Human Factors Evaluation of the Digitized Battlefield (DCX Phase I)

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One of the U.S. Army Research Laboratory's (ARL's) Science and Technology Objective (STO) research projects is to develop standardized field-operational soldier performance metrics to quantify integrated soldier-information system performance on the digital battlefield. This research effort is intended to help the Army leadership assess the impact of digitization on individual soldier and staff performance. The paper describes efforts to define and measure Army Battle Command System (ABCS) information interface functionality and usability. The report explains how the evaluation methods and metrics were developed and improved to produce an evaluation package that can be used in other Advanced Warfighting Experiments (AWEs), Command Post Exercises (CPXs), and simulation exercises.

Key Words: Division Capstone Exercise, ABCS, performance metrics, soldier-system interface

1. Introduction

The U.S. Army Research Laboratory (ARL) supported the Battle Command Battle Laboratory and the TRADOC Analysis Center (TRAC) in studying Human Factor issues during the Division Capstone Exercise (DCX). Specifically, ARL's emphasis was on the Army Battle Command System (ABCS) software that was designed to enhance the 4th Infantry Division (ID) soldier and staff performance during the exercise by providing them a clear understanding of the current state of a battlefield situation with relation to the enemy and environment. In this study, we measured digital effects in terms of attitude change, behavior change, command staff task performance, and soldier-computer interface effectiveness.

To study and improve soldier-computer interface software design, a heuristic method of evaluation was used based on human-system interface research outlined by Molich and Nielsen (1990). The report describes how the evaluation methods and metrics were developed and improved to produce an evaluation package that can be transitioned for use in other Advanced Warfighting Experiments (AWEs), Command Post Exercises (CPXs), and simulation exercises.

1.2 Human Factors (HF) Issue Focus for the DCX

The focus of the HF Issue within the DCX was to develop an analytical understanding of how the commander and the battle staff use and interface with the ABCS. The HF Issues analysis was centered on the human dimension of digitized Battle Command by studying the ABCS human computer interface (HCI) 'usability' characteristics and the ability of the ABCS to provide the commander and his staff the required functionality for planning, information management, decision making, and control of the battle-space.

1. 3 Objective ABCS

The U.S. Army Battle Command System (see Figure 1) Capstone Requirements Document (CRD), Revision 3a (Draft, dated 23 November 1999), described the objective system as follows:

The ABCS will allow commanders to utilize dominant firepower systems more effectively to destroy enemy forces in an extended area of operations while protecting friendly forces. The firepower will be enhanced by providing the commander the ability to make quicker, more accurate decisions, and orchestrate combat power at critical times and places faster than an adversary. Additionally, the ABCS will enhance SA and enable friendly forces to share a common operational picture (COP) while communicating and targeting in real or near-real time. The ABCS will reduce the uncertainty of war situations, decrease decision-making time, and contribute to increased lethality, survivability, and operational tempo while reducing the potential for fratricide. The objective ABCS will use the Joint Common Database (JCDB) that will maintain the data elements required to build and provide the commander's COP of the battlefield.

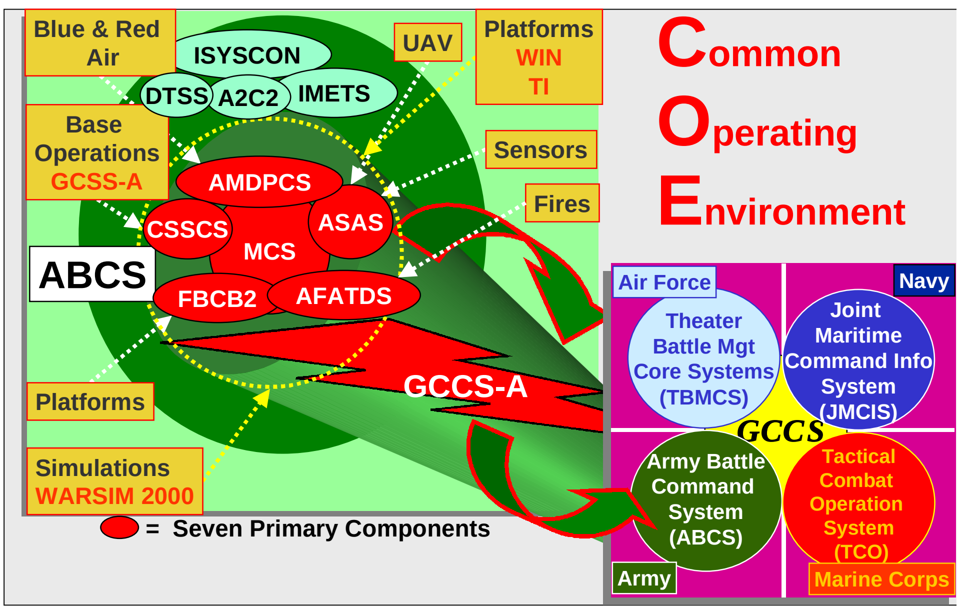

Figure 1. Objective ABCS

ABCS is an evolving "system of systems" that needs individual subsystem testing and evaluation. The entire family of systems will be assessed individually and collectively to ensure that the functional and usability requirements are met as well as the overarching commanders' decision-making and requirements.

