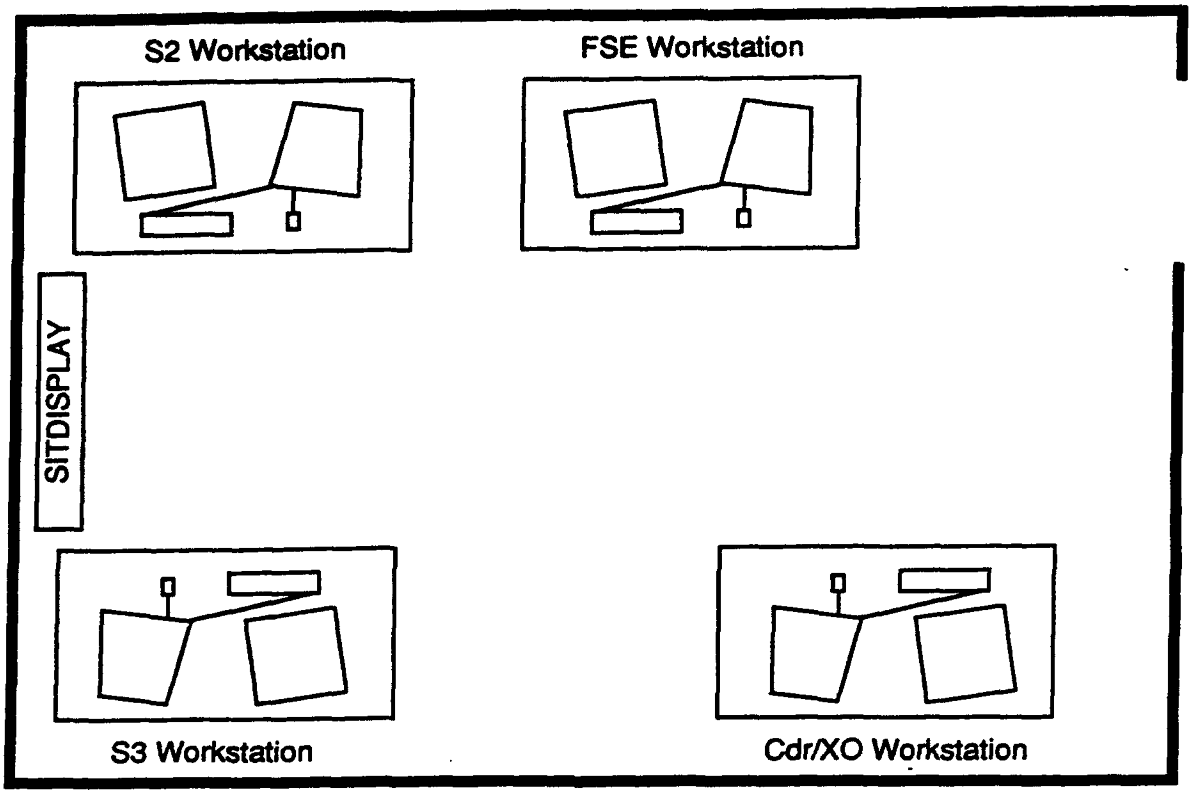

Figure 9. Floor plan of the battalion Tactical Operations Center used in the CVCC condition.

network. This linkage provided the means of implementing command and control procedures and coordination 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 (Figure 10). 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 functional features, described in Atwood et al. (in preparation). A complete guide to the functionality and operation of the TOC workstations may be found in the Battalion Tactical Operations Center (TOC) Job Aid (BDM Federal, Inc., 1992).

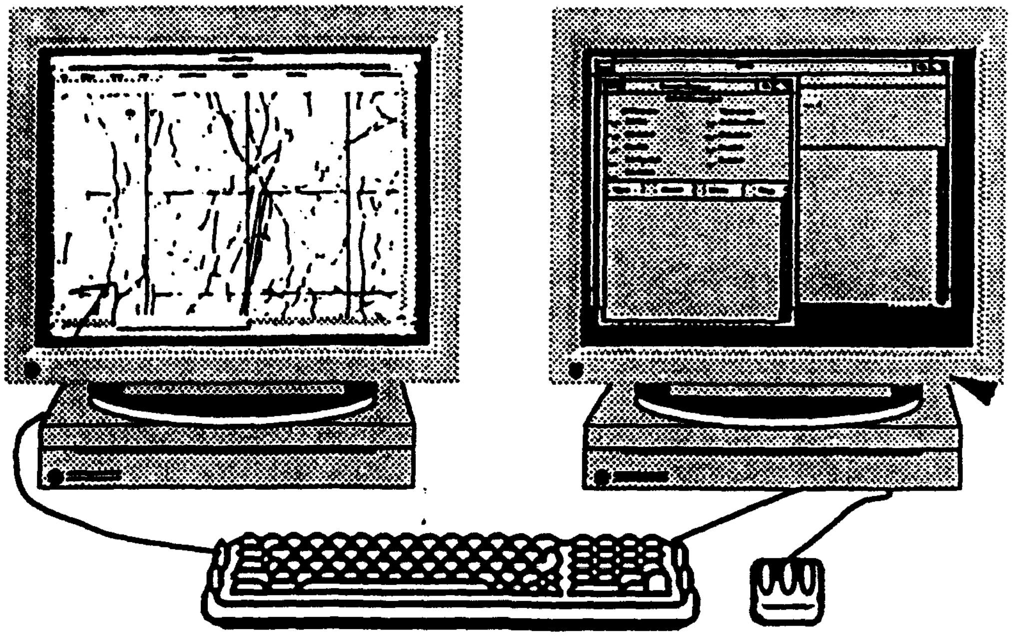

Figure 10. Automated workstation used in the battalion Tactical Operations Center for the CVCC condition.

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 11 shows the radio networks and configuration used in the Baseline and CVCC conditions. All but the battalion O&I net 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 training and the test scenarios, the battalion command net, located next to the battalion PVD, monitored voice messages (e.g., crossing phase lines [PLs], reporting SET). An additional CB radio at the Battle Master's position (brigade O&I net) permitted private radio communication between the battalion TOC and the ECR.

SAFOR operators monitored the nets appropriate to their roles. During training and the test scenarios, five nets were monitored: three company nets, the battalion command net, and the battalion O&I net.

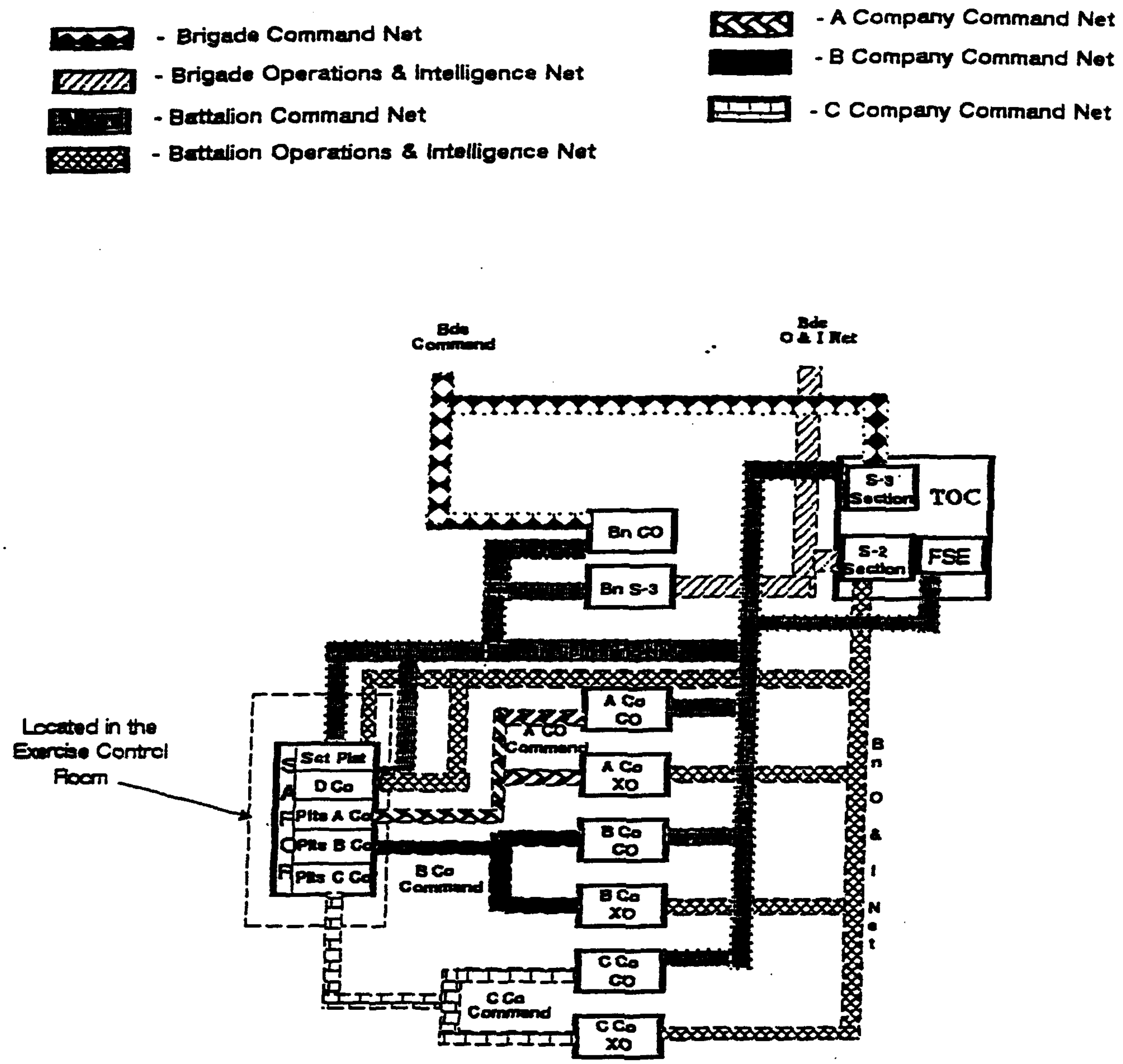

Figure 11. Diagram of the tactical radio networks (voice) implemented in the evaluation.

During both conditions, RadioTelephone Operators (RTOs) 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 manned-simulator CCDs in the CVCC condition. In the Baseline condition, the same reports appeared on the SAFOR workstation and wer then relayed by the radio operator. This automated information included CONTACT reports, SPOT reports, and SITREPs. During both conditions, coordination items (e.g., SET on BP 41) 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 6 lists the control equipment operational during the evaluation.

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

Table 6

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

message traffic. The three SAFOR stations (two for friendly SAFOR and one for OPFOR) supported implementation of all SAFOR activities. A Combat Service Support (CSS) workstation 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 12 depicts the configuration of the ECR during the battalion evaluation. Descriptions of each station and its use can be found in Atwood et al. (in preparation).

Remote communication devices. Each vehicle trainer wore a Maxon 49-HX communicator. 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 (DCA) system. The DCA system provided automated data recording, reduction, management, and analysis capabilities. O'Brien et al. (1992)

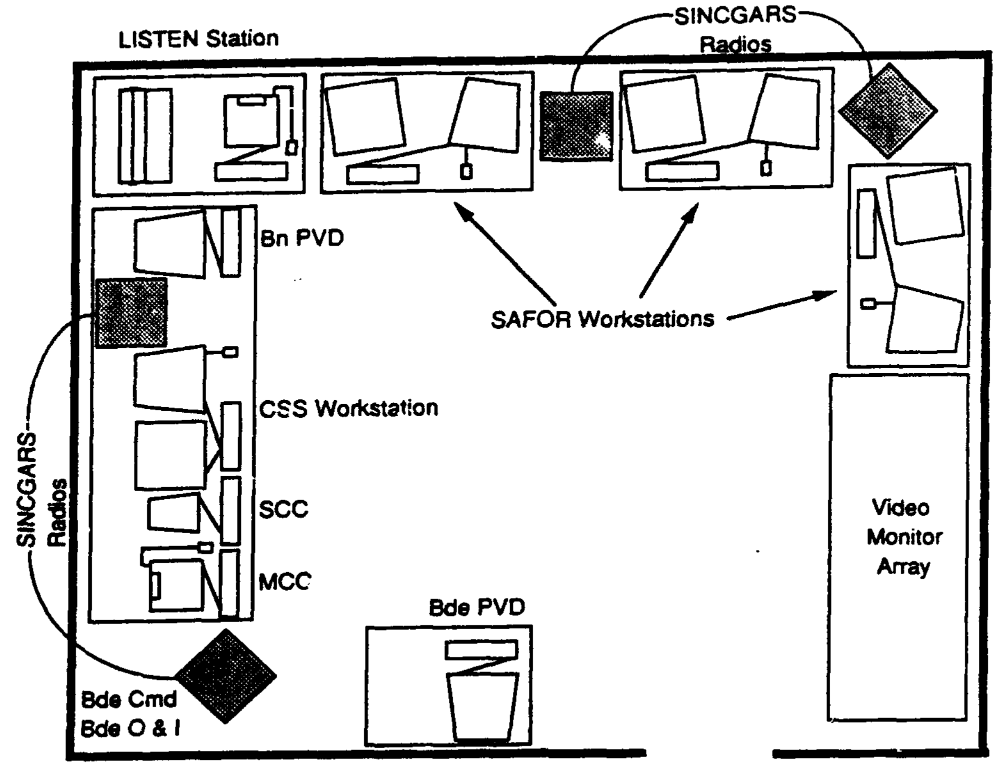

Figure 12. Floor plan of the Exercise Control Room (ECR), showing the layout of exercise control equipment.

provide a detailed description of the data collection, reduction, and analysis procedures developed for this evaluation. 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 of a PL. CCD report contents as well as voice radio transmissions broadcast over the simulation network were available for subsequent analysis.

Two DCA subsystems processed the reduction and analysis of DataLogger recordings. DataProbe™, a data management and analysis software package, extracted data elements from the DataLogger recordings and structured them into intermediate files. DataProbe™ included a SIMNET Data Dictionary to define and label 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 using software routines developed specifically for CVCC databases.

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, unit SOP, navigation aids, and operational exercise-control specifications for unit exercises. Every effort was made to provide equivalent training for both conditions despite content differences.

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 (BDM Federal, Inc., unpublished) contains the actual materials (e.g., lesson plans, briefing charts, evaluation instruments) used in the course of this effort.

Individual training modules. Table 7 summarizes the various modules used for individual training. Atwood et al. (in preparation) describe the materials in each of these modules.

Navigation aids. Each vehicle commander was provided with a standard set of materials to help him navigate during navigation training and tactical exercises. These included: SIMNET terrain maps encased in clear plastic map covers, operational overlays drawn on clear acetate sheets, erasable markers for drawing on overlays and maps, duct tape for securing overlays to the map cases, and map protractors for plotting azimuths.

Crew Training Exercise. Operating in a 5 km by 5 km terrain "sandbox," each crew negotiated a route consisting of a series of checkpoints. In addition to navigating, crews sent tactical reports and engaged enemy vehicles. Each sandbox also contained BLUFOR vehicles to reinforce proper vehicle identification procedures. In the CVCC condition, crews were encouraged to use POSNAV capabilities and digital reports to meet the training objectives. Fuller information on the crew training exercise is available in Atwood et al. (in preparation).

Unit SOP. The battalion SOP (actually an SOP "extract"), provided in paper form to all commanders, included general guidelines for participants regarding maneuver, engagement, communication and reporting, combat support, combat service

Table 7

Summary of Individual Training Modules

Module	Description
Introduction/Overview	Group briefing using script and viewgraphs
M1 Tank versus Simulator	Group briefing using viewgraphs
Seat-Specific Orientation	In-simulator explanation using outline for each crewstation
SIMNET Navigation (Baseline only)	Group briefing using practical exercises
SIMNET Skills Test	Trainer-administered pass-fail task performance
CCD Demonstration	Group session using outline and large-screen projection of interface
CCD Hands-on	In-simulator orientation using outline (explain-demonstrate-practice)
CCD Skills Test	Trainer-administered pass-fail task performance
CCD Refresher	Demonstration, in-simulator practical exercises
CITV Orientation	Group briefing using viewgraphs
CITV Hands-on	In-simulator session using outline (explain-demonstrate-practice)
CITV Skills Test	Trainer-administered pass-fail task performance

support, and command and control. The SOP for both Baseline and CVCC conditions specified the formats to be used for combat reports.

Collective training checklists. During crew, company, and battalion training, a checklist served to remind the vehicle trainer of the M1, CITV, CCD, and POSNAV functions the crewmembers were expected to exercise. The checklists also required the vehicle trainers to make judgments on whether or not the equipment was being used correctly and provided vehicle trainers with opportunities to practice report tallying.

Unit Training Exercises. 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) (concurrent with battalion staff situational training), the battalion STX, and the battalion training scenario. All of these exercises are described in detail in the battalion evaluation support package (BDM Federal, Inc., unpublished).

Detailed descriptions were developed for each training exercise describing the tasks to be trained during the exercise, as well as the conditions, standards, instructions (for the test personnel), and all supporting materials used to conduct the exercise. The company STX, battalion STX, and battalion training scenarios 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, operations orders (OPORDs), scenario event 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. A more detailed description of the collective training events is contained in Meade et al. (in preparation).

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. This scenario was based largely on an earlier version developed by Microanalysis and Design, Inc. (Smart & Williams, unpublished). It was executed in three stages: a delay, counterattack, and delay. Table 8 presents an overview of the tactical structure of this scenario. 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 (summarized below) were used.

Behavioral Observation. Battle Master, PVD, and Vehicle logs were completed by ECR and TOC personnel as well as test personnel observing crew activities (vehicle monitors). Copies of these logs appear in Appendix A. Test personnel in the control room sent flags (electronic event markers) using the PVD to identify key events in the scenarios (e.g., the first CONTACT report sent) and entered the flags on logs. Vehicle monitors entered manually recorded data for selected performance measures such as the number of CCD-type reports sent over the radio by

Table 8

Tactical Structure of the Battalion Test Scenario

Stage	Major Activities
Initial Planning	Mission briefing, planning, leader's recon
1. Delay to Phase II [a]BPs	
A. Pre-engagement	Set up defense
B. Enemy engagement	Fight two [b]MRBs(+)
C. Displacement	Move to Phase II BPs
2. Counterattack to [c]OBJ	
A. Pre-engagement	Receive FRAGO, plan, move to OBJ
B. Enemy Engagement	Fight MRB(+)
C. Prepare FRAGO 2	Receive FRAGO, plan
3. Delay to [d]PL	
A. Pre-engagement	Receive FRAGO, plan, move to BPs
B. Enemy Engagement	Fight two MRBs
C. Chemical Attack	Delay to subsequent BPs

[a]Battle positions. [b]Motorized Rifle Battalion, reinforced. [c]Objective. [d]Phase line.

their vehicle commander. Vehicle monitors also gathered information the DCA system was unable to collect (e.g., vision block versus GPSE usage). In addition, they recorded any observations they felt might help explain any unusual performance by a crewmember (e.g., a vehicle commander who complained about lack of sleep after pulling night duty). The PVD and Vehicle Logs were also used to note equipment breakdowns interfering with established test procedures.

SMI assessment questionnaires. The SMI assessment questionnaire can be found in Atwood et al. (in preparation).

Training assessment questionnaires. Refer to Atwood et al. (in preparation) for a description and copy of the training assessment questionnaire.

Biographical questionnaire. See Atwood et al. (in preparation) for a copy of the biographical questionnaire.

Situational assessment questionnaire. A copy of the situational assessment questionnaire appears in Appendix A.

Control staff operating rules. To ensure consistent implementation of training and testing exercises, two 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 of exercise control document, contingency rules, specified the decision process and options for handling contingencies related to technical and personnel problems. The contingency rules helped to ensure personnel and technical problems were handled in a consistent manner across test weeks. Any significant departures from established control procedures (as might be necessitated by equipment problems) or contingency rules were noted in writing 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.

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 detail 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

Instructions at the start of the evaluation. Upon reporting to the MWTB, participants received a presentation providing an overview 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. All participants were given a point of contact and telephone number in case any conflicts with their participation arose later.

