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VISUAL DISPLAYS FOR THE MODERN ARMY: RECENT FINDINGS FROM THE ARMY RESEARCH INSTITUTE

David M. Regal and Beverly G. Knapp

Battlefield Information Systems Technical Area

SYSTEMS RESEARCH LABORATORY

Franklin L. Moses, Acting Director

U. S. Army

Research Institute for the Behavioral and Social Sciences

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L. NEALE COSBY
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EDGAR M. JOHNSON
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It is clear that tomorrow's Army will come to rely more and more heavily on computer generated visual displays in a myriad of situations. ARI has produced a substantial amount of research directed toward improving the human factors design of information displays. This research has produced design recommendations in such areas as highlighting, color coding, selective call up, design and use of symbols, alphanumeric vs. graphic portrayals, and the manipulation of pictorial information. Keywords; (continued)

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This report provides a list of specific recommendations for the design of effective visual displays, and defines directions that future research might take.

VISUAL DISPLAYS FOR THE MODERN ARMY: RECENT FINDINGS FROM THE ARMY RESEARCH INSTITUTE

BRIEF

Requirement:

To summarize and integrate ARI research dealing with visual displays and provide a listing of resulting design recommendations.

Findings:

ARI has supported (in-house or by contract), a substantial amount of research directed toward improving the design of information displays from a human factors perspective. This research has produced design recommendation in areas such as highlighting, color coding, selective call up, symbology design and use, alphanumeric vs. graphic portrayals, and the manipulation of pictorial information.

Utilization of Findings:

This report should: (1) Help define directions that future research might take. (2) Provide a list of specific recommendations for the design of effective visual displays.

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by

David M. Regal and Beverly G. Knapp

The displays most widely used in today's Army (for planning, situation assessment, and decision making) consist of topographic maps with clear acetate overlays. Battlefield information is added by using a greasepencil to draw on the overlays. This methodology has not advanced substantially over that used in the early part of the century, despite the fact that battlefield management has become much more complex. At present, however, attempts are being made to harness the power provided by computer and computer display technologies to develop more sophisticated tactical displays.

The commander of a tactical operation center (TOC) is faced with a potentially serious information management problem. New sensor technologies and improved communication capabilities increase the volume of incoming information pertaining to both enemy and friendly forces. The complexity of this information can also be increased as a result of the greater mobility, fire power and sophistication of modern weapons systems. TOC commanders must thus deal with a higher volume of information and more complex information, and they must often make decisions more quickly than in the past. Given these facts, it is clear that the use of automated data processing (ADP) to help display and manage battlefield information is of great importance.

To this end, Army personnel are currently examining the rapid advances in ADP technology to determine how computer generated tactical displays can best meet the needs of modern, sophisticated tactical operations.

The capabilities of computer generated displays are already impressive and are likely to improve rapidly in the future. Some advantages of these displays are:

1. Presentation of large amounts of information, including digitized maps.
2. Manipulation of display components, including symbol placement and movement, selective call-up or deletion of groups of symbols, and various techniques for highlighting important information.
3. Electronic transmision of displays between widely separated command centers.
4. Dynamic capabilities that would allow unfolding of a battle plan in time, so that it could be evaluated at every stage.
5. Calculations using the data base, such as determining distances, elevations and fields-of-fire when working with digitized maps.

While the potential usefulness of computer driven displays is beyond question, the effective implementation of this new technology is challenging. Large amounts of information must be presented to the user in a form that allows it to be rapidly assimilated and acted upon.

The main areas of concern in the design of display systems are hardware capabilities, software, and human factors considerations. Hardware capabilities involve factors such as display resolution and memory capacity that place limits on the amount and quality of information presented. While these hardware limitations are very significant, their importance is rapidly decreasing as the current explosion in computer and display technology produces one advance after another.

With advances in display hardware, the problems of information transfer fall increasingly in the area of human factors and software development. Thus, the question is raised as to how large amounts of information can best be organized and presented to have maximum utility for the user. ARI has recognized the critical nature of this issue and has undertaken research directed toward resolving some of these problems. This research, dealing with the soldier-computer interface, is aimed at providing guidelines applicable to all stages of system development -- requirements, design, and operational use. An overview of this work is presented in the following sections.

