GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: November 7, 1978

Project Title: Representing and Displaying Information for Tactical Decision Processing

Project No: G-36-628

Project Director: Dr. Albert N. Badre

Sponsor: U. S. Army; Defense Supply Service - Washington; Alexandria, VA 22333

Agreement Period: From 8/15/78 Until ~~8/14/79~~ 30 Sep 79

Type Agreement: Grant No. MDA903-78-G-04 (thru GIT)

Amount:
$44,285 DSS-W Funding (G-36-628)
4,638 GIT Contribution (G-36-329)
$48,923 Total

Reports Required: Quarterly Progress Reports; Final Report

Sponsor Contact Person (s):

Technical Matters
U. S. Army
Defense Supply Service - Washington
Alexandria Division
5001 Eisenhower Avenue
Alexandria, VA 22333

Contractual Matters
(thru OCA)
Office of Naval Research
Resident Representative
Georgia Institute of Technology
Atlanta, GA 30332

Defense Priority Rating: None

Assigned to: Information & Computer Science (School/Laboratory)

COPIES TO:

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- Project Code (GTRI)
- Other ____________

CA-3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 1/16/81

Project Title: Representing and Displaying Information for Tactical Decision Processing

Project No: G-36-628

Project Director: Dr. Albert N. Badre

Sponsor: USA/DDS/Washington

Effective Termination Date: 9/30/79

Clearance of Accounting Charges: 9/30/79

Grant/Contract Closeout Actions Remaining:

- _ Final Invoice and Closing Documents
- X Final Fiscal Report and closing documents
- _ Final Report of Inventions
- X Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other __________

Assigned to: Information and Computer Science (School/~~Laboratory~~)

COPIES TO:

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EES Information Office
Project File (OCA)
Project Code (GTRI)
Other OCA Research Property Coordinator

CA-4 (1/79)

G-36-628

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

OFFICE OF
THE
COMPTROLLER

June 25, 1980

USA Military District of Washington
Finance & Accounts Office
Attn: ANCOM-FA-AP
1900 Half Street, S.W.
Washington, D.C. 20324

Dear Sir or Madam:

Enclosed is the Final Report of Expenditures for Grant #MDA-903-78-G-04 and Georgia Institute of Technology Check No. 118353 to return the unexpended balance of $1,289.03.

If you have questions or require additional information, please let us know.

Sincerely,

David V. Welch

David V. Welch, Manager
Grants and Contracts Accounting

DVW/BITS/jb
Enclosure
cc: Dr. A. N. Badre
Dr. L. Chiaraviglio
Mr. E. E. Renfro
Mr. O. H. Rodgers
File G-36-628

GEORGIA INSTITUTE OF TECHNOLOGY
ARMY GRANT NO. MDA-903-78-G-04
FINAL REPORT OF EXPENDITURES
8/15/78 - 9/30/79

G-36-628

REPRESENTING AND DISPLAYING INFORMATION FOR TACTICAL DECISION PROCESSING

Total Direct Costs	$ 26,300.96	
Total Indirect Costs	16,695.01	
Total Expended		$ 42,995.97
Total Received		44,285.00
Unexpended Balance		$ 1,289.03

G-36-628

Representing and Displaying Information for Tactical Decision Processing

The First Quarterly Progress Report

Albert N. Badre

For
The U.S. Army Research Institute
for the Behavioral and Social Sciences

August 15 to October 31, 1978

Grant No.: MDA903-78-G-04

School of Information and Computer Science
Georgia Institute of Technology

The First Quarterly Progress Report

on

Representing and Displaying Information
for Tactical Decision Processing

In the first phase of this project, the main effort was concentrated on completing the design of the two experiments and on beginning to develop the material. In this regard the principal investigator, Dr. Albert N. Badre, made a trip to the U.S. Army Research Institute in Alexandria, Va. where work on selecting the military subjects and on the design of the material to be used in the experiments was initiated. In addition, work was begun to modify the existing data analysis program that was used in last year's ARI funded project in order to make it more suitable for the data that will be collected this year.

In completing the experimental design and developing the material for the two experiments, the following modifications and additions were made to the general design as described in the proposal:

A. Fifty subjects will be selected to participate in this experiment. The participants will be military officers from Fort Benning, Georgia. Forty of the subjects will undergo both experiments.

B. The experiment to examine the effectiveness of varying the conditions of information display in terms of chunking remains basically unchanged. Comparison will be made among four basic display conditions. These are: (1) the one-shot display of the scenario; (2) the development of the scenario incrementally by chunks in an order that is already established by last year's results, (3) the development of the scenario by chunks in the reverse of the already established order, and (4) the development of the scenario incrementally by the addition of non-meaningful chunks. The structured battlefield scenarios used in last year's study will be used again for this experiment. However, instead of using slides, a film is being developed to be used in the incremental display conditions.

C. The second experiment was designed to examine the effects of a line of battle actions on the chunking and representing of tactical information. This experiment has been modified in two respects: First, there are now five rather than four comparison conditions. The original four conditions constituted the three conditions where the scenario to be reconstructed occurred in the beginning, the middle, or the end of the sequence, as well as the condition where the scenario to be reconstructed did not occur in a sequence. In addition to these four conditions, a fifth condition was added where the scenario to be reconstructed is to be given in an unstructured line of scenarios; secondly, in designing the material for this experiment, a sequence of nine battlefield scenarios was developed (the sequence is given in the attachment) where a significant aspect of the scenario remained unchanged throughout the sequence. The conjecture being developed here is that the invariant aspect will play a decisive role in the chunking behaviors of subjects in the sequencing conditions. It will have less of an effect for the condition where the scenario is not given in a sequence. It should also not have an effect for the condition where the sequence is unstructured. Five scenarios will be presented for each condition. The criterion scenario to be reconstructed is the one labeled (5 of 10) in the attachment.

In the second quarterly phase of this project the plan is to complete the experimental design, the development of the material, and conduct the experiments.

The following personnel have participated in the first phase of this project:

Principal Investigator:	Albert N. Badre
Graduate Research Assistant:	Cheryl C. Allen
Clerk:	Catherine M. Beise
Student Assistant:	Timothy Cope

Funds expended as of November 1, 1978 are detailed below:

LIST OF PERSONNEL AND TIME SPENT BY EACH AS WELL AS FUNDS SPENT AS OF NOVEMBER 1, 1978

Personal Services

	% Effort 8-15-78 10-31-78	$
Badre, A.N. Assistant Professor and Principal Investigator	25%	1,273.00
Allen, Cheryl C. Graduate Research Assistant	14%	400.00
Beise, Catherine M. Clerk	7%	204.14
Cope, Timothy Student Assistant	16%	289.00
		$ 2,166.14

Retirement Benefits (9.83% of Applicable Salaries)		68.84
Materials & Supplies		-
Travel		255.48
Consultants		-
Indirect Costs (76% of Personal Services)		1,646.27
Total		$ 4,136.73
	Total Budget	44,285.00
	Balance	$40,148.27

Key

Scenario – MRD arrives in battle area, moves to contact, deploys in attack formations, engages in secondary and main attacks, and attempts breakthrough.