(1) The Advanced Field Artillery Tactical Data System (AFATDS). *AFATDS provides automated decision support for the fire support (FS) functional subsystem, which includes both Joint and Combined fires (naval gunfire, close air support, etc.). AFATDS provides a fully integrated FS C2 System, giving the FS coordinator (FSCOORD) automated support for the planning, coordination, control, and execution of close support, counter-fire, interdiction, and air defense (AD) suppression fires.*

(2) All Source Analysis System (ASAS). *ASAS is the Intelligence and Electronic Warfare (IEW) component from battalions to echelons above corps (EAC). ASAS receives and rapidly processes large volumes of combat information and sensor reports from all sources to provide timely and accurate targeting information, intelligence products, and threat alerts. It consists of evolutionary modules that perform system operations management, system security, collection management, intelligence processing and reporting, high value/high payoff target processing and nominations, and communications processing and interfacing. The ASAS Remote Workstation provides automated support to the doctrinal functions of intelligence staff officers (G2/S2) from EAC through battalion, including Special Operations Forces (SOF).*

(3) Combat Service Support Control System (CSSCS). *CSSCS provides critical, timely, integrated, and accurate automated combat service support (CSS) information to include all classes of supply, field services, maintenance, medical, personnel, and movements to CSS, maneuver and theater commanders and logistic and special staffs. Critical resource data is drawn from both manual resources and the Standard Army Management Information Systems (STAMIS) at each echelon.*

(4) Forward Area Air Defense/Air and Missile Defense Workstation (FAADC2/AMDWS). *The FAADC2/AMDWS integrates Air Defense (AD) fire units, sensors, and C2 centers into a coherent system capable of defeating/denying the aerial threat (Unmanned Aerial Vehicles (UAVs), helicopters, fixed wing). The system provides the aerial dimension SA component of the COP. Initially, the Air and Missile Defense Workstation (AMDWS) will provide elements from EAC to battalions the capability to track the air and missile defense battle Force Operations (FO).*

(5) Maneuver Control System (MCS). *MCS is the primary battle command (BC) source, providing the COP, decision aids and overlay capabilities to support the tactical commander and the staff via interface with the force level information database built from the other Battlefield Automated Systems (BASs). MCS provides the functional common applications necessary to access and manipulate the JCDB.*

2. Method

2.1 Data Collection: Subject Matter Expert (SME) Observers and Data Analysts

ARL provided the following resources: (1) an issue proponent analyst manager, three HFE SME observers, and three HF analysts to serve throughout the simulation exercises (SIMEXs) and the AWE. (2) A sub-set of SMEs was assigned by the Operational Test Command (OTC) to support ARL in collecting HF related observations. ARL developed an HF Observer's Guide and provided the HF military SMEs with training just prior to the AWE start of the exercise (STARTEX). The SMEs conducted HF-focused observations throughout the AWE that were recorded on laptop computers for daily downloading to the OTC DCX database repository. (3) ARL executed analysis oversight of the HF observations including the resolution of anomalous observations. (4) ARL developed a two-part HF-focused questionnaire survey. The first part focused on general human factors aspects of command and control issues (e.g., setting up a tactical operations center (TOC), situational awareness (SA), COP, battle-tracking, timely commander decision making, and interoperability of the subsystems). The second part of the survey focused on soldier-computer interface usability aspects of the ABCS in general as well as the specific ABCS subsystems. The two-part survey was administered to the 4th ID ABCS users by the OTC following the DCX end of experiment (ENDEX). (5) Interview questions were developed by ARL and administered by OTC and TRAC to the 4th ID commanders and staff. In summary, the data sources consisted of SME observations, ABCS user 'HF Survey' responses, supplemented by commander and staff interview responses documented by OTC.