Training exercise instructions. 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, readiness condition [REDCON] 1 time, mission start time). The Battle Master also provided special instructions for the exercise at hand, such as exercise-specific communication or coordination provisions.

Scenario instructions. Each 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 rotations. Graphic training aids 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 13 provides an overview of the schedule of events for the CVCC condition; the following sections describe each event. Copies of all lesson materials are available in the support package for this evaluation (BDM Federal, Inc., unpublished).

Day 1 events

1a: General introduction. The objectives of the general introduction were to provide an overview of the battalion evaluation program and schedule, describe the importance of the battalion evaluation to the Army's long range goals for improving battlefield performance, describe the test facilities and general procedures to be followed throughout the evaluation. All participants received the general introduction as a group. At the end of the session, each participant completed a Privacy Act statement and the Biographical Questionnaire.

1b: M1 tank versus M1 simulator. This classroom session highlighted major differences between the M1 simulator and the M1 tank. All vehicle commanders participated.

1c: CCD demonstration (CVCC condition only). This lecture demonstrated the functionality and operation of the CCD to CVCC commanders. A TOC workstation was configured as a stand-alone CCD with a functional CCD screen (mouse-controlled cursor) and the overlays needed for the demonstration. Through an electronic interface, the large-screen monitor mimicked the display of the stand-alone workstation, allowing a group to easily view the CCD during the demonstration. An instructor's assistant manipulated the CCD workstation in accordance with the demonstration outline and instructor cues. CVCC-SEND message files were transmitted to the stand-alone CCD during the demonstration.

1d: Vehicle commander seat-specific training. All commanders received training on the M1 simulator's unique features. While the vehicle 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).

1e: CCD training (CVCC condition only). This equipment training provided detailed instruction and hands-on practice to vehicle commanders in the operation of the CCD and POSNAV. A uniform sequence was followed 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.

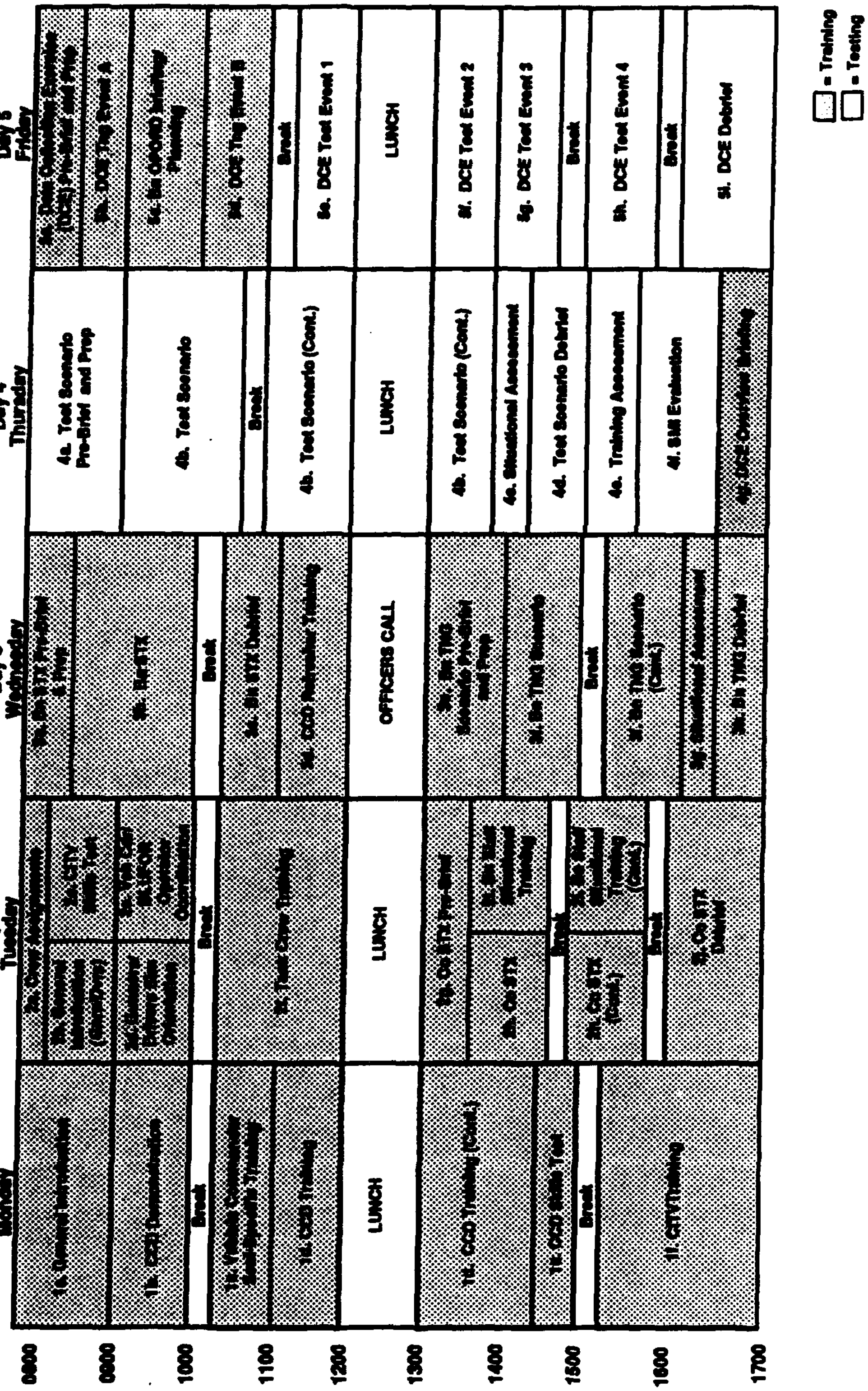

Figure 13. Weekly training and testing schedule for the CVCC condition. Data Collection Exercises (DCEs) are addressed in a separate report (Lickteig, in preparation).

1f: CCD Skills Test (CVCC condition only). This test evaluated commander proficiency on CCD operation. The vehicle trainer read each task to the participant and observed his performance, recording a "Go" or "No-go" on the form. If necessary, upon completion of the test, the vehicle trainer conducted remedial training until the participant could perform each task.

1g: CITV training (CVCC condition only). This training provided detailed instruction and hands-on practice to commanders in the operation of the CITV. An initial classroom session introduced CITV functions and suggested uses. 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.

SIMNET navigation training (Baseline only). Following the M1 tank versus M1 simulator lecture, the Baseline vehicle commanders received training on navigating in the SIMNET environment. This session began with a classroom presentation reviewing conventional navigation procedures (e.g., polar plotting, resection) plus the special tools available in the M1 simulators (e.g., LRF, 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.

Day 2 events

2a: CITV Skills Test (CVCC condition only). CVCC commanders' proficiency in CITV operation was tested immediately Tuesday morning. The vehicle trainer conducted this session in the same manner as the CCD Skills Test. Following administration of the test, the vehicle trainer conducted remedial training, as needed, until the commander could perform each task.

2b: Gunners/drivers simulator orientation. While inside simulators, gunners and drivers were given an orientation to the features and functions of their respective simulator crew stations.

2c: Vehicle commander/BLUFOR operator coordination. This module consisted of a classroom briefing and orientation to BLUFOR (SAFOR) operation, for commanders only. The lecture 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. Instruction emphasized command was exercised by the unit commanders in the manned simulators through immediate intervention or FRAGOs. The capabilities and operating characteristics of the SAFOR were addressed in detail, to include formations, speed (both rate of movement and response time), coordination of fires, and engagement criterion. Limitations such as lack of platoon fire commands and inability to split sections were also addressed.

2d: Tank crew training. All participants practiced collective crew tasks and skills focusing on crew coordination, navigation, and terrain negotiation. Opportunities for initial practice of 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. At the end of crew training, there was a brief review of battalion SOP and the role of company XOs in reporting, focusing on proper responses.

2e: Company STX pre-brief. 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.

2f: Company STX. Company commanders, XOs and their crews executed the company level scenario with minimal involvement of the TOC. The scenario was designed to provide the company commanders and XOs practice in working with SAFOR platoons.

2g: Battalion staff situational training. Concurrent with the company STX, the command group (i.e., battalion commander and S3) and the TOC staff (i.e., battalion XO, S2, Assistant S3, and FSO) practiced working together in parallel with the company STX battlefield activities. Training objectives were to (a) orient the command group on 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. In this two-stage exercise, the command group operated "off-line" (i.e., only interacted with the TOC while the Battle Master role-played the commander/S3), becoming familiar with the capabilities and procedures of TOC operations. During stage one, the command group could rotate at will between their simulator and the TOC, observing activities and listening to communications as the STX unfolded. During stage two, the commander and the S3 were restricted to their respective simulators, but remained in an observer role.

2h: Company STX debrief. Participants were briefed on the overall performance of the unit during the company STX. The Battle Master 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. In addition, feedback was provided from the test support staff and participants regarding issues such as reporting performance.

Day 3 events

3a: Battalion STX pre-brief. Pre-mission activities for the battalion STX followed the same general structure as other training and test scenarios. The battalion XO briefed the battalion OPORD, and 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 Course of Action (COA) overlay was activated on the large-screen monitor in the TOC where the battalion XO "walked through" the operation for the commanders and S3 using sequenced phasing techniques of the COA module.

3b: Battalion STX. The battalion training exercise included two phases. Phase one required the participants to execute a defense, while phase two required a counterattack. The battalion commander was given options in conducting the counterattack. All elements in the battalion, including the battalion TOC staff, participated in the exercise.

3c: Battalion STX debrief. The battalion STX debrief was conducted in the same manner as the company STX debrief.

3d: CCD refresher training (CVCC condition only). To reinforce CCD operating procedures, a refresher training session (for unit and vehicle commanders only) followed the battalion STX debriefing. This session began with an abbreviated CCD demonstration highlighting common problems, and concluded with a message processing exercise.

Navigation refresher training (Baseline condition only). To reinforce SIMNET navigation procedures, each Baseline test group received a navigation refresher training session following the battalion STX debriefing. This crew level exercise basically repeated the crew sandbox exercise, with emphasis on navigation tasks. Each crew used the same sandbox as they did during crew training, negotiating the checkpoints in reverse order.

Officers call. A mid-week 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 SAFOR 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.

3e: Battalion training scenario pre-brief. Pre-mission activities for the battalion training scenario followed the same general structure as the other training and test scenarios. The Battle Master briefed participants on the brigade OPORD, and the battalion XO briefed participants on the battalion OPORD. The TOC staff was available and participated in coordination and planning.

Pre-mission preparation included a leader's reconnaissance conducted for the battalion commander, the S3, and the three company commanders. The battalion XO attached the Stealth sensor to a vehicle simulator which moved according to a previously recorded route. As the vehicle maneuvered on the battlefield, the Stealth followed. This permitted the battalion XO to lead the commanders and staff on a standardized reconnaissance over the simulated terrain, highlighting friendly positions, engagement areas, enemy avenues of approach (no OPFOR vehicles were visible) and areas of terrain masking. The S2 was available at the Stealth to respond to queries about the enemy or terrain. This reconnaissance technique immediately followed the battalion OPORD briefing.

3f: Battalion training scenario. The battalion training scenario was executed in two stages. During stage one, the battalion executed a delay operation. In stage two, they executed a brigade-directed counterattack. 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 delay. Stage two was initiated with the issuance of the battalion counterattack FRAGO. To ensure consistency of the starting conditions at each stage for all rotations, 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.

3g: Situational assessment. At the end of the battalion training scenario, the commanders received a short orientation to the Situational Assessment questionnaire. Details of the questionnaire were addressed earlier.

3h: Battalion training scenario debrief. The battalion training scenario debrief was conducted in the same manner as the company STX and battalion STX debriefs.

Day 4 events

4a: Battalion test scenario pre-brief. Pre-mission procedures for the battalion test scenario followed the same structure as for the training scenarios.

4b: Battalion test scenario. 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 (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.

4c: Situational assessment. At the end of the test scenario, each commander completed a Situational Assessment questionnaire outside his simulator. This questionnaire was similar to that presented in the orientation at the conclusion of the battalion training scenario.

4d: Battalion test scenario debrief. The battalion test scenario debrief was conducted in the same manner as the debrief at the conclusion of the battalion training scenario. In addition, participants were queried as to techniques used to accomplish certain tasks (e.g., target detection and identification, IFF, navigation methods).

4e: Training assessment. A detailed questionnaire asked all participants to rate the quality and effectiveness of the training they received during the first three days of the evaluation. This self-paced questionnaire also solicited opinions for improving each of the training modules.

4f: SMI evaluation (CVCC commanders only). In the CVCC condition, a detailed questionnaire was administered to the commanders to obtain their opinions and insights about the design and operation of the CCD and CITV interfaces. Completion of this questionnaire was also self-paced.

Data Collection Exercise events on Day 4 and Day 5. Participants in this evaluation also completed a series of special Data Collection Exercises (DCEs). These exercises are described in detail elsewhere (see Lickteig, in preparation).

Training of Participants

The training program was tailored by test condition and the participant's role. The preceding subsection, Evaluation Week Schedule, outlined the training events and participant involvement. An earlier subsection, Training and Test Materials, outlines the materials used to accomplish individual, crew, and unit training. The Floor Monitor supervised individual training, and the Battle Master supervised collective training in order to maintain quality control and standardization of procedures. Atwood et al. (in preparation) discuss the training procedures in substantial detail.

Professional role playing. To ensure realistic command and control and combat performance, professional role playing was mandated. Unrealistic behavior had a strong potential to compromise test integrity and skew test results (e.g., 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.

Past CVCC research efforts (O'Brien et al., 1992) indicated some test participants exhibit unrealistic risk-taking behavior during evaluations. This evaluation utilized a kill-suppress option to protect manned vehicles; however, this option is suspected to contribute to that risk-taking behavior (i.e., attitude of invincibility). This behavior is commonly referred to as "Rambo" behavior. The officers call, addressed earlier, specifically emphasized the importance of professional role playing and the potential impact on the test results. Special emphasis was placed 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 pace of battlefield activities realistically 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 reduction and analysis. PVD operators entered flags 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 (e.g., crossing the LD), and selected data elements. The PVD operator also kept a log that provided additional information related to the flags. The flags and logs were used to break scenario recordings into discrete mission 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 simulator 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.

Test personnel administered the previously-described questionnaires to participants at designated points during the test week. During the debriefs following the training and test scenarios, participants' comments and suggestions were transcribed by test support personnel.

Data Reduction and Analysis

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 three steps: database management (data entry and quality control), data reduction, and descriptive 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 (e.g., Biographical Questionnaire). Test support personnel entered data into these files using dBASE III+™ customized data entry screens on a personal computer. 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, DataProbe™ extracted raw data from magnetic tapes recorded during the test scenario and RS/1™ organized the resulting data into files. Research team members reviewed printouts 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. A number of measures required hands-on processing of manually collected data (e.g., counts of voice radio messages). For each measure in this category, data reduction forms were developed to guide the data reducer carefully through each step. Test personnel received training in administering these forms. Data reduction forms were also spot-checked by experienced behavioral scientists on the test support team. When the data reduction forms were complete, the data were directly entered into DBMS files.

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. Special attention was paid to voice reports which could also be supported by the CCD (e.g., a CONTACT report) to determine their accuracies. Once playback of radio traffic was complete, test support personnel reduced the data for selected measures (e.g., transmission time, accuracy) using manual data reduction forms, then entered them into a database for later 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 omit the affected measures from analyses. Only those measures/values influenced by the unplanned event were omitted. This strategy reduced sample size 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 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 individual measures were accomplished using SPSS' univariate ANOVA procedures. The principal independent variables guiding these analyses were condition, with two levels (CVCC and Baseline), echelon (two levels, battalion and company), and stage, with three levels.

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 in the Design of the Evaluation section of this report, 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., 1992). In turn, the measures used in the battalion TOC evaluation were based on measures from earlier CVCC efforts (e.g., Du Bois & Smith, 1989; Du Bois & Smith, 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. (in preparation).

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 (Department of the Army, 1991), these operational issues provided the foundation for organizing hypotheses to describe the expected differences between the CVCC and Baseline configurations. 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 POSNAV icons and overlays were expected to provide an overall advantage for a subset of Maneuver BOS tasks.

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) <u>move on the surface</u>; (b) <u>navigate</u>; (c) <u>process direct fire targets</u>; (d) <u>engage direct fire targets</u>; and (e) <u>control terrain</u>.

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 tasks under the CVCC condition.

Hypothesis 2.1: The CVCC units' ability to conduct surface attack by 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 the tactical map with digital overlays and digital report capabilities, were expected to positively impact 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 (SA1) 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 (e.g., 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

In the paragraphs that follow, operational measures are presented and organized by the hypotheses within each operational issue. Hypotheses were stated in the preceding subsection.

Table 9 presents the operational measures for Issue 1 which were developed to address the following Maneuver BOS functions: Move on Surface, Navigate, Process Direct Fire Targets, Engage Direct Fire Targets, and Control Terrain.

Table 9

Operational Measures by Maneuver BOS Function

MEASURE #	Title
	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 objective (Stage 2)
	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 exercise
	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 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
	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, by echelon
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

(Table continues)

Table 9

Operational Measures by Maneuver BOS Function (Cont'd)

MEASURE #	Title
	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 10 presents the operational measures for Issue 2 which were developed to address the Conduct Surface Attack function of the Fire Support BOS.

Table 10

Operational Measures by Fire Support BOS Function

MEASURE #	Title
	CONDUCT SURFACE ATTACK
2.1.1	Mean accuracy of CFF locations
2.1.2	Percent of CFFs with correct type

Table 11 presents the operational measures for Issue 3 which were developed to address the following functions of the Command and Control BOS: Receive and Transmit Mission, Receive and Transmit Enemy Information, Receive and Transmit Friendly Troop Information, Manage Means of Communicating Information, Assess Situation, and Direct and Lead Subordinate Forces.

Table 11

Operational Measures by Command and Control BOS Function

MEASURE #	Title
	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 request by company commander to clarify FRAGO/overlay
3.1.3	Consistency of relayed FRAGO
	RECEIVE AND TRANSMIT ENEMY INFORMATION
3.2.1	Time to transmit INTEL report full net: battalion TOC to lowest manned net
3.2.2	Consistency of relayed INTEL
	RECEIVE AND TRANSMIT FRIENDLY TROOP INFORMATION
3.3.1	Mean time to transmit SITREP full net: lowest net to battalion TOC
3.3.2	Deviation of BLUFOR location reported in SITREP from actual location
3.3.3	Delay between observed phase line/line of departure/FCL crossing and reported crossing
3.3.4	Delay between observed battle position arrival and reporting SET at battle position
3.3.5	Elapsed time from request for fuel and/or ammunition report until received by battalion TOC (Baseline only)
	MANAGE MEANS OF COMMUNICATING INFORMATION
3.4.1	Average length of voice radio transmissions, by echelon
3.4.2	Mean duration of voice transmissions between battalion TOC and battalion commander/S3, excluding named reports
	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?
	ASSESS SITUATION
SA1.1	During the last stage, how many OPFOR tanks did your company or battalion destroy? (Stage 3)
SA1.2	During the last stage, how many BMPs did your company or battalion destroy? (S[illegible] 3)

(Table continues)

Table 11

Operational Measures by Command and Control BOS Function (Cont'd)

MEASURE #	Title
SA1.3	During the last stage, did you company or battalion destroy any enemy vehicles after the order to delay was given? (Stage 3)
SA1.4	During the last stage, how many tanks in your company or battalion were destroyed? (Stage 3)
SA1.5	During the last stage, how far was your initial battle position from your subsequent battle position? (Stage 3)

Table 12 presents the operational measures for Issue 4 which were developed to address the Collect Threat Information function of the Intelligence BOS.

Table 12

Operational Measures by Intelligence BOS Function

MEASURE #	Title
	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

A list of sample measures and their operational definitions appears in Appendix B, where the emphasis is on measures whose definitions have changed since the report of preliminary data from the battalion evaluation (Leibrecht et al., in preparation). A more complete list can be found in O'Brien et al. (1992).

