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Review of Armor Battalion and Below Automated Command and Control (C²) Soldier Performance Requirements

Philip L. Bolté

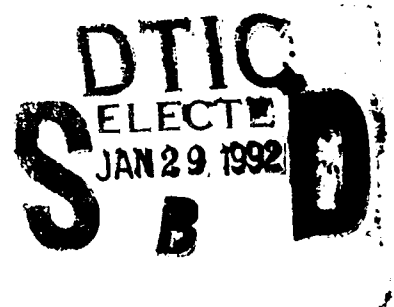
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Automated Command and Control (C²) Soldier
Performance Requirements**

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FOREWORD

The Future Battlefield Conditions Team of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Knox Field Unit is responsible for conducting research in soldier performance and training requirements for armor command and control systems. This research takes full advantage of state-of-the-art soldier-in-the-loop simulation capabilities located in the Close Combat Test Bed (CCTB) at Fort Knox.

This research was conducted under the Science and Technology Task entitled "Training Requirements for the Future Integrated Battlefield." ARI's research in this area is supported by two Memoranda of Agreement (MOA). The first MOA, which is between ARI and the U.S. Army Armor Center and School, supports Research on Future Battlefield Conditions. It was signed on 12 April 1989. The second, which is between ARI and the Tank Automotive Command (TACOM), supports the Combat Vehicle Command and Control System (CVCC). It was signed on 22 March 1989.

The Combat Vehicle Command and Control (CVCC) System is a suite of technologies that support the requirements of AirLand Battle by improving the ability of battalion and below commanders to synchronize, plan, and control combined arms operations on battlefields of the future. This report presents a brief description of the CVCC program from the perspective of user requirements, including the soldier-machine-interface and training. It also contains an overview of the potential problems in an automated command, control, and communication (C³) system from the operational perspective. Finally, it presents a sample of key issues that might be addressed through the use of soldier-in-the-loop simulation. These issues are of key interest to developers of automated C³ systems and to evaluators of those systems.

The information contained in this report has been briefed to numerous personnel, both U.S. Army and NATO allies. Many of these people have participated in demonstrations of the simulation in the CCTB facility. It has been briefed to the Vice Chief of Staff, the Deputy Chief of Staff for Operations, and the Commanding General of Fort Knox, as well as general officers from Germany, Canada, the United Kingdom, and Israel.



EDGAR M. JOHNSON
Technical Director

REVIEW OF ARMOR BATTALION AND BELOW AUTOMATED COMMAND AND CONTROL (C²) SOLDIER PERFORMANCE REQUIREMENTS

EXECUTIVE SUMMARY

Requirement:

The U.S. Army has entered into a program of research related to automated command and control (C²) tools for ground combat vehicles. This program, called Combat Vehicle Command and Control (CVCC), has a bilateral component with the Ministry of Defense of Germany. The program's sponsor is the Tank Automotive Command (TACOM). The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Knox Field Unit is responsible for one of the five CVCC program teams. The purpose of the effort reported here is to describe the CVCC program from the perspective of the ARI-led Team 3 Soldier-Machine-Interface and Simulation team and to identify research requirements.

Procedure:

This report was prepared in three parts. Dr. Barbara Black, CVCC Team 3 leader, prepared the CVCC program description and team function. Brigadier General (Ret.) Philip Bolté, a respected armor expert, prepared the CVCC user's context for automated C² tools and a review of support technologies. Dr. Raymond Mendel, a recognized research psychologist, took information provided by the first two authors and developed a set of proposed research efforts that highlight key soldier performance issues brought about by these automated C² tools.

Findings:

Review of literature on human performance and C² technologies revealed key problem areas requiring research. These include resolving issues such as the communication, display, and management of information; employing embedded training techniques; and investigating the workload associated with automated CVCC. Specific research issues include CVCC-based report content, frequency, and priority requirements within and between platoons, companies, and battalion; identification of echelon-specific CVCC-based report and operations order graphics requirements; optimization of NATO symbology; feasibility of voice input to CVCC; and rapid preparation of CVCC display graphics. Methods for enhancing the statistical power of data collection efforts are suggested.

Utilization of Findings:

Information provided in this report has served as a guide for development of the bilateral portion of CVCC Team 3's program. It has been briefed to key leaders, both U.S. Army and NATO allies, and many of these people have participated in demonstrations of the CVCC simulation in the Close Combat Test Bed facility.



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REVIEW OF ARMOR BATTALION AND BELOW AUTOMATED COMMAND AND CONTROL
(C²) SOLDIER PERFORMANCE REQUIREMENTS

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REVIEW OF ARMOR BATTALION AND BELOW AUTOMATED COMMAND AND CONTROL (C²) SOLDIER PERFORMANCE REQUIREMENTS

Introduction

The U.S. Army is establishing a series of command, control and communication (C3) requirements aimed at developing an automated C³ system that is integrated from the basic level of the individual soldier or combat vehicle to the highest level, the Army's Tactical Command and Control System (ATCCS) (U.S. Army Combined Arms Combat Development Activity, 1988). One major component of this system, proposed in the mid-1980's, was the Intervehicular Information System (IVIS). It is a system for combat vehicles, initially tanks. The U.S. Army Armor School developed a requirements document stating, from the user's perspective, the attributes for an initial IVIS (U.S. Army Armor School, [USAARMS], 1988).

The Armor School has stated that IVIS will be capable of providing near real-time acquisition, processing and distribution of combat information to enable the integration and synchronization of critical Maneuver, Combat Support (CS), Combat Service Support (CSS) and Intelligence assets of the tank battalion/cavalry squadron (USAARMS, 1988). A carefully designed IVIS can relieve the tank commander (TC) of part of his burden by assisting in task accomplishment. A fully functional IVIS type system should provide the vehicle commander with a tactical display containing icons representing locations of known friendly elements updated in real time, as well as anticipated or reported locations of enemy forces. In addition, this display will support the digital transmission of battlefield information including reports and overlay graphics. However, the advent of these capabilities brings with it the very real possibility of applying an additional burden to already overloaded TCs.

Objective of Report

The objective of the current report is to identify key areas of concern in the design of soldier-machine-interfaces (SMI) for proposed automated command, control and communication (C3) systems at vehicle level and to show how simulation can be used to identify possible solutions. This report will describe a research and development (R&D) program called the Combat Vehicle Command and Control (CVCC) program that is designed to demonstrate the value of automated C3 to ground combat vehicles and to resolve automated C3 interoperability issues with North Atlantic Treaty Organization (NATO) allies. This report is intended to provide a brief description of the CVCC program from the perspective of addressing user requirements and soldier machine interface issues. It also contains an overview of the potential problems in an automated C3 system from the operational

perspective. Finally, it presents a sample of key issues which might be addressed through the use of soldier-in-the-loop simulation.

CVCC Program Description

The Vetronics Division of the Tank Automotive Command's (TACOM's) Research Development & Engineering (RD&E) Center has had a long standing interest in developing a standardized computer architecture for incorporation into military vehicles. This architecture would support automated command and control (C2) functions as well as vehicular maintenance, logistics and other functions. The benefits of such an architecture are derived from the compatibility of hardware and software for interoperability and maintenance.

In late 1983, Vetronics Division contracted for competitive versions of a standard VETRONICS architecture (SAVA). The goal was to select the best features of the competing versions and prepare a military specification for use in future combat vehicles. At the same time, Vetronics personnel recognized that it is difficult to evaluate architectures without using applications programs. The IVIS concept scheduled for implementation in the M1 Block II program was selected as the preferred application.

The Vetronics Division awarded two contracts, one to develop a stand-alone or "suitcase" version of automated command and control features, similar to those envisioned for IVIS. The second was to develop a laboratory simulator which contained rapidly reconfigurable software for use in evaluating alternative soldier machine interface requirements. Both efforts were described as initially oriented toward engineering requirements rather than user requirements.

The Directorate of Combat Developments (DCD) at Fort Knox in conjunction with the U.S. Army Research Institute at Fort Knox (ARI-Knox) initiated a program in 1988 to identify and simulate automated C3 functions to help define the user requirements for IVIS. The DCD produced several documents detailing the data elements required for IVIS and proposing alternative soldier machine interface formats for evaluation through simulation (USAARMS, 1988).

Members of the Armor force, like the battlefield users of any C3 system, had a keen interest in participating in the development and evaluation of the soldier-machine-interface formats for the tank application. Full functional, interactive simulation of these formats allows the users to evaluate the relative merits of a given design. This type of soldier-in-the-loop evaluation is critical to the acquisition process. It should take place prior to the development of a required

operating capability (ROC) document and it needs to be continually iterated to produce necessary and sufficient data for accurate design trade-off decisions.

To facilitate this simulation process, ARI-Knox joined with the Defense Advanced Research Projects Agency (DARPA) in 1988 in their simulation technology demonstrations referred to as SIMNET-D (Simulated Network-Developmental). In 1988 and 1989, ARI-Knox used SIMNET-D's modifiable hardware and software, as well as the built-in analytic tools, to evaluate a large number of M1 tank platoons on a position navigation capability (Du Bois & Smith, 1989) and alternative IVIS-like display formats (Du Bois & Smith, 1991).

TACOM's Vetronics Division initiated the Combat Vehicle Command and Control (CVCC) program to address the U.S. Army's automated command, control and communication (C3) issues for ground combat vehicles at the battalion and below level and to develop interoperability requirements from bilateral research with Germany. Issues were generated from many different efforts and emphasis was placed on applying technological advances to C3 systems. These included the IVIS for the M1 tank Block II program, what was once known as the Battlefield Management System (BMS) for brigade and below, and the Armored Systems Modernization (ASM) program's Battalion and Below Command and Control (B2C2). It was out of this environment that the CVCC program was begun by TACOM.

One purpose of the CVCC program is to promote a bilateral program of interoperability research between U.S. and German personnel working in the area of automated C3 for ground combat vehicles. A second purpose is to refine U.S. requirements and specifications for automated C3 systems in ground combat vehicles.

The interoperability goal of the CVCC program involves outlining the hardware and software requirements for interoperability of U.S. and German Armor units (battalion and below only). The means by which participants will attempt to achieve this goal include taking full advantage of state-of-the-art simulation capabilities from both countries and through building prototype vehicles for participation in joint field experiments. The U.S. national goal is to develop specifications for and to demonstrate the value of a C3 subsystem that could be incorporated as a product improvement to the Abrams Block II tank or the Block III tank.

CVCC Team Functions

The Chief of the Vetronics Division and U.S. manager of the CVCC program, Mr. Don Sarna, developed documentation to support both Balanced Technology Initiative (BTI) funding and Nunn

funding for the CVCC program. The BTI funding supports developmental work on conventional systems and the Nunn funding supports programs having an interoperability requirement with our allies. In January '88, a joint U.S./German (GE) meeting was held for three days at Fort Knox to discuss potential linkages between the U.S. IVIS system and the comparable German IFIS system. The outcome of that meeting was the formation of four working groups or teams chartered to address different critical aspects of automated C3. Each team is led by co-representatives from the U.S. and Germany. The national leader is responsible for insuring bilaterally information exchange and for the development and execution of the national CVCC research program.

The teams are: 1) User Requirements, 2) Communications, 3) Soldier-Machine-Interface (SMI) and Simulation, and 4) Vehicle Integration. The U.S. Team 1 is led by the Directorate of Combat Developments (DCD) at the Armor School, while Team 2 is headed by the Communications Electronics Command (CECOM), Team 3 is led by ARI-Knox, and Team 4 by TACOM. The CVCC Program Manager provided guidance as to the functions of these teams but the details of ongoing activities of the teams are determined by the team members. Each team leader is asked to provide a detailed breakdown of issues, time-line/milestones, schedule of U.S./GE team coordination meetings, U.S./GE joint efforts, funding requirements and a listing of team members. Monthly meetings of team leaders with the CVCC Program Manager and semi-annual bilateral meetings are designed to ensure that the program is kept on track and that information is shared.

The responsibility of Team 3, the SMI and Simulation Team, is twofold: 1) utilize soldier-in-the-loop simulation to prove the value of automated C3 to the maneuver forces and 2) recommend the best alternative display formats for providing C3 information to operators and leaders. The information to be displayed will be determined by Team 1. Team 4, Vehicle Integration, will determine hardware and software to be used in the full scale demonstration vehicle. The Vehicle Integration team will also address space claim issues and intra-vehicular information flow. The Communications team, Team 2, will determine the communications hardware and the communication protocols that will be used to transmit C2 information between vehicles or between vehicles and suitcases.

It may be insightful to give a few examples of how these teams are interrelated. Specifically, these examples will indicate how the SMI and Simulation team is dependent upon information from the other teams. For example, to develop automated C3 display formats one must have a working knowledge of the information required to perform the task as it is currently performed, i.e., prior to automation. The User Requirements team provides that information. Secondly, Team 3 must know something about the available hardware technologies (size and

characteristics) which are approved for implementation in combat vehicles. This must come from the System Integration team, i.e., displays, sizes, input control/devices, etc. This indicates what Team 3 can expect to have in terms of display hardware and the level of detail which can be displayed at any given time. The Communications team will provide information on requirements that affect rate and type (graphic or alphanumeric) of information presented.

The goal is to enhance fighting capability of the individual soldier and the Armor unit. Each team must view its role in the context of the effect its decisions will have on the actions of the CVCC operator. Specifically, the ramifications of decisions on how fast and how accurately the soldier can use the information available to him must be considered. This is why simulation plays a key role. It should allow CVCC teams to assess the effects of their decisions on soldier performance in an environment which simulates combat but without the unacceptable burdens of hazard, time and cost.

Some important guidelines were established to help guide the teams. For example:

- *Combat effectiveness in a U.S./GE allied battlefield is the goal.
- *Interoperability in command and control tasks is a necessity for achieving combat effectiveness.
- *Interoperability in command and control cannot efficiently occur at all levels of the battlefield. For example, it probably is not efficient to consider the passage of C2 information between U.S. and GE wingmen in different platoons assigned to different battalions.
- *For the purposes of the CVCC program, interoperability is most desired at the battalion level, i.e., a U.S. battalion commander should have rapid, accurate, and concise communication with his German counterpart and vice versa. The U.S. IVIS program and the German IFIS programs may be too far along in the acquisition process to address bilateral communications at the inter-platoon or inter-tank levels. However, the notion of a NATO compatible battalion terminal which can communicate with all levels in both countries seems feasible. Figure 1 shows a diagram of interoperability at battalion level.
- *Battalion level information is dependent upon the information provided from lower level units as well as higher level units and it is constrained by the information required by higher echelons.