RECENT ARI RESEARCH ON VISUAL DISPLAYS

BACKGROUND

Automated graphic displays can greatly assist the command staff in managing the battlefield. The advantages of using these displays were pointed out earlier. The problem now becomes one of how to most effectively implement this new technology. ARI has made significant contributions in this area.

A number of research projects have been directed toward examining what is known as the "clutter" problem. Clutter is defined as occurring when the amount of information in a display is greater than a user can efficiently process and use. (It does not imply that any of the information is unimportant.) In an attempt to reduce this problem, alternative formatting techniques have been investigated that include various forms of selective data presentation and methods of information highlighting. Work has also been done in the area of tactical symbology, where standard Army symbols (FM 21-30 and FM 21-31) have been shown to be suboptimal for visual displays. Other ARI research directed toward more effective use of computer generated visual displays is also reviewed. An overview of the general factors that are important in effective map design can be found in a paper by Potash (1977).

ALTERNATIVE FORMATTING OF DISPLAY INFORMATION

A user looking at a tactical situation display must be able to extract a variety of information regarding friendly forces, enemy forces, terrain, and the various relationships between these factors. Unfortunately, our perceptual and information processing capacity is limited, and a point can be reached beyond which the addition of more information to a display screen will no longer improve performance, but actually hinder it.

An example of a display with a large quantity of information is shown in Fig. 1. A display of this type is referred to as a high density or cluttered display. Note that although this map shows only the most basic information (unit type, weaponry, and limited terrain features) it already appears cluttered. It can become a chore to extract even simple information (such as the number of armor, artillery, and infantry units)

TEMPORAL FACTORS AFFECTING VISUAL DISPLAYS

A very through review of the literature covering the ways in which temporal factors affect information transfer from visual displays has been produced by Sekuler, Tynan and Kennedy (1980). While this work is especially appropriate as an aid in designing dynamic displays, it is also applicable to certain aspects of static displays, such as refresh rate.

SUMMARY OF ARI FINDINGS

1. Computer generated tactical displays have great potential for significantly improving battlefield management.

2. Alternative formatting techniques can help alleviate the information overload (clutter) problem.

   a) Coding and selective presentation appear to be the most promising alternative formatting techniques.

   b) Double coding dramatically increases user performance in information extraction. This redundant coding should augment symbolic information rather than add new symbols.

   c) Color coding is a powerful technique for segregating information. It must be used with care, however, to assure that it does not interfere with the extraction of information coded using other techniques.

   d) Neighboring map segments can be integrated by either smoothly panning the map or by the presentation of discrete segments. The simpler procedure of discrete segment presentation (with 25% overlap) was found to be superior.

   e) Selective call up is a promising technique for reducing the problem involved in using a cluttered display. In-depth research into the

The computer can also provide information that incorporates a temporal component. By specifying the velocity at which different sections of a route can be traversed, the time needed to reach a destination is easily provided. Dynamic battlefield planning is also possible. By indicating the paths and speed of movement of different units a commander can look at unit deployment at any period during the projected engagement. Work by Rebane, Walsh, Moses, Schechterman and Levi (1980) involved the development of preliminary procedures that allow non-computer personnel to create battlefield situations on computer displays and to assess changing events using dynamic replays and computer calculations of possible outcomes. This work emphasizes the fact that battlefield planners/analysts, without a computing background, can work effectively with computer graphics to structure and analyze battlefield situations.

In other research Moses and Vande Hei (1978) had intelligence analysts make assessments of a classical division attack scenario depicted on a display screen. In one condition the analysts could have the computer specify distances, times, velocities, and directions. In the control condition these aids were not available. Results indicated that responses in the computer aided condition were substantially more accurate than responses in the unaided condition.

It should be stressed that the above examples are only a sampling of the ways computers can aid in battlefield planning. However, they should be adequate, together with previously presented material, to provide a feeling for how a computer system could be developed which, when used by a trained tactician, would be capable of providing truly superior battlefield management.

It is clear that symbol design and selection is an important factor in optimizing the presentation of tactical information. Research on the meaning and structure of symbols is presently being carried out by ARI personnel.