Support Staff

The test support staff was responsible for training exercise participants, controlling all scenarios and exercises, operating the ECR stations, and operating the surrogate battalion TOC. This staff also administered manual data collection instruments. Table 13 summarizes the primary responsibilities assigned to each member of the support 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

Table 13

Responsibilities of the Exercise Control Staff During Scenarios

<u>Exercise Director</u>
- 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

<u>Event Coordinator</u>
- 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

<u>Battle Master</u>
- 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

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

<u>BLUFOR Operators (SAFOR)</u>
- Initialize BLUFOR 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 activities with Battle Master
- Coordinate radio messages with Radio Operator

(Table continues)

Table 13

Roles and Responsibilities of the Exercise Control Staff During Scenarios (Cont'd)

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

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

<u>Floor Monitor</u>
- Supervise RAs during scenarios
- Coordinate with RAs and simulator technicians to help resolve equipment problems

<u>Research Assistants (In simulators)</u>
- 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

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execution of events. This permitted decentralized execution consistent with the research plan.

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 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 (technicians) during equipment malfunctions, and tracking the status and resolution of these problems.

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 impact the evaluation's results and their interpretation, are discussed in this subsection. Facility-based issues have been provided to the MWTB site manager for action, as appropriate.

Given the allocation of manned simulators, the lowest echelon manned within the battalion was the company level (company XO). In other words, only SAFOR elements were operative at the platoon level. Thus, battlefield information from the wingman and platoon leader levels originated from SAFOR algorithms or from BLUFOR operators. The working framework used by the company commanders and XOs to interpret SAFOR-generated reports may have varied across individuals. Further, there was no strong incentive for company commanders and XOs to relay INTEL reports, FRAGOs, and other information to their SAFOR elements. These factors may have influenced the flow of information within the battalion. In combination with the lack of Fire Support Team (FIST) personnel within the companies, these factors also may have affected the battalion's command and control dynamics. One practical consequence was the limited 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 crews reallocated to form a completely manned platoon (Lickteig, in preparation).

Radio net differences between the Baseline and CVCC conditions complicate the interpretation of communication-based performance. The voice radio nets were identical in both conditions: company command and battalion command nets for company commanders, company command and battalion O&I nets for company XOs. However, the CVCC-equipped company XOs had the battalion command digital net instead of a digital O&I net. When the CVCC TOC transmitted digital reports and FRAGOs on the battalion command net, the company commanders and company XOs received them at the same time. But when the Baseline TOC transmitted voice reports and FRAGOs on the battalion command net, the company XOs did not receive them until the company commanders relayed them on the company command nets. This methodological difference would be expected to impact selected aspects of communications, such as time to transmit INTEL reports and FRAGOs.

Due to limited processing capacity of each simulator's computer image generator, the driver's vision blocks occasionally failed to display surrounding vehicles properly. Vehicle images could flash intermittently or disappear for extended periods, depriving the driver of important visual information. These problems degraded the driver's ability to maintain proper position within a tactical formation and to steer clear of neighboring vehicles. Occasional collisions resulted. Additionally, if a vehicle commander found it necessary to verbally guide his driver, the commander's ability to fight his unit or his vehicle may have suffered. Altogether, this limitation could somewhat compromise performance related to positioning and navigation, and perhaps reduce overall attention to C3 activities.

Constraints limiting SAFOR behavior compromised the realism of the simulated battlefield. SAFOR responsiveness was sometimes slowed by keyboard command requirements, especially since one SAFOR operator controlled the actions of several platoons. Maneuver options for SAFOR units were limited; for example, OPFOR platoon vehicles did not disperse when artillery fell. Unrealistic movement of SAFOR elements occurred (e.g., failure to follow cover and concealment principles, circling around tree canopies, scrambled patterns when two units intersect). In addition, SAFOR vehicles never committed fratricide, due to perfect IFF capabilities. As with other DIS evaluations, these and similar limitations require caution when attempting to apply findings to other environments, including actual combat.

Several factors posed special challenges to the crewmembers as they strove to role play professionally. The use of kill suppress to protect manned simulators may have encouraged unnecessary risk-taking when crews discovered they were "invincible." Crews occasionally appeared to be engaging in "Rambo" behavior. Compounding this was the lack of a clear, immediate signal telling the crewmembers their vehicle had taken a killing hit. Combining manned and BLUFOR vehicles in the same unit meant crews could follow BLUFOR elements instead of navigating for themselves. Also, mine fields and obstacles were not implemented on the terrain database, so the crew may have discovered that ignoring them on the overlay carried no penalty. The mid-week officers call addressing these issues was designed to ensure participants were clear about their role-playing responsibilities.

The simulation algorithms modelling ballistic performance, probability of hits, and probability of kills were based on out-of-date 105 mm service round data. In addition, the simulation implementation of target lead differed appreciably from the fielded tank, making it difficult for gunners to master firing at moving targets. Thus, target engagement performance in this evaluation cannot be considered representative of actual tank battalion gunnery performance.

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, including an examination of the comparability of the independent samples assigned to the Baseline and CVCC conditions. The organization of data follows the evaluation's four operationally-based research issues: (a) command and control, (b) battlefield maneuver, including target engagement, (c) attack by indirect fire, and (d) collection of intelligence information.

Focusing 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 Meade et al. (in preparation). 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; 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. (1992) defined the basic set of measures, but several definitions have changed since the battalion TOC evaluation. Appendix B presents the updated definitions for the modified measures, along with selected measures chosen to provide an across-the-board sampling.

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, making it unfeasible to compute some 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. In addition, occasional equipment difficulties led to dropping impacted measures from the database. Consequently, sample sizes in data tables appearing in this section and in Appendix C vary modestly.

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 inception of the evaluation; these constraints were outlined in the Background and Review of Key Literature section. 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) are presented strictly in summary form in this section. A probability level of .05 or less is required before an effect is considered statistically significant. ANOVA summary tables (SPSS output) appear in Appendix D to provide more complete information. [redacted] Appearing in Appendix C are supplemental tables more completely characterizing the distributions of data.

The presentation of performance measures which follows is organized by 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 distilling the noteworthy results.

Command and Control BOS

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

This subsection is organized around the six command and control tasks 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) Direct and Lead Subordinate Forces, (e) Manage Means of Communication, and (f) Assess the Battlefield Situation. The subsection concludes with a summary of findings.

Certain measures automatically took on fixed values for the CVCC condition, due to design features of the CCD and the manned radio nets defined for this evaluation. In particular, the CCD instantaneously transmitted digital reports on the net(s) selected. Since all crewed vehicles in the CVCC condition were on the battalion net for routing of digital reports, the time to transmit a SITREP, for example, from a vehicle to the TOC was zero. As another example, the time to transmit a FRAGO from the TOC to a company XO was also zero. Further, unit and vehicle commanders could not edit digital reports received, so the act of relaying reports could not change their contents. Consequently, perfect consistency of digital reports (e.g., INTEL reports, FRAGOs) as they were relayed was guaranteed.

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 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: 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 task captured the duration of FRAGO transmisssions, the duration of transmissions clarifying the FRAGO, and the consistency of FRAGOs relayed on the company command nets. The performance data are summarized in Table 14. These data were collected only for Stages 2 and 3, when the battalion FRAGOs were issued and executed.

Elapsed time from battalion transmission of FRAGO to receipt by company commander/XO. 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 set at zero, due to the instantaneous digital burst transmission capability. Mean transmission times in the Baseline condition (Table 14) were nearly 10 minutes or greater. 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, no ANOVAs were computed for this measure.

Table 14

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

Measure	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]	12.36 (5.84) *n*=16	0[a]	9.38 (5.05) *n*=15
Duration of request to clarify FRAGO/overlay (minutes)				
Company commanders	-- *n*=0	.43 (.07) *n*=5	.26 (.13) *n*=2	.43 (.23) *n*=12
Company XOs	-- *n*=0	.60 (.46) *n*=7	-- *n*=0	.58 (.55) *n*=3
Consistency of relayed FRAGOs (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]Instantaneous, complete transmission of FRAGOs occurred by virtue of CVCC system design.

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. As seen in Table 14, in the CVCC condition there were no requests for clarification during Stage 2, and only 2 requests in Stage 3 (averaging one-quarter minute). By contrast, Baseline participants issued twelve requests for clarification in Stage 2 and fifteen requests in Stage 3. Durations of the dialogues averaged around one-half minute. Due to the infrequent observations for the CVCC battalions, no ANOVAs were performed on these data.

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 almost never requested clarification. In contrast, Baseline commanders frequently requested clarification of FRAGOs, consuming over six minutes on the radio during each stage.

Consistency of relayed FRAGO. FRAGO consistency was quantified by comparing the contents of the FRAGO relayed by the company commander 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%, because the company commander could only relay the FRAGO exactly as he received it. For the Baseline condition, the mean percentage of information relayed correctly (Table 14) was 19% in Stage 2 and 35% in Stage 3. Because of the fixed values (100%) for the CVCC condition, no statistical analysis was performed on these data. However, the contrast between the two conditions was dramatic, indicating a substantial loss or distortion of information when using voice communications.

Summary of key data. The measures analyzed under this hypothesis did not lend themselves to inferential analysis. Nevertheless, the data for this task convincingly documented performance advantages of the CVCC system. The system's digital capabilities provided instantaneous FRAGO transmission and perfect consistency upon relay, ensuring zero-delay dissemination of orders containing complete, undistorted information. In contrast, Baseline commanders sacrificed 10 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.

Receive and Transmit Enemy Information

Hypothesis: 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 two aspects of INTEL report transmissions: speed of fully disseminating scripted reports, and information loss or distortion resulting from the dissemination process. Table 15 summarizes the performance data supporting this hypothesis.

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 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. In both conditions, time consumed by clarification queries was added to basic transmission time. Only INTELS ultimately relayed at the company level were included in the analysis.

As Table 15 shows, Baseline transmission times averaged more than 1.5 minutes in Stages 1 and 2. Overall, Baseline commanders relayed approximately 10% of the INTELs scripted for the scenario. 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.

Table 15

Performance Data for Receive and Transmit Enemy Information Hypothesis, 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 reports full net (minutes)	0[a]	1.65 (.96) $n=10$	0[a]	1.58 (1.03) $n=3$	0[a]	.82 -- $n=1$
Consistency of relayed INTELs (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]Instantaneous, complete transmission of FRAGOs occurred by virtue of CVCC system design.

Two possibilities could explain the low number of reports relayed in the Baseline condition. The first is a matter of relevance. Company XOs/commanders might not have relayed INTEL reports that they did not consider relevant to their subordinates. The second is a matter of priority. When the company was in contact, INTELs that did not bear on the immediate situation would not have been relayed, in deference to more critical tactical information.

Consistency of relayed INTEL. 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 relayed INTEL reports to a template corresponding to the scripted report, consistency was defined as the percentage of elements accurately relayed, with higher values constituting better performance. As with FRAGOs, the consistency of relayed information was perfect in the CVCC condition, with scores fixed at 100%. Among Baseline units, only eight relayed INTEL reports were scorable. Only in Stage 1 was more than one INTEL report available; during that stage consistency scores averaged 60%. These data were not subjected to inferential analysis. The limited observations indicate substantial loss or distortion of information occurs when INTEL reports are relayed by voice radio.

Summary of key data. The small sample sizes in the Baseline condition and the fixed ("perfect") values for CVCC units precluded statements about statistical probabilities. However, the instantaneous, perfectly consistent nature of digitally transmitted INTEL reports afforded distinct advantages to unit and vehicle commanders using CVCC equipment. These advantages ensured maximum dissemination of intelligence information without degradation of quality or currency. On the other hand, Baseline INTEL reports were seldom relayed, and those that were relayed suffered dangerous loss or distortion of information. Clearly the CVCC capabilities enhanced the battalion's distribution of up-to-date information about enemy activities.

Receive and Transmit Friendly Troop Information

Hypothesis: 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 task focused on the time spent communicating about the unit's activities and status, and on the timeliness of reporting key battle milestones. Table 16 provides a summary of data for this hypothesis.

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-playing support staff member) transmission of a SITREP on a company net until reception of the company SITREP was acknowledged by the TOC. The primary processing time involved was the platoon leader's transmission time and the company XO's relay time. Relaying occurred by voice in the Baseline condition and by digital relay in the CVCC condition. Only SITREPs which were originated at the platoon level and relayed to the TOC were analyzed. Shorter values for this measure were associated with faster transmission and therefore represented better performance.

Table 16 summarizes mean data for this measure. Only in Stage 1 did both conditions generate a sizable number of throughput values. There was a noticeable trend in favor of CVCC units in Stage 1, with Baseline participants taking more than half again as long to transmit SITREPs full net. Due to the small sample sizes for the CVCC condition, no ANOVA was performed on these data. The small sample sizes indicate that the CVCC system's automated logistics reporting reduced the need for participants to send SITREPs.

Table 16

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

Measure	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)	1.75 (1.43) n=5	3.05 (2.84) n=52	-- n=0	2.61 (2.16) n=32	6.22 (4.56) n=2	2.24 (1.72) n=25
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	.38 (.26) n=13	.40 (.43) n=15
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.

The obtained values for this measure were influenced by the difference in the way that SITREPs were compiled by participants in the two conditions. In both conditions, company XOs were responsible for compiling company SITREPs and submitting them to the TOC. When SITREPs were required in the Baseline condition, the XO usually would request the information from the platoon leaders, then compile the aggregate information and transmit the report. These events, and the linkage between platoon and company SITREPs, were easily identified in playbacks to support Baseline data reduction. In the CVCC condition, the SAFOR automatically generated digital platoon SITREPs at computer-controlled times. However, the digital platoon SITREPs were not routinely relayed to the TOC. Rather, the XO could easily generate a company SITREP using the information (location and status) displayed on his CCD, without having to query the platoons. Hence, the DCA routine could not establish a clear link between platoon and company SITREPs. The seven reported SITREPS in the CVCC condition represent platoon SITREPs that were relayed "as is," but they painted only a small part of the reporting picture for CVCC units.

Mean duration of voice radio transmissions between the battalion TOC and the battalion commander or S3. This measure was designed to characterize the typical time which members of the battalion command group spent coordinating with each other by voice radio. Named reports (e.g., SPOT, SITREP) were excluded, leaving "other" transmissions primarily including coordination, analysis, and other general information-sharing activities between the commander, S3, and TOC personnel. The total elapsed time required to complete each exchange was computed from playback information. In general, shorter transmission times were desirable.

The mean durations (see Table 16) 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. However, Baseline participants engaged in substantially more voice radio exchanges than CVCC participants in Stages 1 and 2, outnumbering the CVCC participants at least three- to four-fold. The apparent volume differences between stages were most likely related to the scripted length of each stage, Stage 1 being longest and Stage 3 being shortest. The disappearance of the volume difference between conditions in Stage 3 can be attributed to two factors. First, these data were generated at the vehicle level and the two Baseline units failing to complete Stage 3 were excluded from this analysis, reducing the number of vehicles involved. Second, there was no brigade FRAGO in Stage 3, in contrast to Stages 1 and 2. The analysis and discussion of the brigade FRAGOs may have substantially contributed to the volume of traffic in Stages 1 and 2.

In short, CVCC unit and vehicle commanders coordinated by voice radio much less frequently than their Baseline counterparts, but the length of their individual voice exchanges was comparable. On balance, the CVCC system reduced the amount of voice radio traffic in this category by more than 8 minutes in Stage 1 and almost five minutes in Stage 2.

<u>Delay between observed PL/LD crossing and reported crossing</u>. 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 16) 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 POSNAV features gave the battalion commander and his staff the ability to monitor companies' locations in real time.

<u>Delay between observed arrival and reporting set at BP</u>. 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 (Table 16) showed a sizable advantage for the CVCC condition in Stages 1 and 2. Neither of the main effects nor the interaction was significant. 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. 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. The most noteworthy point is that the CVCC capabilities reduced the need for reporting a unit's status and location. The POSNAV features and the automated logistics reporting capabilities provided a readily-accessible, up-to-date profile. One of the most common CVCC participants' comments 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. Also noteworthy was the reduced need for members of the CVCC command group to coordinate by voice radio. All in all, the CVCC system clearly enhanced the dissemination of friendly unit information.

Manage Means of Communicating Information

Hypothesis: 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 task derive from two measures: the average length and the number of voice transmissions. The latter measure was developed during data analysis to provide additional explanatory power. Summary performance data are presented in Table 17.

Average length of voice radio transmissions. This measure was designed to provide a convenient indicator of the average voice transmission duration. 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 meaningless "clicking" events 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 3 and 5 seconds, the duration of voice transmissions (Table 17) did not differ significantly as a function of conditions, stages, or their interaction. Further, 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 participants' behavior when they communicated by voice.

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. These data 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 all commanders participating in the evaluation.

Total number of voice transmissions. Not planned as part of the original set of evaluation measures, frequency of voice radio transmissions became a parameter of interest as the data for length of voice transmission emerged. As with the preceding measure, a transmission was defined by the keying of a microphone, with events less than 1 second and greater than 30 seconds being ignored. By no means was a transmission synonymous with a complete message or report. 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.

The data for this measure appear in Table 17, 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, $F(1, 19) = 33.52$, $p < .001$). In addition, a significant stage effect was found for all nets except C Company command (e.g., for battalion command net, $F(2, 29) = 11.74$, $p < .001$). The condition by stage interaction was significant for the battalion command, battalion O&I, and C Company networks (e.g., for battalion command net, $F(2, 29) = 3.35$, $p = .049$). 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 14 and 15). Across all networks the reduction factors ranged from 20% to 70%, with the largest reductions appearing 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.

Table 17

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

Measure	Stage 1 CVCC $n=6$	Stage 1 Baseline $n=6$	Stage 2 CVCC $n=6$	Stage 2 Baseline $n=5$	Stage 3 CVCC $n=6$	Stage 3 Baseline $n=5$
Average voice transmission duration (seconds)						
Bn cmd net	4.30 (.54)	4.40 (.68)	4.21 (.60)	4.41 (.45)	3.93 (.30)	4.14 (.46)
Bn O&I net	3.58 (.35)	3.80 (.41)	3.23 (.55)	3.59 (.61)	3.19 (.33)	3.40 (.32)
A Co cmd net	3.83 (.58)	3.82 (.52)	4.06 (.88)	4.08 (.41)	4.05 (.45)	4.25 (.62)
B Co cmd net	3.65 (.56)	4.02 (.87)	3.58 (.37)	3.98 (.65)	3.59 (.49)	3.78 (.63)
C Co cmd net	3.20 (.19)	4.09 (.53)	3.42 (.20)	4.09 (.44)	3.28 (.19)	4.20 (.27)
Number of voice transmissions						
Bn Cmd net	281.17 (48.39)	501.00 (120.80)	169.00 (48.03)	354.00 (97.92)	227.17 (65.80)	282.80 (58.37)
Bn O&I net	89.33 (34.64)	278.50 (69.19)	50.83 (35.27)	168.00 (66.31)	77.83 (59.48)	133.40 (61.91)
A Co cmd net	154.00 (66.88)	249.00 (66.87)	81.33 (38.05)	169.00 (23.40)	74.17 (38.44)	132.20 (63.43)
B Co cmd net	152.50 (25.59)	225.50 (57.61)	97.33 (21.64)	178.40 (42.72)	113.00 (33.77)	161.00 (44.96)
C Co cmd net	89.50 (24.92)	231.00 (50.22)	83.17 (14.52)	168.00 (44.99)	116.00 (35.77)	158.00 (50.90)

Note. Standard deviations appear in parentheses below the means.