COMBAT VEHICLE COMMAND AND CONTROL (CVC2)

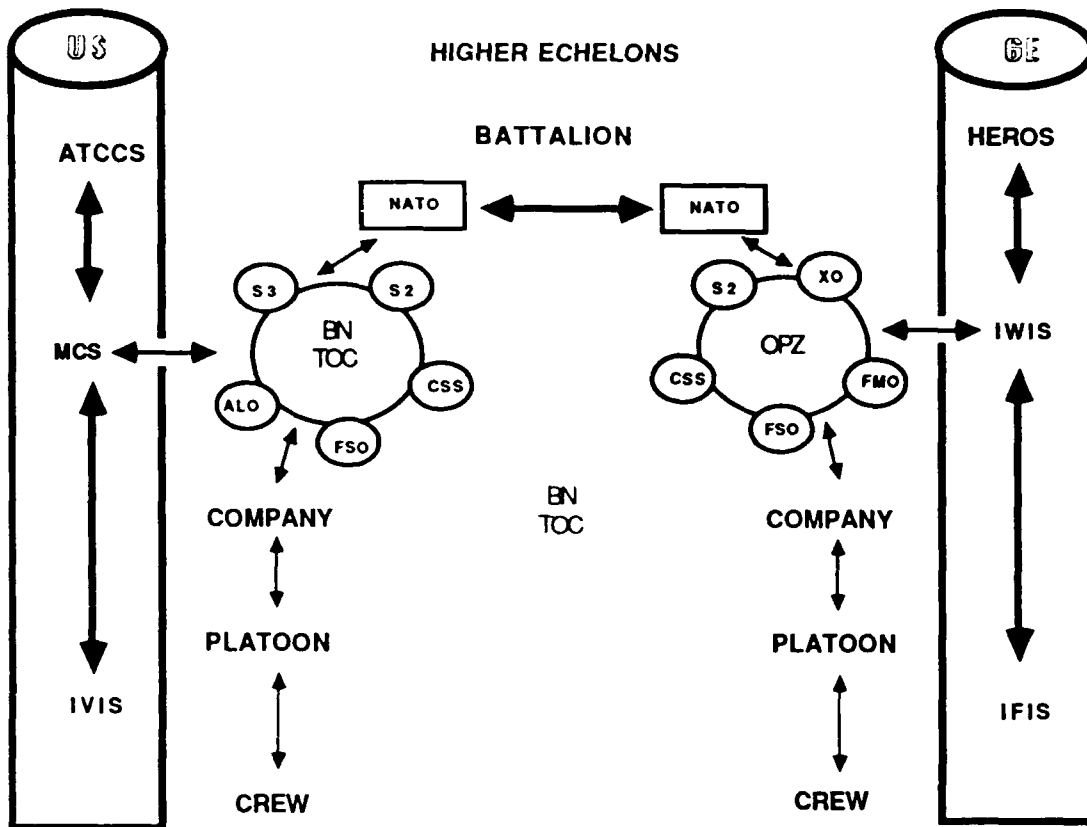


Figure 1. Diagram of Interoperability at Battalion Level

- *It is desired to have C3 capabilities that are integrated into the vehicle, however, where that is not achievable, it is desired to substitute a man-portable automated C3 capability.
- *Current U.S. tank force structure has the battalion commander fighting from a tank, not a command vehicle. However, a battalion tactical operations center (TOC) is used to house all S2 (intelligence) and S3 (operations) as well as other functions. CVCC will have to recognize and plan for this distinction.
- *Simulation research will assume the availability of color displays, high speed data busing to support transmission of graphic overlays, embedded training, advanced control systems (eg., touch panels, etc).

*Vehicle-based automated C3 assumes TOC facilities to handle digital information processing.

*There will be free and full exchange of lower echelon research methods and results between U.S./GE personnel.

*The means of obtaining true battalion level interoperability may violate currently agreed upon NATO formats and regulations. These formats and regulations will be revised as a result of the research. For example, researchers should be free to pursue non-language based methods for communicating command and control information even though current regulations require specific language based structures.

CVCC Research Context and the Battlefield Environment

The following is an overview of the context in which research efforts must be accomplished. This involves limiting the research to critical problems, developing a multi-echelon U.S. simulation, ensuring simulation supports addressing interoperability issues, and ensuring the simulation is fully instrumented to allow the measuring of soldier performance. Research must proceed from platoon-level missions to company to battalion culminating in battalion-level interoperability with GE counterparts.

To keep the CVCC Team 3 plan on an achievable schedule, research issues will be limited to those issues which are critical national issues and those which must be resolved before a joint U.S./GE simulation experiment can take place in FY93. This experiment would involve comparing use of the CVCC capabilities with a baseline condition using current C3 capabilities. Therefore, issues have been prepared based on tasks which would have to be performed at each echelon in order to execute a battalion level mission where U.S. and German battalions are actively defending contiguous areas of responsibility. This mission will commence with an upper echelon operations order (OPORD) provided to the German and U.S. battalion liaison officers. The order will include the full five (5) paragraph format of the OPORD and all supporting annexes. The orders will describe a mission in which the U.S. and German battalions must coordinate their operations in support of a North Atlantic Treaty Organization (NATO) authorized mission objective. Respective battalions will proceed to disseminate the information, coordinate activities, and execute the mission on a SIMNET terrain base.

This experiment will require the simulation of a NATO interface. It must be capable of interfacing the two simulation-based battalion (BN) tactical operations centers (TOCs). The function of this interface will be to perform all

interoperability functions between the U.S. and German forces and provide a direct link between the forces at the battalion headquarters level. The NATO interface is responsible for establishing communications with the subordinate battalion TOCs. Composition of the TOC will include the S2 and S3 sections. Communication nets within each TOC will include the command net, the operations net and the intelligence net, (e.g., scout, surveillance). Communications security will require short radio transmissions, particularly for baseline conditions, and a minimum of face-to-face communications to stress the automated communication capabilities.

The terminals in the TOC will provide electronic information displays required for battalion operations including an operations map of sufficient size and resolution to simultaneously display all terrain and operational overlays required for the planning and execution of the OPORD. Conventional display requirements for the TOC and baseline condition include the combat powers chart with current operations map and its associated charts (combat data task organization, logistics, personnel, combat power, weapon systems status, combat priorities), the tactical intelligence chart with intelligence map and its associated charts (signs and countersigns, intelligence collection tasks, enemy situation, weather), and the fire support chart. Copies of all charts must be retained (baseline condition) in notebooks so that one notebook can be sent to the commander in a forward area, and the second notebook updated and sent forward for extended operations.

Ideally all battalion-down combat systems and the BN commander's tank will be equipped with the CVCC automated C3 system. For the bilateral simulation experiment, U.S. forces will operate from CVCC equipped simulators and German forces from IFIS equipped CVCC compatible simulators. See appendix A for a description of the first interoperability demonstration.

In addition, a number of research requirements must be met to ensure that prototype CVCC systems can be systematically evaluated. Instrumentation of all prototype developments is required to provide automated records of utilization patterns, response times, errors and all communications composed and transmitted. Usability criteria must be specified in quantitative terms such as task completion times, number of errors, message accuracy and learning times. Baseline conditions and standards for conventional C3 procedures must be included as a control condition in evaluative efforts, or at a minimum reliable estimates of conventional C3 performance must be derived. Conventional C3 limitations include authentication and call sign requirements, interference caused by electronic countermeasures or terrain degradation, and net accession times.

Digital communication links will support automated data capture of communication volume by echelon, direction, duration and mission phase.

The execution of a battalion-level mission requires that the following capabilities be available. The SMI for CVCC at the crew/vehicular level must be capable of presenting graphic and text information provided by at least three levels of command above that of the crew, i.e., information from platoon leader's tank, from company commander's tank, and information from battalion commander's tank or the BN TOC. Similarly, information input at the individual crew/vehicular level must be passable to at least three levels above. This passage of information in both directions relieves some of the problems which would otherwise be encountered with the reconstitution of crews and equipment. The attendant soldier-machine-interface issues must be resolved before these capabilities are possible. Achieving these capabilities means that any CVCC system mounted in a tank must contain all functions and be tailorable for the uses of the on-board commander whether he is a tank commander, platoon leader, or company commander. Consistency of the SMI functions would also provide benefits in the training arena. Personnel should not have to learn an entirely new system in vehicles or in the TOC as they are promoted to an increased level of command.

It is important to understand the essence of the battlefield environment in which this automated C3 equipment is expected to operate. Only from a firm understanding of this operational context can the value and limitations of soldier-in-the-loop simulation be identified. Simulation is a cost effective means of addressing critical SMI issues, but no simulation or field trial can provide the full context of the battlefield environment. The results achieved from simulation must be examined in light of the following operational description.

In a combat environment, every tank commander--wingman, platoon sergeant, platoon leader, company commander, and, perhaps to a lesser extent, battalion commander and operations officer--is a warrior, and, in many ways, much like a wild animal. In order to survive, he must be suspicious, careful of exposure, and alert. In defense, he knows that the enemy force will approach in strength and try to kill him so that he cannot impede its progress. In offense, a soldier knows that someone is waiting to kill him as he approaches.

He must be concerned with the threat of enemy tanks, with the possibility of antitank crews firing at him with weapons that reach out beyond the effective range of his tank cannon, and with the threat of a sudden artillery concentration descending on him. He may enter a mine field unexpectedly and only know it when his tank hits a mine or he may suddenly become the victim of an airstrike.

Meanwhile, he must accomplish his mission. In defense, he must react to a violent assault by all the means available to the enemy and kill the attackers as they approach. In offense, he must accept the threats to his life and press on against whatever forces are arrayed against him. All of his senses, particularly sight, must be focused on survival and mission accomplishment.

Now we intend to provide him with the means to extend his senses: to "see" enemy tanks where his eyes fail to perceive them, to "hear" approaching enemy aircraft before his ears can hear them, and to predict enemy actions before his senses signal them.

However, we must be confident that the new capabilities CVCC will provide the tank commander do contribute to his survivability and effectiveness at the time of his greatest need. CVCC can be useful in times of pre- and post-combat, but it will not be essential unless it helps the tank commander survive and kill the enemy.

While there is a common thread to tank commander SMI concerns, whether the tank commander is an armor battalion commander or S3, company commander, platoon leader, or platoon sergeant, there is always a conflict between fighting the tank and attending to C3 functions. Designing and developing SMI configurations that support each echelon of C³ within the BN is critical. Figure 2 provides an artist's concept of a tank commander's workstation containing future automated C3 displays.

In the previous sections, the potential problem areas between the CVCC and its tank commander operator have been considered subjectively. In this section, a more analytic approach is taken and a broader view of the impact of CVCC on operational tank units is considered. The purpose is to develop a better understanding of CVCC operating in a combat environment and, thus, to highlight SMI problems that may be unique to the conditions that exist in battle.

Information Dissemination

CVCC will provide the capability of widely disseminating far more information than could ever be transmitted by current means. One result will be a tendency to provide more information to operational tank units, in the belief that the better informed the combat forces are, the more effective they will be. While this "more is better" attitude may be valid, it is only so up to a point. In combat, the tank commander is interested only in information that can affect his mission accomplishment and his survivability. Irrelevant information will serve only to confuse the tank commander and/or distract him from his primary task. For example, information about an enemy tank company to his front or flank is essential, but he has no immediate interest in the

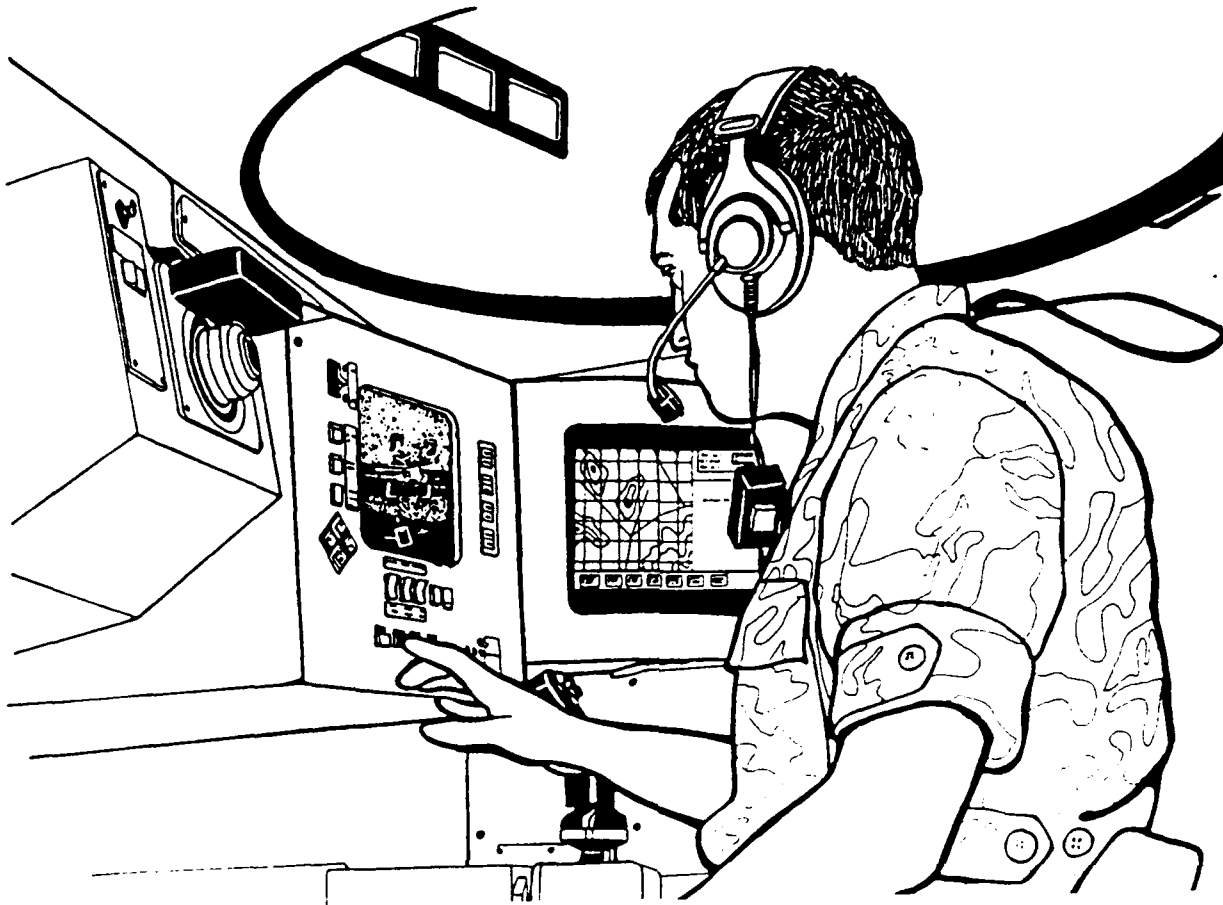


Figure 2. Commander's Workstation Containing Future Automated C3 Display

location of an enemy regiment 40 kilometers away. The threat of an immediate air strike on his unit is of vital interest, but even the loss of the division tactical operations center to an air strike is not of concern to him during an ongoing tank battle.

