Research Report 1320

DESIGN GUIDELINES AND CRITERIA FOR USER/OPERATOR TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS

VOLUME I:

EXECUTIVE SUMMARY

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U. S. Army
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This document is one of a series in the Final Report of Phase I in a project to develop design guidelines and criteria for user/operator transactions with battlefield automated systems. The report is organized in five volumes as follows:

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Item 20 (Cont'd)

I. Executive Summary (this report)
II. Technical Report (TR 536)
III. In-Depth Analyses of Individual Systems
- A. Tactical Fire Direction System (TACFIRE) (RP 81-26)
- B. Tactical Computer Terminal (TCT) (RP 81-27)
- C. Admin/Log Automated Systems (RP 81-28)
- D. Intelligence Information Subsystem (IISS) (RP 81-29)

IV. Provisional Guidelines and Criteria (TR 537)
V. Background Literature (TR 538)

Volume I presents a succinct review of activities and products of the project's first phase. Volume II contains a technical discussion of the project's objectives, methodologies, results, conclusions, and implications for the design of user/operator transactions with battlefield automated systems. Volume III documents analyses of four unique battlefield automated systems selected to represent different stages of system development and different Army functional areas. Volume IV presents provisional guidelines and criteria for the design of transactions. Volume V provides a brief review of selected literature related to guidelines and criteria.

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VOLUME I:

EXECUTIVE SUMMARY

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Human Performance Effectiveness
and Simulation

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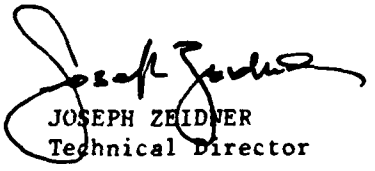
FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with helping users and operators cope with the ever increasing complexity of the battlefield automated systems by which they acquire, transmit, process, disseminate, and utilize information. Increased system complexity increases demands imposed on the human interacting with the machine. ARI's efforts in this area focus on human performance problems related to interactions with command and control centers, and on issues of system design and development. Research is addressed to such areas as user-oriented systems, software development, information management, staff operations and procedures, decision support, and systems integration and utilization.

An area of special concern in user-oriented systems is the improvement of the user-machine interface. Lacking consistent design principles, current practice results in a fragmented and unsystematic approach to system design, especially where the user/operator-system interaction is concerned. Despite numerous design efforts and the development of extensive system user information over several decades, this information remains widely scattered and relatively undocumented except as it exists within and reflects a particular system. The current effort is dedicated to the development of a comprehensive set of Human Factors guidelines and evaluation criteria for the design of user/operator transactions with battlefield automated systems. These guidelines and criteria are intended to assist proponents and managers of battlefield automated systems at each phase of system development to select the design features and operating procedures of the human-computer interface which best match the requirements and capabilities of anticipated users/operators.

Research in the area of user-oriented systems is conducted as an in-house effort augmented through contracts with uniquely qualified organizations. The present effort was conducted in collaboration with personnel from Synectics Corporation under contract MDA903-80-C-0094. The effort is responsive to requirements of Army Project 2Q263744A793, Human Performance Effectiveness and Simulation, and to special requirements of the U.S. Army Combined Arms Combat Developments Activity (CACDA), Fort Leavenworth, Kansas.



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DESIGN GUIDELINES AND CRITERIA FOR USER/OPERATOR TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS VOLUME I: EXECUTIVE SUMMARY

SUMMARY

Requirement:

To develop a comprehensive set of human factors guidelines and criteria for the design of user/operator transactions in battlefield automated systems for use by human factors specialists and system proponents, managers, and developers.

Procedure:

To meet the requirement stated above, a three phase research program was initiated. Phase I is devoted to defining human factors requirements for battlefield automated systems and developing preliminary guidelines and criteria. In Phase II, the technical data base will be developed further and a prototype handbook of guidelines and criteria will be prepared. Phase III will test, evaluate, and refine the handbook, and complete any remaining R&D items.

This document is one of a series reporting activities and products of Phase I. A preliminary analysis was conducted of a broad range of battlefield automated systems to provide an initial baseline of human factors requirements. This baseline data base was then validated and expanded through intensive analyses of four systems selected to represent different Army functional areas and different stages of the system life cycle. The resulting data base served as the foundation for the development of preliminary guidelines and criteria.