MRD HQ
Motorized Rifle Division

MRR HQ
Motorized Rifle Regiment

TR HQ
Tank Regiment

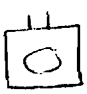
MR Bn
Motorized Rifle Battalion

T Bn
Tank Battalion

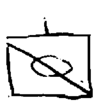
Arty Bn

Mech Inf Bde HQ

Mech Inf Bn



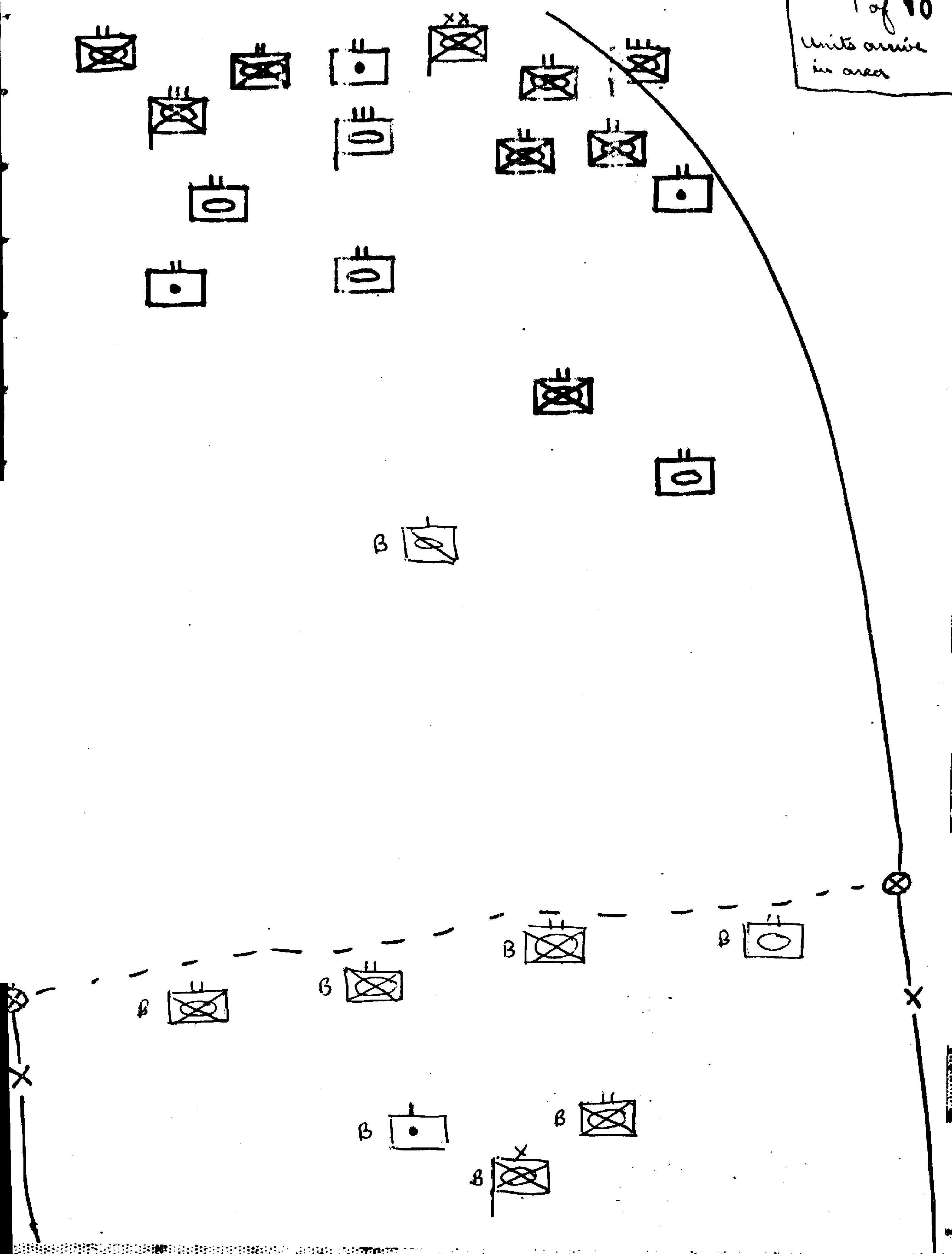
Arm Bn