Therefore, CVCC must be designed to provide information only to those who need it and in priority of its importance to survivability and mission accomplishment. If the system distributes information in a broad and undisciplined manner, tank commanders will receive information they do not need and will be burdened with sifting through and prioritizing it. If this occurs in combat, it will detract from mission accomplishment by seriously diverting attention from the battlefield or by causing a failure to make timely and effective use of critical information.

The need for specific information will differ from tank commander to tank commander. The battalion commander and the operations officer need different information than the company commander, and he, in turn needs different information than is needed by the platoon leader. Even within the platoon, the platoon leader, the platoon sergeant, and the wingmen need different information. Thus, CVCC must provide for discrimination in the information disseminated.

The rules and procedures for dissemination may not need to be much different than they are today. Currently, there are standard operating procedures (SOPs) for who reports what to whom, and perhaps even more important, who is to take action on what information. While "information copies" may be distributed on a considerably wider basis, this should be done only because the information will be of use to the recipient, rather than because "more is better."

What all this means is that, with the means to distribute far more information than can now be disseminated, there must be an effective filtering system so that information goes to those who need it and those for whom it may be of use and not to those for whom it is useless or of marginal interest.

The system needs to be capable of prioritizing information as well as simply filtering it and it must assure that items requiring action clearly identify who is to take the action. Some of this may be done automatically, although, at least initially, it will probably be done by human operators generally in accordance with existing procedures. The important thing is that it be done and that CVCC be developed in such a manner that it is possible to do so.

Information Submission

While the largest amount of information that must be disseminated is flowing down the chain of command and to adjacent elements, much information will be generated at the lower levels. For example, tank commanders will be submitting information up the chain of command and perhaps to adjacent elements. This will include information concerning enemy forces, as well as friendly forces: target location, ammunition and fuel status, unit location, readiness status, etc.

Some of the information flowing up will be critical and highly time sensitive, while other information will be of lower priority. For instance, the platoon taken under fire in an ambush needs all the help it can get as fast as possible. The platoon leader can be expected to report as quickly as possible the "what and where" of such an enemy threat. His message is top priority. On the other hand, the requirement for additional

rations may wait. CVCC must provide the means to get critical and time sensitive information through the system promptly.

Part of this message prioritizing can be accomplished with a degree of automation. The aim is to relieve the tank commander of the burden of prioritization whenever possible. Thus, fuel status, for example, could be stored on board individual tanks for callup when needed within the platoon or company, or at the supporting echelon, with no action being required by the tank commander. Such a feature would also reduce the amount of excess information that might be transmitted.

In combat particularly, there is always an urgent desire at every echelon of command for more information from subordinate units. Commanders at every level need to base their decisions on pertinent information as much as possible. As combat becomes intense, however, the natural tendency of the fighter is to concentrate on fighting and worry little about satisfying the information hunger of his commander. While CVCC should make it easier, through automation of messages, for the tank commander to send information, it can be expected that the existing situation will not change. The commander will never feel that he is getting all the information he needs and the fighter will never feel that information transmission is as critical as his commander thinks it is.

CVCC must make information transmission as simple as possible, especially during combat. It is unrealistic to think that the tank commander in combat is going to take the time to go through a menu selection process to build unit symbols. He is well aware of the fact that he may die because he takes his eyes off the surrounding area in order to punch information into his CVCC. Unless CVCC provides him the means to send information in such a situation as easily as he now can by voice radio, the flow of information in the heat of battle will not improve.

Information Redundancy

If CVCC provides for the easy entry and dissemination of information to all interested parties, there must be concern that redundancy may overload the system and its users. For example, a tank unit might be attacking through a valley. In the distance, an antitank missile is fired and hits a friendly tank. This is vital information, of immediate concern to the fighting element, as well as to its higher commanders. But who reports it? Every tank commander might. A scout on the flank might. The enemy element might be spotted by a remotely piloted vehicle (RPV) and the information processed through intelligence channels. Each transmission of information related to the enemy action or unit would probably be somewhat different, so that the means to avoid redundancy --- or to counter it --- cannot be a simple automatic cancellation of duplicative information. The tank commander who

must react to the information will become confused if redundant information from different sources is fed to him automatically.

Information Filtering

During periods of pre- and post-combat, CVCC can provide the means to transfer accurate and timely information, much of which would require lengthy voice transmissions or physical meetings for an exchange of maps, overlays, etc. On the other hand, during actual combat the informational needs of the tank commander are simple, perhaps limited to a physical area requiring knowledge of the location of himself, the rest of his unit and other friendly forces, the enemy, and whether there is a threat such as an incoming air strike.

The difference in the quantities of information required/desired during these different periods dictate that there be a means of filtering information. Various means could be used, such as the sender assigning a priority to the message and an automatic means for handling different priorities programmed into the receiving computer. A tank commander himself might set his display to limit the amount of information displayed. In the longer term, artificial intelligence could be used to assist in filtering messages.

An important function of a message/information filter should be to eliminate the display of redundant information. It is important that the tank commander get the information he needs, but once he has it, it need not be repeated, even from a different source. The filtering process could begin at higher echelons, but some of it will have to be done at the tank level. While initially, the tank commander may have to rely on his own judgement, in the longer term, an effective filtering system could serve to reduce the tank commander overload at critical times.

Equipment Redundancy

In general, tanks within a unit have the same equipment. Even where a command tank may have an extra radio set, the radio equipment other unit tanks have can perform the same functions, albeit perhaps with a little more difficulty. As a consequence, if the platoon leader's or the platoon sergeant's tank is out of action, he can switch to his wingman's tank and still perform his leadership functions.

If CVCC equipment is not the same in all tanks, so that tanks within the units are not interchangeable and leaders become dependent on the use of CVCC, inoperability of one of the leader's tanks will result in a degradation of unit capability.

It could be nothing more than consideration of costs, or it could be a deliberate desire to limit the information provided to wingmen, but there is logical support for placing a lesser capability within wingman tanks. Before such a decision is made, the impact on unit capability in a degraded mode must be assessed. The more a platoon leader or platoon sergeant relies on the capabilities of CVCC and the more difference there is between CVCC equipment in different tanks, the greater will be the degradation in capability resulting from a leader having to switch to a wingman's tank. It may be that a relatively minor equipment switch could lessen the impact. Such a capability would lessen the negative impact of loss of a leader's tank.

Stress and Fatigue

The importance of stress and fatigue on human performance in combat cannot be overemphasized. The bone-weariness that can occur from lack of sleep and constant threat to life can cause the tank crewman to lose his ability to think logically and to act promptly. The designers of CVCC must take this condition into consideration.

Complicated menus that require a correct sequence of inputs to the system, a system that is intolerant of errors by making it difficult to correct them, or a system that challenges the intellect of the tank commander will not be effective in combat. Tired and stressed tank commanders cannot be expected to perform a complex series of actions without error. CVCC must be user friendly, particularly during actual combat. A system that is satisfactory under pleasant and relaxed conditions may be unsatisfactory under the stress of combat and the fatigue of constant operations.

Direct versus Electronic Communication

One of the advantages offered by CVCC is the elimination of the requirement for key personnel to get together physically in order to plan operations and issue orders. Yet, there is something beneficial, comforting, and reassuring about face-to-face meetings among such personnel. Meetings facilitate intercommunication, the exchange of ideas and information, the raising and answering of questions, effecting coordination, and discussion of rationale and decisions. They provide a reliable means of ensuring full comprehension among all persons involved.

The current practice of assembling company commanders at the battalion Tactical Operations Center (TOC) whenever possible to issue orders can be compared to the issue of orders through the use of CVCC. The amount of information received by the company commander through CVCC will be less comprehensive than that received in a face-to-face meeting with the battalion commander and his staff. Furthermore, clarifications requested to the

order transmitted over CVCC and subsequent explanations will increase radio traffic and could reduce operational security.

Similarly, a company commander issuing an order to his platoon leaders from a vantage point overlooking the operational area could be expected to create in his platoon leaders a much greater confidence that they know exactly what is expected of them.

Nevertheless, it is often not possible to issue orders in the optimal manner of face-to-face meetings. Time is often critical and the rapidly changing situations expected under AirLand Battle doctrine will dictate the transmission of orders by radio even more in the future. Clearly, the ability to transmit operational overlays through CVCC will greatly facilitate this process.

Commanders will probably discover, though, that no matter how effective and efficient CVCC is, the understanding of the commander's intent and the coordination among his subordinates will be better when a face-to-face meeting is possible.

All of these issues must receive proper attention in the development of a CVCC system. Only through use of a soldier-in-the-loop design-test-redesign approach will it be possible to achieve an effective and usable SMI for this multi-echelon C3 system. A series of experiments should be designed to test key issues such as those discussed in the following.

Alerts

Alert information can be generated at higher levels of command (i.e., battalion level and higher) and disseminated downward, or at lower levels (i.e., individual tank or tank platoon) as a report disseminated upward. Yet, there is normally no direct communication between these higher and lower levels beyond one level up and one level down; each element operates in its own net and that of the next higher echelon. Consequently, the programming for alert information dissemination needs to address the intermediate levels through which information passes. The dissemination program could allow decisions with regard to further dissemination to be made at each level or it could provide an automated dissemination scheme at each level.

Should these decisions be made automatically by the system at each level, based on established rules (standard operating procedures) or should the leaders at each level play a role in making these decisions? If done automatically, how do the leaders/commanders go about directing the action to be taken at the next lower level? Further, how will they be assured, as unit attachments and assignments change, that all those who should

receive alert information do, in fact, receive it? What burden will keeping the system current place on users?

Alert prioritization. Alerts received during an active combat engagement compete with the ongoing situation for attention and reaction. The problem facing a commander/leader under these circumstances is quickly knowing the seriousness and immediacy of the threat and what action he must take. In such a stressful situation, there is little time for analysis of the threat and prioritization of actions.

What technique or methodology is required to ensure that alert message traffic automatically receives priority over other traffic consistent with its importance? What audio and visual characteristics that will provide an immediate cue of the level of urgency to each of its recipients can be incorporated into the design, transmission, and/or reception of alert messages? What acknowledgement of receipt and reporting requirements should be imposed on alert message recipients?

Alert display. The graphic accompanying an alert message should be kept as simple and as uncluttered as possible, yet contain the minimum essential information needed by the commander/leader to react to the situation. The content and method of displaying information for various types of alerts could determine its effectiveness in aiding the commander/leader. For example, in alerting a force to the threat of a helicopter attack, it would be of value to show the dead space that could be travelled by the helicopter(s) to get within range and to identify potential pop-up firing positions. In other cases, more conventional information, such as contour lines, approach routes, obstacles, unit boundaries, etc., might assist the commander.

If the map scale being displayed by the tank commander does not include the location of the threat, such as an incoming air attack, it will be difficult to show the threat graphically.

For the various types of alert situations that may be transmitted, what are the optimal graphic display requirements? How should operational and threat map scale incompatibility be handled? How should color and/or brightness be used to enhance the effectiveness of alert messages?

CVCC SMI Issues

Given all the operational concerns expressed in the previous section, the impacts on SMI issues must be discussed. For parsimony of presentation, research issues will be discussed under three headings: SMI Display Issues, SMI Control Issues, and SMI Training Issues.

Display Issues

Flat panel displays of various types are available or are becoming available. Any display used must be of sufficient definition to be legible, especially taking into account the small screen size dictated by available space. Color and brightness levels can enhance the information presentation. Because of the advantages of visually displayed information, the technology incorporated in the display will be a critical factor in the effectiveness of CVCC.

Display type. The display panel is a critical element of CVCC. It must effectively display information essential to the tank commander accomplishing his command and control tasks and provide the means for establishing a simple and effective dialogue between the tank commander and the system. It must do this in a physically constrained and dirty environment under stressful conditions. There are concerns with the effectiveness of any display with regard to display size, clutter, and symbology.

Display size. It is generally agreed that vehicle space constraints will limit the display size to an overall diagonal measurement of between 8 and 9 inches (General Dynamics Land Systems Division, 1988; Lockheed Electronics Company, 1988). If system controls are to be a part of the display (e.g., a touch screen configuration) and a 3:4 aspect ratio is appropriate, then the area for graphic display (e.g., digital map, free drawing) will be approximately 4 x 4 inches in size. A display of this size could seriously limit the amount of easily readable and useful information that could be displayed simultaneously. Another result could be information compressed to such a degree that it is difficult to read or interpret.

Some of the table top systems currently being used for CVCC experiments use cathode ray tube (CRT) displays. The high resolution of these displays, along with their full color and full range of brightness, has a positive effect on the ability to read and interpret the information displayed. However, CRTs are typically too deep, too fragile, and draw too much power to be suitable for tanks (Coates, 1988). Consequently, it can be expected that tank displays will use, at least initially, some type of flat panel display.

The main flat panel contenders are liquid crystal displays (LCD), thin film electroluminescence (EL), and plasma. These technologies are in different stages of maturity but are progressing rapidly. Full or multicolor displays are under development, but are not expected to be available in the near future. A three-color EL display is under development for the Army (Coates, 1988).

In view of the size constraint within the tank and the status of flat panel display technologies, letter and symbol size must be considered carefully in order to provide the tank commander with a readable display.

Display clutter. While it is desirable to display as much information as possible in graphical form, there is a point at which a display panel can become so cluttered that it loses its effectiveness. A cluttered display will confuse the tank commander and interfere with his ability to discriminate between various elements of information. A degree of clutter is acceptable during periods when the tank commander has sufficient time to sort through it. However, it would be unacceptable during periods of intense combat. Some means of selectively tailoring the amount of information displayed would seem appropriate.

The amount of clutter that is acceptable appears to be situation specific (Lockheed Electronics, 1988). A higher level of clutter would be more acceptable during the planning phase, than during the execution phase of an operation. During planning, the tank commander would want operational information overlaid on a digitized map of the operational area with terrain features, contour lines, man-made objects, etc., shown. The overlay might include friendly elements and positions, threat element composition and locations, mission information (objectives, axes of advance, control/coordination lines, etc.), and fire support information. Although a higher level of display clutter would be more acceptable during this phase than during an operation, the planning phase would be facilitated if the tank commander could select the information to be displayed simultaneously. The clutter situation would be less of a concern if only necessary information was displayed. Other information, such as preplanned fires, could be available on call.

In aircraft cockpits, it was found that color coding of discrete elements (symbols or alphanumerics) makes the locating and absorption of information easier and faster (Schmit, 1984). It would appear that CVCC could derive similar benefits though the use of color displays, possibly making a higher level of clutter tolerable. Conversely, the problem of clutter would be aggravated by a monochromatic display.