Findings:

Data obtained for the data base of human factors requirements amply demonstrated the need for guidelines an criteria. Few design differences appeared so serious individually as to threaten mission effectiveness. Nonetheless, various combinations of such deficiencies could significantly degrade system performance if the user/operator confronted them simultaneously or in rapid succession. Opinions offered by members of the development community who have reviewed the preliminary guidelines and criteria suggest they will be useful in the design and evaluation of the human-computer interface in battlefield automated systems.

Utilization of Findings:

Findings from the analysis of individual systems may be useful to proponents in specifying user/operator requirements for future system evolution. In this project, the findings were incorporated in a data base on human factors requirements which provided the "real world" foundation for development of the provisional guidelines and criteria presented in volume IV of this report. The provisional guidelines and criteria will be utilized as the basis for development of the prototype handbook.

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INTRODUCTION

Information is a precious commodity on the battlefield, and commanders have always wished for better and faster ways to obtain it. Modern technology has responded to this need with a wide array of data-gathering devices and methods. Increasingly, the problem is to manage the resulting flood of data, and to convert the data to usable information and intelligence. Currently, more than 60 computer-based information systems are in production, development, or concept definition for deployment at corps and subordinate echelons. As shown in Figure 1, those automated systems eventually will support most of the Army's battlefield functional areas.

ARMY BATTLEFIELD AUTOMATED SYSTEM CATEGORIZATION

System Life Cycle Status / Battlefield Functional Area	ADMIN	LOG	INTEL	EW	FA	ADA	ENG	COMMO	MVR	A-G
CATEGORY I CONCEPT DEFINITION	TAMMIS DISPERS CSS CONTROL*** CS3 REPLACEMENT OLDED		ASAS TEP AGTELIS TACIES		AASS MLRS FDS	ADEWS SHORAD C.		PACKET RADIO JTIDS TYQ 16**	MVR CNTL*** ATHS	
CATEGORY II VALIDATION/ DEVELOPMENT		SAMS SAAS SPBS	SOTAS ITACIES	QUICK FIX TACJAM CAS ECM	RPV TADARS	DAR PATRIOT CSS ECS		TSQ 111** TYC 39 TTC 39 TTC 42*	NBDS PLRS GPS TCS TCT	
CATEGORY III APPROVED PRODUCTION/ INSTALLATION	SIDPERS	CIUS CS3 DAS 3 DSA SAILS DLOGS MRM DSU/GSU MLS	MAGIIC QUICKLOOK II TRAIL BLAZER GUARDRAIL V SLAR ITEP		BCS TPQ 36 TPQ 37 PADS TACFIRE MPDG	TSQ 73 IOC/PCP DST				

* USMC Development
** USAF Development
*** No approved LOA exists

Figure 1. Army Battlefield Automated Systems, Categorized by Status in the System Life Cycle and by Battlefield Functional Area, as of 14 May 1980.

PROBLEM

The proliferation of battlefield automated systems, however, carries with it potential problems. As it turns out, battlefield automation, rather than reducing the human skills required for computer technology, as originally expected, actually imposes demands for even greater skill levels. With the Army's pool of skilled manpower decreasing, we can anticipate a time when insufficient personnel will be available to staff the increasing numbers of complex battlefield automated systems being introduced (Figure 2). In addition,