ALPHANUMERIC DISPLAYS

When designing computer generated visual displays there is sometimes a tendency to ignore or minimize the role of alphanumerics. ARI research (Vicino and Ringel, 1966; Nawrocki, 1972,1973; Moore, Nawrocki and Simutis, 1979) has shown that in some instances alphanumerics are the most efficient form of information presentation. This is especially true for summary data (such as unit strength or supply status) where an alphanumeric listing can replace the need to tediously extract the information from a cluttered graphic display. This research indicates that the most effective displays will often include both graphic and alphanumeric elements.

DATA BASE MANIPULATION

The ability to access and manipulate the data base used to generate tactical map displays provides the analyst with a number of very powerful tools. For example, by simply specifying two end points the computer can quickly provide the distance between them and the azimuth from one to the other. If a curvilinear route is specified, then its length can be calculated easily and quickly. The cumulative elevation gain for a route can be determined -- a potentially important factor when planning troop movements to be made on foot. In a similar fashion, the steepest grades along a route can be derived from contour information and used in planning the feasibility of vehicular movement.

Other important features of an optimal symbol set are described by Ciccone, Samet and Channon (1979). One of these features is identifiability. Given a high density display, it is important that a user be able to easily pick out and identify various symbols. It is also important that symbols be sufficiently distinct from one another to minimize the likelihood of confusion even under adverse viewing conditions. Still another consideration is symbol complexity. If one is concerned with the amount of clutter on a display screen, it is important that the symbols used do not add to the problem. The more complex the symbols the more they will tend to clutter the screen. A good design thus calls for symbols to be as simple as possible while still conveying the desired information.

Still another feature that must be taken into account in the design and selection of symbols is the medium in which they are to be presented. The criteria for effective video display terminal (VDT) displays are not identical to those for drawing with grease pencil on an overlay, nor are they the same as those used for printed material. For example, while a human can draw a circle faster than a square, the computer has a preference for the square, which it can generate faster and store more easily. The graphics capabilities of a display should also influence symbol selection. A system's resolution will determine the smallest size a symbol can be drawn and still be easily recognized. By choosing complex symbols, a designer may be adding to the clutter problem as a result of having to use larger symbols.

To insure the optimal choice of symbols for VDT displays it is important to understand and take into account the system's hardware and software characteristics.

unavailable from a display using conventional symbology. It was also found that users typically responded to this situation by creating their own idiosyncratic symbols to supplement the standard set. This finding clearly indicates the need for the Army to develop a more complete set of symbols. An alternative is to have ADP systems that allow users to define additional symbols that are necessary for mission accomplishment. A file containing the definitions of these novel symbols should be a requirement.

Another important requirement of a symbol set is that the graphic representation of the individual symbols be readily associated with the symbol's actual meaning. This association can take a number of forms such as pictorial similarity, or numerousity to represent unit size. Symbols that have a natural association with the concept they are ment to represent will be learned and interpreted more readily and will make it easier for a user to extract information from a cluttered display. Bersh, Moses and Maisano (1978) and Moses, Maisano and Bersh (1979) determined the strength of association of simple codes and geometric shapes with military concepts. The strengths of these associations were found to be low, while certain non-standard symbols were found to have a high natural association with the military concepts that were studied. In a related project, Hemingway, Kubala and Chastain (1979) compared pictorial symbols to traditional military symbols. Naive subjects were asked to rank symbols in terms of how meaningfully they felt each symbol represented a particular military concept. The subjects generally preferred pictorial symbols over their traditional military alternatives.

SYMBOLOGY

Another factor that bears on the usefulness of tactical displays is the nature of the symbols used. The symbols must not only contain all necessary information, but must also represent it in a fashion that will allow it to be efficiently extracted by the user. There seems to be general agreement among researchers that the symbols currently used by the Army (FM 21-30 and FM 21-31) do not represent the best choice.

Sidorsky, Gellman and Moses (1979) surveyed a number of Army agencies with an active interest in symbology. Their work provides a broad overview of the Army's symbology requirements. In a related work, Landee, Samet and Foley (1979) developed a task-based approach for specifying and analyzing map information requirements. These requirements included both tactical symbology and other information dependent on symbols (e.g., slope derived from contour lines). The work resulted in the production of map development guidelines.

ne requirement of a symbol set is to represent all essential concepts of the task domain. Ciccone, Samet and Channon (1979) developed a task based methodology that allowed them to determine the graphically related tactical information requirements of experienced military tacticians. They discovered that current military symbology did not adequately portray all the required information. In another project, Landee, Samet and Gellman (1980) used a similar methodology to generate a large number of tactical questions relevant to the battlefield information requirements of a TOC command staff. Their results indicate that conventional symbology fails in many respects to meet the basic information needs of users. For example, 43% of the information requirements identified were said by users to be

A project currently in progress will provide additional research on the effective use of information reduction techniques. One feature of this project is aimed at helping with the task of integrating different map segments. In one corner of the screen is a small scale outline of the entire map area of interest. Within this outline is a second outline indicating the size and location of the area currently being presented on the screen. It is hoped that this mode of presentation will aid the user in the task of integrating information across different presentations.