2.2 Materials

2.2.1 ARL's ABCS Issues Section of the Survey and Guide

The Universal Joint Task List (UJTL) was used to identify essential tasks that a combat commander is required to perform in exercising command and control. This list serves as an interoperability tool to help commanders construct their joint mission essential task list. It is a comprehensive hierarchical listing of the tasks that can be performed by a joint military force. UJTL is organized into four separate parts by the level of war: (1) Strategic level-National military tasks, (2) Strategic level-Theater tasks, (3) Operational level, and (4) Tactical level tasks. Each task in the UJTL is individually indexed to reflect its placement in the structure. Thus, the UJTL provided a Command Staff task baseline around which ARL developed its standardized soldier performance metrics research efforts

Utilizing the Department of Defense (DOD) UJTL for command and control (C2) as a foundation, ARL's HF C2 issues section of the survey or guide focused on the interrelationship between the division staff functions or processes required for effective command and control decision making as supported by ABCS software. ARL’s survey metrics methodology involved a cross-linking of FM 101-5 (Staff Organization & Operations, 1997) military decision-making processes (MDMP) with the ABCS software modules believed to support critical command and staff task execution. The U.S. Army’s field manual (FM101-5) states that a staff supports the 'Science of Control' in four primary ways: (1) gathers and provides information to the commander, (2) makes estimates of the set of actions required, (3) prepares plans and orders, and (4) measures organization behavior. To perform this type of support, the staff and commanders use various time-dependent decision-making and information management processes that require extensive staff coordination between and within echelons. Shortcomings in command, control, communications, and intelligence (C3I) automation functionality can lead to serious tactical failures such as inadequate battle plans, inadequate reporting, lack of coordination, and inadequate situation awareness that can result in fratricide.

2.2.2 HF SME Observer Guide

The guide provided information for the SME on which to focus personnel and digitized equipment factors to help answer each associated HF Sub-Issue. The HF issues and examples of Essential Elements of Analysis (EEAs) of the SME Observer’s guide are outlined in Table 1.

TABLE 1
Human Factors Issue Observer Guide for the ABCS Subject Matter Experts

Issues and EEAs	**Description**
(A) Issue HF 01. How adequate, efficient, and user-friendly are the ABCS information interfaces in enhancing soldier and staff performance.	This is part of the U.S. Army's attempt to assess the value of the ABCS for heavy force military operations, it is important to understand the effectiveness of the individual soldier-ABCS system interface.
(1) EEA HF 01.01 Did the soldier-computer information interfaces of the ABCS enhance soldier-operator and staff performance?	Consider the various aspects and features of the screen displays and presentation of information for ease of use in accomplishing and enabling the commander's mission tasks.
B. Issue HF 02. Does the *First Digitized Division Priority 1 computer architecture* support the task and cognitive processes needed to enhance commanders and staff's performance?	
(1) EEA HF 02.01 Did ABCS support adaptive commander or staff by permitting timely development and sharing of commander's intent, facilitate vertical and horizontal cohesion, that support commander or staff teams despite leader changes during the phases of the MDMP regardless of unexpected events?	Consider the ease or difficulty of using the ABCS information formats to obtain battle tracking data to support the commander in making timely and effective decisions by being responsive to unexpected changes during the planning, preparation, and execution phases of the MDMP.
C. Issue HF 03. How do ABCS system reliabilities affect the staff's performance?	
(1) EEA HF 03.01 Do the ABCS information presentation formats and computer interface enhance the staff's ability to quickly and accurately access distributed data sources at any time?	Consider the reliability of the ABCS in supporting the commander and his staff in the execution of C4ISR tasks and accessing distributed data sources during the course of a battlefield mission.
D. Issue HF 04. Is the ABCS architecture effective in the pulling, pushing, and assimilation of information and maintaining a COP and supporting battlefield visualization?	
(1) EEA HF 04.01 How well do the ABCS digitized data format designs and soldier-computer interface help the staff develop, maintain, distribute, and assimilate the COP?	Consider the ease of use of the ABCS media (e.g., VTC) and information presentation formats in supporting the commander and his staff in working collaboratively with other echelons in the development of a COP.

2.2.3 ARL's HF ABCS General and Specific ABCS Subsystem User's Survey.

In the ARL ABCS HF Survey's application, a heuristic methodology was used (a method of usability analysis in which users are presented with an interface design and then requested to comment on it). For the DCX, the 4th ID ABCS operators were asked to rate each usability characteristic (sub-issue item) on a scale from 1 to 5 to rate the ABCS software design as it attempts to support effective execution of critical TOC Staff tasks.