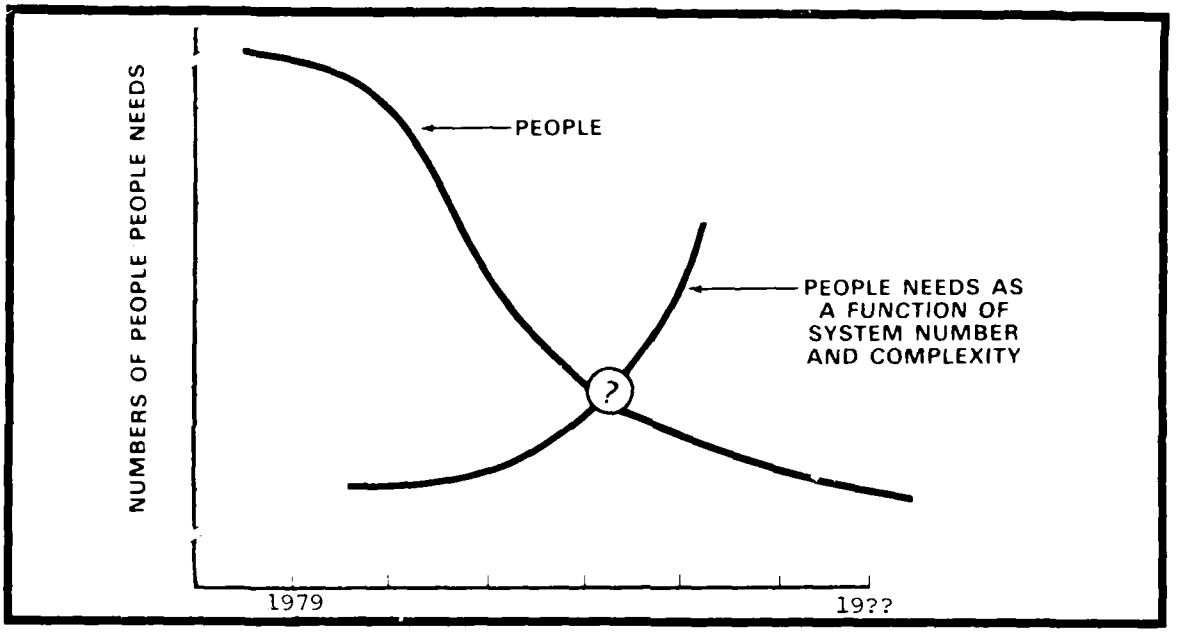

Figure 2. Is There a Point Where we may have More Systems in the Acquisition Cycle Than we have People Available to Staff and Maintain Them?

these systems are not designed with sufficient consideration for the user/operator. Therefore, while a system might be well designed technically, from the user's/operator's perspective it may be less than optimal. Further, existing and projected systems have been developed without coordination among proponents and developers. As a result, each battlefield automated system presents a new learning experience for the user/operator, with little knowledge gained from one system carried over to the next. This skill/demand mismatch imposes unnecessary burdens on personnel and necessitates extra training that could be

avoided by proper system design. As with its well-known and highly prized counterpart in physical and electrical components, behavioral interoperability addresses compatibility issues. Users/operators transfer from one system to another during their careers. More importantly, users of one system frequently must interact with users of other systems. Behavioral interoperability is concerned with designs for systems that permit users/operators to transfer easily from one system to another, and that permit user/operators of different systems to interact conveniently.

That successful system functioning depends on full and fair consideration of user/operator characteristics during development has long been recognized. Nevertheless, virtually nothing has been done to develop a human factors technology to aid efforts to take those characteristics into account.

PURPOSE

The purpose of this project is to fill the need for human factors technology by developing a comprehensive set of guidelines and criteria for user/operator transactions with battlefield automated systems. These efforts will provide to the system design team the tools necessary to capitalize on human capabilities and to compensate for human limitations, thereby enhancing human performance and facilitating coordination among proponents and developers.

The intent of this first phase in the three-phase project was to analyze battlefield automated systems, gathering information to provide a baseline of human factors requirements for user/operator transactions. Another purpose, equally important, was to develop a preliminary set of guidelines and criteria based upon the baseline of information obtained from the analyses of systems.

ACCOMPLISHMENTS

In order to fulfill these purposes, an initial survey of all battlefield automated systems was undertaken. The survey began with a review of the Battlefield Automated Management Plan (BAMP) and the Army Battlefield Interface Concept (ABIC). Since neither program provided suitable data on human/computer interaction, it became necessary to devise special data collection

instruments for conducting system surveys.

The Transaction Feature Analysis (Table 1) and the Transaction Compatibility Analysis (Table 2) techniques were developed to meet this need. The former technique facilitates rigorous and systematic examination of individual design features within a system that affect user/operator transactions. The latter procedure helps to compare design features across systems, or across components such as workstations within a system. The two techniques, which became the first products of this project, were used to examine both Army systems and relevant systems from other services (Table 3).

Table 1.

Overview of the Transaction Feature Analysis Technique

TRANSACTION FEATURE IDENTIFICATION	**TRANSACTIONAL IMPLICATIONS**
DESCRIPTION AMPLIFICATION	**IMPACT ON SYSTEM FUNCTIONS**
Attributes of Design Feature	Quality of Function Performance
Type of Transaction Affected	Timeliness of Function Performance
BEHAVIORAL IMPLICATIONS: IMPACT ON USER	**CONSEQUENCES IMPACT ON SYSTEM MISSION**
Burdens	Quality of System Products
User Do's And Don'ts	Efficiency of Production
Error Probability	**RECOMMENDED RESOLUTION IMPROVEMENTS IN DESIGN**
	Change Design Features
	Eliminate Design Features
	Add Design Features

Table 2.