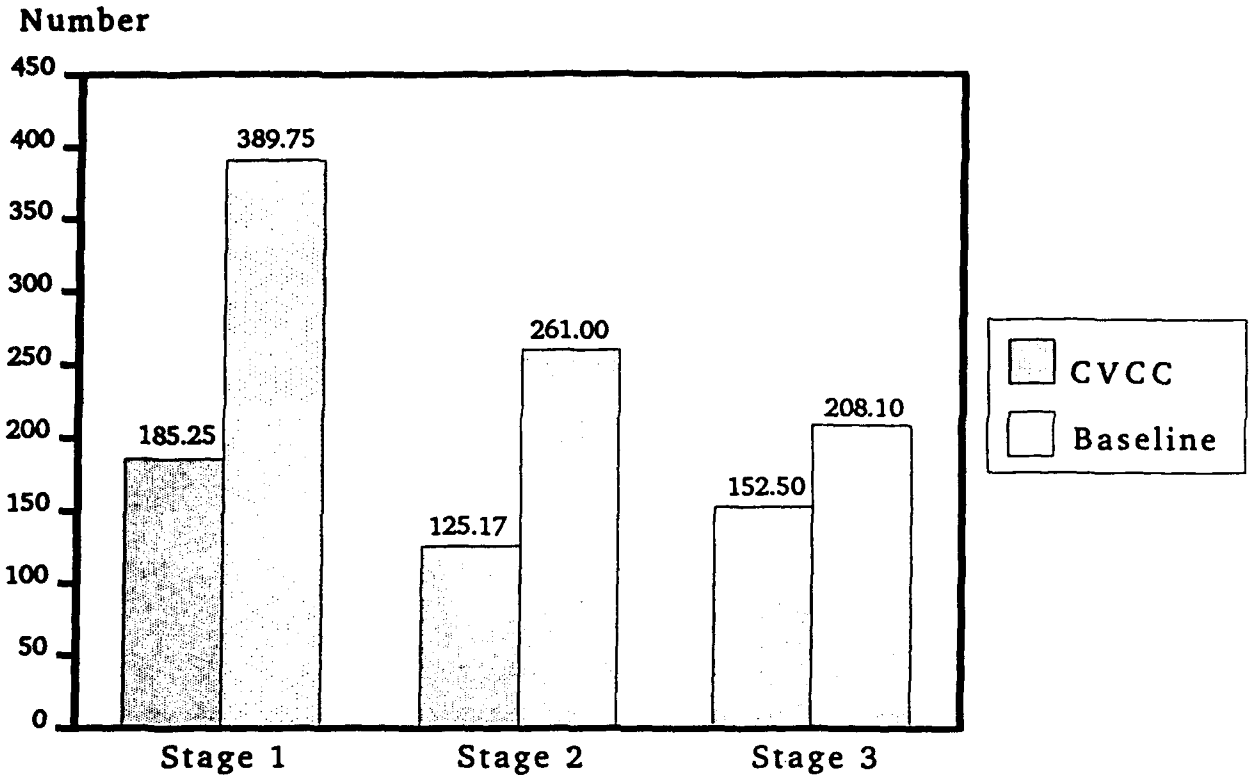

Figure 14. Volume of voice radio transmissions on battalion nets (average per net).

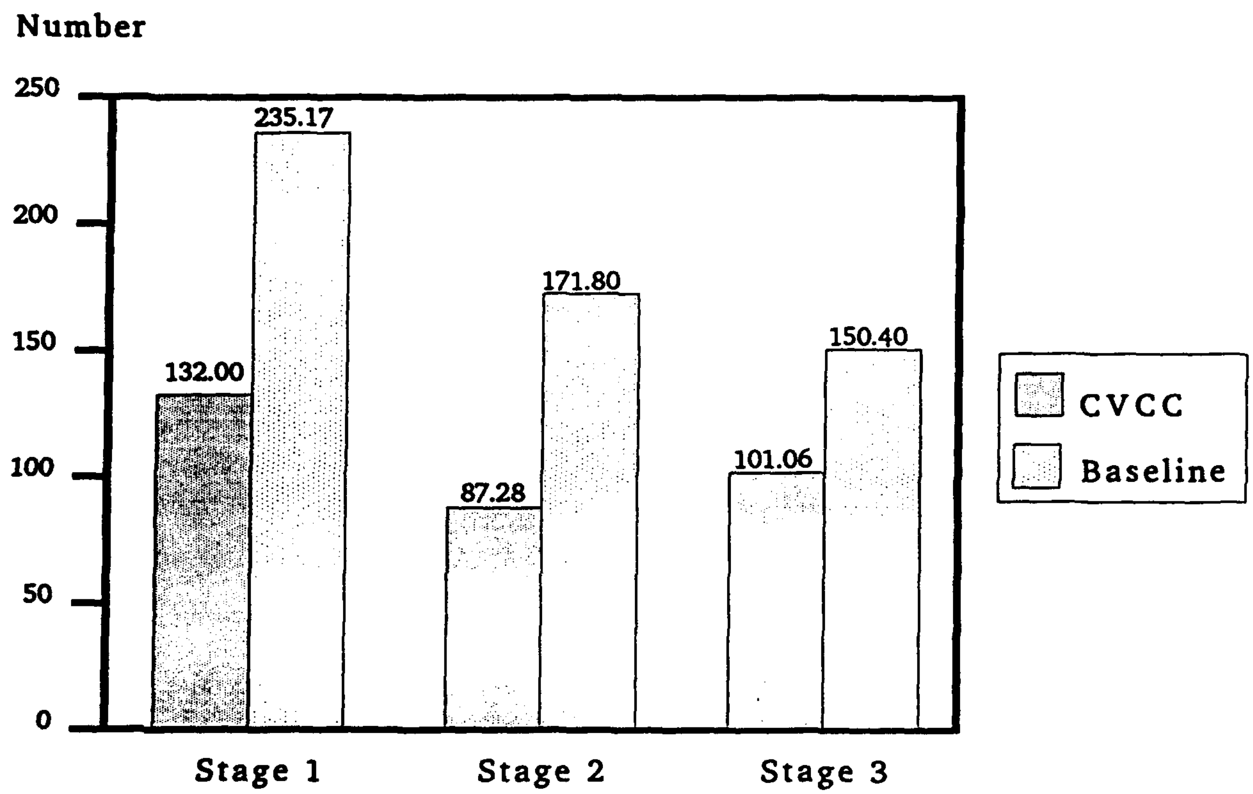

Figure 15. Volume of voice radio transmissions on company nets (average per net).

The differences between stages can be explained by a variety of factors, including the nature of the missions (see earlier discussion in the Receive and Transmit Friendly Troop Information subsection) and variable stage lengths. Actual mission execution times varied between stages, being longest in Stage 1 and shortest in Stage 3.

Summary of key data. Taken together, these results document the value of the CVCC's digital communications capabilities. When the data for number and average length of voice transmissions are combined, the operational impact becomes especially important. In Stage 1, for example, Baseline commanders used the battalion level radio nets for an average of 54.38 minutes, compared to 25.48 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: 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 task 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 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.

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 considered the number of BLUFOR vehicles lost. 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. whereas all but one Baseline battalion successfully massed fires. 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 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.

Summary of key data. No significant differences between CVCC and Baseline conditions were found in any of the four measures supporting this task. 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: 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. A copy of the questionnaire can be found in Appendix A. Table 18 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 18 were not appropriate for units that did not complete Stage 3, and 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. 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 (e.g., 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 18). The effect of condition was not significant. 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.

Overall, Baseline participants reported significantly higher confidence in their responses than CVCC groups ($F(1, 90) = 5.70$, $p = .019$).

Table 18

Mean Performance Data for Assess Situation Hypothesis, by Condition

Measure	CVCC	Baseline
Number of vehicles destroyed (percent correct)		
OPFOR tanks		
Battalion	50.09 (32.55) n=11	40.17 (26.52) n=12
Company	27.57 (23.19) n=35	44.17 (34.19) n=36
OPFOR BMPs		
Battalion	48.09 (33.51) n=11	39.11 (33.10) n=12
Company	46.03 (29.64) n=35	37.31 (30.91) n=36
Own tanks		
Battalion	38.09 (25.61) n=11	27.83 (12.66) n=12
Company	48.20 (34.94) n=35	49.11 (43.31) n=36
Determination whether own unit destroyed any OPFOR during delay (percent correct)		
Battalion	90.91 n=11	75.00 n=8
Company	63.89 n=36	69.57 n=23
Distance from initial to subsequent BPs (deviation in km)		
Battalion	1.02 (1.09) n=11	2.64 (3.77) n=8
Company	1.21 (1.52) n=35	1.53 (1.51) n=24

Note. Standard deviations appear in parentheses below the means.

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.

Confidence ratings for these responses differed only slightly between conditions. Baseline participants registered more confidence in their responses, but no significant effect of condition was found.

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.

Confidence ratings reported in conjunction with this item 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 ($F(1, 90) = 38.46$, $p < .001$).

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 than Baseline participants, but the reverse was evident at the company echelon. Chi-square tests showed there was no significant difference between condition at either echelon.

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 18, 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.

Confidence ratings for this item did not differ significantly as a function of condition or echelon.

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.

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 tasks under the Command and Control BOS. Table 19 summarizes the major findings for this BOS. Overall, the data firmly exemplified the beneficial CVCC contributions to the accomplishment of C3 tasks 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 lack of inferential tests in those cases by no means diminishes the operational importance of the advantages.

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 CVCC-equipped 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.

Table 19

Summary of Major Command and Control BOS Findings

Task	CVCC Advantages
Receive and transmit mission	- More rapid dissemination of FRAGOs - Perfect consistency of info relayed to subordinates - Much less time spent clarifying FRAGOs
Receive and transmit enemy info	- Maximum dissemination of INTEL info - Perfect consistency of info relayed to subordinates
Receive and transmit friendly troop info	- Fewer voice transmissions among command group for coordination - Reduced need to report unit location and status
Manage means of communicating information	- Fewer voice radio transmissions - Reduced voice radio signature - Better accessibility on command networks

The perfect completeness and consistency of the digital FRAGOs and INTEL reports were powerful features of the CVCC system. 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 consistency and the ability to modify transmissions generated elsewhere, a fruitful topic for future research on automated C3.

The CVCC's digital capabilities, including no doubt the automated reporting of logistics status, reduced the voice radio coordination demands on members of the command group. In addition, the 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 had two important benefits from a combat operations perspective. First, it lessened the unit's electronic signature, thereby decreasing susceptibility to detection by the enemy and to electronic countermeasure intervention. Second, it made the radio networks more accessible for critical command and control voice transmissions. Participants 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. Their comments indicated they were more aware of their subordinate units' status than Baseline unit commanders. 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 tasks. The next subsection addresses the results bearing on the contributions of the CVCC system to the execution of battlefield maneuver tasks.

Maneuver BOS

Issue: Does the CVCC system enhance the Maneuver BOS?

Given the CVCC system's POSNAV and CITV capabilities, the expected impacts on maneuvering and engaging the enemy on the battlefield are extensive. Several hypotheses organize the data related to the Maneuver BOS, according to the following BOS-based tasks: (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 tasks.

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: 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 20. The results for each measure are discussed in sequence, then key data are summarized at the end of the subsection.

Table 20

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

Measure	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 (min)	NA	NA	19.43 (4.56) n=6	24.84 (5.79) n=6	NA	NA
Time to reach objectives (min)	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.

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. In other words, the ability to control the battalion's movement so as to maintain contact yet limit exposure to enemy fire was seen as an advantage. 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 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 meters. 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.

Means for this measure are displayed in Figure 16. 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 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.

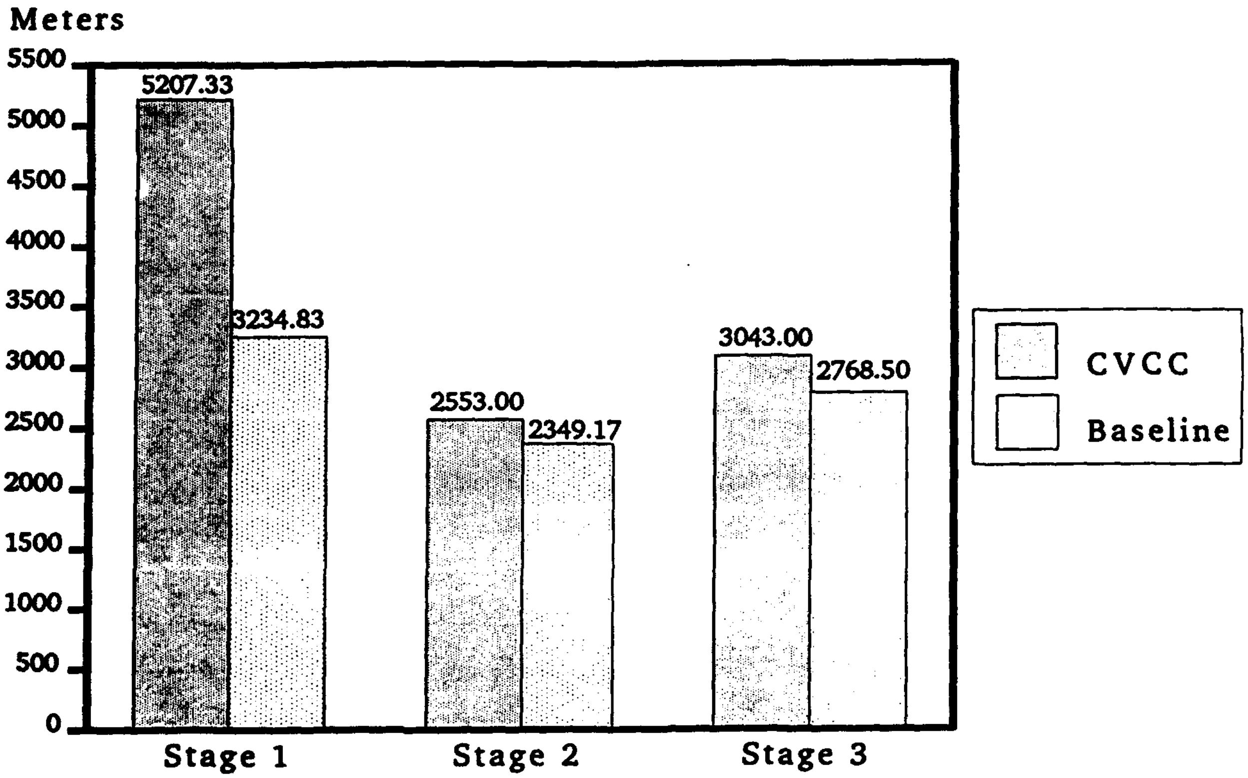

Figure 16. Mean end-of-stage distance between BLUFOR and OPFOR center of mass.

These results show that the CVCC-equipped battalions did a better job of controlling their movement while delaying, resulting in less risk of receiving hostile fire. In the counterattack mission they were able to keep the enemy force at a greater stand-off distance.

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 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 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 = 2.36, df = 7, p < .05). The CVCC units' faster establishment of readiness to execute the mission was no doubt largely the result of the more rapid transmission of the FRAGO (discussed earlier in the Command and Control BOS subsection).

Considering the nature of ideal performance for this measure, it might be preferable to redefine it as a difference or discrepancy score reflecting how close the unit comes to "hitting the bull's eye."

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 modestly shorter in the CVCC condition. 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 ($\underline{t}$ = 2.12, $\underline{df}$ = 10, $\underline{p}$ < .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 POSNAV capabilities.

Range to OPFOR at displacement (Stages 1 and 3 only). The unit and vehicle commanders were given standard instructions 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. For the conditions of this evaluation, longer distances generally corresponded to better performance.

In both delay stages, 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.

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.

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. Following initial intervisibility with an enemy vehicle, a count of all intervisible enemy vehicles was obtained for each manned vehicle every 30 sec until the first main gun firing by the company. 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 20 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 ($F(2, 2240) = 8.09$, $p < .001$). 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 were more inclined to move around the battlefield during delay missions. Further, they were more likely to be left behind when the companies displaced back from their battle positions, compared to company commanders and XOs, sometimes leaving them in closer contact with the enemy. Indeed, the exposure index was especially elevated for battalion echelon vehicles during delay missions.

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 provided limited support to 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, indicating they were better able to control their movement during delay operations and to keep the enemy at safer stand-off 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: The CVCC unit's ability to navigate on the battlefield was expected to be significantly better than the Baseline units.

Table 21 presents the summary data (means and standard deviations) associated with this hypothesis.

Distance travelled. Because of the CVCC's POSNAV 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.

Table 21 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.

Table 21

Mean Performance Data for Navigate Hypothesis, by Stage and Condition

Measure	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 exercise (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	51.29 (1.71) n=5	48.24 (3.88) n=4

Note. Standard deviations appear in parentheses below the means.

Several factors are important in comparing the CVCC and Baseline conditions with respect to these data. CVCC-equipped battalions frequently chose to withdraw further 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 POSNAV'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.

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.

Fuel consumption data are found in Table 21. 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 exercise. 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.

The means for this measure appear in Figure 17. In Stages 1 and 2, the battalions using the CVCC system took less time for mission completion, but the advantage disappeared in Stage 3. The effect of condition was significant ($F(1, 27) = 7.08$, $p = .013$), as was the effect of stage ($F(2, 27) = 54.96$, $p < .001$).

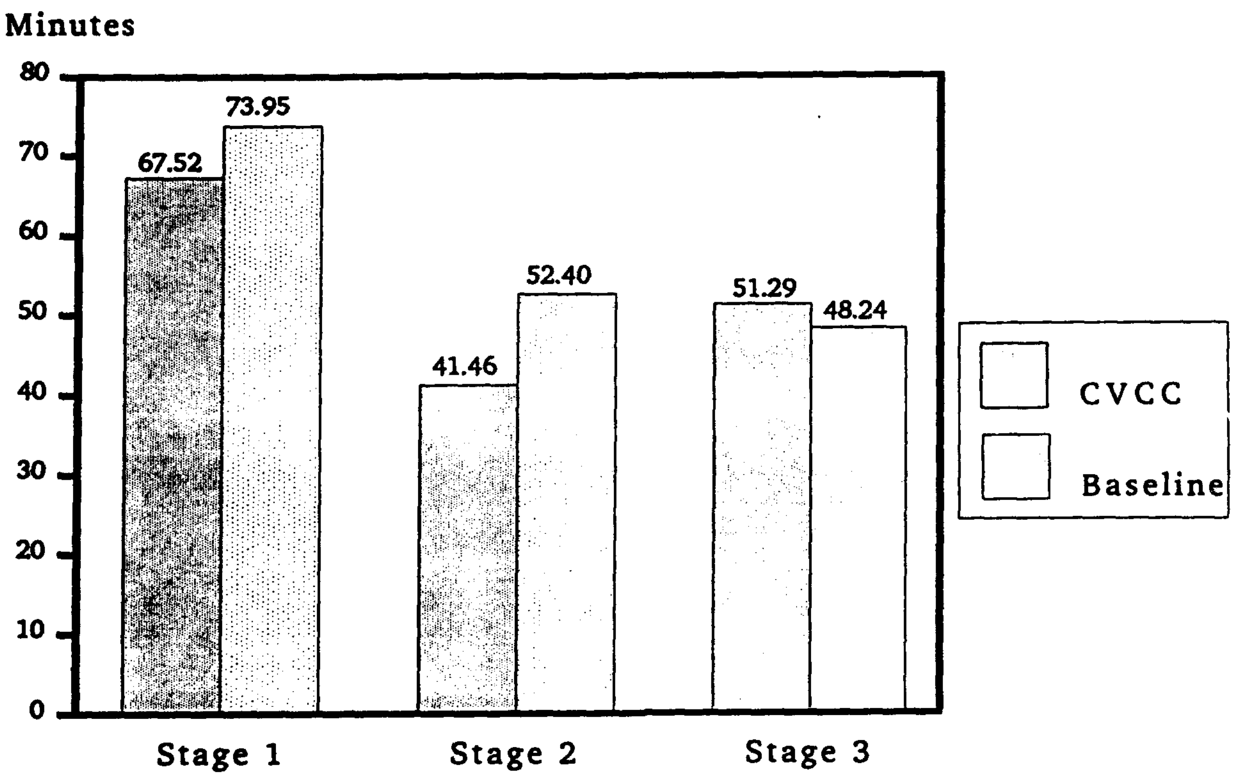

Figure 17. Mean time to complete Stages 1, 2, and 3.