The second type of information reduction to be considered involves a fixed situation map to which features are either added or deleated. This process, in which users control the information displayed, is known as selective call up. For example, if one wanted to assess the positioning of friendly artillery units on a display that was heavily cluttered the task would be made easier by temporarily removing infantry and artillery units from the screen. It is possible to give the user control over the presentation of a large number of features (e.g., unit size, unit type, weaponry, readiness, mobility, terrain features, etc.). The effective implementation of user control of displayed information is currently under study at ARI. In a series of experiments, Regal and Knapp (1984) showed that when users were able to remove extranious information from a display their problem solving speed and accuracy improved significantly. These improvements in performance held across different task types and different levels of clutter.

By viewing only a section of the display the user looses the ability to integrate information across the entire display. This problem can be partially overcome by allowing the user to sequentially view adjoining sections of the display. The impression here is one of a large display being moved behind the display screen. Granda (1978), using an alphanumeric presentation, had subjects search for target stimuli. Only a small part of the display was visible at a time and the search was conducted by allowing the subjects to control which part of the presentation they viewed. It was found that the display could be effectively searched using this panning technique.

In other research, Moses and Maisano (1979) compared two methods of panning a tactical map display.The intuitively more pleasing method involves an impression of the map moving smoothly and continuously behind the screen. A faster and more easiy implemented method provides discrete shifts between neighboring (and partially overlapping) sections of the map. Moses and Maisano (1979) compared these two techniques in an experiment that required Army officers to determine optimum routes that involved multiple map segments. They found that performance using discrete segments (having 25 % overlap) was better than continuous movement.

It is important to keep in mind that sequential presentation of map segments requires a substantial amount of the user's effort be directed toward integrating across frames. The technique should be used with some care and its benefits will clearly be a function of the specific task at hand.

extraction (to differentiate unit strength) no significant advantage was found.

In another experiment, Hemingway and Kubala (1979) used color to differentiate types of military units (Infantry, Armor, Artillery and Mechanized Infantry). They conclude that color coding increased the speed of information extraction, while not influencing the accuracy of performance.

Farrell and Potash (1979) and Potash, Farrell and Jeffrey (1979) used color as a double-cue supplement to contour lines on military maps. Again, the speed of information extraction (in contour related tasks) was increased without any loss of accuracy.

INFORMATION REDUCTION

"Information reduction" is an alternative formatting technique that reduces clutter by dividing up the available information and displaying just part of it at a time. By allowing the user to display only information that is relevant, it is possible to effectively process a much larger data base than would be the case if all information were presented at once.

One form of information reduction involves magnification. By presenting only a section of the total display, expanded to fill the screen, the information density and thus clutter can be reduced and specific sections of the display can be examined in detail.

interfering with other types of information of interest to the user. For example, one could use different colors to effectively differentiate between unit types (Infantry, Armor, Artillery). However, the user might also be interested in identifying the number of units at full strength. This identification requires attending to symbols that cut across unit type and means that the user must ignore the colors that designate unit type. If the color highlighting is very salient it can be difficult to ignore and can actually interfere with the ease of extracting information indicating unit strength.

Thus, when implementing a highlighting technique one must be concerned with more than just how well it facilitates information extraction in the category of interest. The extent that it might interfere with the user's ability to effectively deal with other categories of information must also be taken into account.

In one research project, Sidorsky (1977) evaluated the use of color as an aid in extracting information from a tactical situation map. Color was used to highlight either shape or alphanumeric codes on a number of tasks. Performance was compared to that obtained without the use of color. The tasks were of a type that required attention to more than a single dimension. For example, in one problem subjects had to determine both type and strength of units depicted on a terrain map. Problems like this are most efficiently solved by extracting information in a specific order -- in this example, by first identifying unit type and then unit strength. When color coding was used to indicate the first level of information extraction (unit type) the speed and accuracy of information extraction improved dramatically over that obtained when only shape or alphanumeric coding was used. However, when color was used at higher levels of information orientation, underlining, numerousity, and tagging. When these codes are used singly or in combination, a great potential exists for aiding users in processing large amounts of graphic information.