Overview of the Transaction Compatibility Analysis

SPECIFY TRANSACTION TYPE:
Interaction of Interest

- ✓ Input
- ✓ Interface
- ✓ Network
- ✓ Process
- ✓ Derivitive
- ✓ Product

IDENTIFY DESIGN FEATURES:
Relevant Attributes of System Elements

- ✓ Control Methods
- ✓ Presentation Formats
- ✓ Data Entry and Handling Procedures
- ✓ Message Composition Methods
- ✓ Data Retrieval Procedures
- ✓ Glossaries
- ✓ Error Handling Techniques

RECTIFY DATA:
Facilitate Comparisons Between Items

- ✓ Lists
- ✓ Matrices

IDENTIFY DIFFERENCES

- ✓ Between Features
- ✓ Within Features
- ✓ Combinations

DEVELOP RECOMMENDATIONS

- ✓ Common Design Features
- ✓ Standard Task Modules

Table 3.

Systems Surveyed with Transaction
Feature Analysis Technique

TACFIRE	IISS
TOS[2]	BCS
TCT	MAGIS (USMC)
DS4 AUTO RUN BOOK	SDA (USMC)
DLDED	ISIS (RAND)
PHOENIX AUTO RUN BOOK	DAS3
BETA	

In order to acquire greater detail in the human factors analysis of the user-computer interface, four specific battlefield automated systems were selected for in-depth examination: TACFIRE, TCS, IISS, and DLDED. For each of the systems investigated, a separate report has been prepared for readers whose particular interest may focus on one system or another. Documentation has also been prepared on relevant ARI research literature dealing with human factors guidelines and criteria.

RESULTS

The results of both the survey and the detailed analyses clearly indicated that battlefield automated systems exhibit a wide range of differences related to user/operator transactions. While these systems share many common design features which perform the same functions, those features vary widely from one system to the next. Figure 3 illustrates some of the inconsistencies in general design features that were observed in various systems. As an example, many systems employ the same keyboard; however, as Figure 4 indicates, different systems incorporate different keyboard configurations. Lack of uniformity shows up even within a given system. Figure 5 illustrates different keyboard configurations used on two TACFIRE terminals. On one, the alphanumeric keys are arranged in alphabetical order with non-alphabetic keys on the bottom row; and the other terminal employs a modified office typewriter keyboard. In addition, those terminals exhibit radical discrepancies in their numeric keypads, with one keypad designed as a "desk top calculator" and the other arranged in the touch telephone format.

System differences are by no means confined to hardware considerations. Figure 6 shows that variations in menu display configurations are as great as those in hardware configuration. In addition, menu selection methods differ greatly among Army systems, as well as menu formats and the ways in which menus are utilized.

Inconsistencies among systems became even more apparent when examining specific transaction features in greater detail. Different transaction methods are used by different systems to accomplish the same function. For instance, in using control methods to instruct the computer what functions to perform and in what order, combinations of methods frequently are incorporated. The most

GENERAL DESIGN FEATURES	SYSTEMS				
	TACFIRE	TCS	I^2S^2	MADIS	ISIS
COMMAND TYPE	o Hardware o Preformatted message	o Menus o Preformatted messages o Hardware	o Menus o Command language o Hardware	o Menus o Command language o Hardware	o Command language
COMMAND ENTRY METHOD	o Function keys o Message entries	o Keyboard o Function keys o Message entries	o Light pen o Function keys o Keyboard	o Function keys o Keyboard	o Keyboard
AVAILABILITY OF HELPS/ USER AIDS	o None	o 2 levels of support	o HELP from GIM menu o Some displays have integral HELPS	o Tutorial messages	
SHOWBOX FILES	o No	o Staff working files	o Yes	o Yes	o Yes
TYPE OF SYSTEM	ARTY C^2	C^2	Intel	Intel	File Handling
APPLICATION ENVIRONMENT	Division & below	Case	Theater	Division	
INTENDED USERS	Higher-level artillery specialists	CDR; G2 & G3 staff officers	CDR, G2 Intel analysts	CDR, G2, Intel analysts	
INTENDED OPERATORS	Lower-level artillery specialists	G2 & G3 staff Enlisted personnel	Intel analysts	Intel analysts	o Some
USER-DEFINED COMMANDS	o None	o None	o Report formats built in GIM-II o Macro language	o None	o Some
USER-DEFINED INPUT CODES	o None	o None	o Report formats built in GIM-II o Macro language	o None	

Figure 3. Differences Among General Design Features of Selected Battlefield Automated Systems.