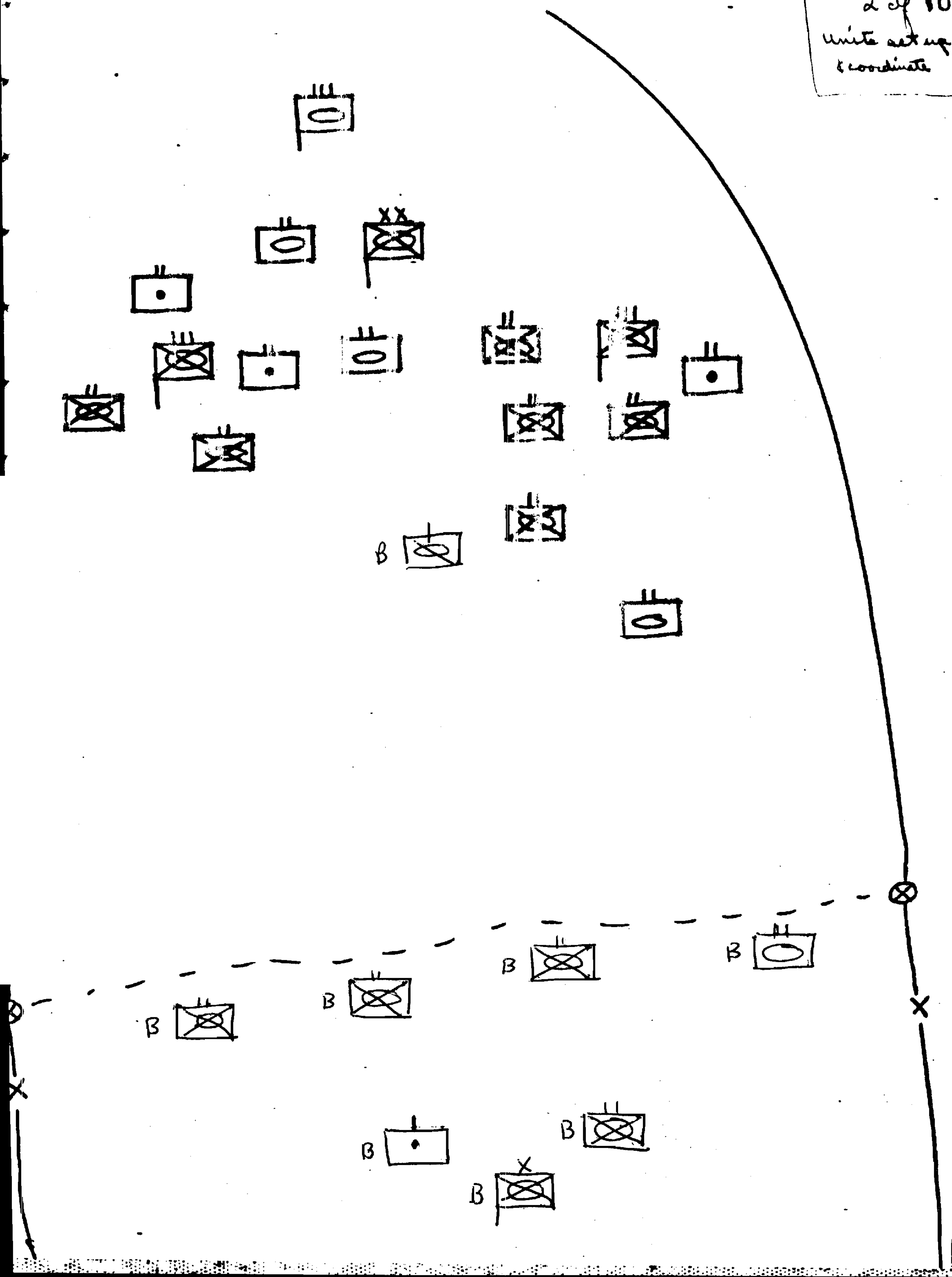
Arm Cav Troop

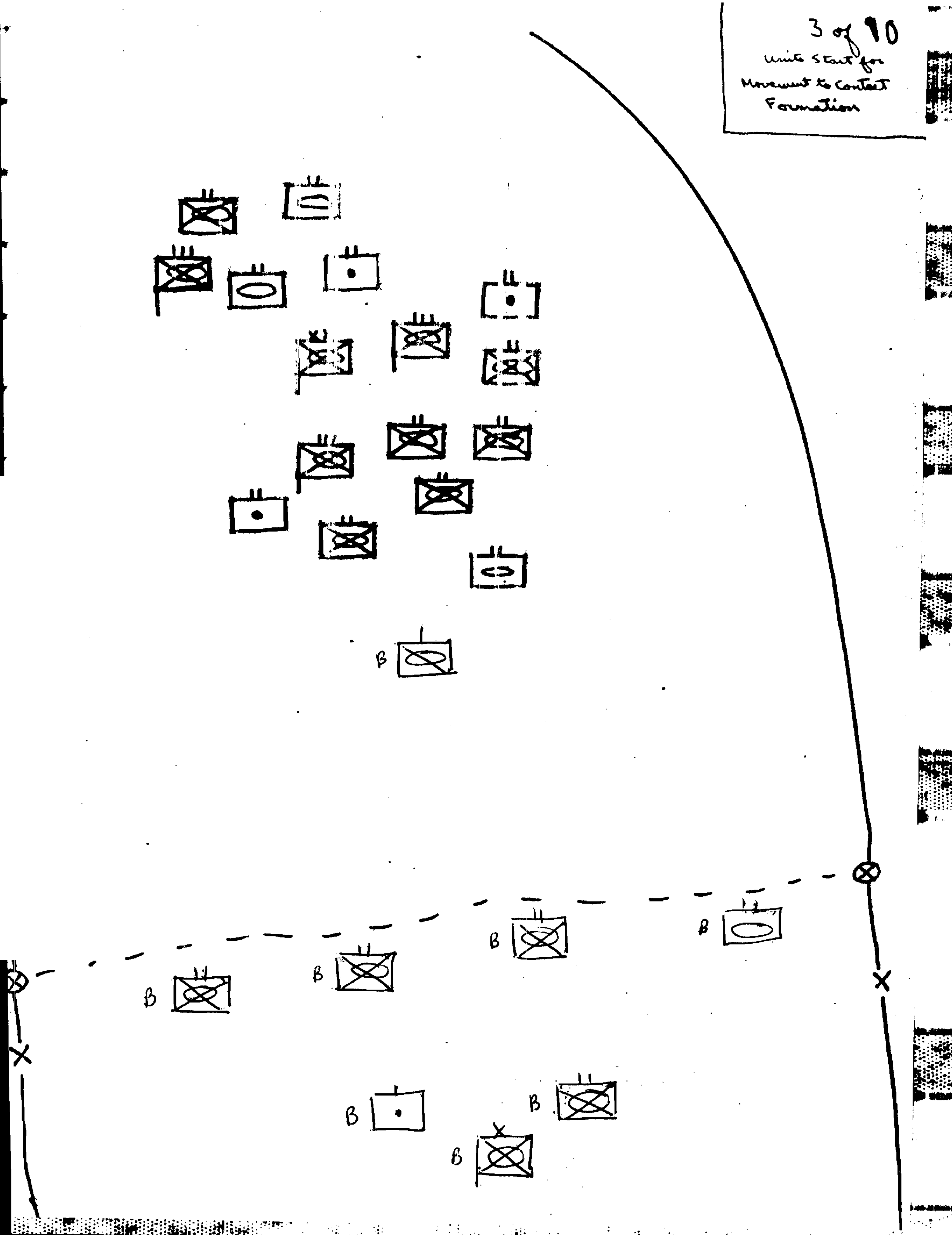
Arty Btry

Units arrive in area

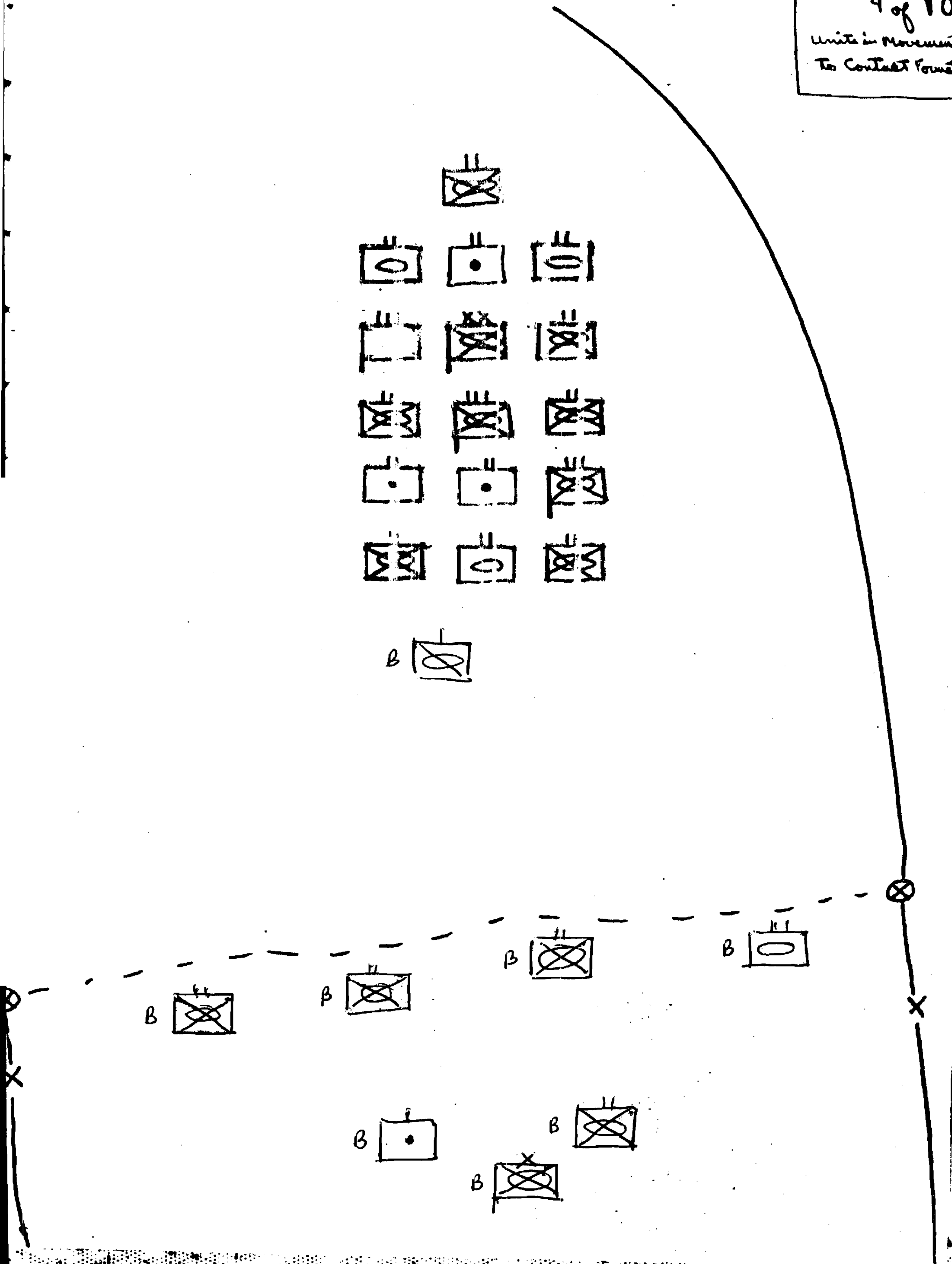


2 of 10
units set up
& coordinate

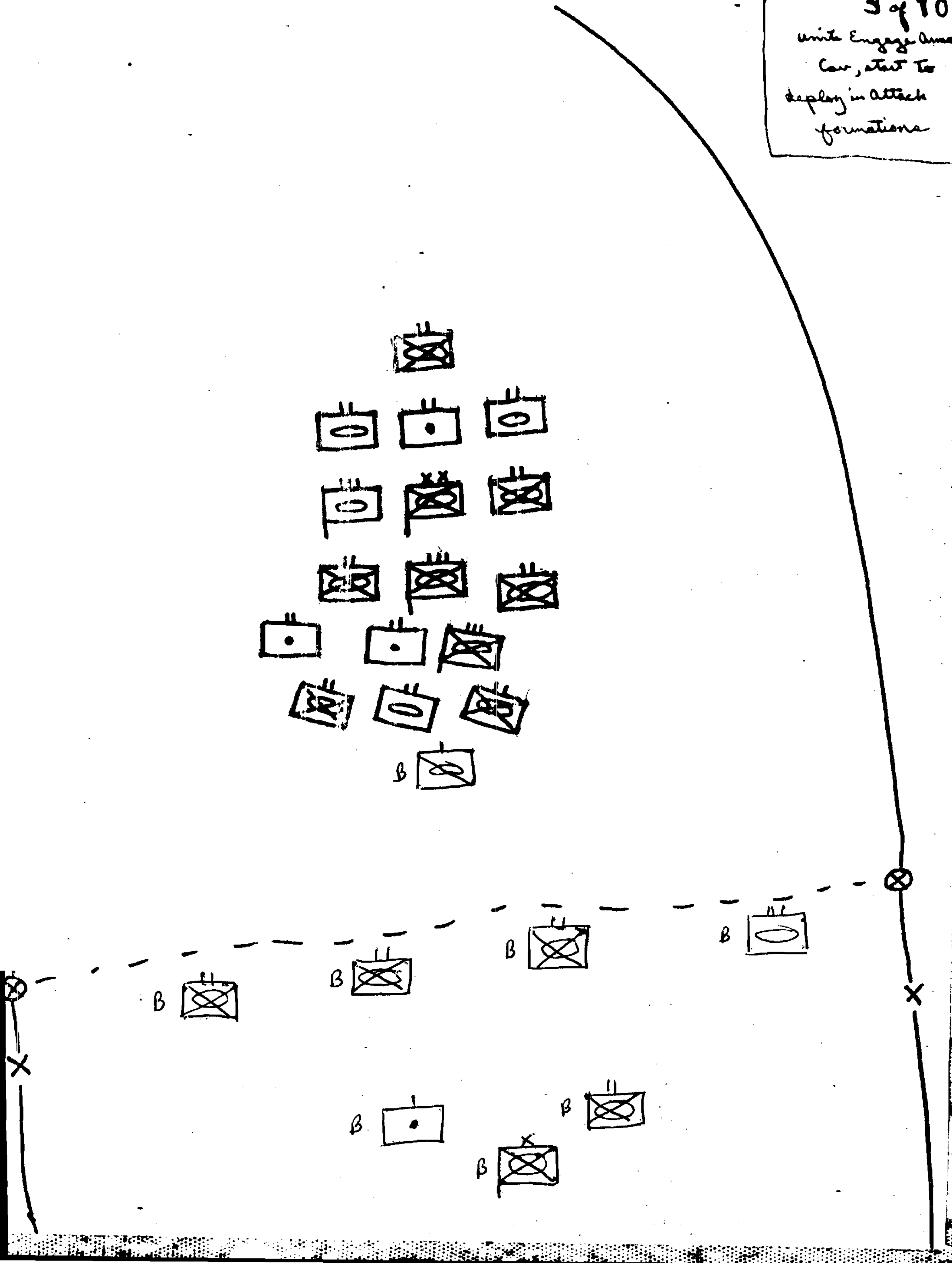



3 of 10
Units Start for
Movement to Contact
Formation