The condition by stage interaction was also significant ($F(2, 27) = 3.60$, $p = .041$). The differences between stages were undoubtedly due to variations in tactical events built into the test scenario.

The apparent disappearance of the CVCC advantage in Stage 3 is misleading. 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 were excluded from the analysis of Stage 3 completion times, since their Stage 3 values were indeterminate. 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.

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

Summary of key data. The results provided modest support of the hypothesis that navigation in battalion operations would benefit from the CVCC system's POSNAV capabilities. Battle Master observations indicated that CVCC crews much more frequently moved 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 was the fact that CVCC participants, especially drivers, overwhelmingly commented that POSNAV was a great advantage. One CVCC battalion commander observed that reduced fear of getting lost was a great psychological 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 POSNAV 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.

Process Direct Fire Targets

Hypothesis: 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 22.

Table 22

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

Measure	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 (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.

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 appear in Figure 18. Overall, the mean ranges for CVCC-equipped vehicles exceeded those for Baseline vehicles. The condition effect was significant ($\underline{F}(1, 240) = 5.50$, $\underline{p} = .02$). In addition, the effect of stage was significant ($\underline{F}(2, 240) = 18.56$, $\underline{p} < .001$), as was the condition by stage interaction ($\underline{F}(2, 240) = 3.53$, $\underline{p} = .031$). The effect of echelon was not significant. The significant stage effect reflected primarily the greater ranges occurring in Stage 1, regardless of condition, most likely the result of longer line-of-sight conditions in the terrain setting for Stage 1. The CVCC vehicles enjoyed a greater advantage in Stage 3 than in Stages 1 or 2. The reason 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.

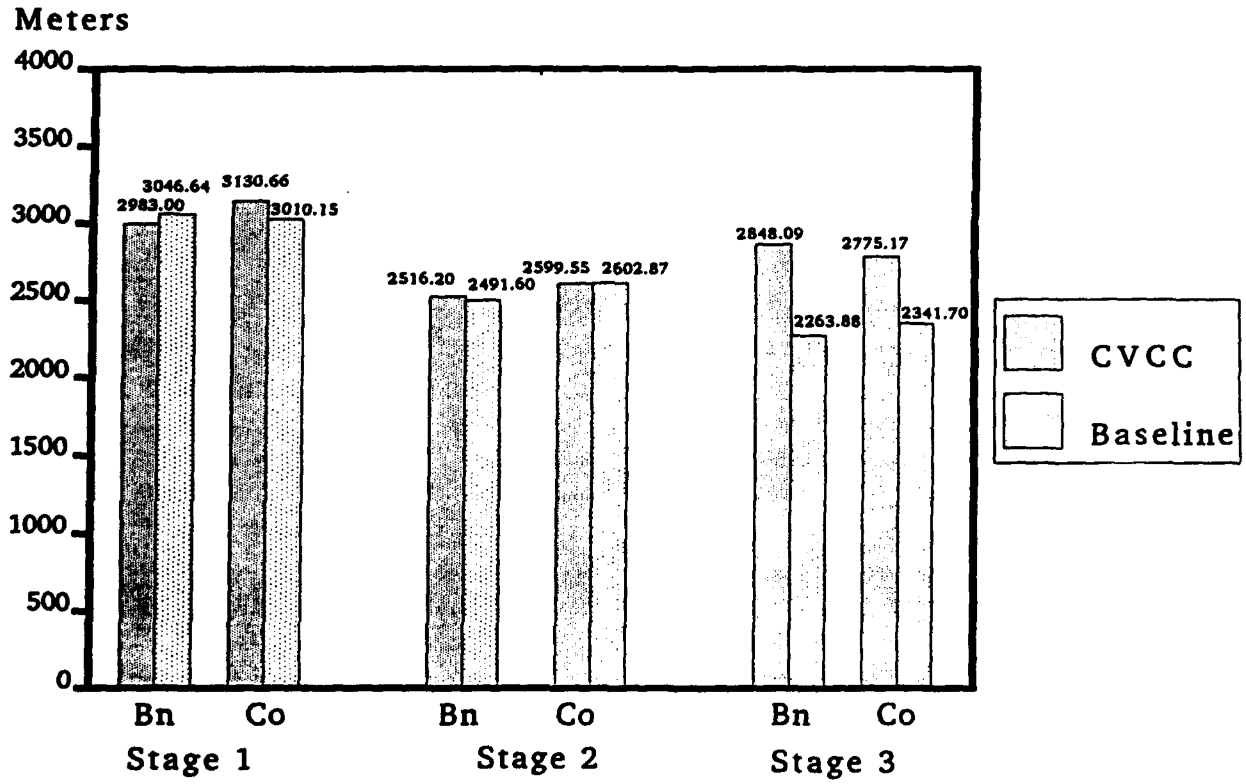

Figure 18. Maximum lase range means.

<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 by the commander and the gunner were compared to select the shorter interval. For each stage the average per vehicle was computed. 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.

Mean data for this measure are displayed in Figure 19. 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.

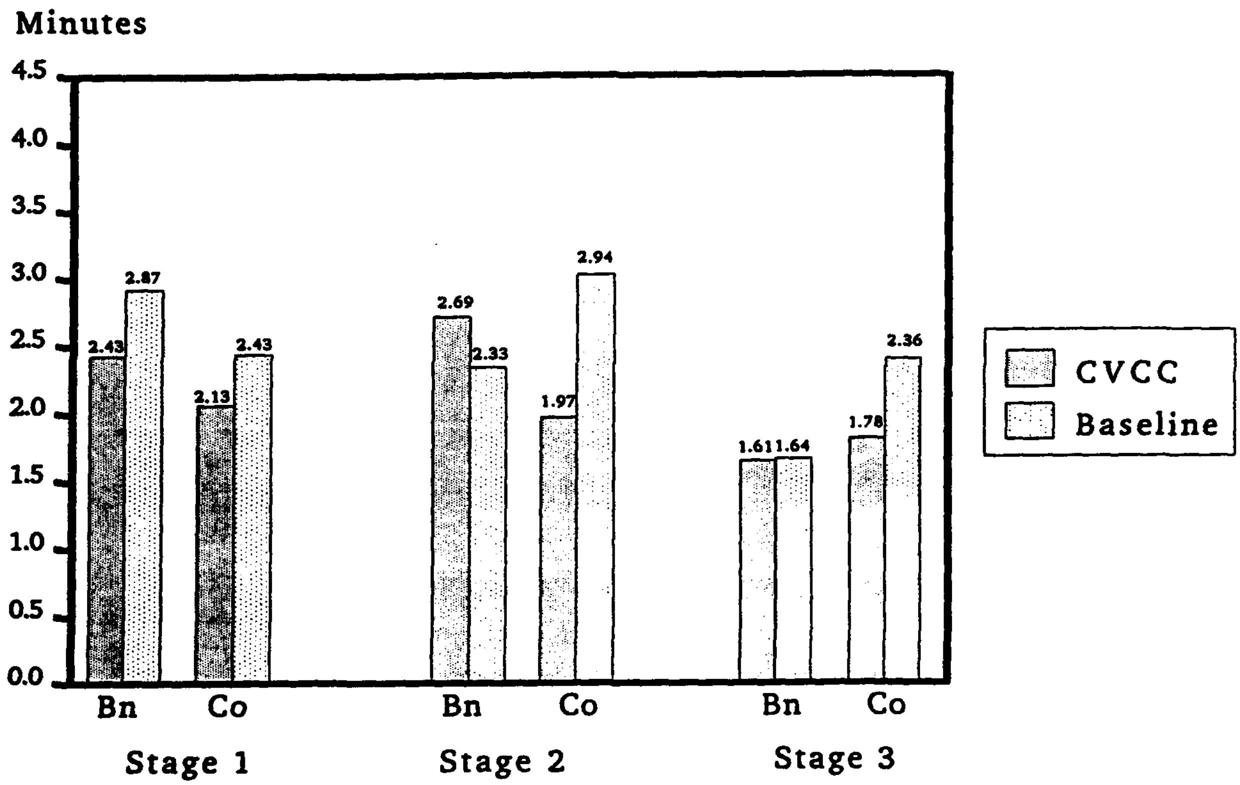

Figure 19. Mean time to acquire targets.

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 3 were less broken or cluttered, so that early visual detection of moving enemy vehicles was more likely.

Time between lases to different targets. As an index of speed in acquiring sequential targets, this measure quantified the time interval separating successive lases to different enemy vehicles. 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. 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 22 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.

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. 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 22. 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 of the 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 were undoubtedly due to the hunter-killer advantage of the CITV, enabling the vehicle commander to search the battlefield in thermal mode simultaneously with the gunner.

Engage Direct Fire Targets

Hypothesis: 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 23 contains summary data (means and standard deviations) for the measures supporting this hypothesis.

Table 23

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

Measure	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
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 NA 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

Note: Standard deviations appear in parentheses below the means.

(table continues)

Table 23

Mean Performance Data for Engage Direct Fire Targets Hypothesis, by Stage and Condition (continued)

Measure	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	.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	.08 (.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 23) 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. 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 23, 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.

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. 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 23. 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 ($F(2, 27) = 7.61$, $p = .002$), in line with the lower ratios during Stage 2 which apparently reflected the numerical superiority of the BLUFOR in the offensively oriented counterattack.

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 23) 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.

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 23) 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 23. Although consistently fewer manned tanks in the CVCC condition sustained killing hits, the 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., POSNAV, 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 (i.e., fratricide hits were excluded). 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 23 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 (mean target hit range), the only difference being the end-point (killing versus hitting a target). The data for the measure (see Table 23) 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. No plausible explanation for the significant condition by echelon interaction is readily apparent, though it is consistent with the trends 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 23. 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 23 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 Figure 20, where an overall difference in favor of CVCC-equipped vehicles can be seen. The effect of condition was

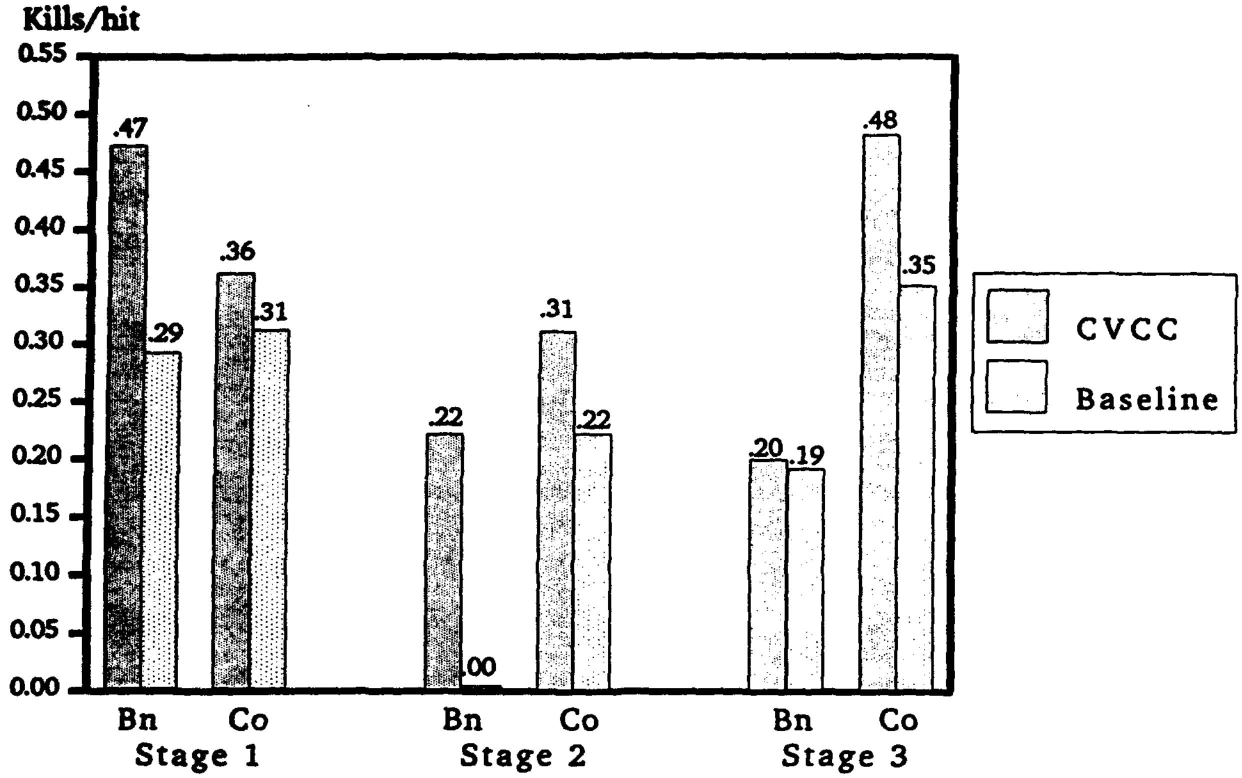

Figure 20. Mean kills per hit ratio for manned vehicles.

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 24. The Baseline battalions consistently killed more of the enemy in the 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).

Table 24

Mean Enemy Kills in Primary Engagement Areas, by Condition

Measure	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

Summary of key data. Only one of the measures for this task supported the hypothesis that the CVCC capabilities would benefit the direct fire engagement of enemy targets. The kills/hit ratio was significantly higher for CVCC-equipped vehicles, indicating greater effectiveness for those rounds hitting targets. A plausible explanation for this is to postulate better round selection among the CVCC crews, which may have been possible due to the earlier target acquisition performance discussed in the preceding subsection. In effect, CVCC crews had more time to make the decision to fire and to select the type of round most appropriate for the target type and range. In general, the overall lack of significant condition effects for the measures quantifying target engagement performance was not surprising. No participating crews served below the level of company XO, and company and battalion leaders typically focused on C3 responsibilities rather than directly engaging the enemy. The equivalence of firing activity between the CVCC and Baseline conditions indicated that, at the company and battalion echelons, the presence of the CVCC equipment did not by itself distract the crews from performing their normal combat tasks.

Control Terrain

Hypothesis: 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 on-line 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 (standard deviation, 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 task 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 when engaging direct fire targets.

Summary of Findings

The measures analyzed under this BOS yielded support for the expected beneficial impact of the CVCC system on battlefield maneuver tasks. There was clear evidence in four of the five tasks 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 POSNAV capabilities, which 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 assessment of battalion performance compared to the assessment of isolated crews.

The higher kills/hit ratios for CVCC-equipped crews have not been reported in earlier research, but they appear to indicate better round selection. The faster target acquisition seen in the CVCC condition may have given the crews more time to make the decision to fire and to select the type of round most appropriate for the target type and range.

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 performing their normal combat tasks. This reinforces similar results reported by Leibrecht et al. (1992).

The comparability 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 tasks. 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 Baseline company commanders and XOs may have rivalled the information reaching their CVCC counterparts. 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 inolvement 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. Performance information from an alternative allocation of crews, which included a fully manned platoon, is presented in Lickteig (in preparation).

Table 25

Summary of Major Maneuver BOS Findings

Task	CVCC Advantages
Move on Surface	- Safer end-of-mission stand-off ranges in all stages - 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	- Enhanced kills/hit ratios in all stages

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 following subordinate units and often admitted doing so in the test scenario. This circumstance would largely explain the rare misorientation and straying out-of-sector which occurred in this evaluation.

Fire Support BOS

Issue: 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 Conduct Surface Attack 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.

Conduct Surface Attack

Hypothesis: The CVCC units' ability to conduct surface attack by 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. This computational process yielded distance measurements of the discrepancies between actual and reported locations. The smaller the discrepancy, the better the accuracy.

Complete data for this measure appear in Table C-5. As seen in Figure 21, during Stages 1 and 2 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 ($F(1, 70) = 22.10$, $p < .001$). The effect of stage was also significant ($F(2, 70) = 4.41$, $p = .016$), as was the condition by stage interaction ($F(2, 70)$, $p = .001$). The poorer accuracy seen in Stage 2 for both conditions is most likely the result of contacting and engaging the enemy while on the move during the counterattack. Obtaining precise location information is more difficult during tactical movement, although the CVCC capabilities prevented Stage 2 accuracy from degrading greatly when compared with Stage 1. The apparent trend in Stage 3 indicating Baseline accuracy better than CVCC is puzzling, especially given the tactical similarity between Stages 1 and 3. Curiously, the "best" accuracy scores for both conditions occurred in Stage 3, suggesting perhaps a warm-up or practice effect. Considering the small sample size (n

= 3) for the Baseline condition in Stage 3, caution is in order in interpreting Stage 3 differences between Baseline and CVCC conditions.

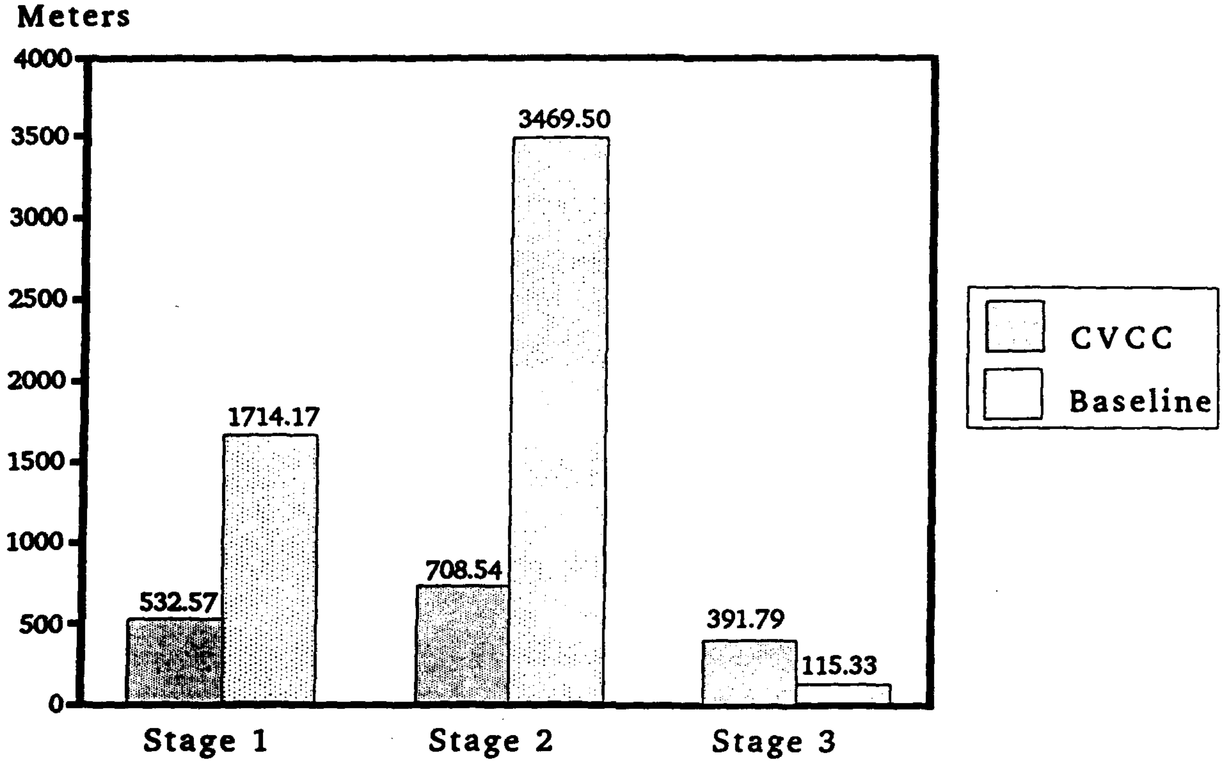

Figure 21. Mean accuracy scores for enemy locations contained in CFF reports.

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 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 C-5). 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.