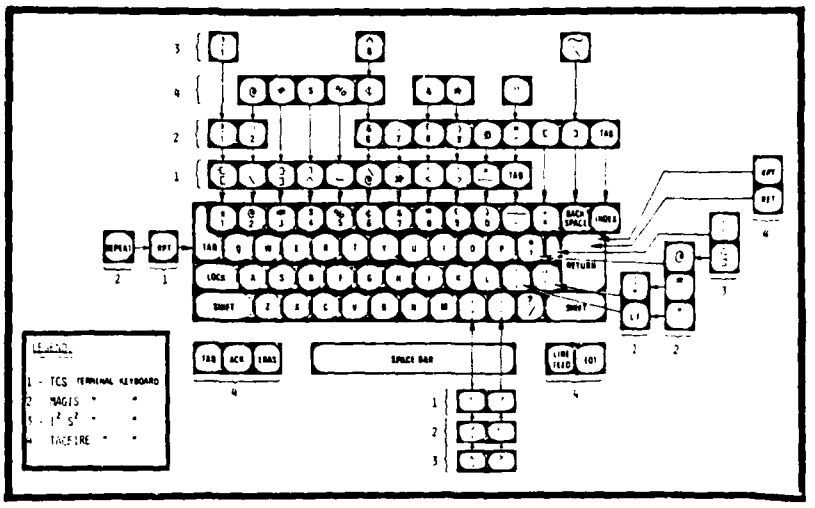

Figure 4. The Standard Office Keyboard Configuration and Variations Found in Selected Battlefield Automated Systems.

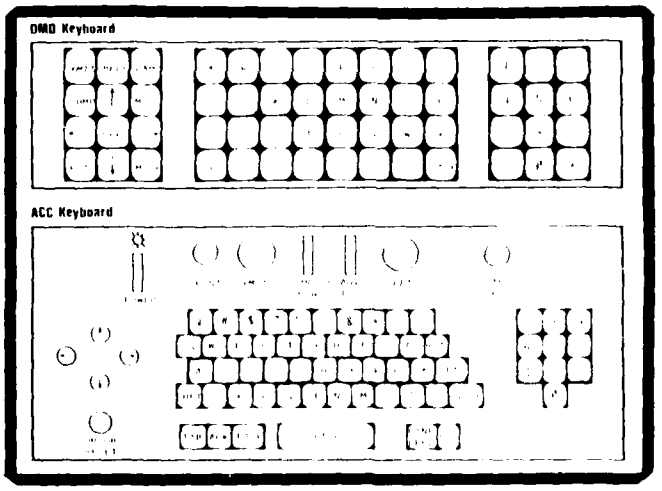

Figure 5. Two Keyboard Configurations Used in TACFIRE.