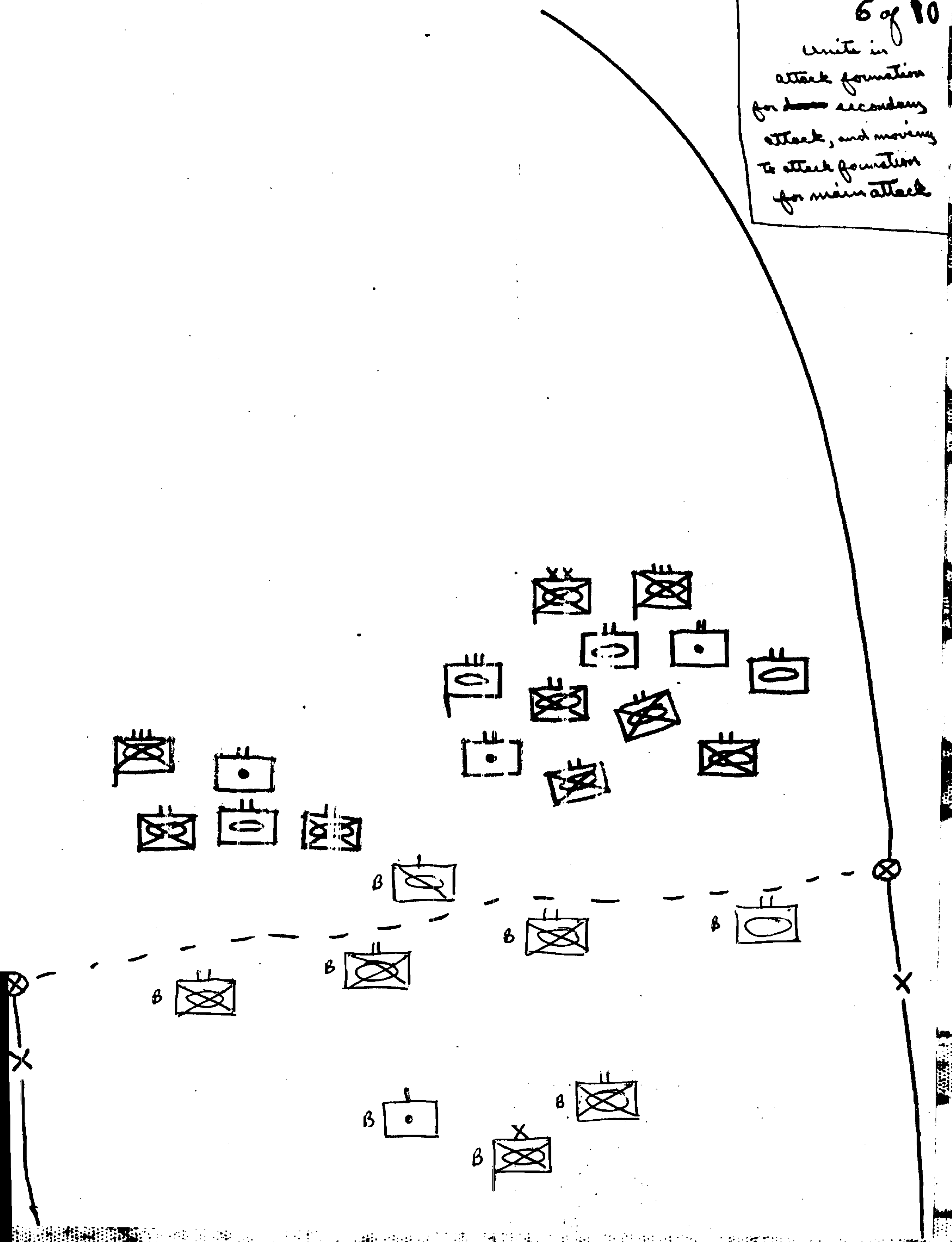
Units in Movement To Contact Formation



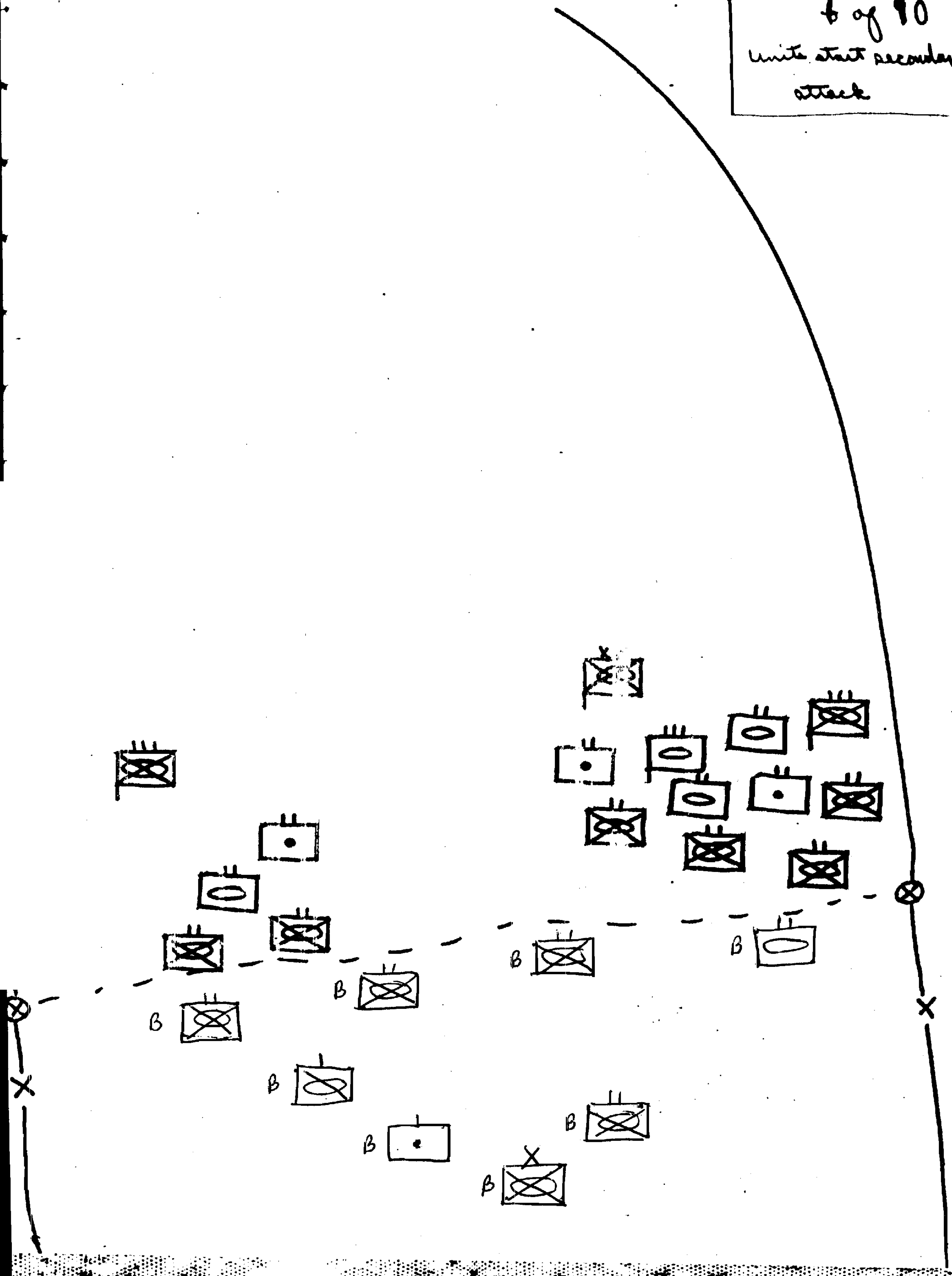
units Engage Armored Cav, start to deploy in attack formations



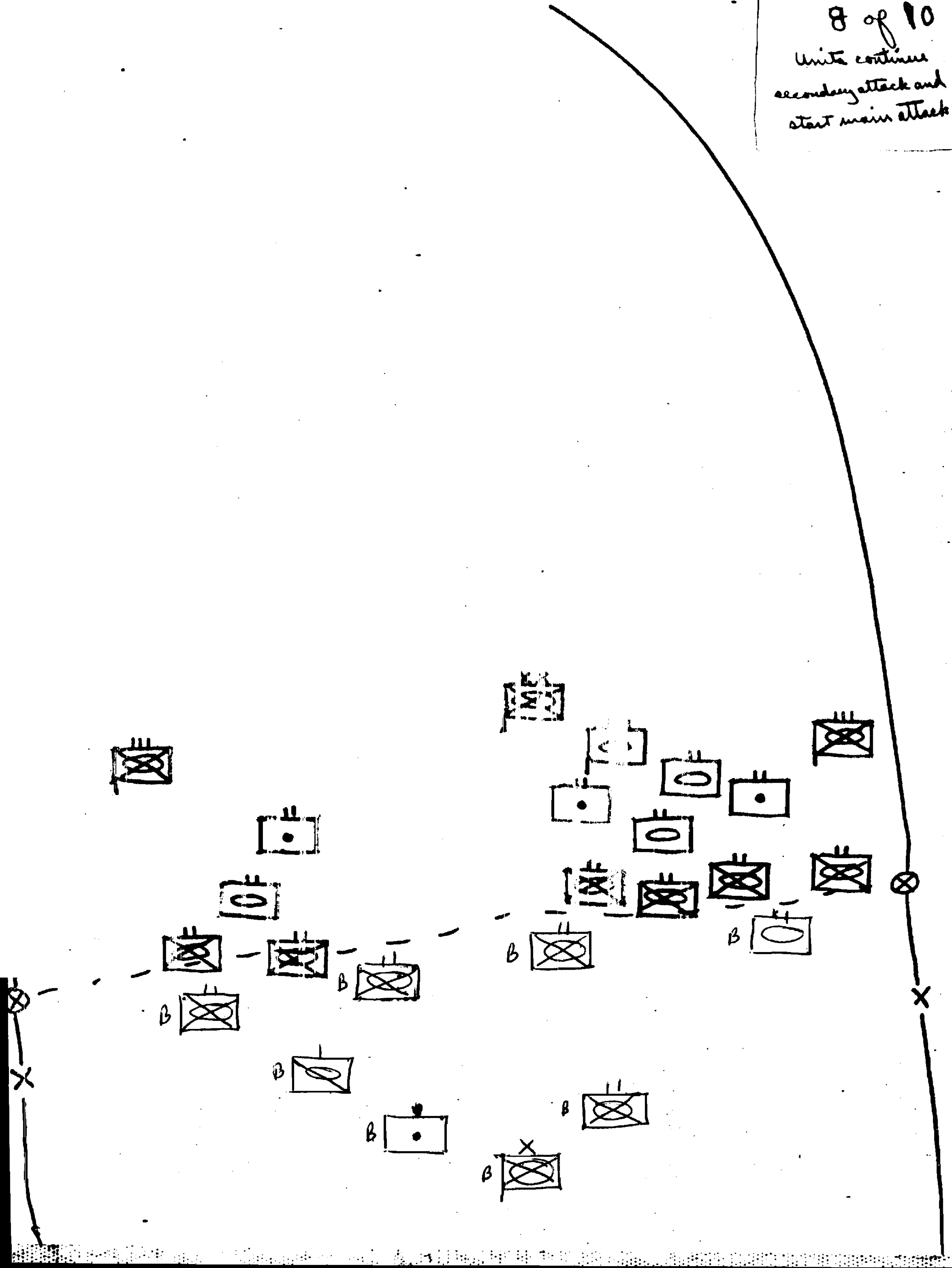
Units in attack formation for secondary attack, and moving to attack formation for main attack