In one research project,Vicino, Andrews and Ringel (1965) investigated the use of various coding techniques to indicate when changes in a display had occurred. Their interest was in finding a code which was very efficient in alerting the command staff to updates of specific information. On each trial subjects were shown two successive slides of a map containing symbols representing military units. The second slide differed from the first in that units were either added, deleated, or moved. It was the subject's task to identify these changes. Performance, using three different techniques for highlighting the changes (hard-copy, single-cue, and double-cue coding) was compared to unaided performance. Single-cue coding involved adding features to the unit symbol to indicate changes. For example, an "N" was put next to a symbol that was added. This was found to improve performance substantially over the unaided situation. The double-cue coding situation involved keeping the added features of single-cueing and in addition, highlighting the relevant unit symbols by increasing the width of lines used to draw them. Double-cue coding produced the best results, with performance being considerably better than even the single-cue coding technique. Having a hard-copy of the first slide to compare to the second slide as an aid in identifying the changes was not found to be very useful within the time limit given.

Another coding technique explored by ARI researchers is that of color coding. The use of differential color to highlight specific categories of information on tactical maps has been shown to be very effective. In fact, it is so effective that it must be used with care so as to avoid

Research evidence has pointed to some disadvantages of using techniques 1 and 2 (multiple displays and reduced detail displays). Potash and Jeffrey (1978) have argued that multiple displays are not worth the added hardware expense and that there are problems introduced by the need to integrate information across more than one display. Granda (1976) has found that the reduced detail technique may be viable for some tactical tasks, but unfortunately user surveys have indicated the need for more displayed information rather than less, especially in the face of increasingly complex battlefield environments (Ciccone, Samet and Channon, 1979; Landee, Samet and Gellman, 1980). ARI research has focussed on the two remaining techniques (coding and selective presentation) as the most effective methods of alternative formatting for high density displays. Details of recent research findings regarding these techniques is presented next.

CODING

Coding techniques enhance assimilation of displayed information by making certain portions of that information "stand out" from the rest. This is accomplished by differentiating particular symbols, elements, or features within the display by either highlighting or emphasizing them by adding an auxiliary code. All information remains on the display, but critical dimensions are emphasized or redundantly portrayed. Hemingway, Kubala and Chastain (1979) and Parrish, Gates, Munger, Towstopiat, Grimma and Smith (1983) have reviewed different coding techniques and made recommendations for their use. A sampling of these techniques include various uses of: color, brightness, character size, blinking, shape, from such a display. Research has shown that searching for information in a high density display can be time consuming and fatiguing (Bloomfield, Beckwith, Emerick, Marmurek, Tei and Traub, 1978). Thus, a situation can exist in which important information is available but not used -- a situation in which the probability of successful battlefield planning is reduced. The purpose of alternative formatting techniques is to increase the amount of information that a commander or command staff can effectively deal with (see Gellman, 1979; Knapp, Moses and Gellman, 1982).

Alternative formatting techniques are intended to produce displays with improved perceptual characteristics without changing the basic symbols or hardware being used. These improvements are achieved through software manipulation and involve variations in dimensions such as color, luminance, magnification, selective deletion and temporal variations.

ARI research has addressed four alternative formatting techniques intended to facilitate a user's ability to extract information from a graphic display. These are:

1. Multiple Displays. The use of more than one display to present information.

2. Reduced Detail Displays. Removal of fine grain information from the display.

3. Coding. Highlighting certain information to maximize symbol differentiation.

4. Selective Presentation. Presentation of various sub-sets of the total information available.

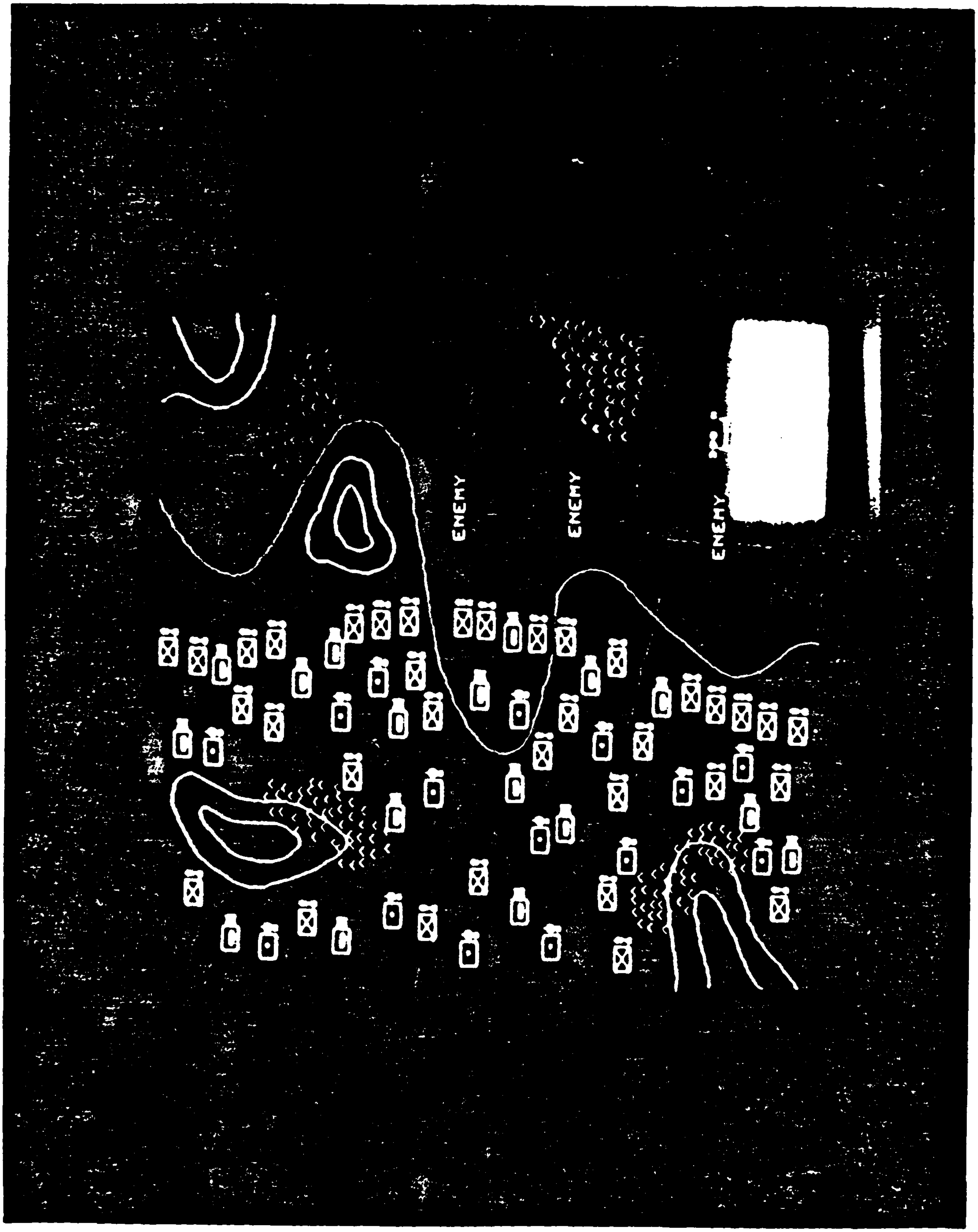

FIGURE I

usefullness of this technique are planned for the near future.

4. Improvements are needed in the tactical symbology presently used by the Army.

a) A symbol set that more completely represents all required functions is needed.

b) Individual symbols should be chosen so that their graphic representation is more readily associated with their actual meaning.

c) For use in high density displays, symbols should be kept as simple as possible, but still be different enough from one another so as not to be confused.

d) The design of symbols to be used with VDT's should take into account the hardware and software characteristics of the system.

5. There are instances in which alphanumeric representation of information is preferable to graphics. The most effective displays will often include a combination of graphic and alphanumeric elements.

6. The ability to manipulate the data base used to produce tactical displays provides the user with numerous aids to battlefield management. These aids include easy calculations of factors such as, route length, azimuths, velocity of movement and dynamic planning.

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