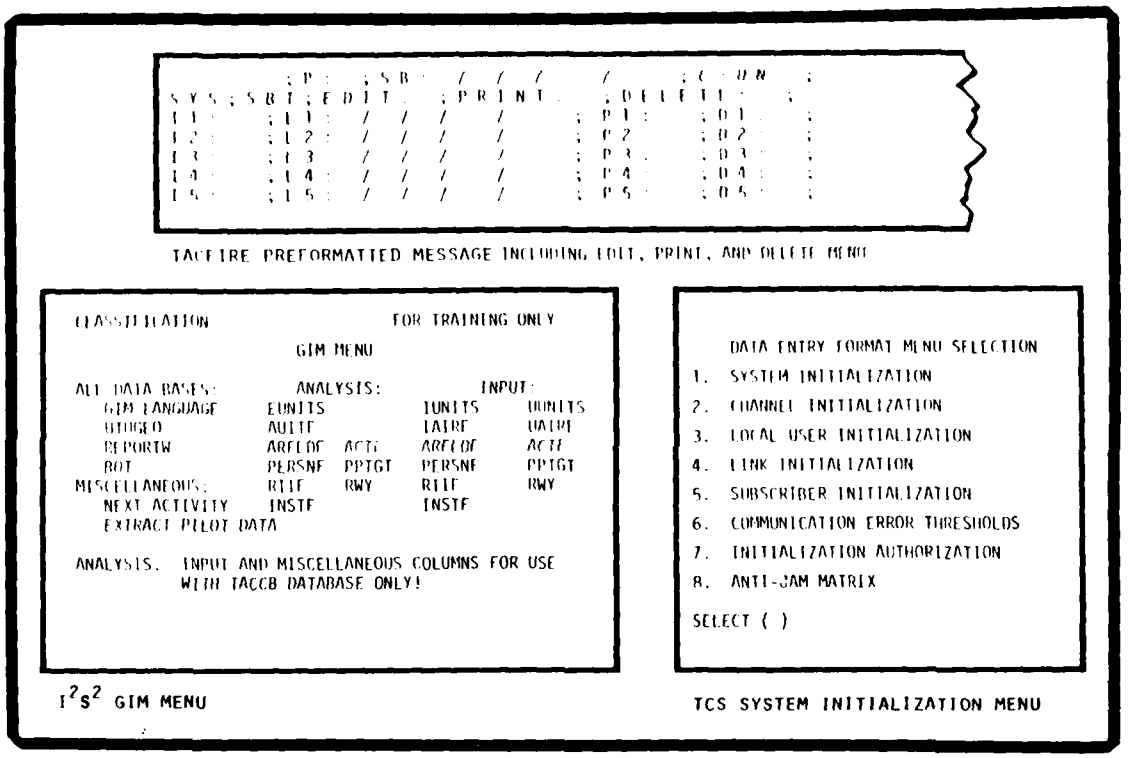

Figure 6. Menu Display Configurations in Three Army Battlefield Automated Systems.

unique hybrid method observed was the format selection matrix on the TACFIRE ACC SPA (Figure 7). The two matrices, as they stand alone are satisfactory; they are organized by message type and logically constructed. However, of the 47 codes common to both, 28 are presented in different locations on the two matrices. Any user who becomes familiar with one menu could easily become confused when assigned to use the other.

Errors in selecting message formats could be significant, perhaps unacceptably high, particularly when the user/operator is under stress. Inherent problems in the SPA message format matrices can be resolved, however, with redesign of the message format selection matrices by placing all codes common to division and battalion in the same location (Figure 8).