TABLE 2
ABCS Human Computer System Usability Characteristics

Tempo
Utility
Flexibility in Use
Prevent Fatigue
Use Army Doctrine
Provide Process Shortcuts
Consistency Between Modules
Minimize Demand on Human Memory
Provide Feedback
Good Error Recovery
Common Framework
Intuitiveness

TABLE 3
Tactical Operations Center (TOC) Staff Tasks

Setting up Local Area Network (LAN) Addresses
Using Communications Networks
Developing Situational Awareness
Determining the Commander's Critical Information Requirements
Determining Locations of Enemy & Friendly Units
Building Overlays & Templates
Creating, Editing, Updating Data Bases
Building Friendly & Enemy Order of Battle
Building & Modifying Synchronization Matrix
Preparing Unit Task Organizations
Computing Force Ratios
Determining Equipment & Personnel Resources
Coordinating Joint Services Defense Resources
Preparing Defense Assessments
Developing Courses of Action
Making Accurate & Timely Decisions
Preparing Briefings
Preparing Operation Orders & Reports
Sending & Receiving Information

The 'usability factor' has a direct impact on staff performance because shortcomings in system usability lead to underlying error patterns, attention deficits, and excessive workload which can be linked to inappropriate decisions and priorities, serious delays in operational tempo, and failures in effective staff coordination and communications. This ABCS HF Survey was guided by many human-computer system issues (see Table 2) that have been defined in the research literature (Nielsen & Molich, 1990; Molich & Nielsen, 1990; Nielsen & Levy, 1994; Smith & Mosier, 1986) as reflecting hardware and software design with good interface usability. The usability characteristics include: whether the computer system contains simple and natural dialogue, applications reflect military doctrine, 'speaks' the user language, minimizes user memory load, remains consistent between different modules and across applications, provides user feedback, provides clearly marked exits from modules, provides process shortcuts, and prevents errors. Examples of more complex staff tasks involving cognitive aspects of decision-making (see Cannon-Bowers & Salas, 1998) are presented in Table 3.

These metrics addressed critical functional dimensions of staff performance within the Military Decision Making Process that included: (1) Mission Analysis, (2) Course of Action (COA), (3) Information Assimilation, (4) Generation of Messages and Reports, (5) Workload Distribution, and (6) Development, Distribution and Maintenance of Situation Awareness.

3. Results and Discussion

3.1 Analysis of Data

The ABCS User's Survey responses were obtained from using a five-point Likert-type scale to quantify the systems' functionality and usability. Chi-Square analyses were performed to determine the significance of the percentage of responses in each of the five rating-scale cells. To obtain adequate statistic power in cases where there were very small sample sizes, the number of response category cells was collapsed to meet the power requirements of the Chi-Square statistical method. Descriptive data was obtained from SME observers and operator comments. Their documented narrative responses were analyzed using the HF issue observer guidelines (Table 1) and the ABCS usability characteristics listed in Table 2.

3.2 Issue HF 01.01 - How adequate, effective, and user-friendly are the ABCS information interfaces in enhancing soldier and staff performance?

3.2.1 AFATDS

In general, the AFATDS was effectively used to produce fire support products more quickly than using non-digital means. Operators thought it was easy to construct graphics using AFATDS tools. However, some SMEs noted that the lack of interoperability between the ABCS sub-systems for graphics and overlays caused the targeting officer to have to manually input the fire support overlays.

Set-up, initialization instructions, new user, master list, unit ID's, status, communication, LAN modification were system start up tasks that were considered to be the most complicated processes of the AFATDS system. Operators used a "cheat card" with 21 steps, each step requiring up to 4 sub-steps to complete each major step.

Operators thought this process was too complex, requiring 30 minutes under the best conditions.

The SA picture generated by the AFATDS was not felt to be timely and was too cluttered to be used. The AFATDS screen display was hindered by the sheer volume of information being presented which made the COP difficult to understand. Unit icons were superimposed on one another, on top of obstacle graphics, and on top of general axes of advance, which made it difficult to pick one specific icon and retrieve information about it.

The AFATDS feedback regarding help and prompts was adequate for some functions such as troubleshooting, but incomplete for others such as graphics production. Operators reported that if they got an error message there was not a clear indication on how to fix the problem. On-screen instructions, prompts, and menus were generally good, but operators agreed that error messages should be adequately supported by information or methods that correct the error. Abbreviations, acronyms, codes, icons, and symbols were good. They directly replicated artillery symbology

The interface facility with avoiding input errors, and showing selected attributes was good. For example, if an operator entered an incomplete grid number, the system would not permit him to proceed. The system was good at preventing accidental keystrokes. System prompts requested the operator to verify execution of keystroke errors.

Operators suggested that AFATDS was a fine tool for fire support planning and mission processing. For example, SMEs reported that the 2nd Brigade Combat Team Fire Support Element (FSE) was able to maintain timely and accurate status of all firing units. as well as the Blue and Red SA provided by ASAS.