Symbology. The symbolic display of information makes effective use of valuable display space and permits more rapid recognition than the use of alphanumerics (Schmit, 1984). One matter for concern is the level of interaction steps that may be required by the tank commander to generate and position unit symbols. There may also be potential difficulty of accurately reading symbols on a small graphic display. Furthermore, the availability and use of map terrain symbology may be limited.

Unit symbols can be built in a step-by-step manner or can be chosen from an extensive menu. The approach of build-in-symbols is consistent with the user's initial CVCC requirement document (USAARMS, 1988) and has been demonstrated in a prototype system (Lockheed Electronics, 1988). Lockheed reported that in initial evaluations, the process was found to be time consuming, requiring extensive interaction between the commander and the computer. The alternative method of providing prebuilt symbols selected from a menu simplifies the process, but is still time consuming because of the number of levels necessary to arrive at the desired symbol. Further research is needed to determine the optimum solution to the problem with emphasis given to minimizing the demands on the tank commander and the time required to perform the function.

Displayed unit and equipment symbols must be easily readable. To some extent, using a high-resolution color display and enabling the tank commander to control clutter could aid in achieving this goal. However, a more basic approach to solving the problem might be to examine whether or not conventional symbols are best for CVCC to use in terms of simplicity and interoperability. Other symbology has been investigated to enhance information content and reduce the negative effects of clutter (Harris, Fuller, Dyck, & Rogers 1985; General Dynamics Land Systems Division, 1988; Hawrylak & Miller, 1985; U.S. Army Tank-Automotive Command, 1981). Should an alternative symbology system be adopted, compatibility with accepted NATO symbology would have to be maintained at some level to ensure interoperability.

The automation technology exists to make significantly more map information available to the tank commander through CVCC than is available on a simple digital map reproduction. For example, shading or color coding could be added to assist in showing terrain relief, trafficability, and cover. Based on assumed threat locations information could be displayed to aid in route selection. Masked or dead space could also be displayed. Furthermore, the system could enable the tank commander to rotate the display to suit his individual map orientation preference (Harris et al, 1985). Information of this type would be valuable during the planning phase and would not contribute to needless clutter if available on call.

Alerts. The Maneuver Control System (MCS) portion (Appendix 3 to Annex D) of the Operational and Organizational (O&O) Plan for ATCCS requires that the system provide audible and visual prompts for incoming information and that the priority and nature of incoming alerts be shown. With the normal demands on the tank commander to look other places than the display panel, this is an important interface requirement. However, audible alerts particularly can become annoying if they persist. A tank commander choosing to ignore an alert for a higher priority

activity would find a persistent audible signal distracting and annoying. Such signals have been used in automobiles and fighter aircraft and are often disabled by the operator, negating any possible benefit. Visual signals, although less annoying if persistent, can also be distracting.

Menus. The number and levels of menus presented to a tank commander in order to perform a function or task are a matter for concern. The magnitude of the concern differs depending on the operational mode of the tank, the situation being more critical during combat than the pre- or post-combat phase. Some tailoring of procedures might be possible.

With respect to the use of menus for report preparation, the more automation that could be incorporated, the less the burden on the tank commander. Such data as identification of the sender, date/time group, location of sender, etc., could be inserted automatically, possibly reducing the number of menus required.

Research should be conducted to address the type, size, resolution, and location of potential CVCC displays. The type of display refers, for example, to electroluminescent, cathode ray tube (CRT), monochromatic versus chromatic, etc. Display size is an issue which must be resolved based on engineering space claims as well as information display requirements. Resolution required is a hardware/software trade-off issue. Increased resolution requirements raise costs. Higher resolution allows more information to be obtained from the display than would otherwise be possible. Location of CVCC displays within the vehicle will drive size and space claim requirements. Workstation design techniques should be used to optimize the location of displays within the current constraints.

Advanced display technologies should be utilized and evaluated, such as: pull-down windowing using a MacIntosh computer, helmet-mounted displays, and in-direct manipulation of symbology data. User tailorability is an important display issue. Software should allow displays to be flexible and adaptable to a given user. Some commanders may prefer dealing with text, while others may prefer military symbology or pictorial representations. This tailorability should allow the operator to preset desired default values and functions of his choice. This tailorability should support the command structure's requirement to have a common perception of the battlefield, that is to say, while each user may have preferences he should be able to travel up and down the range of available data to determine how his piece of the battlefield relates to other levels of command. This is the only way in which synchronization can be achieved across echelons.

Display issues must also contend with the ramifications of subsystem integration. For example, as sensor suites become increasingly predominant in new weapon systems, the CVCC display will have to accommodate the information they provide and do so in a meaningful fashion. It is doubtful that we can or would want to address "sensor fusion" issues within the CVCC program, however, it is imperative that in our simulation experiments we provide data to the CVC2 system from at least one external sensor system. The most logical choice is the M1 tank Block II subsystem referred to as the Commander's Independent Thermal Viewer (CITV). This subsystem has a counterpart which is already fielded in the German Leopard II, the staget sight. Finally, the CVC2 system provides its own ramifications in the form of old data. The research issue which must be addressed is how to meaningfully replace old data with new data and what criteria are used to determine duplication of information at each echelon.

Control Issues

Overview. CVCC is being developed with the intention of unburdening the tank commander in performing his command and control functions. The potential danger in introducing the system, however, is that operating (and maintaining) the system may create additional burdens, either in workload requirements or in additional skill and training requirements. These new system demands will tend to offset a portion of the benefits provided by the system and could detract from the tank commander's performance of his other duties. Of concern should be the SMI means selected for CVCC, so that they are compatible with the cognitive, psychomotor, and physical capabilities of the tank commander. The control means should minimize attention diversion from the battlefield and be effective in the operational environment in which CVCC will be used. It is noteworthy that concern regarding the Light Helicopter Experimental (LHX) has already been expressed (U.S. Army Aviation System Command, 1987).

Input/Output. The initial IVIS requirement document (USAARMS, 1988) calls for interaction via touch sensitive screen. In a static, nonoperational mode, use of a touch screen would provide a quick and natural method for inputting data. In an operational environment, the use of a touch screen might present interface problems.

Among the SMI concerns related to a touch screen are the requirement for the tank commander to operate in both open and closed hatch modes, so that his position relative to the display will change; having to touch the display screen with accuracy while on the move; and possibly having to use the touch screen while wearing gloves.

Alternatives to a touch screen interface that are compatible with the projected CVCC operating environment are available. These include curser control and voice. Curser controls include mouse, track ball, and thumb controller. Of these, the thumb controller may offer the best solution. It can be integrated easily into the tank commander's control handle, accommodates the point, select, and draw functions, and represents a minimal space claim (General Dynamics Land Systems Division, 1988). However, there may be user resistance to mixing weapons functions and administrative functions on the handle. Thumb control technology is mature and low risk, but whether it is the best solution must be determined.

A tank commander has many demands on the use of his hands. It might be desirable, therefore, to have the CVCC respond to a number of voice commands, perhaps as a backup to physical interfacing. Discrete word recognizers with a vocabulary of approximately 100 words are being tested for fighter aircraft (Reising & Emerson, 1984). They are speaker dependent, which should facilitate isolating other crew members from inadvertently interfacing with the system. If the automatically developed speech template were not to provide adequate assurance against accidental triggering of the system, then other means to control the interface with the computer are probably available. The tank commander would also have to be assured that his use of the intercommunications system to communicate with the crew would not trigger a CVCC response. Requiring the use of a hand for this would at least partially negate the benefits of any CVCC voice interface. The LHX system specification addresses this type of requirement for the helicopter pilot (U.S. Army Aviation Systems Command, 1988).

Helmet mounted displays are effective in providing a pilot-cockpit panel interface in high performance aircraft (Reising & Emerson, 1984). Whether such an interface would have any applicability to the tank commander-CVCC situation because of helmet size restraints and ground clutter might be worth pursuing.

Determining user preferences for input devices for CVCC is an important issue that requires extensive investigation. Presently, prototypes for C3 systems have primarily employed touch sensitive displays or cursor manipulation devices such as a mouse or joystick. For Armor systems, in particular, commander's control and activation of resident weapon subsystems requires intensive manipulation of manual control systems. Any requirement for additional manual inputs associated with CVCC results in significant trade-offs.

CVCC with its electronic map manipulation functions is expected to provide substantial assistance for displaying and manipulating map data and overlays particularly given the narrow confines of the commander's "workstation". Analyses of user

requirements by DCD and ARI-Knox show that users prefer touch-based input devices, but this has not been thoroughly evaluated in an operational, on the move, context. Keyboards were not preferred by the majority of platoon level respondents.

To minimize user input requirements, voice actuation capability would appear to be an important avenue for future research. The most obvious concern is voice recognition reliability in a noisy and stressful battlefield setting. In addition to a natural language input medium, the focus on interoperability requires an investigation of language translation systems.

If near-term input devices for CVCC are not voice-based, it is strongly suggested that interoperable communications rely primarily on graphic and map-based tactical data inputs. Symbology software must afford users a rapid and effective medium for unit and control measure manipulation (e.g., placement, scaling, orientation, labelling). It is also recommended that the CVCC design and its communication protocols use graphic and map-based tactical information instead of the more time-consuming text entry or text selection from preformatted menus.

Training Issues

Training will be of prime importance when CVCC is introduced. The CVCC subsystem is a computer and interacting with a computer is inherently different than interacting with the mechanical and hydraulic subsystems with which tank commanders are familiar. While the advent of the M1 tank gave the armor force a digital system to replace its old analog systems, even the M1 did not require the extensive software brought about by this new CVCC subsystem. The tank commander will have to know how to use this computer-based system effectively while still performing his other functions.

There seems to be an expectation among those involved in CVCC development that soldiers will have no trouble learning to operate the system. This premise appears to be based largely on the perceived high comfort index of young people with computers and video games. The expectation may prove to be totally correct. However, until established as valid, the training required to prevent overload should be a matter for concern.

The potential for CVCC to automate, or at least partially automate many of the tasks associated with C3, does not eliminate the need for a thorough investigation of CVCC training requirements. An initial concern for any evaluation of CVCC prototypes is that training requirements and a training program for that prototype have been identified and developed prior to CVCC evaluation. Past U.S. and German research efforts on automated C3 have suffered from inadequate training of the

soldiers operating these systems. ARI has provided one complete day of training on SIMNET for a position navigation (POSNAV) device (DuBois & Smith, 1989) prior to evaluation exercises and two days training on combined POSNAV/IVIS platoon level research (DuBois & Smith, 1991).

CVCC prototypes must ensure that prompting instructions are continuously provided to novice users that give clear and consistent guidance while attempting to utilize any CVCC function. User inputs and selections must be clearly indicated (e.g., reverse-video) and entry errors detected and clarified with instructional feedback.

The computer-based nature of CVCC provides a ready medium for embedded training and this is strongly recommended as a supporting function in the development of CVCC prototypes.

As CVCC systems are developed they will result in a reconsideration and reallocation of crew and commander task assignments. "Information is power" and the real-time distribution of combat data provides commanders with a unique opportunity to delegate responsibilities (e.g., to gunners, drivers within the crew, or subordinates such as tank commanders, platoon leaders) and to assume greater initiative and control on the battlefield. As evaluations of CVCC at each echelon are conducted, changes in duty-position task assignments will more clearly emerge. Training, as well as doctrinal programs should exploit this CVCC advantage. On a related note, differences in user skills and information requirements should be anticipated so the CVCC can be tailored to offset reconstitution and reassignment contingencies.

Integration Issues

Workload. When considering integration issues, a key measure to review is that of workload. The SMI design of the CVCC system must take into account not only the tasks required for CVCC operation but also those for target acquisition, crew coordination and other duties. All of these contribute to the tank commander's overall workload. If workload is too high, some tasks may not be performed correctly or at all.

Referring to military aircraft pilots specifically, the characteristics of the increasing workload listed below are equally applicable to the tank commander (Schmit, 1984): a heavy and increasing information load; time stress for the increasing proportion of the mission profile; an increasing communications load; an increasing systems/sensor management load; significant loadings on short-term memory; and increasing environmental stresses.

The tank commander must be able to concentrate his efforts on fighting his tank in times of actual combat and doing all he can to ensure its survivability. On the other hand, an effective CVCC could lessen his load somewhat during those times and greatly increase his efficiency during non-stressful periods by having the means to send and receive masses of data quickly and accurately.

One concern is the conflict between providing the tank commander with the means to transmit and receive a wealth of information without overloading him during actual combat. The tank commander today is already overburdened. The pace of modern warfare and the demands of new weapon systems are increasing this burden. Technology in the form of CVCC can serve to lessen the total burden, but the concerns expressed above are real ones. The Army must proceed with caution into the realm of CVCC lest it increase, rather than decrease the tank commander's load. The careful application of technology to solve some of the potential SMI problems should result in an effective CVCC that helps, rather than hinders, the tank commander in the performance of his duties.

Target Acquisition. The CVCC system must be integrated with the target acquisition systems on-board the vehicle to maximize combat effectiveness and minimize workload. Information presented on the CVCC display must be compatible with information provided in the displays for such systems as the Commander's Independent Thermal Viewer (CITV) or the Multiple Target Acquisition System (MTAS). For example, orientation icons should provide consistent information from display to display. Other areas where integration can be useful include such capabilities as map to sensor slew, i.e., touching the map and having one of the vehicle sensors move to that azimuth.

Interoperability. The CVCC system must be interoperable with the Army Tactical Command & Control (ATCCS), the communication-electronic systems within the tank, and with the German CVCC equivalent. Requirements to interface with the ATCCS will put demands on the CVCC design. The inputs from sensors and systems must not present the tank commander with a variety of outputs, but rather conform to the standards of CVCC. Interoperability with the German system will require unique features.

Of concern is the possibility that ATCCS will put constraints upon the CVCC design such that the SMI features of the system cannot be optimized. The MCS-CVCC processor is required by the ATCCS O&O Plan to transmit data over the Army's communications system and communication security (COMSEC) devices without disrupting voice communications (USAARMS, 1988). A matter of concern is whether this requirement will result in

unaffordable complexity. One solution is CVCC displays that use NATO symbology and terminology.

The vetronics architecture and the IVIS starter package document require that other communications-electronic systems within the tank feed into CVCC. Of concern is the possibility that there will not be sufficient discipline within the development community to provide optimal interface between new systems and CVCC. The tank commander must not be faced with CVCC outputs that are inconsistent; they must be optimized to present the least interpretive burden to him.

If interface with the German system is to be provided, it must be incorporated in the tank or provided by a communications channel through the task force TOC. While symbology must be translated into NATO format even if it is not used on the CVCC display, English-to-German translation presents a greater problem. Presumably, the vocabulary of whatever system is used can be limited. Just how this will be accomplished must be a part of the CVCC development.