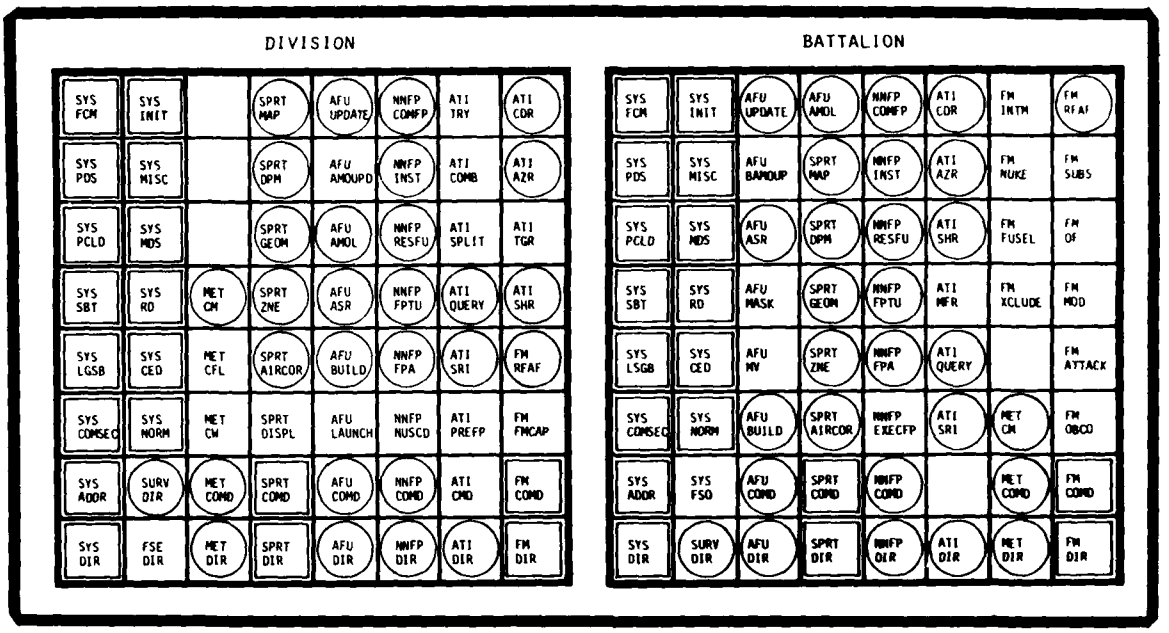

Figure 7. TACFIRE SPA Message Format Selection Matrices for Division and Battalion Computers.

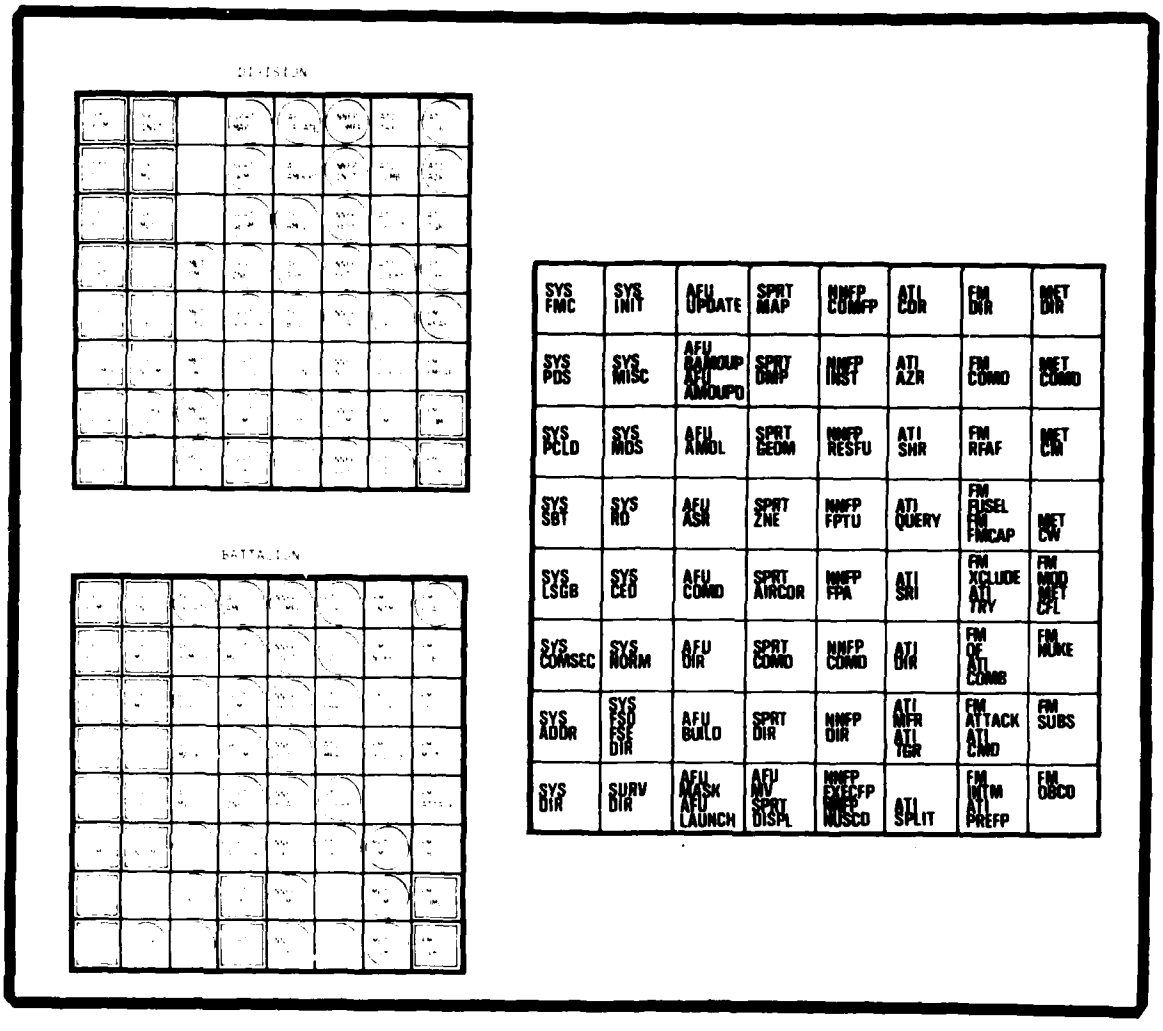

Figure 8. Redesign of TACFIRE Division and Battalion Message Format Matrix Structures.