The concern for system reliability (e.g., lock ups, false error messages) required the operators to insert or duplicate tasks with manual or analog methods. This caused an increase in operator and staff workload that resulted in a decrease in their effectiveness.

Generally, required information was on the data displays, but various improvements were suggested. The interface could be improved if the operator didn’t have to flip back and forth between screens during "Calls-for-Fire" to verify certain target characteristics. The number of menus and screens needed to complete processes were generally adequate. However, in the case of sending free-text messages, the operator was required to perform eight steps. The operators report that this process was too complex and needed to be simplified in a way that is similar to using commercial e-mail systems.

3.2.2 ASAS

It was reported that technical problems prevented the ASAS link with the Joint Common Data Base (JCDB) which caused the S2 to use manual tracking methods to organize Spot Reports and perform critical actions.

ASAS operators had no problems with functions involving system set-up (e.g., initialization instructions, new user identification, master list, unit ID’s, status, communication, LAN modification) and TOC relocations. An adequate interface was provided for working with maps, but the software increased the operator's workload compared to the prior version’s Terrain Evaluation Module (TEM) versus the Joint Mapping Tool Kit (JMTK). These problems resulted in the majority of the ASAS operators (69%) rating the “maps drawing tools as unfriendly. Although the standard report formats were not difficult to use, the operators preferred creating free-text reports because it was easier and more familiar for them. The majority of the operators rated the use of the standard report format as being adequate.

The ASAS did not provide adequate feedback to allow the average operator to tell what effects his actions were having on the system. Although the software was generally good at helping the operator avoid data entry mistakes, there appeared to be a potential problem regarding visual cues and selected data entry attributes.

On-screen instructions, prompts, and menus were generally good. Operators found the message prompts to be useful. The task for creating a message distribution list was easy. Abbreviations, acronyms, codes, icons, and symbols were good except for their representation in the military symbols (MILSYM) manager module. There is a substantial display of icons in MILSYM, but they have no labels. Less experienced troops cannot identify them at first glance.

The amount of frustration and stress experienced appeared to increase when the ASAS or the overall digital system did not function properly or the system crashed. Operators felt that the software products and ASAS interface were “unstable” (e.g., system freezes and function failures). Consequently, they could not use their system to directly communicate with other ABCS systems.

The number of menus and screens needed to complete processes was adequate, but generally thought to be too numerous. For example, during a spoiling attack, the ASAS operator needed to perform a communication operation on the system to verify connectivity. To do this the user had to navigate through more than four menus and sub-menus before he could actually contact the recipient.

Operators (77%) reported that inputting information into the RWS databases was easy. They almost exclusively used the short form that appeared to be adequate for their purposes. They suggested that if they had the ability to enter battle damage assessments (BDA) it would improve their processing interface and more timely support the command regarding BDA. INTEL staff tracked the BDA manually.

3.2.3 CSSCS

In general, CSSCS operator tasks were considered fairly intuitive regarding automated processes. Some CSSCS operators reported the software was flexible and allowed them to modify their processes. These operators liked the ability to change echelon reporting levels so one could look at specific assets of interest. However, other operators reported that the software did not give users options to modify the processes or sequences of support task requirements. As a result, the operator had to use MS EXCEL instead of the CSSCS for maintenance reporting.

CSSCS reported digitization increased their speed regarding receiving OPORDs compared to non-digital methods. The CSSCS software interface was considered to be soldier friendly. Operators reported consistent interface controls, presentation, familiar words and menus. CSSCS "drag and drop" procedures were very soldier-friendly. The CSSCS main menu bar and pull-down menus were easy to use.

CSSCS fatigue levels were reduced by using digitized versus non-digitized methods. Operators saw a fatigue reduction with specific digital functions such as logistics statistics (LOGSTAT) reporting and Unit Task Organization (UTO) processes. Operators reported that the UTO automated update process for planning and execution was a useful tool. CSSCS colored displays were easy to use. Operators found the "Gumball" formatted display screen showing logistical resources to be very helpful.

Standard report formats were not difficult to use, especially using the Rapid Data Entry option. However, other operators used free-text messaging because they thought they were getting inaccurate and outdated data. Consequently, they often used voice means to get current data. It was easy to use the Equipment-Force Echelon Status Report. Likewise, the Equipment-Item Status report, the Battle Loss Unit Summary Report and the Personnel Daily Summary Force Echelon Report were easy to use. The process to obtain a Class III Bulk Force Echelon Report was easy. The Baseline Resource Item List (BRIL) and Critical Tracked Items List (CTIL) forms were easy to use.