Table C-5 presents complete descriptive data for this measure. Figure 22 displays the means, showing a consistently greater proportion of CFFs containing correct enemy vehicle types in the CVCC condition. The performance advantage

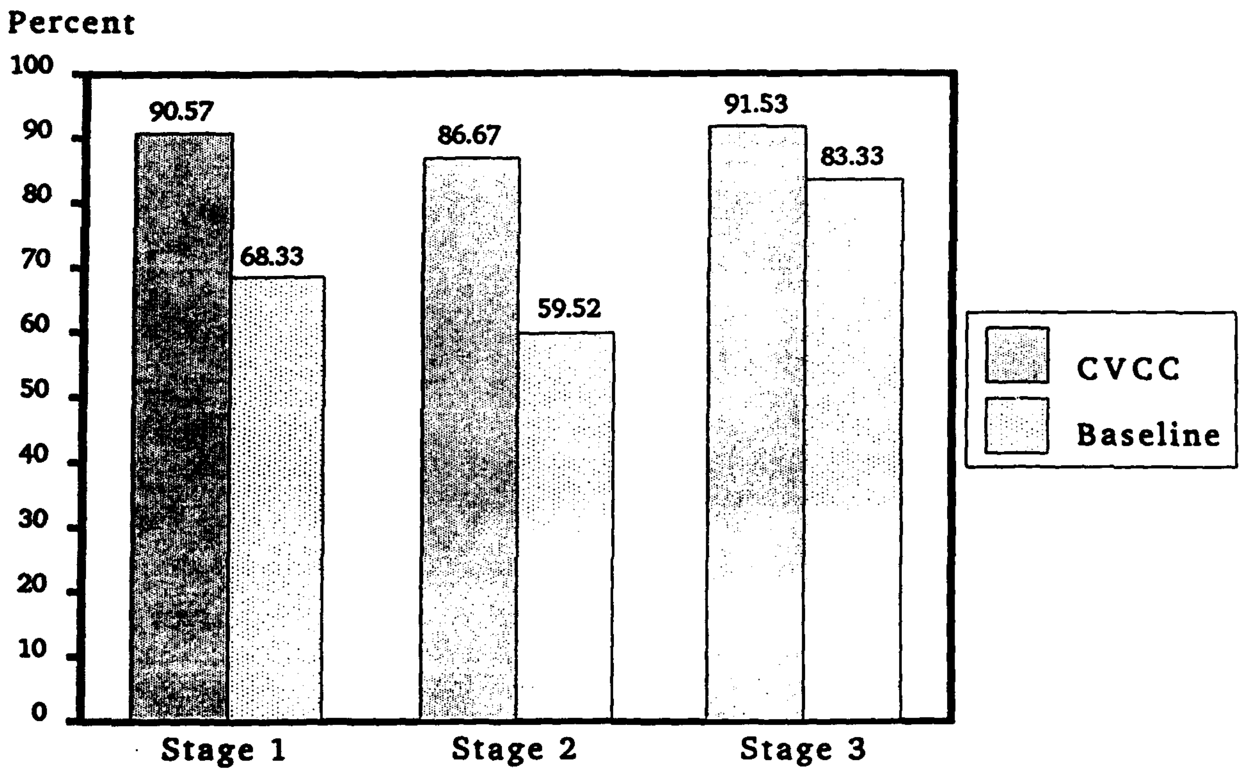

Figure 22. Mean percentage of CFF reports correctly identifying vehicle type.

of the CVCC system was significant, as evidenced by the significant effect of condition ($F(1, 72) = 8.95$, $p = .004$). Neither the effect of stage nor the condition by stage interaction was significant.

Paralleling the preceding measure, the standard deviations for this measure are smaller for the CVCC condition in all three stages. Although the differences are not dramatic, the consistency of this trend suggests less variability of performance when using the CVCC equipment. This can be expected to contribute to enhanced battlefield effectiveness.

These data establish that the CVCC capabilities increase the overall accuracy and consistency of reporting the type of enemy vehicle in CFF reports.

Summary of Findings

Table 26 summarizes the findings pertaining to the conduct of surface attacks 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 principal, 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 26

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 all stages
# CFFs with complete information	- Greater volume of usable information in all stages

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.

Fully 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 section 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 section on the Intelligence BOS discusses the CVCC's impact on the accuracy of information reported about enemy activities.

Intelligence BOS

Issue: 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: 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 participant-generated CONTACT, SPOT, and SHELL reports, and on the descriptive accuracy of the target identification process reflected in CONTACT and SPOT reports. Table 27 summarizes the data for this hypothesis.

Table 27

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

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Location accuracy (deviation, in meters)						
CONTACT reports	547.4 (677.0) n=30	3752.3 (10570.4) n=15	623.8 (921.7) n=18	1896.0 (2154.7) n=12	355.7 (497.3) n=19	390.1 (630.3) n=6
SPOT reports (observed)	n=	n=	n=	n=	n=	n=
SPOT reports (destroyed)	n=	n=	n=	n=	n=	n=
SHELL reports	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
Percent CONTACT 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
Correctness of SPOT report number and type						
Observed	n=	n=	n=	n=	n=	n=
Destroyed	n=	n=	n=	n=	n=	n=

Note: Standard deviations appear in parentheses below the means.

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 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. The mean deviations for this measure can be found in Table 27. Location accuracy was significantly better among CVCC units than among Baseline units (for condition, $F(1, 94) = 4.48$, $p = .037$). The largest difference between conditions occurred in Stage 1 (see Figure 23), 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.

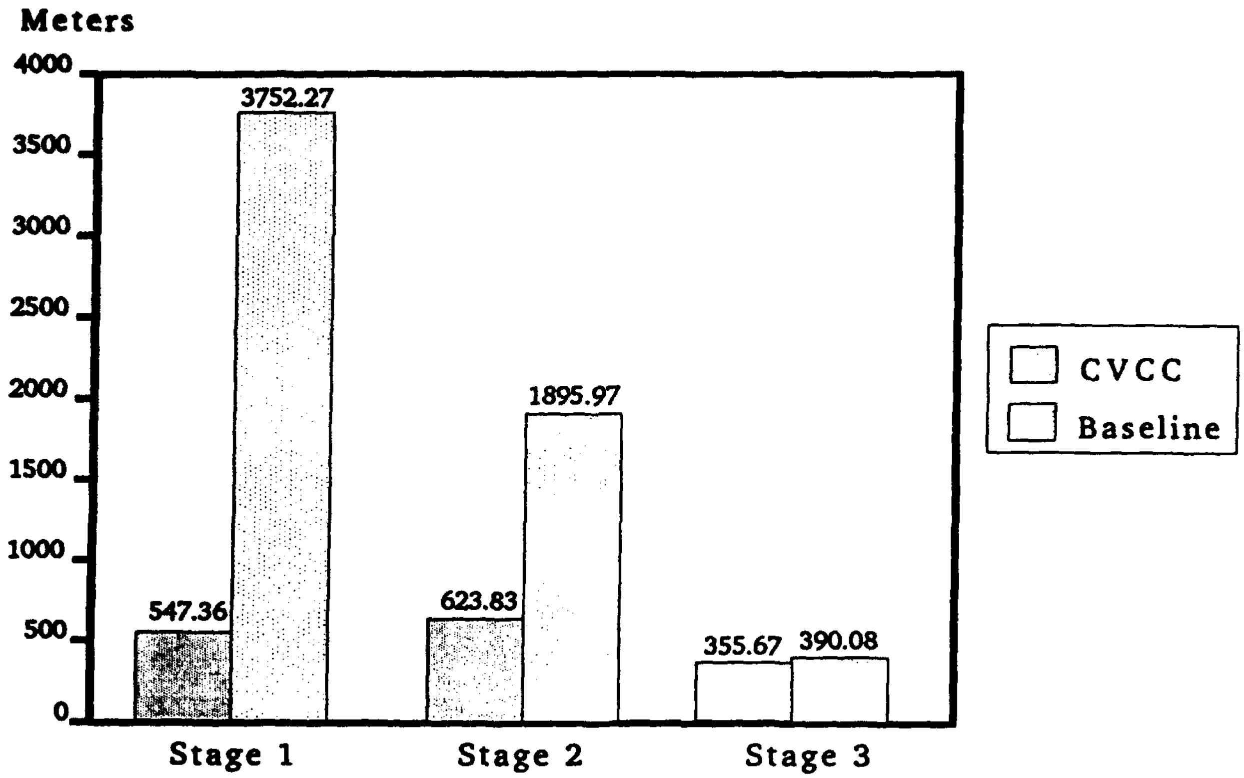

Figure 23. Mean deviation (in meters) of enemy vehicle locations reported in CONTACT reports.

In all three stages, the standard deviations for the CVCC battalions were substantially smaller than those for the Baseline battalions. As discussed earlier in this report, the more consistent performance of the CVCC units is a distinct advantage.

One data point that clearly influenced the data was a Baseline CONTACT report (Stage 1) that was 41,778 meters off. This most likely occurred due to the transposition of grid numbers (e.g., reporting a grid of 456123 as opposed to 123456). While such a mistake would eventually be discovered and corrected as message information was processed, such an event typically involves follow-up transmissions between the originator and other stations on the network to confirm the actual location of the enemy activity. Given the automated reporting features inherent to the CVCC system, analogous events are very unlikely.

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 (Table 27) revealed that CVCC commanders sent substantially more CONTACT reports containing locations. Thus, the CVCC capabilities enabled participants to provide a larger quantity of fully usable enemy information to the TOC staff.

Accuracy of SPOT report locations. As with CONTACT report location accuracy, this measure quantified the 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. 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.

[Note: Data for these measures are to be reanalyzed following DCE data analysis. Supporting tables and discussion to be completed when analysis is complete.]

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 27). In other words, the CVCC's capabilities resulted in a larger quantity of usable enemy information reaching the TOC.

Accuracy of SHELL report locations. 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. Smaller distance values for this measure constitute better accuracy.

As seen in Table 27, 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 LRF to input report locations. In most cases the LRF 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 27, 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.

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 24), 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.

Correctness of SPOT report number and type. 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. This measure was computed separately for the observed and destroyed components of the SPOT report. The computations yielded percentage scores ranging from 0 to 100%, with higher scores representing greater accuracy.

[Note: Data for these measures are to be reanalyzed following analysis of DCE data. Supporting tables, figures, and discussion to be completed when analysis is complete.]

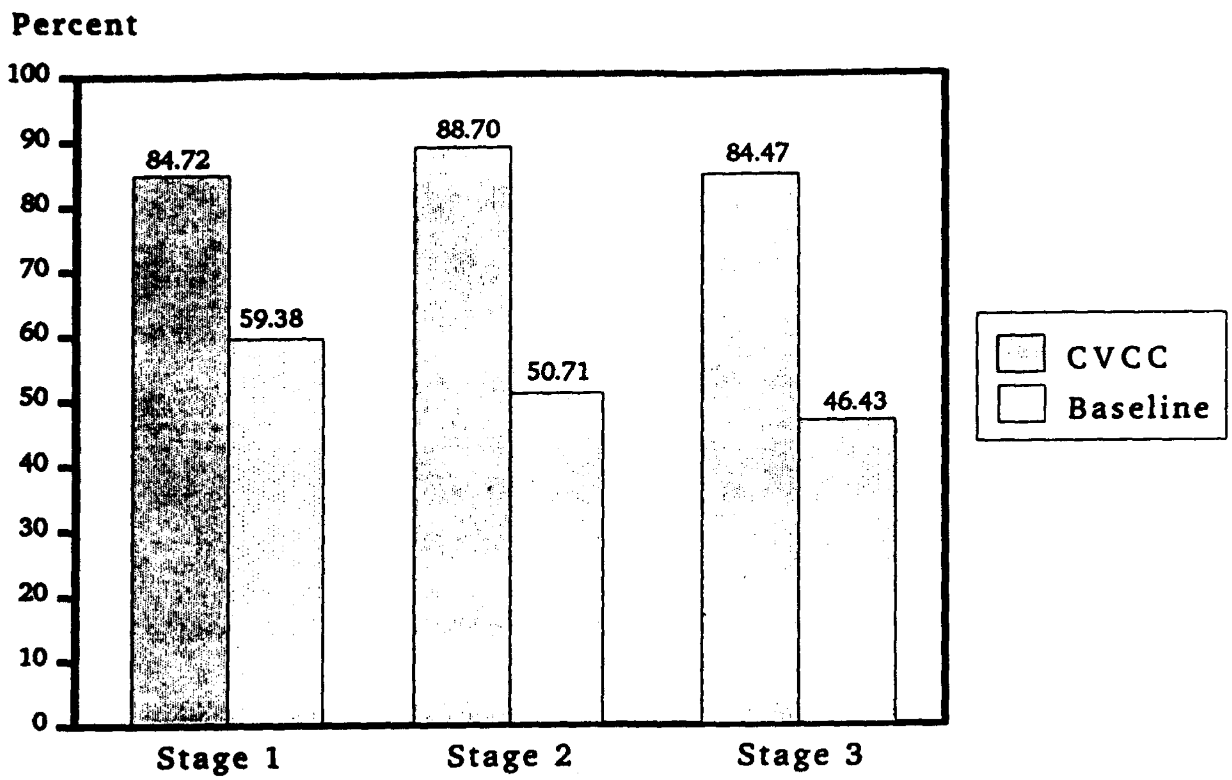

Figure 24. Mean percent of CONTACT reports with correct vehicle type.

Summary of Findings

Table 28 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.

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 LRF, 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 reports (CONTACT, SPOT, and SHELL) 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.

Table 28

Summary of Major Intelligence BOS Findings

Measure	CVCC Advantages
Accuracy of CONTACT report locations	- Better accuracy of enemy locations reported in all stages
Accuracy of SPOT report locations	TBD
% CONTACT reports w/correct type	- Better identification of enemy vehicle type in all stages
Correctness of SPOT report number and type	TBD
# reports with complete info	- Greater volume of usable info for CONTACT, SPOT, and SHELL reports

Across the four BOSs, the major findings of the battalion evaluation highlight the contributions of the CVCC capabilities to the conduct of mounted warfare. For a full account of the evaluation's findings, the reader is encouraged to review the companion reports by Atwood et al. (in preparation) and Meade et al. (in preparation). The following section discusses major lessons learned during the course of the evaluation, addressing both operational and methodological implications.

Lessons Learned

During the course of this evaluation the research staff accumulated observations regarding lessons of value in planning and conducting future research. By and large these observations stemmed from participant feedback, discussions among the research staff, integrated observations during execution of scenarios, and extrapolations from performance data. This section discusses the major lessons learned dealing with operational effectiveness aspects as well as methodological issues. 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 complement one another. Even with digital reporting available, much important combat information is conveyed via voice radio exchanges. Most of the voice-transmitted information 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. From a tactical perspective, the reduced radio signature is important in decreasing the unit's vulnerability to electronic detection and electronic countermeasures. although digital transmissions would somewhat offset the reduction of voice transmissions.

Digital transmissions in the battalion evaluation could not be modified as they were relayed. This characteristic offered perfect 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 desired 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. It reduced their burden in terms of requirements to transmit information about the status of their fuel, ammunition, etc.

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.

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 expressed a firm desire for 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.

Digital transmission capabilities can lead to individual users receiving large numbers of reports, FRAGOs, overlays, etc. 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, such tools 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. In addition, TOC workstations could filter out reports by type of report. Other tools could be developed for future research, such as discrete addressing (discussed in the previous paragraph).

Automated C3 systems can successfully integrate information for users. In the current evaluation, a relatively simple form of integration was implemented: POSNAV icons could be selected to represent units instead of individual vehicles. In addition, TOC workstations could aggregate reports of the same type which met specified timing and location criteria; related reports were clustered together and a single icon represented them on the electronic map. However, the individual reports remained separate. 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

Automated navigation systems such as POSNAV typically have dramatic effects on combat performance, and participants are almost unanimous in praising their capabilities. The positive effects in comparison to conventional means are more subtle at the battalion level than at lower echelons. Nevertheless, performance of navigation tasks may offer an established anchor for quantification in future research efforts.

Automated navigation systems give the crew a substantial sense of confidence in their ability to avoid getting lost. This tends to produce greater freedom of movement, which can lead to travelling greater total distance while executing combat missions.

Digital overlays displayed on an electronic tactical map are an important feature in enhancing tactical movement. The ability to transmit such overlays from the TOC to vehicles is a major advantage. In the battalion evaluation, many participants expressed a desire to be able to edit overlays received from the TOC before relaying them, in order to tailor them to the needs of subordinate units. Thus, rigid consistency of digital information may not always be appropriate.

Providing automated information to the vehicle driver, especially in graphic form, is an important aspect of an automated navigation system. This feature enables the driver to assume much greater responsibility for navigating, and it reduces the need for coordination between vehicle commander and driver. This illustrates the contribution of system features which provide relevant information to all members of the crew.

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. Techniques for ensuring realistic role-playing are discussed later in this section (Experimental Procedures subsection).

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 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.

Destroying the Enemy

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.

Vehicle commanders operating at higher echelons (company command, battalion command) are primarily responsible for directing the combat activities of their units. The attention they pay to engaging the enemy is therefore less than it would be at lower echelons. When an investigator assigns crews no lower than the company command echelon, as in the current evaluation, engagement performance may be affected in a manner which appears to counter the advantages expected of advanced systems.

The use of automated C3 equipment does not necessarily distract the crew from fighting the battle and engaging the enemy. This indicates that vehicle commanders can integrate experimental equipment into the performance of their jobs without modifying the basic parameters of the job itself.

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. Accordingly, future IFF implementations should model greater reliability.

Excessive risk-taking behavior ("Rambo" behavior) may inflate engagement-based measures for crewed vehicles, especially if kill suppress is used to prevent loss of those vehicles. This highlights the importance of techniques for ensuring realistic role-playing, discussed later in this section (Experimental Procedures subsection).

Intelligence Gathering

Performance related to gathering intelligence information is especially sensitive to the effects of automated C3 capabilities, at least as they were implemented in the CVCC system. Thus this is an important area for assessment in future research efforts.

In the battalion evaluation, quantification of performance in this category focused on accuracy of reported enemy locations. The primary effects depended on inputting precise location information to reports calling for locations of enemy vehicles. In addition, the volume of usable information (i.e., reports containing valid locations) emerged as a useful index of performance effects.

General Considerations

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. Their initial reactions to the equipment will not usually match their final assessment.

The type of tactical operation frequently influences the use of automated C3 capabilities. For example, participants in CVCC research often comment that the CCD is more useful in the defense, when they have more time to use it. Similarly, the CITV's autoscan mode is typically used substantially in defensive missions and rarely during offensive operations. Differences such as this are to be expected, and future research efforts would profitably probe for tactically-related trends and the reasons for them.

Qualified crewmembers utilizing experimental equipment sometimes discover unexpected ways to use the advanced capabilities. For example, in the current evaluation occasional participants used the CITV to establish fields of fire and target reference points. This underscores the value of the soldier-in-the-loop approach in conducting simulation evaluations.

Participants' perceptions of their own performance don't always match the objective reality of their performance. In the battalion evaluation, for example, CVCC participants commonly reported having an especially good picture of the battle, but their recall of details of the battle was not consistently better than that of their Baseline counterparts. This illustrates the importance of obtaining objective performance data in future research efforts.

Evaluation Methods

Task Organization

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 allocation of actual crews, 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

Communication 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, 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.

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 phases: 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. 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 risk interruptions during execution. Overtaxing the SAFOR system results in slow responsiveness and more 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.

Simulation Capabilities

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 crews (especially drivers) 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 (e.g., MODSAF, Computer Generated Forces). Enhanced 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.

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. As in the current evaluation, it is sometimes possible to implement different crew allocations in separate phases of testing.

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. 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. Implementation of a thorough training program helps ensure a viable test of the conditions of interest and helps protect the quality of the database.

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. A clear signal telling the crew that they have received a killing hit is needed to discourage "Rambo" behavior. It is difficult to adjust measures of performance to account for ostensible attrition of vehicles protected by kill suppress, but quantitative information about kills sustained can be obtained easily to help explain performance data.

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 means might include penalties for repeated incidents of unwanted behavior and asking the ranking participant to intervene.

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.

Participants routinely expressed a desire for feedback on their performance in the battalion evaluation. Feedback was provided in the post-scenario debriefing, without making evaluative comments ("good" versus "bad"). More detailed feedback could be provided if desired, but care should be exercised to avoid injecting experimenter bias or contaminating the current group's performance by comparing them to previous groups. Performance feedback can enhance the training benefit received by the participants as a result of their support of the evaluation.