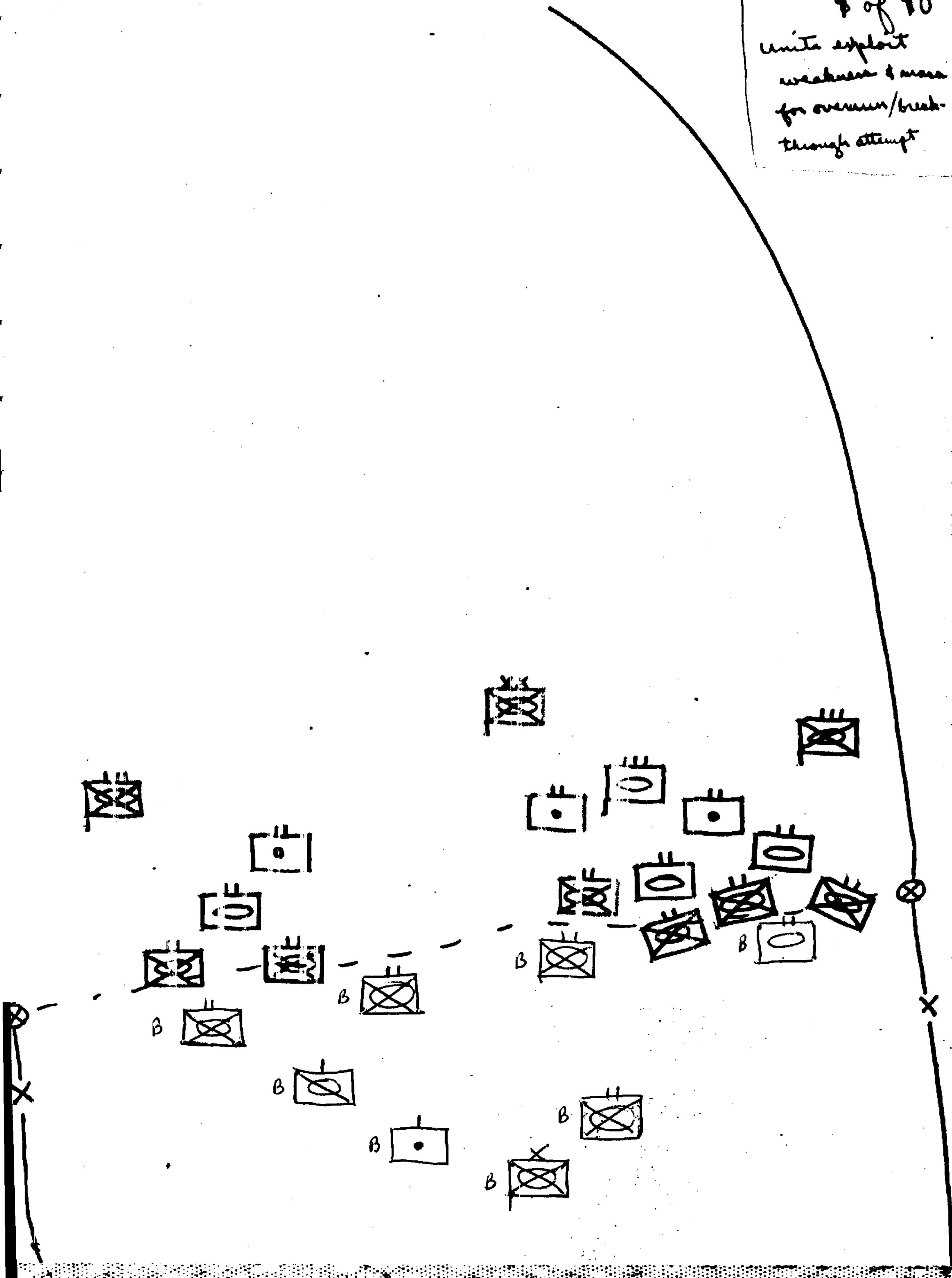
7 of 90
units start secondary attack



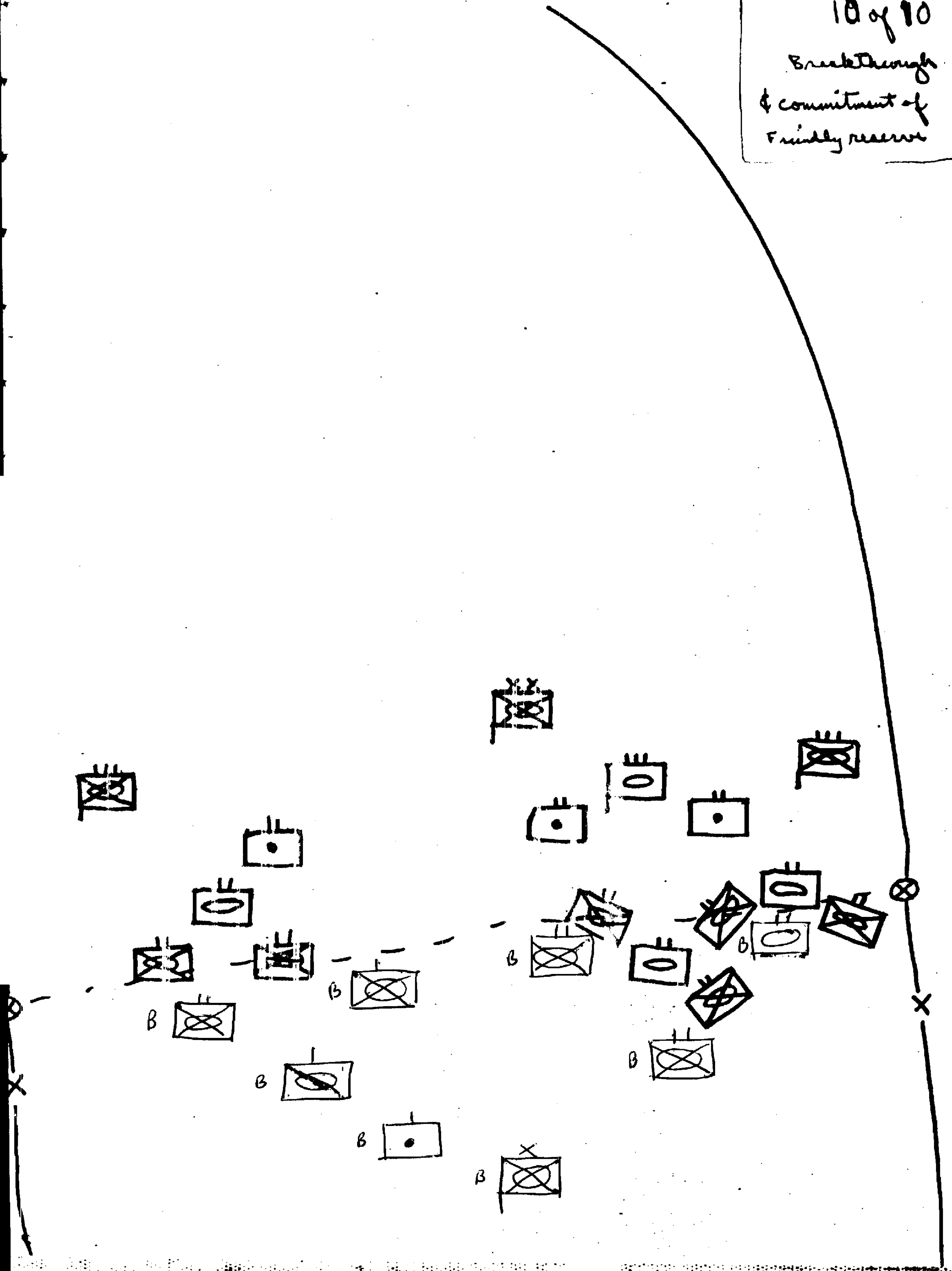
Units continue secondary attack and start main attack



units exploit weakness & mass for overrun/break-through attempt



Breakthrough & commitment of Friendly reserve



G-36-628

Representing and Displaying Information for Tactical Decision Processing

The Second Quarterly Progress Report

Albert N. Badre

For
The U.S. Army Research Institute
for the Behavioral and Social Sciences

November 1, 1978 to January 31, 1979

Grant No.: MDA 903-78-G-04

School of Information and Computer Science
Georgia Institute of Technology

February 10, 1979

The Second Quarterly Progress Report

on

Representing and Displaying Information
for Tactical Decision Processing

In the second quarterly phase of this project, the effort was concentrated on completing the experimental design, developing the material, and conducting the experiments.

Completion of the experimental design included preparing the material to be used in the experiments, finalizing the details of the procedure, and selecting the data gathering instruments. On the whole, the general design as described in the proposal and the first quarterly report remained intact with the following additions and modifications:

A. Thirty six volunteer military officers from Fort Benning, Georgia were selected to participate in the experiment.

B. The final design and procedure specifications for the first experiment to examine the effectiveness of varying the conditions of information display may be summarized as follows:

   1. Three structured scenarios, P_1, P_2, and P_3 were used, each in the four presentation modes described in the first quarterly report.

   2. The officers were randomly assigned to four groups of nine participants in each group.

3. Each participant was shown the three scenarios, whereby he saw each scenario in one of three of the four different modes of presentation.

4. Within each group the presentation of the scenarios was counterbalanced in order to average out possible order effects on performance. The following table shows how the presentation modes and the scenarios were distributed over the groups:

Scenarios \ Groups:	A	B	C	D
P_1	Meaningful chunks (M)	Non-meaningful chunks (N)	All-at-once (A)	Meaningful chunks-reverse (MR)
P_2	All-at-once	Meaningful chunks-reverse	Non-meaningful chunks	Meaningful chunks
P_3	Non-meaningful chunks	Meaningful chunks	Meaningful chunks-reverse	All-at-once

Scenarios were sequenced on a movie film in such a way that the three scenario presentations for a participant in a group could be processed in order by always skipping forward on the film, as in the example below:

A:

P_1	M
P_2	A
P_3	N
P_1	M
-	
-	

B:

P_1	N
P_2	MR
P_3	M
-	
-	

C. In the experiment to examine the effects of a line of battle actions on the chunking and representing of tactical information, the final design and procedure may be summarized as follows: 1) Thirty-five of the previous thirty-six officers participated. They were randomly assigned to five equal groups. 2) Each group was associated exclusively with one of five modes of presentation. The modes of presentation differed on the position where the scenario-to-be reconstructed, #6, occurred as shown below:

a) 6 7 8 9 10 (6 is first)

b) 4 5 6 7 8 (6 is middle)

c) 2 3 4 5 6 (6 is last)

d) 6 (alone)

e) 9 1 6 8 2 (6 is middle, out-of-sequence order).

3) Under each mode, the complete line of scenarios was presented on a rectangular cardboard at once and held in

view for forty-five seconds before being removed. Then the display was changed and a blank "map" was placed in the position where scenario #6 had occurred indicating that the participant should reconstruct #6.

D. After both experiments were finished, sixteen participants were asked to perform the copying experiment (as described in the proposal). Each participant copied only one of the four scenarios used in both experiments. Thus, each scenario was copied by four different participants. Another eighteen participants were asked to perform a "circling" procedure on the four scenarios. Here, the participants were given a copy of each of the scenarios and were asked to enclose within one circle the symbols that the participant felt belonged in one group. They were told to select their own criteria for grouping. All participants circled each of the four scenarios.

On January 29, 30, and 31, Dr. Badre and a student assistant, Timothy Cope, as well as Captain David Candler of the Army Research Institute, Alexandria, went to Fort Benning, Georgia, and with the aid and cooperation of the ARI field unit at Fort Benning, conducted the two experiments successfully.

In the third quarterly phase of this project, the plan is to complete data coding and entry and to develop the data files and supporting programs to be used in the computer analysis of the data.

The following personnel have participated in the second phase of this project:

Principal Investigator:	Albert N. Badre
Graduate Research Assistant:	Cheryl C. Allen
Clerk:	Catherine M. Beise
Student Assistant:	Timothy Cope
Laboratory Assistant	Arthur Maccabe

The expended as of January 31, 1979 are detailed below:

LIST OF PERSONNEL
AND TIME SPENT BY EACH
AS WELL AS FUNDS SPENT
AS OF FEBRUARY 1, 1979*

	Grant Funds		Matching Contribution	
Personal Services	% Effort	$	% Effort	%
Badre, A.N. Assistant Professor & Principal Investigator	21%	2,360	9%	1,040
Allen, Cheryl C. Graduate Research Assistant	27%	1,750		
Beise, Catherine M. Clerk	21%	1,422		
Cope, Timothy Student Assistant	27%	1,088		
Arthur Maccabe Laboratory Assistant	3%	198		
		6,818		
Retirement Benefits (9.83% of Applicable Salaries)		232		102
Materials and Supplies		260		
Travel		560		
Consultants		679		
Indirect Costs (76% of Personal Services)		5,182		790
Total Expenditures		$13,731		$1,932

*Based on the records of the School of Information and Computer Science, not the official records of the Georgia Institute of Technology.

G-36-628

Representing and Displaying Information for Tactical Decision Processing

The Third Quarterly Progress Report

Albert N. Badre

For

The U.S. Army Research Institute for the Behavioral and Social Sciences

February 1, 1979 to April 30, 1979

Grant No.: MDA 903-78-G-04

School of Information and Computer Science
Georgia Institute of Technology

May 10, 1979

The Third Quarterly Progress Report

on

Representing and Displaying Information
for Tactical Decision Processing

In the third quarterly phase of this project, the effort was concentrated on completing data coding and entry, developing the data files, writing and selecting some of the supporting computer programs used in data analysis, and running a preliminary analysis on the data.

The data from the two experiments and the copying task were coded and entered for analysis at three levels of detail: symbol, chunk, and scenario. The data file for the symbol level analysis was built first from the raw experimental data on order of symbol placement, time of symbol placement, and accuracy. This raw data file is then to be entered to a computer program which will "chunk" it according to various file outputs with chunks as the case unit. This program will also add the relational data to the raw symbol file. The average IPT for use in chunking the experimental data was computed from the copying task raw data (within glance inter-placement times) at 1.138 seconds. The times which fall within a glance in the copying task were averaged together to produce the IPT. (This was done with an option to the above computer program.) The symbol level raw data file was the input to another computer program which generated another file with the scenario as the case unit. The scenario file was used for ANOVA on the accuracy of recall levels with respect to various modes of presentation. The contents of each data file are described as follows:

(1) Appendix I describes the raw data gathered for each symbol in each scenario. To this data file, tactical relation descriptions will be added by a computer program that is now being developed. Also non-tactical formal relationships will be added, e.g., spatial proximity, common color, common type.

(2) The chunk data file will be generated by a program which reads the raw data file, computes the IPT, and from this computes a set of IPT chunks for each scenario. The program also will contain a table of tactical relations for each scenario. The program, when finished, will be able to do the following things:

   a) update the raw data file to include chunk membership for each symbol;

   b) create a new file, with the chunk as case unit; this file will contain for each chunk:

      (1) identifying information -

         Experiment #
         Group
         Scenario
         Mode of presentation
         Chunk # (in order of placement)

      (2) placement time for 1st piece in chunk

(3) # of pieces in chunk

(4) % accuracy of chunk

(5) relations between pieces in the chunk

(6) # of relations in a chunk.