Technologies Supporting CVCC

In this section, the SMI issues resulting from the concerns identified earlier in this paper are highlighted in order that proper consideration to their resolution can be given. These issues are discussed in detail in the following paragraphs. They have been grouped according to the various functions CVCC is expected to assist the tank commander in performing within the tank. Related technologies are discussed where applicable, as well. A number of technologies have been mentioned in considering the SMI concerns. In this section, they are isolated for further consideration.

Position Navigation and Graphics Capability

There is a trade-off between the amount of information required and the complexity of the display. While technology can probably provide virtually any level of terrain detail desired, it is important to answer a number of questions concerning the detail really required. Also, it is important to determine the level of detail which offers the greatest benefit to the tank commander.

Should the display be an exact duplicate of a printed map sheet? Should only certain key terrain features be shown? If elevation is to be shown, is there a better way to show it than using contour lines? Is a selection of terrain feature overlays -- perhaps selected by color -- required?

Map scale. Maps are currently generally provided in scales of 1:25,000; 1:50,000; 1:100,000; and 1:250,000. A determination

must be made if these choices are adequate and appropriate. A large scale map is appropriate for platoon operations, but an air strike warning could be expected to demand a much smaller scale if it is to be shown on the display. Clearly, some selection of map scales is required.

What scale maps should be available in the CVCC system? Are current scales adequate? What alternate map scales need to be provided the tank commander and how should they be selected?

Map Orientation. It should be possible to present the map display to the tank commander with any orientation, i.e., north at the top or in any other position. The system may give the tank commander choices or a particular orientation will need to be selected before full development of the system. How the area shown is selected and changed must be determined.

Should north always be at the top of the display? Would it be better to orient the map in the direction the turret is turned or the direction of movement? Should the operating tank commander's vehicle always be at the center of the map or should a selected area of terrain be shown. How should the terrain shown be changed, i.e., automatically, by the tank commander, or by the unit commander? Should all tanks within an element, for example, a platoon, have the same area of terrain displayed?

Symbology to be used. The easiest interface between CVCC and other systems would be accomplished by using conventional (NATO standard) map symbols. However, it may be that there is a better symbology to use for CVCC specifically, one that might, for example, give the tank commander more information.

Should conventional map symbology be used? If not, what system would optimize use of CVCC by the tank commander? If an unconventional symbology is used, how will it interface with the U.S. MCS and the German IFIS system?

Color/brightness levels. The number of colors offered will contribute to complexity and cost of the CVCC system, yet a range of colors would make the display easier to read by the tank commander and provide more information. Brightness levels might substitute to a degree for colors. Brightness level could also be used to distinguish between types and/or importance of information.

How many colors are appropriate? What are the trade-offs between complexity/cost and utility of a number of colors? How many levels of brightness are clearly distinguishable by the tank commander, considering particularly the varying light conditions? How many brightness levels should there be? To what degree can brightness levels be substituted for colors?

POSNAV information update interval. The level of accuracy required by the tank commander of his tank location and that of other vehicles in his unit will have an impact on the complexity of the electronics and on the amount of communication capability devoted to this particular feature. Updating can be related to time, distance moved, or perhaps some other interval.

How often should the POSNAV information be updated? Should it be at particular time intervals or should it be related to distance moved since the last update? Is there some other appropriate method that should be used for determining the update interval? Should the updating interval be different for the tank Commander's own tank than it is for information transmitted concerning POSNAV information?

POSNAV information transmittal. Within a particular vehicle, POSNAV information will be readily available and can be displayed with frequent updates. There is a question, though, concerning how often such information should be transmitted and whether transmission should be automatic or the information available on call.

Should POSNAV information be broadcast at intervals or should the information be available and transmitted only in response to a query?

Level of unit information to be displayed. POSNAV information will be available from each vehicle in a unit. However, the command level at which individual vehicle information should be displayed is an issue. Clearly, a platoon leader cares about the location of each vehicle in his platoon, but the division commander is interested in unit locations rather than individual vehicle locations.

To what echelon of command should individual vehicle locations be shown? What about information concerning flank units? At what level should individual vehicle POSNAV information be translated into unit location and how should this be accomplished?

POSNAV information relayed to driver. While the tank commander is interested in his location vis a vis the map, the enemy, other vehicles in his unit, etc., the primary interest of the driver is in following a route or direction.

How much information should be relayed to the driver? How should his information be displayed? Does he need a map display or only a heading and some information on distance?

Operator input. There are various ways for the tank commander to provide input to the CVCC system. These have been

discussed earlier, including such methods as touch panel, curser movement, and various types of hand controls.

The physical location and the physical interface between the tank commander and the CVCC system must be compatible with the physical environment of the tank.

What is the optimal method of facilitating operator input to the CVCC system? How can a free draw capability best be achieved?

System Integration

Integration of other system information into the CVCC system will unburden the user if properly accomplished. CVCC can provide central processing and display of information that other systems within the tank generate, including that related to fire control, logistics, diagnostics, and embedded training. The key to integration success is use of the vetronics architecture, interface with which must be a requirement of all subsystems developed for the tank. The degree to which information from these other systems is integrated and processing automated must be determined.

As the CVCC system is developed, new capabilities, such as identification friend or foe (IFF) or a laser warning, must be integrated into the system. To what level should fire control information be integrated with CVCC? Should, for example, turret orientation and laser rangefinder generated range be combined automatically with own tank position information and target location automatically displayed? Should monitoring of ammunition and fuel status be automatically displayed and/or should there be built-in alerts when critical fuel and ammunition levels are reached, and should these levels be fixed or set by the tank commander, unit SOP, or a higher level commander? Should diagnostic information be completely integrated into the CVCC system and should it include alerts?

Transmittal of information. Some of the information generated by systems within the tank is of particular interest to other echelons of a command external to the tank.

For example, the fuel and ammunition status of the tanks within a platoon is of interest to those responsible for resupplying the platoon on a timely basis. Automatic broadcast of this information could result in monitoring of an entire unit by its logistic element, without the need for the individual tank commander or platoon leader to take any action. The logistical element could then plan and conduct rearm/refuel operations in the most logical manner.

On the other hand, the automatic broadcast of most fire control information generated during each engagement would be inappropriate to provide to higher headquarters. It would likely result in overload of the higher commander and wasted communication capability. Nevertheless, a tank commander might want to pass on to his commander, on occasion, fire control information, such as location of a target or the rate at which targets are being engaged, by using as much automation as possible.

Similarly, it would clearly not be desirable to broadcast all of the diagnostic information generated within each tank. However, a tank commander having mechanical difficulties would like to be able to automatically provide as much diagnostic information as possible to the unit maintenance echelon at his discretion.

To what degree should the transmission of information generated by on-board systems be broadcast automatically and/or how should the tank commander control the dissemination of such information?

Fire Support Planning

Manually transcribing alphanumeric fire support plans to maps is a time-consuming process. The automatic transmission of fire control plans in graphic form within the CVCC system will alleviate that burden on the tank element commander. However, the exclusive use of information on an overlay risks cluttering the tank commander's display to an unacceptable degree.

How much fire support plan information should be transmitted and displayed in graphic form and how much in alphanumeric form? How much of the alphanumeric information should be displayed graphically, and how should the remainder be readily available to the tank commander who may require it on short notice? Can it be available graphically on call so as not to clutter the display needlessly?

Implementation of fire support plans. Good fire support planning enables the fighter to call quickly and accurately for appropriate fire on designated targets. Requests for target engagement can be made through the use of standard formats. Implementation of optimal automation in requesting fire support will reduce the burden on the tank commander and result in timely fire support.

How can requests for preplanned fire support best be simplified and automated so that they create the least burden on the fighter and result in maximum speed and accuracy in transmission?

Orders

The CVCC system promises great enhancement of the ability to issue orders, both when time is available for orderly preparation for an operation and when operational exigencies demand issue of a fragmentary order (FRAGO) by radio. At the company level, operation orders should be presented in the format of an execution matrix accompanied by a graphic display. The execution matrix essentially eliminates the narrative presentation of the plan. Nevertheless, a limited menu of standard words, phrases, and abbreviations will be required to prepare the matrix.

Preparation of the graphic will require the ability to draw such features as objectives, unit boundaries, axes of advance, etc., and to select or compose, and to locate unit symbols on a basic map display. The procedures for accomplishing this need to be optimized by minimizing the steps required by the operator to generate the display. Anything less will be burdensome, time consuming, and frustrating to the tank commander.

In the issue of orders, the methodology for mixing displayed (alphanumeric or graphic) information with voice transmission must be determined. Unless issuing orders through the use of displayed information makes the issue of orders more effective, the system will not be used.

What standard dictionary menu is required to produce an execution matrix? How essential is it that the user have the ability, with minimal training, to amend the dictionary by adding or deleting words (e.g., objective or phase line names)? What is the optimum approach to the problem of selecting/composing and locating units symbols?

Language interface with German IFIS. It is not clear at what level interface between and German forces will occur. Indications are that the interface will occur at the battalion (task force) level, although the desirability of interface capability at the platoon, or even tank, level has been expressed. There is merit to interface at the lower level because fighting at the platoon level along international tactical boundaries may well rely on adjacent platoon operations where the platoons are of different nationality.

Standard NATO agreements (STANAGS) can result in effective communication without translation to a degree, particularly in the area of standard symbology, but some level of automated English/German translation would seem to be required.

From an operational viewpoint, at what organizational level should the IVIS/IFIS interface be established to optimize combat effectiveness of adjacent forces? If it is at battalion level, how will companies and platoons function when operating adjacent

to each other? How much automated translation capability is required and how will it be incorporated in the IVIS/IFIS systems?

Reports

The CVCC system will reduce significantly the effort necessary to produce reports by automating to some degree the collection and updating of system and threat information, and inserting the information automatically in reports.

How extensive can the automation of reports be within the CVCC system? Are current reporting forms appropriate for use with CVCC?

Display of reported information. In compiling reports, the preparer's task would be made simpler and completeness of reports would be better if appropriate report formats displayed the data elements entered automatically and cued the commander for missing data. Logistic and personnel reports could typically be prepared in this manner. It may be beneficial, though, for operational reports to be overlaid on a graphic. This procedure would facilitate understanding of the report and could eliminate the need for manually transferring report data to the map.

How should the CVCC system simplify the preparation of reports for submission?

Simplification of reporting during combat. Procedures for reporting during combat should be designed to expedite the flow of critical combat information while minimizing diversion of the attention of the fighter from fighting. The maximum amount of automation is important and there must be an effective way to mix alphanumeric, graphic, and voice information.

Several issues related to how the tank commander will use future systems have been investigated at the crew and platoon level in research efforts using state-of-the-art soldier-in-the-loop simulation located at Fort Knox. The following section provides a brief overview of key efforts.

Related ARI-Knox Research

The ARI-Fort Knox Future Battlefield Conditions research program has conducted soldier-in-the-loop assessments on several proposed improvements to the Abrams tank fleet. The results from the experiments on these new technologies are discussed below.

The CITV is a surveillance and target acquisition system to be used by the M1 TC. The CITV allows the TC to search a sector, identify and hand off targets to the gunner, and continue the search (Quinkert, 1987, 1988). Research effort by Quinkert

(1990) has indicated that the main advantage of the CITV over the conventional target acquisition methods is for targets that are acquired and engaged after the initial target. The result is an increase in number of detections and kills, at a significantly faster rate. Evaluations of the other systems, POSNAV and IVIS, have proved that these systems have advantages over the conventional C3 methods.

The POSNAV system was designed to provide the vehicle commander with position location and an automated heading reference system. In 1989, Du Bois and Smith empirically evaluated the POSNAV system by configuring a simulation of the system into: 1) a grid system (POSNAV-G) and; 2) a terrain system (POSNAV-T). These two systems were compared to the conventional navigational methods. In almost all battlefield situations, the POSNAV systems enabled crews to navigate more efficiently than the crew using conventional techniques (Du Bois & Smith, 1989). More specifically, Du Bois and Smith (1989) found that POSNAV crews reported increased capabilities in terms of determining own-tank location, maintaining own-tank orientation, determining the location of other battlefield elements, performing map terrain association, navigating point to point, bypassing obstacles, and reacting to enemy fire.

The IVIS was designed to provide automated C3 capabilities to the TC. The IVIS is a computer-based digital terrain map with preformatted menu-driven reports, touch panels, and radio-interface units for intervehicular transmission. An assessment of the IVIS system (Du Bois & Smith, 1991) indicated that tank crews and platoons using IVIS technology performed significantly better than control crew and platoons with conventional equipment. The data indicated that IVIS improved unit performance in mission execution time and success, report times and accuracy, FRAGO execution, battle position occupation, and obstacle bypass efficiency.

Future CVCC evaluations are listed in Figure 3. The goal of the CVCC simulation experiments is to proof the concept of automated C2 tools and to investigate key SMI and training issues. A second goal is to have a joint U.S./GE battalion-level capability by FY93.