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.

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.

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. Measures 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 following pilot testing. There is a need for more effective techniques to verify and validate algorithms.

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 computer's disk memory for a single scenario. This means only one week can be processed at a time, and returning later to that same week requires reloading the tapes into memory. The DCA hardware should be upgraded to permit storage of the complete database from all test weeks. 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 also considered when they were operationally meaningful. This occurred where fixed values for the CVCC condition (e.g., instantaneous transmission times, perfect report consistency scores) made it unfeasible to perform inferential tests. The combined major findings support definitive conclusions regarding the operational effectiveness of the CVCC system's advanced capabilities, as follows:

1. The CVCC's digital transmission capabilities enabled more rapid dissemination of orders and more complete dissemination of INTEL reports among the battalion's leaders.

2. The perfect consistency (and completeness) of digital FRAGOs and INTEL reports was a dramatic improvement over the poor consistency of corresponding information disseminated by conventional means. The apparent clarity of digital FRAGOs led CVCC unit and vehicle commanders to seek clarification only rarely.

3. The CVCC's automated logistics reporting led to a much reduced need for company commanders and XOs to report unit location and status.

4. The digital reporting capabilities of the CVCC system greatly reduced the number of voice radio transmissions, including those for coordination among the battalion's command group. This finding, together with the digital burst transmission of CCD reports, decreased the battalion's voice radio signature. Participants reported easier access to radio networks.

5. Unit and vehicle commanders generated reports (CONTACT, CFF, SPOT) containing substantially more accurate information about location and type of enemy vehicles. This was attributable to the CVCC system's advantages in acquiring and communicating information, especially precise location information.

6. Given the relative ease of preparing CCD reports with accurate location information, CVCC unit and vehicle commanders generated a decidedly greater volume of usable information in their reporting activities. This was seen clearly for CFF, CONTACT, SHELL, and SPOT reports.

7. The CVCC system's enhanced capabilities enabled battalions to complete combat missions more quickly. Their timing of movement-dependent milestones was more consistent than Baseline battalions' during the counterattack, and they reached their counterattack objectives more quickly.

8. The POSNAV features afforded CVCC unit and vehicle commanders greater apparent freedom of movement than was observed among Baseline participants.

9. The collective capabilities of the CVCC system enabled battalions to maintain safer end-of-stage stand-off ranges.

10. CVCC-equipped crews were able to detect enemy targets at greater maximum ranges than Baseline crews.

11. The CITV's hunter-killer advantages produced faster target acquisition among crews using the CVCC system.

12. Enhanced kills per hit ratios among CVCC-equipped units suggested crews using the CITV were better able to select the ammunition most appropriate for the target type and range.

13. Crews using the CVCC system participated as fully in engaging the enemy as did Baseline crews.

The reader should bear in mind these conclusions are based on the performance of tank battalions operating in the distributed 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 must 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. 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 burgeoning research initiatives as well as plans to integrate distributed simulation in large-scale training exercises such as Louisiana Maneuvers (e.g., Ross, 1993).

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 measures, including staff capabilities, will optimize the impact?

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

9. What modifications to combined arms TTP 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 distributed interactive simulation models of automated C3 systems, and how can the validity be improved?

The answers to these and related questions will have a fundamental influence on future directions for the digitized battlefield. With an empirical, soldier-in-the-loop foundation to guide the automation of C3 for the combined arms environment, the difficult challenges in synchronizing combat activities can be met. The resulting enhancement of horizontal integration will boost force effectiveness under a broad range of mission contingencies. Armed with new C3 tools carefully based on systematic research, the ultimate payoff can be expected to be a dramatic improvement in the probability of success in future conflicts.

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Appendix A

Sample Data Collection Instruments

Contents of Appendix A:

April 13, 1992

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."

<u>DATA ELEMENT</u>: 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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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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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:____________________________

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.

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 ~~b~~ody 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: ___________

DATA ELEMENT: 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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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?

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_______ **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:____________________________
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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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March 16, 1992

PVD OPERATOR LOG

DEFENSIVE SCENARIO

Formative Bn Evaluation

Date:____________________ File: BFE_D _ _ _ _

PVD Operator:____

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:_________

_______ Bn TOC requests SitRep from Companies [Bn O&I net]

BDE ISSUES INTEL: "ALL SOURCE INTEL REPORTS SIGHTING OF MRB, POSSIBLY 2ND ECHELON OF MRR, MOVING ES940650."

OPFOR ARTILLERY BARRAGE ON BPS 10, 20, 30

_______ D Co controller reports elements of TF 1-2 (friendly) moving to the rear. [in ECR]

BDE ISSUES INTEL: "210 ACR REPORTS ONLY LIGHT CONTACT IN THEIR SECTOR."

BDE ISSUES INTEL: "All source INTEL reports sighting of 2nd Ech MRB/1st Ech Regt, ES9756, moving N.

_______ A Co requests permission to delay to BP 13 [Bn O&I net or Bn Cmd net]

_______ Bn Cdr orders Bn to delay back [Bn O&I net or Bn Cmd net]

Out of Sector/Misoriented Vehicle(s):

_______ Vehicle(s) out of sector or misoriented (Circle which) Vehicle(s): _______________

_______ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (*self/other vehicles/ECR*)? _______________

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

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Stage 1:

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 COUNTERATTCK TO SW FROM VIC PL SPADE; 1-92 MECH 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 company crosses PL JACK
_______ A Co reports crossing PL JACK [Bn O&I net]

BDE ISSUES FRAGO 1.

_______ A Co at BP 13
_______ A Co reports SET at BP 13 [Bn O&I net]

_______ B Co at BP 23
_______ B Co reports SET at BP 24 [Bn O&I net]

_______ A Co requests permission to delay to BP 11 [Bn O&I net or Bn Cmd net]

_______ Bn Cdr grants permission for A Co to delay to BP 11 [Bn O&I net or Bn Cmd

Out of Sector/Misoriented Vehicle(s):

_____ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): _______________

_____ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? _______________

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

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Stage 1:

_______ C Co at BP 33
_______ C Co reports SET at BP 34 [Bn O&I net]

_______ A Co company crosses PL CLUB
_______ A Co reports crossing PL CLUB [Bn O&I net]

_______ B Co company crosses PL JACK
_______ B Co reports crossing PL JACK [Bn O&I net]

_______ A Co at BP 11
_______ A Co reports SET in BP 11 [Bn O&I net]

_______ B Co at BP 24
_______ B Co reports SET at BP 24 [Bn O&I net]

_______ C Co company crosses PL JACK [NOTE: the BP straddles the PL; C Co may not cross PL]
_______ C Co reports crossing PL JACK [Bn O&I net]

_______ C Co at BP 34
_______ C Co reports SET at BP 34 [Bn O&I net]

Out of Sector/Misoriented Vehicle(s):

_____ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): _______________

_____ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? _______________

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

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Stage 1:

S11 reports SET screen line 2.

BDE requests SITREP

________ A Co company crosses PL SPADE
________ A Co reports crossing PL SPADE [Bn O&I net]

________ A Co at BP 12
________ A Co reports SET in BP 12 [Bn O&I net]

________ Bn TOC requests SitRep from Companies [Bn O&I net]

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

Out of Sector/Misoriented Vehicle(s):

______ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): ________________

______ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? ________________

DO THE VCRs AND DATALOGGER NEED TO BE TURNED OFF?

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

Stage 2:

_______ Bn Cdr calls in STARTEX TIME: _____

BDE DIRECTS TOC TO ISSUE FRAGO

_______ A Co crosses PL SPADE
_______ A Co reports crossing PL SPADE [Bn O&I net]

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."

_______ A Co company crosses PL QUEEN
_______ A Co reports crossing PL QUEEN [Bn O&I net]

_______ A Co crosses LD
_______ A Co reports crossing LD [Bn O&I net]

_______ B Co crosses LD
_______ B Co reports crossing LD [Bn O&I net]

_______ C Co crosses LD
_______ C Co reports crossing LD [Bn O&I net]

Out of Sector/Misoriented Vehicle(s):

_____ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): ________________

_____ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? ______________

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

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Stage 2:

SCOUTS REPORT CROSSING LD

OPFOR ARTILLERY ON A AND B COMPANIES

_______ A Company at Objective RAIN
_______ A Company reports SET on Obj RAIN [Bn O&I net]

BDE INTEL: ALL SOURCE INTEL REPORTS HAEVY VEHICLE MOVEMENT, ESTIMATE TWO REGIMENTAL FORMATIONS VIC ES8165 AND ES9071, MOVING N.

_______ B Company at Objective SNOW
_______ B Company reports SET on Obj SNOW [Bn O&I net]

_______ C Company at Objective FOG
_______ C Company reports SET on Obj FOG [Bn O&I net]

_______ Bn TOC requests SitRep from Companies [Bn O&I net]

_______ BREAK (End of Stage: Participants remain in sims)

Out of Sector/Misoriented Vehicle(s):

_____ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): ______________

_____ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? ____________

DO THE VCRs AND DATALOGGER NEED TO BE TURNED OFF?

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

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Stage 3:

_______ Bn Cdr calls in STARTEX TIME: _____

_______ A Co reports SET at BP 25 [Bn O&I net]

_______ B Co reports SET at BP 45 [Bn O&I net]

_______ C Co reports SET at BP 35 [Bn O&I net]

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

ON BDE NET: 1-92 CDR REPORTS FACING ELEMENTS OF 79TH GTR.

_______ Platoon controller for A Co reports GAS [in ECR]

_______ Platoon controller for C Co reports GAS [in ECR]

_______ Permission to delay to BPs along PL Queen is requested [Bn O&I net or Bn Cmd net]
Specify Requestor: _______________________________

_______ Bn Cdr orders Bn to delay back [Bn O&I net or Bn Cmd net]

BDE ISSUES INTEL: "2ND ECHELON MRB+ SIGHTED VICINITY ES 8673, MOVING NORTH."

BRIGADE ORDERS 1-10 AR TO DELAY TO PL QUEEN (if necessary)

Out of Sector/Misoriented Vehicle(s):

______ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): ________________

______ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? ________________

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

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Stage 3:

______ A Co crosses PL QUEEN
______ A Co reports crossing PL QUEEN [Bn O&I net]

______ A Co at BP 11
______ A Co reports SET on BP

______ B Co crosses PL QUEEN
______ B Co reports crossing PL QUEEN [Bn O&I net]

______ B Co at BP 46
______ B Co reports SET on BP

______ C Co at BP 36
______ C Co reports SET on BP

______ END OF EXERCISE (Participants out of sims for Situational Assessment)

Out of Sector/Misoriented Vehicle(s):

______ Vehicle(s) out of sector or gets misoriented (Circle which) Vehicle(s): ______________

______ Vehicle(s) return in sector or correctly orients (Circle which)

What caused vehicle to return in sector or to correcly orient (self/other vehicles/ECR)? ______________

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

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March 16, 1992

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

<u>BREAK</u> (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

BREAK (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

END OF EXERCISE (Participants out of simulators: Administer SITUATIONAL ASSESSMENT)

Additional Notes/Flags:

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H = Help F = Flag C = Comment

August 21, 1992

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
Anything Noteworthy or Out of the Ordinary.

Novel uses of the Equipment
Questions that the TC asked you

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<u>BREAK</u> (End of Stage 1: Participants cut of simulators)

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

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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:

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Stage 2 (Def):

STARTING SITUATION: A Co is in BP 12; B Co is in BP 24; C Co is in BP 34; and D Co is in BP 11. D Co stays in reserve and A, B, and C advance to take Objectives RAIN, SNOW, AND FOG, respectively. Simulation is initiated when BattleMaster orders Bn Cdr to implement FRAGO 1.

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."

S11 reports screening from CP5 to LD

Bn TOC requests SitRep from Companies; All companies consolidate on Obj's

Did TC transfer FRAGO to paper map (to what extent)?____________

____

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

Stage 2 (Def):

Record:

Coordination between TC and crew
Problems with the Equipment
Anything Noteworthy or Out of the Ordinary.

Novel uses of the Equipment
Questions that the TC asked you

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BREAK (End of Stage 2: Participants remain in simulators)

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

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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:

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Stage 3 (Def):

STARTING SITUATION: A Co is on Obj RAIN; B Co is on Obj SNOW; C Co is on Obj FOG; D Co is at BP 11.

Simulation is initiated when BattleMaster *orders* Bn Cdr to implement FRAGO 2

D moves to BP 46; A, B, and C Co's move to establish defensive positions in BPs 25, 45, and 35, respectively.

OPFOR artillery barrage along PL ACE

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

A and C Cos report "GAS"

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

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

Did TC transfer FRAGO to paper map (to what extent)?______________

____

<u>Report</u>	<u>Tally</u>
Adjust Fire	
Ammo	
Call for Fire	
Contact	
Snel:	
SitRep	
Spot	
Inte:	
FRAGO	
NBC	
OTHER	

Stage 3 (Def)

Record:

Coordination between TC and crew
Problems with the Equipment
Anything Noteworthy or Out of the Ordinary.

Novel uses of the Equipment
Questions that the TC asked you

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END OF EXERCISE (Participants out of simulators for SITUATIONAL ASSESSMENT)

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

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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:

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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

BN CDR & S3 SIM DUTY POS ____________

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 the battalion destroy?

Number of enemy tanks destroyed: ______

______ 2. During the last stage, how many BMPs did the battalion destroy?

Number of BMPs destroyed: ______

______ 3. During the last stage, did the battalion destroy any enemy vehicles after the order to delay was given?

Yes ______ No ______

______ 4. During the last stage, how many tanks in the battalion were destroyed?

Number of battalion tanks destroyed: ______

______ 5. How far (in km) were the initial BPs from the subsequent BPs (as established in the last FRAGO)?

Distance (km): ______

<u>SITUATIONAL ASSESSMENT QUESTIONNAIRE - Test Scenario</u>

CO CDRS & XOS SIM DUTY POS ____________

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 basic set of measures is defined by O'Brien et al. (1992). All measures which have changed since that report are included in this appendix. In addition, occasional unchanged measures are included to provide a sampling for each hypothesis evaluated.

The term "Standard DCA Output" refers to measures for which DCA routines exist as part of the standard DCA library. Documentation for these routines can be obtained from the senior MWTB analyst. An asterisk (*) denotes definitions that have changed since the battalion TOC evaluation (O'Brien et al., 1992).

Measures Terminology

The following definitions provide a ready reference for terms which might be used uniquely in this appendix, or for which it might be helpful to have such reference.

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.
Report Type	Refers to all possible digital reports, (including overlays). Which are: ADJUST FREE TEXT, FIRE, AMMO STATUS, CALL FOR FIRE, CONTACT, SHELL, SITUATION, SPOT, INTELLIGENCE, NBC, and OVERLAY
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 verbal 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 BLUFOR vehicle is exposed during a defined exposure period. For each BLUFOR vehicle, the exposure period begins when initial intervisibility with a non-dead OPFOR vehicle is established and lasts until the first fire from that BLUFOR vehicle's company.

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 fire from that vehicle's company 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: Stages 1 & 3: 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 will not include vehicles greater 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 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 BLUFOR 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 manned vehicles 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 will not be included.

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 gunner 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 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 Veh Cdr (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

Conduct Surface Attack

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 RS/1 table. CVCC: Essential report elements are input directly to RS/1 table via DCA.

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.

Determine direct distance between reported location and the CoM of the three OPFOR vehicles closest to that reported location.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

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 the time the Bn TOC initiates transmission of a FRAGO to the time the last Co Cdr receives the FRAGO (reception completed includes time to last clarification, if any). For CVCC condition, FRAGO consists of FREE TEXT message containing FRAGO and accompanying overlay.

ANOVA Summary: Condition X Stage

Expected N (per Cell): 1/stage/week

3.1.2: Duration of request by Co Cdr/XO to clarify FRAGO/overlay

Operational Definition: The average length of the Co Cdr request(s) for clarification of FRAGO and/or the accompanying overlay.

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 manned vehicle receives (reception completed includes time to last clarification, if any) the INTEL.

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/Co/Plt nets, enter into database for input to RS/1 table. CVCC: Essential report elements are input to RS/1 table via DCA.

For each report, compute elapsed time from initiation at TOC until received by last manned vehicle on lowest net; cumulate across nets. For Baseline compute transmission times from start of transmission to acknowledgement on the receiving net, including elapsed time for clarification (if any). For CVCC compute transmission times from SEND time until report arrives in last receiving queue of lowest manned net; add elapsed time for clarification at lowest net.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

3.2.2: Consistency of relayed INTEL

Operational Definition: The consistency of INTEL report contents, comparing relayed INTEL to scripted INTEL (expressed as a percentage).

Collection/Reduction Summary: Baseline INTELs are recorded from all nets on playback tapes. Contents are compared to original text. No data are collected for CVCC condition, as original and relayed INTEL or FREE TEXT messages contain identical information.

Elements from INTELs (listed 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 a scorer is unsure of the appropriate rating, the item will be reviewed by an SME and the appropriate Y or N rating will be assigned).

Stage 1

Script Time	Content	Rating	
T-5:00	What: BRDM	Y	N
	#: 1	Y	N
	Where: ES839720	Y	N
	Activity: Recon (performing recon)	Y	N
	Heading: Stationary	Y	N
T-2:00	What: BRDM	Y	N
	#: 2	Y	N
	Where: ES806699	Y	N
	Activity: Recon (performing recon)	Y	N
	Heading: Stationary	Y	N
T-0:00	What: 146th MRR	Y	N
	Where: ES990400	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N
T+5:00	What: MRB (2nd ech of MRR)	Y	N
	Where: ES940650	Y	N
	Activity: Moving	Y	N
T+9:00	What: 1-92 Mech	Y	N
	Where: PL KING	Y	N
	Activity: in heavy contact	Y	N

T+10:15	What: 210 ACR	Y	N
	Where: In sector	Y	N
	Activity: Light contact	Y	N
T+16:00	What: MRB (of 1st Ech MRR)	Y	N
	Where: ES9756	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N
T+23:00	What: 1-92 Mech	Y	N
	Where: to PL CLUB	Y	N
	Activity: Delaying	Y	N
T+26:00	What: 144th RAG	Y	N
	Where: ES910725	Y	N
T+30:00	What: 1-92 Mech	Y	N
	Where: PL JACK	Y	N
	Activity: Crossing	Y	N
T+30:30	What: MRB (-)	Y	N
	Where: PL JACK	Y	N
	Activity: penetrated (attacking across)	Y	N
T+38:00	What: 1-92 Mech	Y	N
	Where: PL CLUB	Y	N
	Activity: crossing, establishing EA	Y	N
T+41:00	What: MRBs(+)(2nd ech of 144, 140 MRRs)	Y	N
	#: 2	Y	N
	Where: ES9668, ES8763	Y	N
T+51:00	What: Co(-)	Y	N
	#: *	Y	N
	Where: penetrated PL CLUB vic 1-10 bdry	Y	N
	Activity: stopped	Y	N
T+53:00	What: 210 ACR	Y	N
	Where: PL JACK	Y	N
	Activity: Light contact	Y	N
	Heading:	Y	N

<u>Stage 2</u>

T+74:30	What: 146th MRR	Y	N
	Where: ES9063	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N
T+86:00	What: MRB(+)	Y	N
	Where: ES8180	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N

T+90:15	What: 210 ACR	Y	N
	Where: proposed bdry vic PL JACK	Y	N
	Activity: Set	Y	N
T+96:00	What: Heavy vehicle movement, estimated Regtl formations	Y	N
	#: 2	Y	N
	Where: ES8165, ES9071	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N
T+97:00	What: MRB(+) @ about 30% strength	Y	N
	Where: PL CLUB	Y	N
	Activity: Establishing hasty defense	Y	N
	Heading:	Y	N

Stage 3

T+111:00	What: 146th MRR (lead echelon)	Y	N
	Where: ES8774	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N
	What: 79th GTR (lead echelon)	Y	N
	Where: ES7870	Y	N
	Activity: moving	Y	N
	Heading: N	Y	N
T+114:00	What: 210 ACR	Y	N
	Where: to PL ACE	Y	N
	Activity: moving to establish	Y	N
T+118:00	What: 210 ACR	Y	N
	Where: PL ACE	Y	N
	Activity: set, no enemy contact	Y	N
T+119:00	What: 1-92 Mech	Y	N
	Where: PL ACE	Y	N
	Activity: Set, prepared to defend, resupply TOW ammo complete	Y	N
T+130:30	What: 79th GTR (elements of)	Y	N
	Where: 1-92 sector	Y	N
T+133:00	What: Tank Bns (-)	Y	N
	#: 2	Y	N
	Where: PL ACE	Y	N
	Activity: penetrated (attacking across)	Y	N
	Heading:	Y	N

	What: 1-92 Mech	Y	N
	Where: to PL QUEEN	Y	N
	Activity: delaying	Y	N
T+134:00	What: MRB(+) (2d ech of MRR)	Y	N
	Where: ES8673	Y	N
	Activity: Moving	Y	N
	Heading: N	Y	N

Analysis Summary: Descriptive summary for Baseline condition

Receive and Transmit Friendly Troop Information

3.3.1: Mean time to transmit SITREP full net: lowest net to Bn TOC

Operational Definition: The elapsed time, in minutes, from the lowest net transmission of the SITUATION report to the time the Bn TOC receives the company SITREP.