The CSSCS provided some feedback to assist operator functions, but improvements need to be made. Prompts were sometimes vague by identifying an error but not providing information to correct the error. CSSCS was reported as being "fair" to "good" in providing error prevention or recovery capability. On-screen instructions, prompts, and menus were generally good. Some operators considered the prompts incomplete and needed to be more useful by providing the necessary information to resolve a fault, failure, or error. Operators particularly liked the icons, codes, and acronyms. Being able to click on icons and symbols for identification was a great help to the user.

Overall, operators rated CSSCS messaging (e.g., receiving, preparing, & sending) less than adequate. They said the process should be as easy as commercial e-mail. The process of addressing and sending required too many steps. The CSSCS Message address screen was easy to use, but it did not contain all the addresses required for message distribution. The number of menus and screens needed to complete processes was generally thought to be too numerous.

The system was good at preventing accidental keystrokes, with the exception of the "power" key. Accidentally striking the "Power" key locked up the system. In order to unlock a subsystem, the entire system had to be rebooted.

The CSSCS placed a "moderate" to "high" demand on human memory. The multiple number of menus to perform certain tasks (e.g., messaging) was excessive. When some CSSCS operators processed volumes of information they made "cheat sheets" to remember the required operations.

3.2.4 FAADC2 / AMDWS

AMDWS allowed the operator to monitor current air operations while assisting the commander to plan for future events. The commander had complete SA during the Air Force close air support (CAS) mission conducted during enemy advancement into a sector. The air defense (AD) battle captain at the Division Tactical Analysis Center (DTAC) command center had a live feed and was able to share information with the staff and the Forward Air Controller. This system gave the staff SA of the deep fight when used in conjunction with the Joint Surveillance Target Attack Radar System (JSTARS) picture. Status updates by the system FAAD engagement operations (EO) were generally good. Air tracks were timely as long as radars were functioning. The air defense artillery

(ADA) cell provided the air SA picture to the DTAC and DMAIN. The SA picture was clear and concise, aided the staff in identifying enemy air activities, and accelerated the MDMP.

The users of the system stated that the start up and sharing of information provided by the system would be improved if the internet protocol (IP) addresses used to identify subordinate units were more user friendly. If the user did not know the intended recipients' IP address he was not able to directly send e-mail to the individuals who needed the information. Instead, he had to place the information on the TAC web and hope the appropriate user looked and found the information in a timely manner. Operators could not modify the communications table or change the node configuration. These modifications were performed by the contractor.

The graphic user interface allowed for operator flexibility. Shortcuts capabilities were helpful, but FAADC2 had better shortcut capabilities than AMDWS. The graphics and drawing tools for developing products were considered to be adequate.

AMDWS was reported to be adequate regarding error prevention and helping operator recovery. The interface for avoiding input errors, and showing selected attributes was adequate. Certain tools (e.g., grid locations in line-of-sight analysis) could use more "Help" analyses because the error involved was not obvious to the operator.

The demand on human memory needed to complete tasks was not excessive for the operator but could be further reduced by eliminating some of the windows needed to complete a task. On-screen instructions, prompts, and menus were generally good. Abbreviations, acronyms, codes, icons, and symbols were also good. There were no problems in the use of the mouse to click and double-click on functions. The system was good at preventing accidental keystrokes.

The common message processor (CMP) messaging system met specified requirements but the operators preferred to use free-text messages indicating a need to improve user friendliness. The system prioritized users' incoming messages and permitted the user to prioritize his messages, but operators did not use these capabilities. The process of creating a message distribution list was considered adequate.

3.2.5 MCS

The software was fairly consistent in function. Operators reported that their general fatigue level was less with MCS than with non-digital means, but mental fatigue may be greater. The MCS appeared to require moderate demands on human memory. Memory demands were high for tasks requiring multiple commands, menus, and screens, especially during peak information periods.

The graphics and drawing tools for developing products were reported by SMEs to be adequate for performing many critical tasks. In general, operators preferred using the automated overlay tools rather than producing overlays manually. The benefits of the automated methods were decreased task time and workload.

Many of the operators (23%) felt the graphics and drawing tools to be difficult to operate. There were some difficulties with naming conventions, overlay construction, and problems with drawing boundaries. Operator suggestions to improve the interface were to allow the immediate transfer of the commander's sketch to an "overlay" to save time and ensure "actual" commander representation.

MCS users reported that the interface for the development of the COP was good. They believed the COP to be the best application of the MCS.