Proposed CVCC Research

Principles Guiding the Specification of the Proposed Research

Several considerations guided the selection of the particular subset of research issues delineated below from the literally scores of research-worthy questions identified in the previous sections. These considerations are: 1) the projected gain in CVCC system effectiveness resulting from the knowledge produced by the research effort, 2) the time frame within which

CVCC SIMULATION SCHEDULE

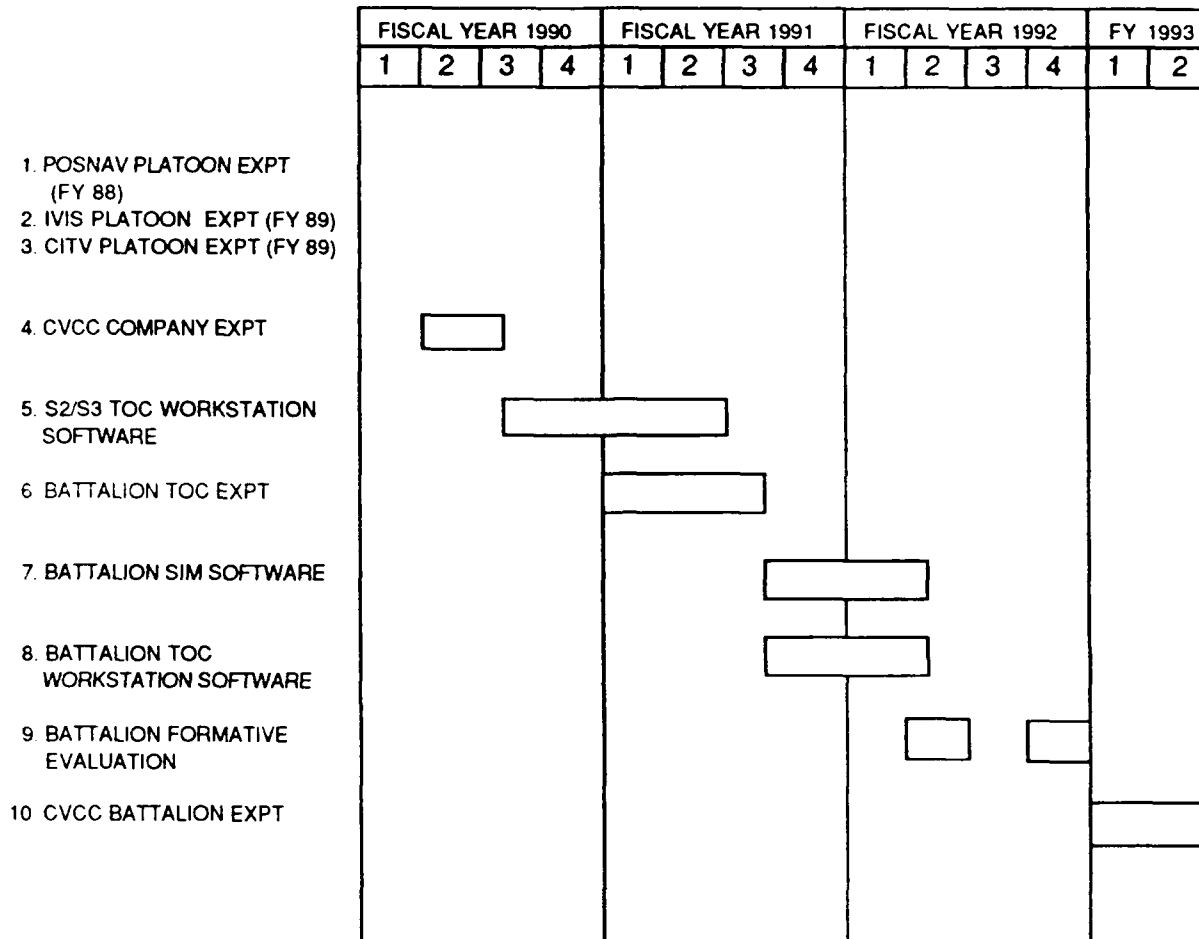


Figure 3. Future Technology Evaluations for CVCC

the research must be completed, 3) the compatibility with existing technology, and 4) the logical sequencing of individual research efforts, the results of which impact the need for and direction of many of the other proposed experiments.

Recent platoon level experiments on the SIMNET-D-based prototype of the CVCC system have provided a wealth of information regarding the problem areas demanding immediate attention if CVCC is to fully realize its already well documented potential. For example, these experiments have made it abundantly clear that there are dramatic gains in route planning and navigation speed and accuracy resulting from the use of the prototype CVCC system.

These experiments have also highlighted a number of troublesome, though clearly circumventable barriers to the smooth and efficient flow of information through the CVCC system. As an illustration, the CVCC system's capacity to provide the soldier with critical information is so powerful that the soldier can rapidly become debilitatingly overloaded. In response, he may attempt to cope by failing to attend to vital reports. Accordingly, mechanisms must be developed to automate the information filtering and prioritizing process. More to the point here, this example illustrates a threshold problem identified through hands on experience with a CVCC prototype for which behavioral science research can provide a solution in a relatively short term.

The expected time required for completing the research needed to address key issues also helped determine the research issues selected for discussion. Given that our objective is to provide guidance for design specifications issued in early 1993, key issues that can be reasonably addressed in this time frame were given particular emphasis. Provided there is the requisite commitment of resources, it is reasonable to expect that all of the proposed experiments can be completed within the above time-frame.

Related to the time consideration is the compatibility with existing technology. Given the rapid pace of technological advances, it is easy to fall prey to a pattern of assuming that new technologies will become available that will solve major system problems. This can lead to the failure to address related problems for which current technology is capable of providing solutions. The first proposed experiment is a case in point. It addresses the issue of CVCC input through voice-recognition. If voice-recognition input technology were sufficiently advanced, it clearly would be a nearly ideal solution to a number of problems related to the efficient and non-distracting input of data to CVCC. However, simply assuming this capability will be available in the next three years invites the risky decision not to proceed with research on a number of issues that can and must be solved in this time period if less exotic, but currently available technology is actually utilized.

The guiding principle here was to proceed with the research necessary to implement an effective CVCC system based on known technology. This ensures that a workable system can be designed in a timely manner. Nevertheless, where a developing technology appears to have enormous potential for improving the CVCC system, as in the case of voice-recognition, we propose concurrent research directed at that goal.

In sum, the experiments specified in Tables 1-10 are the product of the aforementioned considerations. Following the more detailed specification of these experiments is a more

general discussion of additional research questions which clearly need attention. In most instances, these represent CVCC issues that should be the object of study, but which at the present juncture do not appear to be as pivotal as the ten experiments delineated below. Research on them need not necessarily occur during the next three years in order to have a highly functional CVCC system specification in early 1993.

Table 1

Problem I: Feasibility of Voice Input to CVCC

OBJECTIVES:

Based on literature review and empirical investigation, identify variables likely to impact accuracy of voice recognition in a tank environment and determine the range of commands that can be reliably understood through voice recognition under combat conditions.

TASKS:

1. Review literature on voice recognition issues relevant to CVCC tasks in tank environment.
2. Determine accuracy of voice recognition under tank battle environmental conditions (e.g., under various levels of noise, stress, etc.).
3. Determine the vocabulary necessary for effective voice-recognition based communication with CVCC.
4. Determine length of recognizable vocabulary consistent with (2) above.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs, probably three to five TCs for one or two days.
- Live tank for acoustic analysis & voice recognition tests.

INPUTS:

- Knowledge of combat conditions relating to noise and stress
- Knowledge of Army-preferred oral commands

OUTPUTS:

- Feasibility of voice recognition input to CVCC
-

Table 2

Problem II: Determine Optimal Cursor Control Procedure for CVCC Input

OBJECTIVES:

Based on literature review and empirical investigation, determine effects of various cursor control procedures including touch-screen, mouse, joy-stick, and thumb control on speed and accuracy of input to CVCC under tank combat conditions (e.g., vibration, movement, dirt, donning gloves, etc.).

TASKS:

1. Review literature relevant to cursor control input speed and accuracy under stress and adverse environmental conditions.
2. Identify environmental factors (e.g., motion, heat, limited workspace, gloves) characteristic of tank combat likely to impact cursor control effectiveness.
3. Conduct research necessary to evaluate speed, accuracy, train-up requirements, and user acceptability of alternative cursor control devices under conditions identified in (2) above.
4. Prepare report containing recommendations for militarizing the CVCC cursor control system.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs, probably ten to twenty Tcs for two to four hours.
- Live tank or simulator with high tank motion fidelity.

INPUTS:

- Size of display
- Type of display

OUTPUTS:

- Optimal cursor control device for particular display
-

Table 3

Problem III: Establish CVCC-Based Report Content, Frequency, and Priority Requirements Within and Between Platoons, Companies, and Battalion

OBJECTIVES:

Define text and graphics information needs and priorities enabling the specification of report content, report priority, and report routing for CVCC-based communications at the platoon, company, and battalion levels.

TASKS:

1. For each echelon (i.e., platoon, company, battalion), identify CVCC-based perceived information needs, both sent and received, during all phases of tank operation.
2. For each echelon above, develop and evaluate alternative strategies (e.g., automated, assigned by sender or recipient) for determining priority attached to reported information.
3. Determine the impact on conclusions in (1) and (2) above of voice-recognition based reporting system rather than cursor entry report input.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs, approximately three to five for each echelon (platoon, company, & battalion)
- Manned multiple simulators (SIMNET-D).

INPUTS:

- Basic understanding of projected CVCC capabilities (e.g., display size, inputting demands)

OUTPUTS:

- Specification of report content requirements by echelon
 - Specification of report priority by echelon
 - Specification of technique for and origin of report prioritization
 - Impact of voice recognition input on above specifications
-

Table 4

Problem IV: Redundant and Unacknowledged Reports in CVCC Report Queue

OBJECTIVES:

Based on literature and empirical investigation, identify automated strategies for identifying and eliminating redundant combat information from being entered in and retrieved from CVCC report queue and for providing verification that vital reports were read.

TASKS:

1. Identify, classify and document types of report queue redundancy problems experienced with completed SIMNET-based CVCC experiments.
2. Identify and review relevant literature to identify existing knowledge regarding automated strategies (e.g., artificial intelligence, statistical decision models) for identifying redundant data.
3. Develop echelon-tailored (platoon, company, battalion) automated strategies and/or reporting protocols which will permit the filtering of redundant reports.
4. Develop efficient strategies to provide acknowledgment that transmitted reports were received and processed by intended recipient(s).
5. Perform SIMNET-based experiment to demonstrate the effectiveness of strategies developed in (3) and (4) above in a task-loaded environment.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs familiar with CVCC reports at platoon, company and battalion levels.
- Multiple simulators (SIMNET-D) for platoon, company, and battalion level simulations.
- U.S. to GE TOC link.

INPUTS:

- Specification of planned report types, content, and priority.

Table 4 (cont'd)

- Echelon (platoon, company, battalion) differences in extent and nature of redundancy problem.

OUTPUTS:

- Filtering software and report protocol specifications enabling the automated reduction or elimination of undesirable redundancy in CVCC report queue.
 - Capability to ensure vital reports were read by intended party.
-

Table 5

Problem V: Optimal CVCC Map Features and Scale for Route Planning and Navigation

OBJECTIVES:

Identify combination(s) of map terrain features, map scale, and CVCC special features display capabilities (e.g., LOS, perspective view) which optimize speed and accuracy of route planning and navigation.

TASKS:

1. Develop series of tactical navigational problems representative of the range and combinations of surface features and battlefield circumstances likely to confront NATO armored forces.
2. Identify map terrain features including but not limited to grid, contour, vegetation, roads, rivers, and structures potentially useful for route planning and navigation under circumstances identified in (1).
3. Identify combination of map scaling options most useful for solving navigational problems identified in (1).
4. For CVCC display special features capabilities (e.g. Line of Sight [LOS], perspective view), identify conditions and map feature combinations which may impact their usefulness for route planning and navigation in problems developed in (1) above.
5. Design experiment(s) to determine combination(s) of map features identified in (2), (3), and (4) which maximize speed and accuracy of solutions to problems in (1).
6. Perform experiment(s) in (5) and prepare report detailing procedures, results, and conclusions. At a minimum, report should establish empirical basis for defining pre-set defaults for various map scale/terrain & special feature combinations.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs familiar with platoon, company, and battalion level (three to six per echelon) route planning and navigation tasks and problems.
- Tabletop and/or manned simulators.

Table 5 (cont'd)

INPUTS:

- CVCC display specifications including size, color and shading capability, and resolution

OUTPUTS:

- Designation of optimal CVCC map scale, terrain, and special features display capabilities
-

Table 6

Problem VI: Icon vs. Map Movement to Efficiently Track Changing Location

OBJECTIVES:

For CVCC display on which own tank icon remains stationary (centered) while map moves versus display where map is stationary while tank icons move, assess relative effect on speed and accuracy of location perception and effects on user reaction. Evaluate CVCC-based map section movement techniques.

TASKS:

1. Identify series of test exercises by evaluating suitability of navigation tasks defined in V(1) and supplement as necessary.
2. Design experiment(s) to evaluate effectiveness of alternative map/icon movement formats on soldiers' navigational performance and soldiers' preference.
3. Determine technologically feasible set of procedures for manual scrolling of map.
4. Design experiment to evaluate soldier speed, accuracy, and reaction to alternative manual scrolling techniques.
5. Perform research in (2) and (4) and prepare report summarizing procedures, results, and implications.

PROJECTED RESOURCE REQUIREMENTS:

- TCs serving as subjects.
- Tabletop or manned simulator

INPUTS:

- Specification of CVCC display size, resolution, & color capability
- Specification of anticipated CVCC map scale and terrain features
- Specification of cursor/input device for controlling map movement

Table 6 (cont.)

OUTPUTS:

- Specification of optimal procedure for tracking automated icon movement on map.
 - Specification of optimal procedure for manual scrolling of map display
-

Table 7

Problem VII: Maintenance of Direction and Location Perspective on CVCC

OBJECTIVES:

Determine optimal display strategy for minimizing directional confusion when reading CVCC display.

TASKS:

1. Review literature relevant to automated strategies for minimizing directional confusion while performing CVCC based navigation in a "buttoned down" tank.
2. Based on (1) and SME input, identify alternative CVCC display algorithms for minimizing directional confusion. These algorithms should include, but not be limited to, (a) displayed map always aligns with true North, (b) displayed map always aligns with direction of hull, and (c) displayed map always aligns with main gun.
3. Design experiment(s) to determine optimal strategy among those identified in (2) above. Design should permit evaluation of desirability of user selectable "orienting" strategy.
4. Conduct research delineated in (3) and prepare report summarizing methods, results, conclusions, and recommendations.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs (six to eight TCs) to assist in identifying potential orienting strategies.
- Tabletop CVCC display or SIMNET
- TCs serving as subjects

INPUTS:

- Rudimentary CVCC display physical characteristics
- General specification of CVCC map display content

OUTPUTS:

- Specification of optimal approach for maintaining

Table 7 (cont'd)

directional orientation based on CVCC map display capabilities.

- assessment of desirability of building in a user-selectable versus a fixed algorithm for maintaining directional orientation.
-

Table 8

Problem VIII: Identification of Echelon Specific CVCC-Based Report and Operations Order Graphics Requirements

OBJECTIVES:

Determine CVCC-based report and operations order, text and particularly graphics requirements at TC, platoon, company, and battalion levels, and for each information type for which it is available, identify current NATO symbology.

TASKS:

1. Given CVCC capabilities, determine full range of specific types of text and graphics report and operations order information (e.g., unit, equipment, axis, boundary designators) desired at tank, platoon, company, and battalion levels. The focus here is upon text and especially graphics requirements supplemental to existing Army doctrine (i.e., 100-5) which are uniquely possible in an automated CVCC environment.
2. For each echelon, determine the relative priority of each of the information types, and identify combat and non-combat situations which are expected to moderate the prioritization.
3. For each of the information types, identify the standard NATO symbol(s) used to represent it, and identify each information type for which no established NATO symbols presently exist.
4. Collect user suggestions for symbols to represent information types for which current NATO symbology is lacking or regarded as confusing or cumbersome.
5. Prepare report detailing the findings from the above research activities.

PROJECTED RESOURCE REQUIREMENTS:

- SMEs knowledgeable about tank, platoon, company, and battalion tactics and information needs.
- SMEs thoroughly familiar with current NATO and alternative symbologies.

Table 8 (cont'd)

INPUTS:

- Basic specification of current and anticipated CVCC input and display capabilities.