A computer program has been written that generates accuracy data. The program reads raw data and computes the percent of accurate symbol placement for each scenario. The output of this program is a file with scenario as a case unit. The file contains the following for each scenario:

a) Identifying information -

Experiment #
Group
Scenario
Mode of presentation

b) % accuracy for each scenario.

A preliminary accuracy analysis based on about fifty percent of the collected data has been completed. Initial results suggest that the order in which chunks are presented as well as the structural content of chunks have an effect on assimilation accuracy. Also, the presence of invariances in the presented information seems to have an effect on both chunking strategies and assimilation accuracy.

In the fourth quarterly phase of this project, the plan is to finish the analysis of the data and complete the final report.

The following personnel have participated in the third phase of this project:

Principal Investigator	Albert N. Badre
Graduate Research Assistant	Cheryl C. Allen
Student Assistant	Timothy Cope
Student/Clerical Assistant	Lynn Daley

The expended as of April 30, 1979 are detailed below:

LIST OF PERSONNEL
AND TIME SPENT BY EACH
AS WELL AS FUNDS SPENT
AS OF MAY 1, 1979*

Personal Services	Grant Funds % Effort	Grant Funds $	Matching Contribution % Effort	Matching Contribution $
Badre, A. N. Assistant Professor & Principal Investigator	17%	3,027	10%	1,664
Allen, Cheryl C. Graduate Research Assistant	32%	3,400		
Beise, Catherine M. Clerk	14%	1,422		
Cope, Timothy Student Assistant	24%	1,477		
Daley, Lynn Student/Clerical Assistant	2%	131		
Maccabe, Arthur Laboratory Assistant	2%	198		
		9,655		1,664
Retirement Benefits (9.83% of Applicable Salaries)		298		164
Materials and Supplies		532		
Travel		814		
Consultants		679		
Indirect Costs (76% of Personal Services)		7,338		1,264
Total Expenditures		19,316		3,092

* Based on the records of the School of Information and Computer Science, not the official records of the Georgia Institute of Technology.

APPENDIX I

Battlefield Scenarios — Raw Data File

	Data Item	Card Column	Form
1.	Subject # (01, ...28...)	1-2	I2
2.	Experiment # (1,2,3,4)	3	I1
3.	Scenario # {Exp.1 → 1,2,3; Exp.2 → 4}	4	I1
4.	Mode of presentation {Exp. 1 → M,A,N,R; Exp. 2 → F,M,E,S,R}	5	A1
5.	Data acquisition comments	7-8	I2
6.	Order of symbol placement (01...34)	10-11	I2
7.	Between glance indicator (0,1)	13	I1
8.	Placement ipt (# cycles (hex)) (0000...FFFF)	15-18	A4
9.	Symbol id# (99-no match) (01,...24,99)	20-21	I2
10.	Symbol color (1=Red, 2=Blue)	25	I1
11.	Color accuracy (0=no, 1=yes)	27	I1
12.	Symbol value (0,1,2,3,3-5,4,6,7,8,9-5)	29-30	I2
13.	Symbol value accuracy (0,1)	32	I1
14.	Subject placed symbol location ({A,B,C,D},{1→8,F,X})	35-36	2A1
15.	Static location accuracy (0,1)	38	I1
16.	Relative location accuracy (0,1)	40	I1
17.	Overall accuracy using 10,12,14 (0,1)	45	I1
18.	Overall accuracy using 10,12,15 (0,1)	47	I1
19.	Overall accuracy using 16,17 (0,1)	50	I1

Representing and Displaying Information for Tactical Decision Processing

FINAL REPORT

Albert N. Badre

For

The U.S. Army Research Institute
for the Behavioral and Social Sciences

August 14, 1978 to September 30, 1979

Grant No.: MDA 903-78-G-04

School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia

September 30, 1979

The research described in this report was completed with the assistance of Ms. Cheryl Allen, Ms. Lynn Daily, and Mr. Timothy Cope.

TABLE OF CONTENTS

Representing and Displaying Information for

Tactical Decision Processing

Albert N. Badre
Georgia Institute of Technology

1. Introduction

It is well recognized that the effective management of tactical information is one of the major problems faced in command decision making. A commander has to gather, represent, process, assimilate, and use large amounts of information, often in situations of rapidly changing tactical scenarios, in relatively short time periods. One proposed way to cope with the information management problem has been through the design and use of command and control decision-aiding systems such as the Army's Tactical Operations System.

There is a growing consensus that such on-line decision-aiding and information management systems become increasingly useful when they are designed to be front-end user-compatible (Palme, 1975; Miller and Thomas, 1977; Miller, 1977; Badre, 1979). Because computer decision systems are "information processing" ones, they are likely to be more user-compatible if they are designed to adapt to the information processing capabilities and limitations of the user. For example, it is well recognized that in general a computer system can augment the user's limitations effectively for tasks that require large amounts of time to perform manually, or that are dependent for success on either rapid processing times or exhaustive search capabilities. On the other hand, tasks that require heuristic search strategies are likely to be performed more successfully by humans than by machines.

For tactical decision situations, one of the main tasks required in designing user-compatible on-line systems is the specification of criteria for the development of algorithms that search for, classify, and order the display of chunks of tactical information such that they are meaningful to the decision-maker. The identification of meaningful chunks and the order in which they are to be displayed for rapid processing and assimilation in decision making requires the implementation of well conceived experimental data collection techniques. In the previously funded research project by the Army Research Institute* the focus had been on designing experiments that permitted us to locate and determine various characteristics of the informational chunks that novices and experts formulate when viewing and analyzing static map positions of tactical situations. It was clear from the data

*"Selecting and Representing Information Structures for Battlefield Decision Systems," U.S. Army Research Institute for the Behavioral and Social Sciences (Grant #DAHC 19-77-C-0022, 1977-78).

analysis that meaningful chunks of information are identifiable for coherent (structured) battlefield map positions. In addition, for coherent positions, the size of the chunks as well as the frequency with which meaningful chunks are formulated were significantly greater than the size and frequency for noncoherent positions. It was also clear from the initial data analysis that the average chunk is composed of a number of relations between unit designator symbols. Chunked relations tended to occur associatively with high frequency over subjects. Given the above results, the aim of this study was to investigate the effects of the sequential displaying of chunks on the assimilation of tactical information as well as the effects of presenting dynamic tactical situations with invariant features on the characteristics of chunking.

2. Rationale and Context of Research

In the previously funded project by the Army Research Institute (Badre, 1979), the underlying thesis, borrowed from and supported by previously completed research on tactical games (Badre, 1979; Frey and Adesman, 1976; Chase and Simon, 1973), is that the expert analyzes and processes the viewed battlefield positions in terms of well formed structures (chunks), and that these structures provide the basis for selecting and valuating the foregrounds of play or action. The information to which the problem solver (e.g., the battlefield commander) attends on a given position constitutes the foreground of that position. The well formed structures are the tools and elementary vocabulary, possibly non-verbal, used in foreground perception and synthesis. Furthermore, when the constraint of sequential processing applies, as it may in the viewing and analysis of on-line displays, the expert problem solver is likely to process his information in an incremental predetermined order of meaningful chunks.

The implication of the chunking conjecture for the design of on-line decision systems is that in order to make such systems user-compatible, the informational characteristics and order in which information is to be displayed would have to conform to the rules of chunking identified in the user's practices and behaviors. But in order to relate the chunking conjecture more realistically to battle situations, we must consider the effects of dynamic tactical scenarios on chunking. It seems reasonable to assume that in dynamic battle situations (i.e., situations where for example active defense tactics are employed and where possibly every six kilometers of enemy advance require a new battlefield scenario), the underlying representation for selecting a set of structures and their associated foregrounds is not governed solely by or limited to the unique scenario under analysis. Rather, it stems as well from the given position's relations to the sequence of battle positions that were its immediate predecessors as well as those that are immediately anticipated by it.

Accordingly, in addition to testing the sequential-presentation-of-chunks conjecture, it is worthwhile to begin investigating the effects of a line of play or battle action on the expert's representation as it may be manifested in the characteristics of his chunks and perceived foregrounds. Several key questions need to be explored regarding representations arising from the considerations of lines of actions and positions in contrast to considerations of single positions. For example, what in practice is an appropriate algorithmic representation for a line of actions? How does the battlefield commander construct his algorithm as a basis for executing an action? What are the atomic action components of such algorithms; i.e., what constitutes an action? For example, in a tactical game, are the actions a set of valued moves or a set of valued associations between structures, configurations, states, or foregrounds? Is a line of associated foregrounds itself a well formed foreground or is it simply a set of discrete positions that are sequentially related by a search or move algorithm? Do the chunking characteristics of a position change as a function of its placement in a sequence? These are some of the short and long range questions about chunking and representation of battlefield scenarios that would need to be investigated for designing effective tactical decision-aiding systems.

3. Objectives

The general theme of this study is that the expert represents, stores, and retrieves tactical information in meaningful chunks, and that the informational characteristics of those chunks vary as a function of the length of the battle segment to which the commander is exposed. Accordingly, the goal of this study was to investigate experimentally the following conjectures:

a) For effective on-line display techniques, if tactical information from a battlefield map is presented sequentially and incrementally by meaningful chunks, it will result in higher assimilation and recall than if it is presented in a sequence of non-meaningful chunks;

b) Likewise, sequentially presented meaningful chunks will result in higher recall than simultaneously presented chunks;

c) Chunking characteristics will differ if a battlefield scenario is presented out of context under one condition and then presented as a member of a sequence of scenarios under another condition;

d) Given a coherent sequence of battlefield scenarios, one where the scenarios fall logically and realistically in the order presented, both accuracy of recall and chunking characteristics will not differ significantly as a function of the ordinal of placement of the criterion scenario (the one to be reconstructed) in the sequence;

e) Given a random non-coherent sequence of battlefield scenarios, chunking characteristics and accuracy of recall will differ significantly as a function of the criterion scenario's position in the sequence suggesting recency of presentation and memory differential effects.

4. Research Methodology

In order to examine the above stated conjectures, two experiments were designed and conducted. The general procedure was to utilize battlefield scenarios to be reconstructed and copied under varying conditions of presentation and viewing by a select group of battlefield commanders (to be referred to as participants). In the simplest form of the reconstruction task, the participant is first shown a battlefield scenario. He is permitted to study the scenario for a prespecified amount of time after which it is removed and he is asked to reconstruct it. As the participant is reconstructing the scenario symbols, the experimenter makes certain time and symbol placement order recordings. In the copying task the participant is given the same battlefield scenario as in the reconstruction task and is asked to copy it on a blank diagram as rapidly and as accurately as possible. The same type of data is recorded here as in the reconstruction task. The data is used jointly from both tasks to determine accuracy of recall and chunk boundaries. The intent is to use those techniques in order to analyze the effects of varying the presentation of information in the battlefield scenario on both accuracy of recall and chunking characteristics. Accordingly two experiments were conducted along the lines described below.