The MCS filter function interface was operator friendly. Operators reported that filter functions supported force level control and SA throughout the Division. If the display was not too cluttered then it was easy to identify military units by clicking on the appropriate icon representation for the unit. Operators (46%) reported that the icon identification interface was friendly

The interface facility with avoiding input errors, and showing selected attributes was accurate, but in order for the operator to determine whether he had selected the correct attributes in the system, he had to physically stand up in the shelter, pull the system keyboard out to its furthest position, and look on the top of the keyboard above the number keys to determine whether or not the correct attributes had been selected. Suggestions to improve the interface were to display the attributes on the monitor, or make the keyboard more accessible. The system was good at preventing accidental keystrokes. System prompts requested the operator to verify execution of keystroke errors.

SMEs reported that the system was adequate for receiving and preparing messages, but not for sending messages. Surveyed operators (58%) found that the message handling capabilities of the MCS were unfriendly or only adequate. The system tended to lock-up with multiple addressing, so operators often had to send messages one at a time which added to their workload. In addition, acknowledgement of their message was by voice that also increased the messaging time and workload.

Operators reported that MCS was not very good at providing error prevention and recovery. Operators (64%) felt that the interface for unlocking a subsystem was only adequate or unfriendly. They reported that the system crashed too easily and would like the system to have more processing power.

Some operators felt that the use of the MCS increased the speed of performing certain critical tasks compared to non-digital means. The plans and orders were transmitted electronically by the system to the organizational structure. However, other operators reported that the system did not increase their task performance compared to non-digital means. They cited problems with system reliability, long initialization time (45 min.), and that reports using system information may be outdated.

3.2.6 ABCS Data Filters

Filters reduce screen clutter and thereby minimize workload associated with readability and understandability of information. When displaying targets on the COP, the screen becomes extremely cluttered and masks key graphical information from the commander. TTPs must be established for data display filtering at each echelon of command to ensure that only relevant material is displayed. Filtering capabilities need to be developed for detecting specific obstacles such as mine fields. During the DCX, a lack of enemy minefield information resulted in fratricide (simulated).

3.2.7 Does the ease of use of the ABCS information designs and interfaces help distribute products faster and distribute them to the proper places?

ABCS allows units to distribute information products (overlays, reports, and messages) among units that have the core ABCS systems, but limits in bandwidth prevented efficient passage of graphics and other large products. The limited bandwidth caused overlays to be sent in pieces that leaves many opportunities for failure with both the sender and receiver. However, a digitized unit has far greater internal messaging capability than a non-digitized unit. The majority of survey respondents indicated that ABCS had a positive impact on their ability to receive critical graphs and messages in a timely fashion. Generally, digitization enabled the command to disseminate products to more places and faster.

3.3 Issue HF 02. Does the *First Digitized Division Priority 1 computer architecture* support the task and cognitive processes (e.g., information assimilation, situational awareness, and decision making) needed to enhance commanders and staff's performance?

3.3.1 General

While ABCS does not currently have all the requirements specified for the objective system, the ABCS has the capacity to support the commander and staff's task and cognitive processes better than the manual systems involving acetate covered maps and "yellow canary" message books. However, standing operating procedures (SOPs) linking the current features of the system to the team and individual cognitive processes that comprise the command and staff operations could improve the system's performance. The sources of situational awareness necessary to conduct these processes are supported by the following three ABCS capabilities:

(1) ABCS can display friendly unit locations in near real time in each command post and operations center throughout the Tactical Internets (TI), and at a level that suits the requirements of the decision maker at each location. ABCS makes unit location data available to the system operators. The human factors challenge is for battle staff members to know what unit information they need and how to display it on the appropriate screens.

(2) With the exception of file size constraints in sending graphics files from ABCS to FBCB2, ABCS can create and disseminate battlefield geometries among the command posts and operations centers. The system permits operators to create lines, shapes and symbols relatively easily and to disseminate them quickly through several procedures. Thus, the operational graphics received at each location are exact copies of the original, a feature that is not possible when overlays have to be reproduced manually, one at a time. Also, the graphics are disseminated electronically, a faster process than courier distribution. The drawing tools are less facile than the human hand, consequently, the operational control measures are more difficult to tailor to the exact flow of terrain features, e.g., stream beds, ridgelines, country roads. The drawing tools are also more time-consuming than hand graphics.

(3) Currently, ABCS's capability to support the intelligence analysis and fusion processes is superior to earlier manual processes. ASAS's All Source Correlated Database (ASCDB) has an impressive capability to receive, store, and display (based on analysts' queries) a wide range of combat information provided by sensor systems. The principal shortcoming is that overlays of enemy unit locations developed in ASAS cannot be

combined in one composite display with the current friendly unit situation and the battlefield geometries. Instead, the enemy unit overlay must be displayed on a separate screen. From a human factors perspective, this is not satisfactory. However Tactics, Techniques, and Procedures (TTPs) documents could be developed to integrate the enemy unit locations into the friendly unit display.