OUTPUTS:

- Specification of text and particularly symbology requirements necessary to fully exploit CVCC text and graphics display capabilities.
 - Differentiation of text and graphics information priorities by echelon and mission.
-

Table 9

Problem IX: Optimizing NATO Symbolology to Support CVCC-Based Communications

OBJECTIVES:

Identify optimal set of symbols for CVCC-based display of report and operations order information to ensure rapid and accurate communications among echelons and inter-operability with IFIS.

TASKS:

1. Review literature to determine current state of knowledge regarding the speed, accuracy, and cognitive demands of standard NATO symbolology versus alternative symbolology.
2. Based on (1) above and information obtained from Experiment VIII, systematically evaluate adequacy of NATO symbolology for meeting all anticipated CVCC capabilities. Determine if alternative or supplemental symbols are needed.
3. Given CVCC (and IFIS) display characteristics, and based on information derived from Experiment VIII and (1) and (2) above, identify and/or develop two sets of symbols capable of representing the full range of designated report and operations order information. One set should conform as closely as possible to existing NATO symbolology. The other set should be guided solely by considerations of speed and accuracy of recognition for CVCC-based displays.
4. Based on the information gathered in the above tasks, design experiment(s) required to empirically evaluate the utility of each of the symbol sets for CVCC display. Utility measures should include speed and accuracy of recognition, ease of input, training considerations, and IFIS inter-operability.
5. Perform research in (4) above.
6. Prepare report summarizing the findings from the above tasks.

PROJECTED RESOURCE REQUIREMENTS:

- Tabletop or manned simulators

Table 9 (cont.)

- Multiple simulators (e.g., SIMNET-D)
- Possibly U.S. to GE TOC
- SMEs thoroughly familiar with current NATO and alternative symbologies.

INPUTS:

- Basic specification of current and anticipated CVCC input and display capabilities.
- Specification of text and particularly symbology requirements necessary to fully exploit CVCC text and graphics display capabilities.

OUTPUTS:

- Analysis of adequacy of NATO symbology for CVCC displays.
 - Specification of symbology optimizing CVCC display and communication capabilities.
-

Table 10

Problem X: Rapid Preparation of CVCC Display Graphics

OBJECTIVES:

Develop and evaluate template and alternative strategies for rapidly and accurately preparing symbology-laden CVCC graphic displays.

TASKS:

1. Based on findings from Experiment VIII, prepare template (i.e., "most probable set") of CVCC graphics symbols for each combination of echelon (i.e., TC, platoon, company, battalion, & U.S. to G.E. TOC) and mission (e.g., hasty attack, resupply, etc.).
2. Develop software enabling rapid selection, display, and positioning of selected template symbols on CVCC screen.
3. Drawing in part on scenarios developed in Experiment V., design experiment to investigate impact of template approach to graphics preparation on user speed, accuracy, and acceptance for sample of echelon by mission combinations.
4. Perform research in (3) above.
5. Prepare report summarizing the findings from the above tasks.

PROJECTED RESOURCE REQUIREMENTS:

- Multiple manned simulators (SIMNET-D) representing TC, platoon, company, battalion, and U.S to G.E. TOC.

INPUTS:

- Basic specification of current and anticipated CVCC input and display capabilities.
- Specification of text and particularly symbology requirements necessary to fully exploit CVCC text and graphics display capabilities.

or

- Specification of symbology optimizing CVCC display and communication capabilities.

Table 10 (cont.)

OUTPUTS:

- Specifications for a system to enhance the speed and accuracy of preparation of CVCC based graphics.
-

Additional Research Issues

Supplementing the major investigative efforts detailed in the preceding tables are a number of additional issues that merit attention in the CVCC development process. Though the latter issues tend to fall more into the realm of refinements, we believe research targeting these questions will produce results that will greatly enhance the effectiveness of the CVCC system.

Sample size requirements of the proposed research. An important issue in the present context is the question of the demands on soldier time and upon simulator resources where soldiers and simulators are essential resources in the proposed research efforts. A single, fully manned tank simulator requires four soldiers. Research focusing on tank commanders (TC) will presumably require a number of TCs, and for fidelity, quite possibly their full complement of three subordinates in each tank. Thus a TC level experiment requiring just ten subjects can easily involve forty soldiers. Research examining platoon level data dramatically increases this requirement. For example, ten units of observation with five in an experimental group and five in a control group, would require 40 TCs and possibly an additional 120 subordinates. At the company level, these numbers become overwhelming. An experiment at the company level with just ten units of observation calls for 640 soldiers. At the battalion level, these numbers mushroom to well over 2,000 if we collected data from ten battalions.

Obviously, when focusing upon a particular echelon, the proposed research does not require "full staffing" at all levels below it. Nevertheless, the illustration serves to point out that realistic simulation research can involve very substantial troop commitments, or at the very least, attention to simulating the massive amount of data that can be expected to be entered into the CVCC system at the battalion TOC level and below.

These considerations forcefully underscore the need to utilize research strategies which maximize the amount of information that can be gleaned from experiments requiring as few subjects as possible. In part this can be accomplished by simulating soldiers at various points in the CVCC network. But this can only be carried so far without endangering the validity of the conclusions derived from the proposed research. Thus, particular attention must be given to sample size minimization approaches.

Along these lines, a number of approaches should be considered. These include repeated measures and partially confounded designs, quasi-experimental strategies, use of statistical controls as in covariance designs, and statistical power enhancement techniques. Most of these approaches are well

known but the statistical power issue warrants particular attention.

Preliminary work on the impact of CVCC suggests its impact on a number of effectiveness measures is very large (Du Bois & Smith, 1989; 1991). This argues that obtaining power through the use of large samples may be unnecessary. In fact, some maintain that an appropriate response in this situation might be to adjust one's alpha level upward, for example, from .05 to .10 (Cascio & Zedeck, 1983). While some increase in the likelihood of a Type II error results from this approach, it may well be a reasonable trade-off in the present context. Perhaps the real issue here is simply to remember that there is no particular statistical rationale that prescribes that we remain wedded to the ".05 alpha level".

Another well known, but often overlooked set of statistical power enhancing strategies is based on the reduction of within-group variance. Researchers laying out specific approaches to the experiments called for in this document should give particular attention to this issue. Assignment of subjects to particular experimental conditions based on homogeneity of measures related to the dependent variable(s) under investigation will reduce the number of subjects required to detect the effects of interest. This is a selection-oriented approach. Alternatively, within-group heterogeneity may be reduced by providing ample "pre-treatment" training. Often differential prior exposure to a particular piece of apparatus or to a problem similar to that used in the research tosses considerable "noise" in the path of researchers seeking to detect hypothesized effects. Finally, any efforts to increase the reliability of the dependent measures can result in very substantial reductions in the sample size requirements. Though discussion of the variety of strategies for increasing the reliability of behavioral measures is well beyond the scope of this document, researchers designing the specific investigative efforts discussed below should give careful attention to procedures for enhancing the psychometric properties of their dependent measures (Lord & Novik, 1968; Nunnally, 1967). In sum, whether through subject pre-selection, training, and/or careful development of dependent measures, proposals to address the research questions raised in this document should give explicit consideration to these statistical power enhancing approaches.

Physical Layout (Format). Issues of concern here pertain to the physical layout of the IVIS display. A primary concern is the allocation or partitioning of the limited space on the display screen. Should areas of the screen be dedicated to particular functions or should a more flexible windowing system be utilized? While the latter would appear to have a number of substantial advantages (e.g., better use of limited display space, reduction of clutter), use of a windowing system raises a

number of important questions. To what extent should the windowing system be standardized versus user tailorable? What is the most effective "default" configuration? Combined with a menu-based system for selecting various functions, how many levels of menus can be implemented without causing soldiers in a high stress situation to become "lost" in the system?

A related layout issue is the best use of icons versus text (alphanumerics) in CVCC-based reports. This issue of course relates to the symbology and report content experiments described earlier as well as the menuing issue just mentioned. Whether the research on this issue is integrated into these investigations or is conducted independently, this symbology issue must be addressed.

SOP versus automation. CVCC greatly enhances the ease with which information may be passed among units and between echelons. In view of this capability, a significant problem can arise if the rules governing the forwarding of reports of various kinds are not clearly understood. For example, should reports containing fuel status, ammunition available, or systems rendered inoperative require action on the part of the TC in order to be passed along? Or should this information be "automatically sensed and forwarded" without any action required by the TC? Especially if the latter approach is adopted, what mechanism is required to ensure that vital reports were actually received by the intended recipient(s)? Does a system for affirmatively acknowledging the receipt of reports need to be created? If so, should this procedure be automated as well?

Embedded Training. An important concern is the ease with which a soldier can acquire the knowledge and skill necessary to operate the CVCC system. Ideally, the capability to train soldiers to use the CVCC system can be built directly into the CVCC software. Thus, simply by interacting with the CVCC system, the soldier can develop the required proficiencies. Not only is this capability important from the perspective of the time and expense associated with the initial train-up of a soldier, but also because in battle, soldier without extensive CVCC system experience may unexpectedly be required to replace an injured superior. Thus work exploring the feasibility of developing the interactive software needed to train-up the CVCC system operator should begin as soon as the system is reasonably well defined. This effort should also consider the additional CVCC memory requirements created by this capability.

Related to this initiative is the issue of security. If the system is equipped with the capability of teaching the unfamiliar soldier how to operate it, presumably it will also teach the enemy soldier who manages to capture an M1. Obviously the power of the CVCC system in the wrong hands is a major concern. Accordingly, serious attention must be given to

devising mechanisms for ensuring that the embedded training is provided only to those authorized to receive it.

Decluttering/Updating. The vast amount of information which the CVCC system can display calls for strategies for periodically removing non-essential information. Failure to do so will rapidly lead to a display which is so densely packed with overlapping information that it is more likely to mislead or confuse than to facilitate information transfer. For this reason, "de-cluttering" strategies must be developed. Algorithms which identify what information can be removed and when it is timely to do so must be developed in order to remove the burden of these housekeeping chores from the combat soldier. Removal of information from CVCC display however creates the need for a method by which the information can be recovered if necessary. For example, if an officer in the heat of battle assumes command of a new tank, he may need to review prior events in order to make prudent tactical decisions. Accordingly, research into strategies for storing and efficiently retrieving historical information from CVCC must be undertaken.

Psychological Impact of Visual versus Auditory Information Exchange. Auditory communication by means of radio has been the traditional mode by which tactical information is typically exchanged in the field. The CVCC system, as presently configured, relies much more heavily on a visual mode utilizing text, symbols, and graphics. This change has many implications. Already mentioned is the need for research addressing message acknowledgment/confirmation issues which arise when the customary auditory confirmation is not available. The more subtle psychological implications also deserve attention.

The comparatively sterile, invariant nature of visual reports appearing on the CVCC display simply may not evoke the same response as an urgent "call for fire" screamed over the radio. It is reasonable to expect the more impersonal visual mode of communication to impact both sender and recipient very differently than direct voice contact. Senders may feel far more isolated, while recipients may indeed be less responsive to urgent information which visually demands no more attention than the more routine information exchange. Potentially, these responses could undermine the effectiveness of the combat unit as mutual confidence and responsiveness erodes. Thus we believe a careful examination of these more subtle "reaction" issues is clearly merited.

Fire Control System. Another issue worthy of consideration is the gains associated with integrating the fire control system with other CVCC functions. For example, it is certainly technically feasible to link the fire control system to the reporting function within CVCC such that firing the main gun automatically results in the preparation and perhaps dispatching

of a report. The ammunition used and the location of the target certainly can be automatically detected by existing sensors. Capitalizing on this capability would relieve, or at least reduce in part, the distracting burden of sending reports. Not only would such a procedure result in very timely reports, but also free the soldier to concentrate his attention on achieving battle success.

Target Acquisition System. As with the fire control system, the technology exists to allow information about objects located in the TC's CITV to pass automatically to CVCC. This potentially could greatly increase both the speed and accuracy with which spot reports or even graphics are prepared and dispatched. Before implementing this capability, answers to a number of important questions must be found. How much control should the TC retain concerning when and what CITV-sighted objects are passed to CVCC? How should such reports be sent, automatically whenever certain types of objects are sighted or only by explicit action by the TC specifically? These are a few of the issues that must be addressed if an effective link between CITV and CVCC is to be achieved.

External Data Sources. Increasingly, modern warfare involves the use of a broad array of external sensing or detection devices, in addition to the internal devices discussed above. As an example, increasing use is being made of sophisticated infrared and sonic sensors to detect and locate enemy activities in the battle area. Again, the capability exists to integrate the data gathered by these sensors into the CVCC system. The research questions here include which sensor information should be displayed, how frequently should this information be updated, to what extent should this information be displayed only at the CVCC user's request, into which CVCC functions should the information be integrated, and what procedures need to be developed to ensure the CVCC display does not become so cluttered with the insertion of sensor data that the display becomes uninterpretable or confusing.

Summary

This document has identified a wide array of SMI research questions which must be answered before the tremendous potential of a fully functional CVCC system can be fully realized. This report has identified key CVCC supporting technologies and placed those in a user-oriented battlefield context. It has highlighted ten research areas that address issues that should be given priority in the allocation of research resources over the next three years. They are identified as priority issues because the problems they seek to address currently represent substantial barriers to the effective utilization of CVCC. They highlight areas where the failure to seek feasible solutions can lead to

the CVCC technology overwhelming rather than assisting the soldier in the conduct of his mission.

In addition, this report concludes with a brief description of each of a number of other research questions which merit attention. These questions are discussed somewhat more summarily than the previous ten research areas because the issues are somewhat less critical, in the short term, to the successful fielding of a CVCC system in the next three years. At the same time, although perhaps less urgent, serious research efforts directed at these latter areas will undoubtedly substantially enhance the combat effectiveness of the CVCC system.

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Appendix A

Description of the U.S./GE Interoperability Demonstration¹

The U.S./GE Interoperability Demonstrations will be conducted at the Closed Combat Test Bed (CCTB) site in Fort Knox, Ky and at the IABG Corporation site at Lichtenau, Germany. The purpose of these exercises is: to demonstrate the ability to pass simulated critical combat information through proposed digital communication systems using mutually agreed protocols; to determine the key items of information required to permit this interoperability; to support the development of requirements for a NATO interface to permit wider interoperability; and to form a basis for future real-time joint simulation experiments.

The critical combat information will consist of friendly and enemy information and graphical map overlays. U.S. forces in operational CCTB simulators, equipped with Combat Vehicle Command and Control (CVCC) system and a simulated battalion tactical operations center (or a stand alone IVIS) will be used to generate and send the critical battlefield information to a GE simulation at Lichtenau, GE. At this time the exact nature of the GE simulation is not known. This demonstration seeks to identify implications necessary to support later battalion level U.S./GE interoperability simulation experiments.