4.1 Experiment I. The finding of ongoing and previously reported research (Badre, 1979; Chase and Simon, 1973; Frey and Adesman, 1976) that in problem solving situations displayed information is encoded and represented by the expert in meaningful chunks leads to the suggestion that on-line displayed tactical information should be developed for the user in discrete meaningful chunks. Accordingly the conjecture to be examined here is that if tactical information is presented to the battlefield commander incrementally and sequentially by meaningful chunks, it is likely to lead to greater information assimilation (measured by recall accuracy) than if the same information is presented either by a sequence of non-meaningful chunks or all at once. Also, it is conjectured here that the order of presentation of meaningful chunks will have a significant effect on assimilation performance.

4.1.1 Subjects. Thirty-six volunteer military officers from Fort Benning, Georgia were selected on the basis of experience to participate in the experiment.

4.1.2 Material. The material for this experiment consisted of the three structured battlefield scenarios (see Appendix I) used in earlier research (Badre, 1979). The symbols of each scenario were grouped into two sets of chunks. One set consisted of meaningful chunks and the other of non-coherent chunks whose constituent symbols are not likely to be related in meaningful patterns. The degree of meaningfulness (coherence) of a chunk for a given scenario and the order in which it was presented are based on the previously collected data (Badre, 1979). The scenarios were developed and presented on film.

4.1.3 Design and Procedure. Comparisons were made among four basic display conditions. These are: (1) the one-shot display of the scenario; (2) the development of the scenario incrementally by chunks in an order that is already established by last year's results; (3) the development of the scenario by chunks in the reverse of the already established order; and, (4) the development of the scenario incrementally by the addition of non-meaningful chunks.

Three structured scenarios, P_1, P_2, and P_3 were used, each in the four presentation modes described above. The officers were randomly assigned to four groups of nine participants in each group. Each participant was shown the three scenarios, whereby he saw each scenario in one of three of the four different modes of presentation. The presentation of scenarios was counter balanced within each group to average out possible order effects on performance. Table 1 shows how the presentation modes and the

Table 1. Summary of Scenarios x Groups x Modes of Presentations

Scenarios \ Groups	A	B	C	D
P_1	Meaningful chunks (M)	Non-Meaningful chunks (N)	All-at-once (A)	Meaningful chunks-reverse (MR)
P_2	All-at-once	Meaningful chunks-reverse	Non-meaningful chunks	Meaningful chunks
P_3	Non-meaningful chunks	Meaningful chunks	Meaningful chunks-reverse	All-at-once

scenarios were distributed over the groups. Scenarios were sequenced on a movie film in such a way that the three scenario presentations for a participant in a group could be processed in order by always skipping forward on the film, as in the following example:

A	P_1	M
	P_2	A
	P_3	N
	P_1	M
	–	
	–	
B	P_1	N
	P_2	MR
	P_3	M
	–	
	–	

Each participant was told that this is an experiment in information processing. He was told that an experimental run would consist of three trials. In each trial a battlefield scenario would be displayed briefly on film. The scenario may be shown all at once in one exposure or may be developed incrementally in a sequence of several film frames, each frame lasting between two and three seconds. After eighteen seconds of viewing time, the scenario was removed and the participant was asked to reconstruct it on a sheet of paper that has on it the outline of a battlefield background. For reconstructing the scenario, the participant used rubber stamps with the proper symbols. A pre-test slide was used for practice. The reconstruction task was followed immediately by the copying task. Here the participant was asked to copy the symbols on each slide as accurately and as rapidly as possible.

4.2 Experiment II. The overriding theme motivating this experiment is that in real battle analysis, the underlying representation as manifested in chunking and foregrounding behaviors resides not in the single position under analysis, but in a time sequence of related battlefield scenarios. In order to examine the three previously-stated conjectures that are related to this theme (see the section on objectives), an experiment was designed where the criterion scenario to be reconstructed was presented under different conditions of sequencing.

4.2.1 Subjects. Thirty-five of the previous thirty-six officers participated in this experiment. They were randomly assigned to five groups of equal size.

4.2.2 Material. The material for this experiment consisted of a sequence of nine distinct scenarios that follow each other in a realistic order of battle action (see Appendix II). The sequence represented nine distinct battlefield positions where movement over time gave rise to new battlefield scenarios. The scenarios were presented to the participant in ordered sequences of five scenarios at a time.

4.2.3 Design and Procedure. The thirty-five participants were randomly assigned to five equal groups and underwent the same procedure for the reconstruction and copying tasks as in Experiment I. Each group was associated exclusively with one of five modes of presentation. The modes of presentation differed on the position where the scenario-to-be-reconstructed, #6 (see Appendix II), occurred as shown below:

a) 6 7 8 9 10 (f is first

b) 4 5 6 7 8 (6 is middle)

c) 2 3 4 5 6 (6 is last)

d) 6 (alone)

e) 9 1 6 8 2 (6 in middle, out-of-sequence order).

Under each mode, the complete line of scenarios was presented on a rectangular cardboard at once and held in view for forty-five seconds before being removed. Then immediately the display was changed and a blank "map" was placed in the position where scenario #6 had occurred indicating that the participant should reconstruct #6.

After both experiments were finished, sixteen participants were asked to perform the copying experiment (as described in the proposal). Each participant copied only one of the four scenarios used in both experiments. Thus, each scenario was copied by four different participants. Another eighteen participants were asked to perform a "circling" procedure on the four scenarios. Here, the participants were given a copy of each of the scenarios and were asked to enclose within one circle the symbols that the participant felt belonged in one group. They were told to select their own criteria for grouping. All eighteen participants circled each of the four scenarios.

5. Results and Discussion

5.1 Data Collection and Analysis. For both of the experiments the data collection was the same. There are essentially two kinds of data collected for both the reconstruction and copying tasks. These are symbol placement times and order of symbol placements. In the first case, one of two experimenters records the times of the placement of symbols via a cassette tape recorder. This procedure goes on until the participant discontinues to place the symbols. This same experimenter also keeps time for the five-seconds presentation in the reconstruction task. For the copying task, in addition to recording the symbol placement times, the experimenter records the times for the beginning and end of a glance to the diagram from which the participant is copying. The second type of data collected is the order in which the symbols are placed on the blank diagram. This data is collected by the second experimenter who stands behind the participant and records the ordinals by using a blank diagram and writing the ordinal number in the location corresponding to that used by the participant to write the symbol.

There are four fundamental measurements that may be associated with the data described above. These are: (a) the number of accurately placed symbols; a symbol is placed accurately if both its value and location are correct; (b) the order of placement of accurately placed symbols; (c) the inter-placement times (IPT); and (d) the within-glance symbol identification and time counts for the copying task.

Several assumptions are made. First, in the copying task, it is assumed that successive glances to the diagram from which symbols are being copied, the stimulus diagrams, define the boundary of chunks. That is, the symbols that are placed on the response diagram between two glances to the stimulus diagram are referred to as the within-glance symbols and considered to constitute a chunk. Second, the average IPT is computed for the within-glance symbols of each subject and used to define the chunk boundaries in the reconstruction task. Symbols placed at or below the computed IPT will be assumed to belong to the same chunk; those falling above the computed IPT will be considered to come from two different chunks, hence defining a chunk-boundary in the reconstruction task. Finally, the content characteristics of chunks in the reconstruction task is compared with those in the copying task. Chunk comparison, for both groups of subjects, is made on data characteristics such as the size of a chunk, IPT distributions, within chunk symbol relations and patterns, and order of chunk placements on diagrams. The order of placement is an indication of the importance of the chunk.

The data from the two experiments and the copying task were coded and entered for analysis at three levels of detail: symbol, chunk, and scenario. The data file for the symbol level analysis was built first from the raw experimental data on order of symbol placement, time of symbol placement, and accuracy. This raw data file was then entered to a computer program which "organizes" it according to various file outputs with chunks as the case unit. This program also adds the relational data to the raw symbol file. The average IPT for use in chunking the experimental data was computed from the copying task raw data (within glance inter-placement times) at 1.138 seconds. The times which fall within a glance in the copying task were averaged together to produce the IPT. (This was done with an option to the above computer program.) The symbol level raw data file was the input to another computer program which generated another file with the scenario as the case unit. The scenario file was used for statistical test on the accuracy of recall levels with respect to various modes of presentation. The contents of each data file are described as follows:

(1) Appendix III describes the raw data gathered for each symbol in each scenario. To this data file, tactical relation descriptions were added by a computer program. Also non-tactical formal relationships were added, e.g.,

spatial proximity, common color, common type.

(2) The chunk data file was generated by a program which reads the raw data file, computes the IPT, and from this computes a set of IPT chunks for each scenario. The program also contains a table of tactical relations for each scenario. The program performs the following functions:

a) update the raw data file to include chunk membership for each symbol;

b) create a new file, with the chunk as case unit; this file contains for each chunk:

(1) identifying information -

Experiment #
Group
Scenario
Mode of presentation
Chunk # (in order of placement)

(2) placement time for 1st piece in chunk

(3) # of pieces in chunk

(4) % accuracy of chunk

(5) relations between pieces in the chunk

(6) # of relations in a chunk.

A computer program has been written that generates accuracy data. The program reads raw data and computes the percent of accurate symbol placement for each scenario. The output of this program is a file with scenario as a case unit.

The file contains the following for each scenario:

a) identifying information -

Experiment #
Group
Scenario
Mode of presentation

b) % accuracy for each scenario.

5.2 Presenting Chunked Information and the Accuracy of Recall. The overall percent accuracy for comparing the various modes of presenting chunked information is shown in Table 2. An analysis of variance yields a significant main effect for modes of presentation with $f(3, 92) = 8.317$, $p < .01$. It is clear

Table 2. The Overall % Accuracy and Standard Deviations for the Four Modes of Presentation.

Code	Value Label	%	Standard Deviation
1	Meaningful chunks	41.32	.1958
2	All-at-once	50.33	.1812
3	Non-meaningful chunks	31.44	.1453
4	Reverse chunks	29.33	.1331

from inspecting the means that presenting information sequentially and incrementally by meaningful chunks results in higher assimilation than if the same information is presented in a sequence of non-meaningful chunks. A t-test comparing the two means yields significance at $t(44) = 1.93$, $p < .06$. Also the means show that the meaningful mode is significantly superior to the mode where the meaningful chunks are presented in the reverse order of reconstruction at $t(47) = 2.52$, $p < .05$. A t-test yielded non-significant difference between the mode where the chunks were presented all at once and that where they were presented incrementally in meaningful chunks, at $p > 0.1$.