3.3.2 Critical Events, Unexpected Changes, and Uncertainty. The timeliness and detail in the friendly unit situation display on the COP permitted the staff to monitor critical events in the current operations order better than manual systems. However, the system had no special features to monitor changes in the enemy situation. Initial information on emerging enemy activities was generally disseminated verbally or by message before the analysts were able to post appropriate enemy unit icons to the COP. The capability of the system to create and disseminate text or graphic files rapidly and accurately greatly enhances the units' ability to react to unexpected changes. ABCS has no special features to facilitate the commander and staff managing uncertainty.

3.3.3 Support to Decision Making. ABCS provided indirect support to decision making during the planning process. The maps and graphics tools and the office products allow the operational planning teams (OPT) to visualize the operation and to quickly create planning products throughout the flow of the planning process. The synchronization matrix allows the OPT to capture the decisions made during the course of action wargame, and easily translate the decisions into the task and purpose statements in the execution paragraph of the operations order. During the execution phase, the fact that unit locations are automatically updated in the system, by the Force XXI Battle Command Brigade and Below (FBCB2) computer, freed the commander and staff to concentrate on synchronizing the subordinate units' shaping and decisive actions, and anticipate subsequent actions necessary to maintain operational tempo. In contrast, in non-ABCS operations centers, the staff must expend considerable effort updating each subordinate unit's current location while concurrently attempting to concentrate on the tactical elements of the operation.

3.4 Issue HF 03. How do ABCS system hardware and/or software reliabilities affect the staff's performance?

ABCS Reliable Throughout DCX I. The networks worked well throughout the DCX. At almost no point did staff members lack connectivity for purposes of sending or receiving data over the networks. The fact that the networks were highly reliable is a success for ABCS. Although network reliability is a technical issue, testimony to the system reliability was the ability of the units to quickly re-establish their internal and external networks after displacing their TOC or TAC.

3.5 Issue HF 04. Is the ABCS architecture effective in the pulling, pushing, and assimilation of information and maintaining a Common Operational Picture (COP) and supporting battlefield visualization?

3.5.1 Key to COP is the Joint Common Database (JCDB). The data comprising the COP is extracted from the JCDB. The JCDB receives and distributes three elements of information that are the core of the COP: (1) friendly unit locations, (2) current battlefield geometries, and (3) enemy unit locations. ABCS performed very well on friendly unit locations and the current battlefield geometries, but due to technical shortcomings, the battle staffs had to devise alternate solutions to display a reasonable view of the current enemy situation.

3.5.2 "Blue" Situational Awareness. The "friendly unit locations" function is the only one of the three that is executed almost entirely by the system. The key is the FBCB2 computer. The reporting signal moves from the lower TI to the upper TI where "Embedded Battle Command" translation software on each ABCS system, converts the FBCB2 data to a format that can be read by the ABCS systems. The data goes to the JCDB, and automatically populates the ABCS Common Operational Picture at that location

3.5.3 Operational Graphics. MCS-Light is effective in preparing and distributing graphics and overlays. Once created, the basic overlay is saved via the maps and overlays function on MCS-Light, and when saved initially, is actually saved in an MS Access database identified in the MSC-Light Microsoft (MS) Explorer window as a "JCDB" folder. Depending upon the filter settings, appropriate graphics are created on the COP based on data stored in the JCDB.

3.5.4 "Red" Situational Awareness. The major shortfall in the COP was the difficulty displaying the current enemy situation. The JCDB was not able to populate the COP with enemy unit locations on a timely basis. Operators believe that the enemy unit locations are transferred from the All Source Correlated Database (ASCDB) in ASAS to the JCDB. The system is designed so that the Blue unit locations are refreshed on the COP display first, and the Red unit locations, second. The Blue refresh rate is apparently set for more frequent intervals and will override a Red refresh cycle in progress. Thus, the Red unit locations were continuously overridden by the Blue refresh rate. The alternate solution was to display the ASCDB version of the current enemy locations in a separate window on the COP display. Consequently, the Blue and Red displays were adjacent but not superimposed. Accuracy (defined as where the enemy unit is now) is more a TTP problem than system design. HF areas of improvement include: (1) ensuring that Spot Reports are integrated into the digitized system, (2) data filters are used appropriately, and (3) intelligence analysts are trained to a high degree of proficiency.

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