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/Plt nets, enter into database for input to RS/1 table. CVCC: Essential report elements are input to RS/1 table via DCA.

For each report, compute transmission time for each net: From initiation at lowest net until company report received by the TOC; cumulate across nets. For Baseline compute transmission times from start of transmission to acknowledgement on the receiving net. For CVCC compute transmission times from SEND time until report arrives in receiving queue.

ANOVA Summary: Condition

Expected N (per Cell): Occurrence dependent

3.3.2: 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 RS/1 table. CVCC: Essential report elements are input directly to RS/1 table via DCA.

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

<u>Manage Means of Communicating Information</u>

3.4.1: Average length of voice radio transmissions, by echelon

Operational Definition: The average duration of voice radio transmissions, as defined by keying the microphone. Compute average per manned vehicle. Transmissions shorter than 1 second or greater than 30 seconds will be eliminated.

Collection/Reduction Summary: DCA routine determines duration of radio transmissions between microphone key events; excludes transmissions shorter than 1 second or greater than 30 seconds.

ANOVA Summary: Condition X echelon

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

Direct and Lead Subordinate Forces

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. 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. Applies to defensive stages 1 & 3.

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

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 will be treated as separate reports. The "observed" and "destroyed" elements of the SPOT report will be scored independently. For descriptive purposes a tally (%) will be kept of 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 RS/1 table. CVCC: Essential report elements are input to RS/1 table via DCA.

To score the "SPOT-Observed Report:"

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 Report:"

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 type): 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 will be treated as separate reports. The "observed" and "destroyed" elements of the SPOT report will be 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 RS/1 table. CVCC: Essential report elements are input directly to RS/1 table via DCA.

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 report, 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 type): 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

Appendix C

Descriptive Data Tables for Performance Measures

Table C-1

Descriptive Data for Move on Surface Hypothesis (Maneuver BOS)

Measure	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 (4.58) 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 Objective (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 parenthesis), minimum, maximum, and number of observations (*n*). Some measures were not applicable, and appear in the table as NA.

Table C-2

Descriptive Data for Navigate Hypothesis (Maneuver BOS)

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Distance Travelled (in meters)						
Bn Echelon	13517.85 (7352.13) 5405.37 30823.92 n=11	13512.32 (8171.88) 5961.81 31002.81 n=12	7455.64 (3341.92) 1326.22 13467.45 n=11	8509.48 (3114.25) 6146.34 17470.88 n=12	8005.98 (2585.29) 5477.71 13381.97 n=10	6550.48 (2394.84) 3330.48 11310.58 n=8
Company Echelon	13378.94 (5083.24) 6013.09 21889.76 n=36	11270.19 (4062.69) 3150.75 20350.78 n=36	9597.20 (2521.80) 4721.14 15093.33 n=35	10043.98 (2823.81) 5678.78 15467.29 n=36	9037.29 (3242.25) 3782.19 16127.39 n=30	7525.50 (2514.20) 3437.48 12732.51 n=23
Fuel Used (in gallons)						
Bn Echelon	20.74 (8.23) 11.18 37.31 n=11	22.91 (10.90) 13.96 47.41 n=12	12.63 (3.78) 9.41 18.66 n=11	16.29 (4.74) 12.07 27.80 n=12	14.87 (3.09) 11.65 21.48 n=10	12.64 (3.11) 9.09 19.51 n=8
Company Echelon	20.22 (6.89) 10.63 38.04 n=36	18.99 (5.77) 7.74 33.22 n=36	17.53 (8.92) 9.18 72.32 n=35	16.18 (4.84) 9.03 28.36 n=36	15.04 (5.09) 8.08 26.71 n=30	12.29 (3.68) 6.49 19.87 n=23
Time to Complete Stage (in minutes)	67.52 (4.34) 63.38 75.47 n=6	73.95 (7.11) 66.72 87.28 n=6	41.46 (3.95) 36.81 48.68 n=6	52.40 (9.72) 41.97 67.15 n=6	46.71 (11.33) 23.80 52.95 n=6	48.24 (3.88) 44.62 53.52 n=4

Note. Each data cell includes the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (*n*).

Table C-3

Descriptive Data for Process Direct Fire Targets Hypothesis (Maneuver BOS)

Measure	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 parenthesis), minimum, maximum, and number of observations (*n*).

Table C-4

Descriptive Data for Engage Direct Fire Targets Hypothesis (Maneuver BOS)

Measure	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 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)

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n). Some measures were not applicable, and appear in the table as NA.

Table C-4

Descriptive Data for Engage Direct Fire Targets Hypothesis (Maneuver BOS) (Cont'd)

Measure	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)

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (*n*). Some measures were not applicable, and appear in the table as NA.

Table C-4

Descriptive Data for Engage Direct Fire Targets Hypothesis (Maneuver BOS) (Cont'd)

Measure	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 parenthesis), minimum, maximum, and number of observations (n). Some measures were not applicable, and appear in the table as NA.

Table C-5

Descriptive Data for Conduct Surface Attack Hypothesis (Fire Support BOS)

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Accuracy of CFF Report Locations (observed; in meters)	532.57	1714.17	708.54	3469.50	391.79	115.33
	(473.51)	(3068.93)	(923.32)	(1073.19)	(501.39)	(52.37)
	20.00	0.00	41.50	1644.50	36.00	77.00
	1846.00	7934.00	3050.00	4378.00	2295.00	175.00
	n=25	n=6	n=14	n=6	n=22	n=3
Percent of CFF Reports with Correct Type (observed)	90.57	68.33	86.67	58.33	91.53	83.33
	(17.70)	(24.83)	(29.68)	(32.12)	(24.15)	(28.87)
	50.00	50.00	0.00	0.00	0.00	50.00
	100.00	100.00	100.00	100.00	100.00	100.00
	n=25	n=6	n=15	n=8	n=22	n=3

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n).

Table C-6

Descriptive Data for Receive and Transmit Mission Hypothesis (Command and Control BOS)

Measure	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	12.36	0.00	9.38
		(5.84)		(5.05)
		1.88		3.08
		23.57		22.82
		n=16		n=15
Duration of Request to Clarify FRAGO/Overlay (in minutes)				
Bn Cdr	--	1.07	--	0.47
	--	(0.98)	--	(0.47)
	0.25	0.20	0.16	0.08
	0.25	3.18	0.35	0.83
	n=1	n=7	n=2	n=5
Company Cdr	--	0.43	--	0.43
	--	(0.07)	--	(0.23)
		0.32		0.15
		0.50		0.95
	n=0	n=5	n=0	n=12
Company XO	--	0.60	--	0.58
	--	(0.46)	--	(0.55)
		0.17	(0.16)	0.27
		1.50	(0.35)	1.22
	n=0	n=3	n=2	n=3
Percent of FRAGO Elements Correctly Relayed	100.00	18.97	100.00	35.27
		(12.41)		(17.21)
		0.00		9.09
		50.00		72.72
		n=17		n=15

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n). FRAGOs were transmitted in Stage 2 and 3 only. All CVCC FRAGOs (overlays and text) were transmitted instantaneously and with perfect (100%) consistency.

Table C-7

Descriptive Data from Receive and Transmit Enemy Information Hypothesis (Command and Control BOS)

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Time to Transmit INTEL from Bn Cdr to Co Cdr (in minutes)	0.00	1.65 (0.96) 0.73 3.63 n=10	0.00	1.58 (1.03) 0.56 2.63 n=3	0.00	-- -- 0.82 0.82 n=1
Percent INTEL Elements Correctly Relayed	100.00	60.32 (39.95) 0.00 100.00 n=6	100.00	-- -- 100.00 100.00 n=1	100.00	-- -- 25.00 25.00 n=1

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n). All CVCC INTELs were transmitted instantaneously and with perfect (100%) consistency.

Table C-8

Descriptive Data for Receive and Transmit Friendly Troop Information Hypothesis (Command and Control BOS)

Measure	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)	1.75	3.05	--	2.61	--	2.75
	(1.43)	(2.38)	--	(2.15)	--	(1.72)
	0.95	0.08		0.30	3.00	0.11
	4.30	10.45		8.63	9.45	6.79
	n=5	n=52	n=0	n=32	n=2	n=25
Duration of Communication Between Bn TOC and Bn Cdr/S3 (in minutes)	0.56	0.51	0.52	0.45	0.38	0.40
	(0.58)	(0.57)	(0.47)	(0.45)	(0.26)	(0.43)
	0.17	0.01	0.03	0.03	0.13	0.13
	2.58	4.23	1.67	1.80	1.15	1.82
	n=42	n=142	n=20	n=88	n=13	n=15
Deviation of BLUFOR Location Reported in SITREP (in meters)	989.05	--	802.96	--	869.26	--
	(312.22)	--	(673.37)	--	(232.60)	--
	652.77		427.61	915.00	459.67	
	1503.55		2170.61	915.00	1056.37	
	n=6	n=0	n=6	n=1	n=6	n=0
Difference Between Observed and Reported PL/LD/FCL Crossings (in minutes)	0.91	1.13	1.28	0.73	0.43	--
	(1.59)	(1.45)	(1.04)	(0.72)	(0.30)	--
	0.02	0.08	0.18	0.03	0.67	
	5.26	4.25	3.35	1.95	0.80	
	n=10	n=12	n=12	n=6	n=4	n=0
Difference Between Observed BP Arrival and Reporting SET (in minutes)	1.36	3.29	1.79	2.26	5.43	2.57
	(1.58)	(3.83)	(0.15)	(3.93)	(3.90)	(3.53)
	0.05	0.05	1.65	0.05	0.08	0.05
	4.60	12.88	1.95	9.21	8.91	6.60
	n=11	n=12	n=3	n=5	n=4	n=3

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n).

Table C-9

Descriptive Data for Manage Means of Communicating Information Hypothesis (Command and Control BOS)

Measure	Stage 1 CVCC $\underline{n}$=6	Stage 1 Baseline $\underline{n}$=6	Stage 2 CVCC $\underline{n}$=6	Stage 2 Baseline $\underline{n}$=5	Stage 3 CVCC $\underline{n}$=6	Stage 3 Baseline $\underline{n}$=5
Average Length of Voice Transmissions (in minutes)						
Bde Command Net	5.21	4.25	4.71	4.39	4.61	4.31
	(1.11)	(0.66)	(1.14)	(1.01)	(1.14)	(0.06)
	3.56	3.41	3.28	2.92	3.42	3.56
	6.28	5.07	6.46	5.60	6.38	4.93
Bn Command Net	4.30	4.40	4.21	4.41	3.93	4.14
	(0.54)	(0.68)	(0.60)	(0.45)	(0.30)	(0.46)
	3.64	3.51	3.36	3.99	3.46	3.58
	4.88	5.22	4.95	4.91	4.24	4.64
Bn O&I Net	3.58	3.80	3.23	3.59	3.19	3.40
	(0.35)	(0.41)	(0.55)	(0.61)	(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	4.08	4.05	4.25
	(0.58)	(0.52)	(0.88)	(0.41)	(0.45)	(0.62)
	3.40	2.97	3.34	3.63	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	3.98	3.59	3.78
	(0.56)	(0.87)	(0.37)	(0.65)	(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	4.09	3.28	4.20
	(0.19)	(0.53)	(0.20)	(0.44)	(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)

Note. Each data cell (from top to bottom) includes the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations ($\underline{n}$).

Table C-9

Descriptive Data for Manage Means of Communicating Information Hypothesis (Command and Control BOS) (Cont'd)

Measure	Stage 1 CVCC n=6	Stage 1 Baseline n=6	Stage 2 CVCC n=6	Stage 2 Baseline n=5	Stage 3 CVCC n=6	Stage 3 Baseline n=5
Number of Transmissions						
Bde Command Net	58.33	135.50	26.00	39.80	32.50	34.00
	(28.40)	(74.85)	(10.64)	(11.00)	(13.50)	(27.44)
	29.00	44.00	16.00	11.00	22.00	9.00
	90.00	217.00	40.00	99.00	58.00	81.00
Bn Command Net	281.17	501.00	169.00	354.00	227.17	282.80
	(48.39)	(120.80)	(48.03)	(97.92)	(65.80)	(58.37)
	247.00	339.00	133.00	225.00	131.00	180.00
	378.00	681.00	260.00	481.00	283.00	325.00
Bn O&I Net	89.33	278.50	50.83	168.00	77.83	133.40
	(34.64)	(69.19)	(35.27)	(66.31)	(59.48)	(61.91)
	28.00	219.00	23.00	110.00	19.00	29.00
	131.00	363.00	113.00	272.00	178.00	186.00
A Company Net	154.00	249.00	81.33	169.00	74.17	132.20
	(66.88)	(66.87)	(38.05)	(23.40)	(38.44)	(63.43)
	83.00	163.00	30.00	147.00	32.00	40.00
	266.00	350.00	127.00	208.00	132.00	213.00
B Company Net	152.50	225.50	97.33	178.40	113.00	161.00
	(25.59)	(57.61)	(21.64)	(42.72)	(33.77)	(44.96)
	107.00	160.00	68.00	138.00	76.00	82.00
	173.00	328.00	129.00	240.00	177.00	195.00
C Company Net	89.50	231.00	83.17	168.00	116.00	158.00
	(24.92)	(50.22)	(14.52)	(44.99)	(35.77)	(50.90)
	53.00	165.00	56.00	91.00	65.00	109.00
	118.00	295.00	98.00	209.00	171.00	239.00

Note. Each data cell (from top to bottom) includes the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n).

Table C-10

Descriptive Data for Direct and Lead Subordinate Forces Hypothesis (Command and Control BOS)

Measure	Stage 1 CVCC	Stage 1 Baseline	Stage 2 CVCC	Stage 2 Baseline	Stage 3 CVCC	Stage 3 Baseline
Percent of Bn that Met Commander's Intent	81.93 (19.14) 53.13 100.00 n=6	89.97 (6.70) 80.86 97.46 n=6	94.35 (9.29) 77.70 99.90 n=6	94.35 (9.55 77.63 99.90 n=5	66.21 (26.21) 19.02 97.46 n=6	84.11 (19.89) 55.78 98.44 n=4

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (*n*).

Table C-11

Descriptive Data for Collect Threat Information Hypothesis (Intelligence BOS)

Measure	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	1362.77	409.51	1105.94	375.74	649.88
	(470.39)	(2072.15)	(458.31)	(1406.74)	(588.19)	(382.68)
	1.00	41.00	2.00	31.00	0.00	85.00
	1700.00	6502.00	1735.50	4469.50	2188.00	907.00
	n=34	n=17	n=21	n=16	n=18	n=4
Accuracy of SPOT Report Locations (destroyed; in meters)	394.61	--	405.66	--	328.65	--
	(423.05)	--	(429.59)	--	(532.14)	--
	1.00		0.67		0.00	
	1700.00		1229.00		1724.00	
	n=32	n=0	n=20	n=0	n=17	n=0
Correctness of SPOT Report Number and Type (observed; percentage)	81.23	68.27	94.23	65.61	81.47	56.75
	(27.68)	(33.71)	(12.80)	(28.78)	(30.45)	(29.36)
	0.00	19.05	50.00	0.00	0.00	37.00
	100.00	100.00	100.00	100.00	100.00	100.00
	n=34	n=17	n=21	n=17	n=19	n=4
Correctness of SPOT Report Number and Type (destroyed; percentage)	79.43	--	91.56	--	73.52	--
	(27.04)	--	(13.76)	--	(32.08)	--
	0.00		50.00		0.00	
	100.00		100.00		100.00	
	n=33	n=0	n=20	n=0	n=18	n=0
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)	547.36	3752.27	623.83	1895.97	355.67	390.08
	(677.02)	(10570.41)	(921.71)	(2154.73)	(497.26)	(630.30)
	3.00	105.33	7.00	52.00	1.00	38.00
	2698.00	41778.00	3037.00	6880.00	1742.00	1666.00
	n=30	n=15	n=18	n=12	n=19	n=6
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 parenthesis), minimum, maximum, and number of observations (n).

Table C-12

Descriptive Data for the Situational Assessment Hypotheses

	Percent Correctly Identified		Confidence Rating	
Measure	CVCC	Baseline	CVCC	Baseline
Number of OPFOR Tanks Destroyed				
Bn Echelon	50.09	40.17	2.45	308
	(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				
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 Were Destroyed				
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

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (n).

Table 13

Descriptive Data for Situational Assessment Hypothesis

Measure	Deviation Between Actual and Reported Distance (in meters) CVCC	Baseline	Confidence Rating CVCC	Baseline
Distance from Initial BP from Later BP				
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

Note. Each data cell includes (from top to bottom) the mean, standard deviation (in parenthesis), minimum, maximum, and number of observations (_n_).

Appendix D

Analysis of Variance Summary Tables

[Incomplete]

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	4167.925	3	1389.308	39.341	.000
COND	250.113	1	250.113	7.082	.013
STAGE	3881.569	2	1940.785	54.957	.000
2-way Interactions	254.014	2	127.007	3.596	.041
COND STAGE	254.014	2	127.007	3.596	.041
Explained	4421.939	5	884.388	25.043	.000
Residual	953.492	27	35.315		
Total	5375.431	32	167.982		

Appendix E

List of Acronyms

LIST OF ACRONYMS

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
ATCCS	Army Tactical Command and Control System
ATHS	Airborne Target Handover System
BDM	BDM Federal, Inc.
BLUFOR	Blue (friendly) Forces
BOS	Battlefield Operating System
BP	Battle Position
C2	Command and Control
C3	Command, Control, and Communications
CCD	Command and Control Display
CFF	Call for Fire
CIG	Computer Image Generation
CITV	Commander's Independent Thermal Viewer
CRT	Cathode Ray Tube
CSS	Combat Service Support
CVCC	Combat Vehicle Command and Control
DCA	Data Collection & Analysis System
DCD	Directorate of Combat Developments
DIS	Distributed Interactive Simulation
ECR	Exercise Control Room
FRAGO	Fragmentary Order
FSO	Fire Support Officer
GLOS	Gun Line of Sight
GPS	Gunner's Primary Sight
GPSE	Gunner's Primary Sight Extension
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
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
POSNAV	Position Navigation
PVD	Plan View Display
QC	Quality Control
RA	Research Assistant
REDCON	Readiness Condition

LIST OF ACRONYMS (Cont'd)

ACRONYM	DEFINITION
SAFOR	Semiautomated Forces
SCC	SIMNET Control Console
SIMNET	Simulation Network
SIMNET-D	Simulation Network--Developmental
SIMNET-T	Simulation Network--Training
SINCGARS	Single Channel Ground and Airborne Radio System
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
TIS	Thermal Imaging System
TOC	Tactical Operations Center
TRP	Target Reference Point
TTPs	Tactics, Techniques, and Procedures
XO	Executive Officer