This demonstration should occur on two consecutive days between 0730-1030 EST (1330-1630 German Time). U.S. and GE officers and observers are expected to be stationed at both sites to observe the tactical exercises and the transmission of data.

On one day a U.S. Armor platoon and battalion Tactical Operations Center (TOC) will conduct a tactical exercise in the CCTB CVCC test bed. The U.S. platoon will consist of a single manned M1 simulator and the three semi-automated M1s. The semi-automated M1s will be an IVIS platoon tethered, as described in the current version of the SIMNET Semi-Automated Forces.

The Bn TOC will be configured with a version of CVCC capabilities to emulate a NATO terminal for the purposes of this demonstration. On this day the GE terminal located in Lichtenau, GE will receive information from the U.S. site at Fort Knox consisting of a series of messages which will provide the following types of information over the demonstration network: friendly vehicle location and status report; enemy contact report; and graphical map overlay. This message traffic is to be

¹The information presented here is taken from a memorandum prepared by Arthur Pope of BBN Systems & Technologies, Inc., 11 July 1989.

in accord with the previous agreement on the protocols between the U.S. side and the GE side. The U.S. understanding on these protocols is recorded in the draft memorandum attached as an inclosure.

On the next day, using simulated IFIS capabilities, the GE station will send simulated critical battlefield information to the U.S. BN TOC at Ft. Knox, Ky. This information will include friendly locations and status, enemy locations, and graphical map overlays. On this day, the simulated U.S. NATO terminal will receive information configured in the agreed protocols for display.

As mentioned above, the U.S. site on day one will require a single manned CVCC M1 simulator, a SAFOR terminal (to generate the tethered IVIS-platoon), and a Bn TOC equipped with a simulated NATO terminal. In addition, the U.S. site in CCTB will require a Management Command and Control (MCC), a Plan View Display (PVD), a STEALTH, and a modem. Figure A-1 presents the anticipated CCTB network configuration for this exercise. The TOC will contain a battalion level simulated work station (or stand alone IVIS), which must be capable of sending and receiving CVCC reports and vehicle locations from the U.S. simulators, and transmit the same information to the GE terminal in the previously agreed upon protocol.

Data transmission during the first exercise will use a dedicated 1200 baud full-duplex serial channel specified in the protocols. For this initial demonstration communication will be uni-directional but paralleled by a telephone voice channel on each day. On one day the U.S. terminal will send information and the GE terminal will receive. While on the other day, the GE terminal will send information and the U.S. terminal will receive. Two-way data transfer will be undertaken at subsequent dates during the follow-up interoperability exercises.

The exact details of the GE site configuration are not known at this time since its exact equipment will be specified by the GE working group. An IFIS equipped command post is anticipated to receive information sent from the U.S. terminal on one day and to send information to the U.S. terminal on the other day of the demonstration. The only requirement at this time is that the U.S. and the GE sites send and receive according to the specified protocol. A map of the FT. Knox terrain will be provided to GE researchers to facilitate interpretation of the U.S. data received. Copies of the graphical overlays to be transmitted are furnished ahead of time for use in validating data transmissions during the demonstration.

The GE side is requested to provide maps and, if available, an electronic representation of the terrain selected for the GE

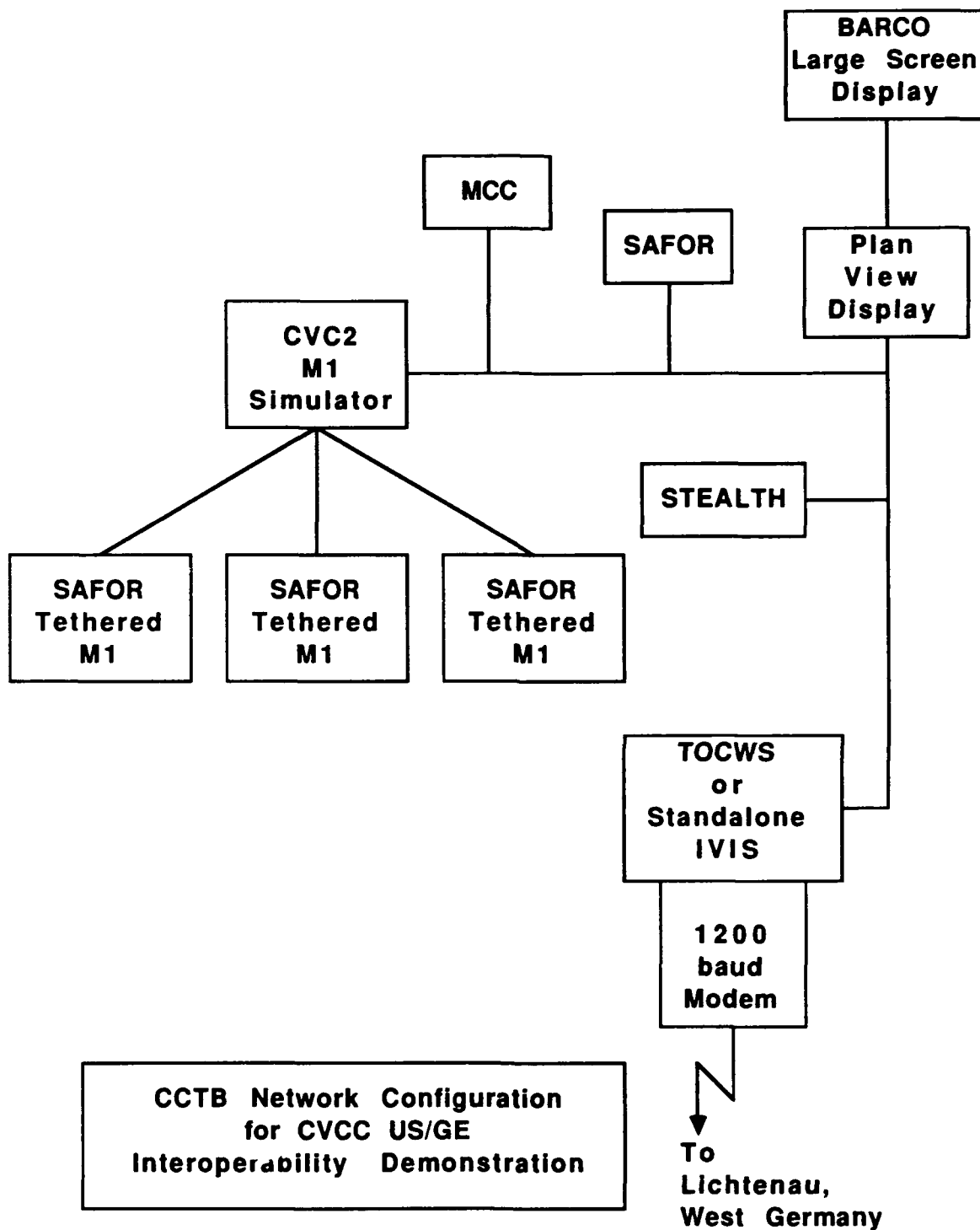


Figure A-1. Anticipated SIMNET-D Network Configuration for U.S./GE Exercise

transmission of tactical data which will be transmitted. Also, copies of any overlay/graphical data transmissions are requested so that material received can be verified.

The data format provides for exchange of the following types of information between TOCs: periodic reports of the location and status of friendly vehicles; enemy contact reports, transmitted at or near the time that contact is established; and graphical map overlays composed of icons, lines, and text labels, transmitted at the request of a human operator.

The data will be exchanged by means of a full-duplex serial communication channel connecting one item of equipment in each of the two TOCs. Although the same protocol will be used for communication in each direction, messages traversing the channel in one direction are independent of those traversing it in the opposite direction. The format of these messages and the conventions by which messages are to be transmitted and interpreted is described below.

A serial communication channel will interconnect the two simulated TOCs. That channel may be a point-to-point switched or dedicated circuit (over either wire or radio), or a virtual circuit through a packet switching network.

Of these alternatives, the use of a point-to-point circuit was considered most appropriate for early demonstrations due to simplicity. The following considerations will apply to the use of such a circuit: the High Level Data Link Control (HDLC) will be used as a link layer protocol; the messages described below will be placed in HDLC data frames, with an integral number of messages in each frame; the maximum HDLC frame size is yet to be specified; within a frame, the bits of each octet of a message will appear in order of significance, with the most significant bit first; when two or more octets together form a field of a message, they appear in order of significance, with the most significant octet first; there will be no explicit use of flow control to regulate the rate at which frames are transferred; the capacity (throughput) of the channel will be determined according to the requirements of the demonstrations for which it is to be used. A 1200 baud channel is expected to suffice for demonstrations involving units of up to company size.

Locations on the terrain surface will be specified using a Cartesian coordinate system corresponding to a Universal Transverse Mercator (UTM) mapping of the earth's surface. The origin of this coordinate system will be at the southwest corner of the terrain region to be used for the simulation. The exact location of the origin will be established in advance for the particular terrain region being used. The positive X axis is directed east from the origin; the positive Y axis is directed north. For the purpose of communication between simulated TOCs,

a location will be described by its X and Y coordinates. Each coordinate will be an integer number of meters from the origin, represented as an unsigned, 16-bit integer. (Note: This permits the terrain region to be at most 65 km by 65 km.) The coordinates are provided in the order X coordinate, then Y coordinate.

Several types of messages have been defined, each with a particular format as described here. Every message, regardless of type, begins with these two octets which are a single octet identifying type of message followed by a single octet specifying the length of the remaining portion of the message, in octets.

The location and status of a friendly vehicle (i.e. a vehicle belonging to the reporting battalion) is reported in a single message. This message is sent whenever any of the following conditions occurs: some period of time (tentatively chosen to be 10 seconds) has elapsed since a message describing it was last sent; or the vehicle has moved by some minimum amount tentatively chosen to be 50 meters) since a message describing it was sent; or the vehicle's operational status has changed since a message describing it was last sent. The format of a friendly vehicle report message is presented in Table A-1.

When elements of a battalion establish contact with the enemy, they will report that contact to their battalion TOC. At that time or shortly thereafter, the battalion TOC may notify the adjacent TOC of this contact by transmitting an enemy contact report message.

There is not necessarily a one-to-one correspondence between enemy contact reports generated within a battalion and those transmitted to an adjacent battalions's TOC. A message communicated to an adjacent TOC may, for example, represent several contact reports produced within the battalion over a short period of time. The format of an enemy contact report message is shown in Table A-2. The Unit Quantity and Unit Size field will be used together to specify both the number and type of enemy formation(s) contacted. For example, these fields can specify formations such as "2 vehicles", or "1 company". (Note: Additional Unit Quantity and Vehicle Type Codes should be defined to represent cases in which these attributes were not reported by the observer.)

A graphical map overlay is named and data collection of instances of graphic symbols. The symbols are drawn from a repertoire that includes line, icons, and textual labels. Each instance of a symbol is associated with a location on the terrain surface.

An overlay will be transmitted from one TOC to the other at the instigation of a human operator. An overlay is communicated

Table A-1

Format of a Friendly Vehicle Report

MESSAGE TYPE

Friendly Vehicle Report

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 0
1	Message Length	Contains 10
2	Company	Vehicle's company, encoded as an ASCII character
3	Platoon	Vehicle's platoon, encoded as an ASCII character
4	Unit	Vehicle's position within its platoon, encoded as an ASCII character
5	Vehicle Type	Type of vehicle: 0: Leopard I 1: Leopard II 128: M1 129: M2/3
6-9	Vehicle Location	X and Y coordinates of the vehicle
10	Vehicle Status	Operational status of vehicle: 0: operational 1: has suffered a firepower kill 2: has suffered a mobility kill 3: has suffered both firepower and mobility kill 4: is totally destroyed
11	Orientation	Orientation of the vehicle relative to grid north, encoded as an 8-bit unsigned integer. Example values are: 0: north 4: east 128: south 192: west

Table A-2

Format of a Enemy Contact Report

MESSAGE TYPE

Enemy Contact Report

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 1
1	Message Length	Contains 12
2-5	Enemy Location	X and Y coordinates of the enemy's location
6-9	Contact Time	Time of contact, in seconds, since a particular epoch. (The epoch is yet to be specified; 00:00:00 GMT, January 1, 1970 is proposed.)
10	Unit Quantity	Quantity of enemy units contacted
11	Unit Size	Size of enemy units contacted: 0: individual vehicles 1: platoons 2: companies 3: battalions
12	Vehicle Type	Type of vehicle: 0: T72 1: BMP 2: T80

as a series of messages of particular types, occurring in the following order: a start of overlay message is transmitted; zero or more overlay line, overlay icon, and overlay text messages are transmitted; and end of overlay message is transmitted. Interspersed among these messages may be any number of messages of other types, not related to overlays (i.e., friendly vehicle report and enemy contact report messages). However, messages related to the communication of overlays will only be transmitted in the order specified above. An overlay start message identifies an overlay and signals the start of its transmission. The format of this message is shown in Table A-3. An overlay line message describes a polyline symbol defined by up to twelve vertices. Its format is shown in Table A-4. An overlay icon message describes an icon to be drawn centered at a specified location. Its format is shown in Table A-5. An

overlay text message describes a textual label of up to 12 characters to be drawn centered at a specified location. Its format is shown in Table A-6.

Table A-3

Format of Overlay Start Messages

MESSAGE TYPE

Overlay Start

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 2
1	Message Length	Contains a value between 5 and 12, inclusive
2-5	Revision Time	Time at which the overlay was last revised (or first created) in seconds since a particular epoch. (This epoch will be the same as that chosen for the enemy contact report message.)
6...	Overlay Name	Name of the overlay, as a string up to 12 ASCII characters.

Table A-4

Format of Overlay Line Messages

MESSAGE TYPEOverlay Line

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 4
1	Message Length	Contains a value between 9 (for two vertices) and 49 (for twelve vertices), inclusive
2	Line Type	Type of line: 0: phase line 1: boundary line 2: battle position 3: minefield boundary 4: channel, or axis
3-6	Vertex 1	X and Y coordinates of the first line vertex
7-10	Vertex 2	X and Y coordinates of the second line vertex
etc		

Table A-5

Format of Overlay Icon Messages

MESSAGE TYPEOverlay Icon

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 5
1	Message Length	Contains 5
2	Icon Type	Defines the type of icon to be drawn. The interpretation of octet is yet to be specified.
3-6	Icon Location	X and Y coordinates at which the icon is to be centered

Table A-6

Format of Overlay Text Messages

MESSAGE TYPE

Overlay Text

<u>Octet(s)</u>	<u>Field</u>	<u>Interpretation</u>
0	Message Type	Contains 6
1	Message Length	Contains a value between 5 and 16, inclusive
2-5	Text Location	X and Y coordinates at which the textual label is to be centered
6...	Text	Textual label, as a string of up to 12 ASCII characters