CONCLUSION

Differences such as those described above are pervasive in Army systems; in general, battlefield automated systems are characterized by transaction design features that are incompatible with human capabilities and limitations. While individual design deficiencies, considered individually, may not be paralyzing to the user/operator, the effects of such inconsistencies are cumulative. When the user is faced with multiple design deficiencies, often occurring simultaneously, human performance is impaired. When users/operators cannot function optimally, neither can the system.

Results from the analyses of battlefield automated systems provided the foundation for the development of guidelines and criteria. The format for these detailed guidelines is shown in Table 4. Recommendations for implementation of desirable design features are presented in summary matrices such as that illustrated in Table 5.

Table 4.
Design Guideline Format

G. CROSS INDEXING

2.1 FIXED ALPHANUMERIC DISPLAYS
2.2 VARIABLE-LENGTH ALPHANUMERIC DISPLAYS
2.3 GRAPHIC DISPLAYS
3.0 DATA ENTRY ASSISTANCE
3.4 EDITORS
7.4 ERROR CORRECTION TECHNIQUES
7.7 ERROR DETECTION TECHNIQUES

Table 5.

Example of a Matrix Summarizing Guidelines for Use of Highlighting According to the Highlighting Application

KEY:
1 = Best
2 = Second Choice
3 = Not Recommended

HIGHLIGHTING METHOD	HIGHLIGHTING APPLICATION: UNUSUAL VALUES	INFORMATION CHANGED	INFORMATION TO BE CHANGED	HIGH-PRIORITY MESSAGES/CODES	ALARMS	SPECIAL AREAS OF DISPLAY	COMMAND/DATA ENTRY ERRORS	WARNINGS OF CONSEQUENCES	INDICATE SEARCH TARGETS
BRIGHTNESS CONTROL	1 *	1 *	1 *	1 *	2	1 *	1 *	1 *	1 *
CHARACTER SIZE CONTROL	1	1	1	1	3	3	1	1	2
ALL UPPER CASE	2	2	2	2	3	3	2	2	3
REVERSE DISPLAY	2	2	2	2	2	3	2	3	1
UNDERLINING	2	2	2	2	3	3	2	2	3
DIFFERENT FONT	2	2	2	2	3	3	2	3	3
COLOR CONTROL	1	1	1	1	2	1	1	1	1
BLINKING, PULSATING	3	3	3	2	1 *	3	3	3	2
BOXING	3	3	3	1	3	1	2	1	2
ARROWING	2	2	2	3	3	3	2	3	2
SYMBOLIC TAGGING	2	2	2	3	3	3	3	3	2
ALPHANUMERIC TAGGING	3	3	3	3	3	3	3	3	3
POSITION DISPLACEMENT	2	2	3	3	3	3	2	3	2

* Recommended as 1st choice for standardization purposes

The design guidelines will support system proponents and developers in selecting design features which best match the requirements and capabilities of anticipated users/operators. Thus, the skill-demand mismatch that currently imposes excessive performance requirements on users/operators will be reduced, thereby reducing the training burden that accompanies so many contemporary systems. An additional benefit of this user-oriented design will be an increase in behavioral interoperability, as that concept was described earlier.

It is not the purpose of this project to trivialize user-system interaction in battlefield automated systems, but one fact must be recognized. The users of these systems are supposed to work in a functional area; they are not supposed to be computer operators. The design of the system should allow the user to focus on developing greater skills in their career fields, rather than

peripheral system operation skills. Furthermore, that design should allow the user to concentrate on the generation of system products, not on how to make the system work.

We need to stop talking about user requirements, as though they were somehow different from system requirements. Users are components of systems. A tank doesn't fight without a crew; neither does a Cobra. And battlefield automated systems don't function without users and operators. User requirements are system requirements. If we don't build systems to meet all their requirements--human as well as hardware, software and product--then those systems will fail. And if they do fail, then we will have paid the greatest of all system life cycle costs: the cost of building battlefield automated system that cannot do the job.

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