Those results suggest that not only is it important to present information in meaningful structures, but in the case where the information cannot be presented all at once, the effectiveness of information assimilation increases when the meaningful structures are presented in a proper sequence. It also may be noted that the presentation of non-meaningful chunks resulted in higher accuracies than the presentation of meaningful chunks in the reverse-reconstruction order. This can be explained by looking at the similarities of identically available symbols at successive incremental labels between the meaningful, reverse, and non-meaningful presentations. Table 3 makes it clear that the non-meaningful and meaningful modes have many more symbols

Table 3. Mean Number of Symbols That are Available Over the Three Scenarios For Each Increment of Chunks

Increments	A	B
1	.33	0
2	1	0
3	2	0
4	5.33	0
5	9.67	3
6	11.33	8
7	15.67	14.33
8	21.33	20
9	24	24

A = Common symbols for non-meaningful and meaningful.
C = Common symbols for meaningful and reverse.

in common (9.67 for the three scenarios) after five increments than do the meaningful and reverse (3 for the 3 scenarios). Hence, the scenarios of the non-meaningful mode contain highly meaningful structures for a longer period of time than do the scenarios of the reverse mode. The availability of highly meaningful structures for longer viewing and assimilation durations may have lead to higher accuracy performance for the non-meaningful conditions than for the reverse one.

5.3 The Effects of Sequential Context on Chunking Characteristics and Accuracy of Recall. In order to determine the effects of sequential context on accuracy of recall as well as on certain key characteristics of the reconstructed chunks, several comparisons between contextual modes were analyzed.

Accuracy. The extent to which the association between scenarios is well or loosely structured may be inferred by comparing the conditions where the scenario-to-be-reconstructed is placed at either the start, the middle, or the end of a sequence of scenarios. The assumption is that if there is a significant difference on accuracy between the three conditions, then a memory differential and interference effect may exist. If on the other hand, there is no significant difference between the three conditions, then it may be suggested that the viewer is processing the salient feature, the foreground, of the entire sequence and not simply the foreground of individual scenarios. Table 4 shows an analysis of variance for the three conditions. The analysis yields a non-significant F, hence supporting the suggestion that the viewer is foregrounding the entire sequence of scenarios.

A t-test comparison on accuracy of reconstruction between a non-coherent sequence and a coherent one yielded non-significance with $t(11) = 1.42$, $p > .1$. It is important to note that both

Table 4. Analysis of Variance for the Effect of the Criterion Scenario Sequential Position by Accuracy of Reconstructed Symbols

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	.0037	(2)	.0018
Within Groups	.3203	(16)	.0200
Total	.3240	(18)	
F = .0918	SIG. = .9128	ETA SQRD = .0113	

sequences contained the same invariant symbols, symbols that do not undergo change from one scenario to the next. The reconstructed symbols were constituted mostly of those that were invariant. This result suggests that the invariant features of an information display may be central to the process of assimilating and foregrounding. It may also be true that the availability of invariances may have an effect on how information is chunked.

Chunk Characteristics. In order to determine the effects of providing invariances in sequential context on various chunking characteristics, a comparative analysis was made between the condition where the criterion scenario is presented alone, and the condition where it is presented in the context of a coherent sequence of scenarios. The coherent sequence of scenarios contains several invariant symbols.

It should first be noted that the reconstructed scenarios were segmented into chunks using the interplacement time measure (Badre, 1979). Table 5 shows that the average number of chunks per scenario for all modes of presentation was 7.46. An analysis

Table 5. Analysis of Variance for Mean Number of Chunks Per Scenario by Presentation Context of Criterion Scenario

Context of Criterion Scenarios	Sum	Mean	Std Dev.	Sum of Square
First of 5	38.0000	7.6000	1.8166	13.2000
Middle of 5	49.0000	7.0000	2.4495	36.0000
Last of 5	45.0000	6.4286	3.4087	69.7143
Middle of 5 (unstructured sequence)	42.0000	7.0000	2.1909	24.0000
Single (alone)	65.0000	9.2857	3.1472	59.4286
Total	239.0000	7.4688	2.7590	235.9688

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	33.6259	(4)	8.4065
Within Groups	202.3429	(27)	7.4942
Total	235.9688	(31)	

F = 1.1217   SIG. = .3669   ETA SQRD. = .1425 of variance yielded a non-significant F. This finding replicates earlier results (Badre, 1979), that the IPT measure yields a $> \pm 2$ chunks per scenario.

In order to determine whether sequential context has an effect on the size of a chunk, a comparative analysis was made for the five modes of presentation. Two different units of chunk content were used to determine size: symbols and tactical relations between symbols. An analysis of variance for the means in Table 6 yielded non-significance among the five modes with respect to the number of symbols per chunk, with $F(4,26) = 1.802$,

Table 6. Means and Standard Deviations of the Number of Symbols per Chunk for the Five Modes of Contextual Presentations

Contextual Position of Criterion Scenario	Mean	Std. Dev.
First of 5	2.2000	1.4405
Middle of 5	2.0000	.7071
Last of 5	2.9286	.9759
Middle of 5 (unstructured sequence)	2.8000	.8367
Single (alone)	1.8571	.5563

$p > .1$. This result is consistent with the no-difference results over modes for accuracy of reconstruction and number of chunks per scenario. A similar analysis for number of relations per chunk yielded a non-significant $F(4,26) = .6905$, $p > 1$. The average number of relations per chunk is 1.64.

An indirect way of determining the effects of an invariance in a sequence of scenarios on assimilation effectiveness is to examine the order in which symbols are reconstructed. Earlier research showed that when a subject reconstructs a scenario, when the scenario is presented out of context, he invariably places a significantly greater number of red symbols in the first two reconstructed chunks. A likely hypothesis is that an invariance provides a basis for foregrounding displayed information and thus is a focal point of information assimilation. Hence, if given a group of invariant symbols all of which are blue, it is highly probable that the participant would begin by reconstructing more blue symbols than red ones in the first two reconstructed chunks. In comparing the color of reconstructed symbols for the first two chunks, between the sequential context mode and the mode where the criterion scenario was presented alone, it was clear that the availability of an invariance made a significant difference. For the mode with no invariance, the percent of red symbols in the first reconstructed chunk is 78%; for the first two reconstructed chunks, it is 43%. This result replicates earlier findings. For the presentation mode where an invariance is provided, the percent of red symbols in the first two chunks is zero. The difference between the two modes for the mean number of red symbols over the first two reconstructed chunks is significant at $t(12) = 2.12$, $p < .05$. This finding is a clear indication that the availability of invariances in information displays may have an effect on chunk content and the way information is perceived and organized.

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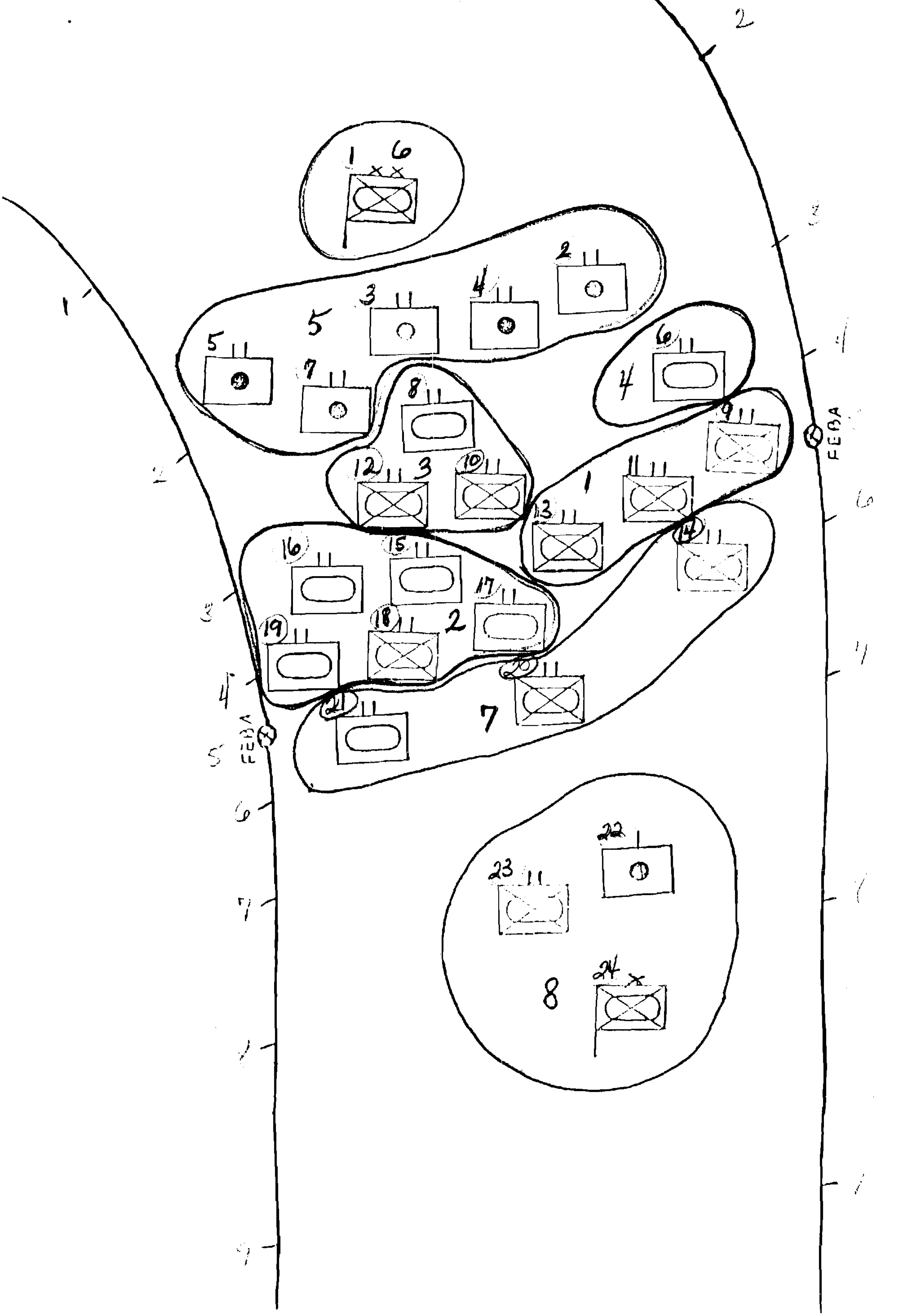
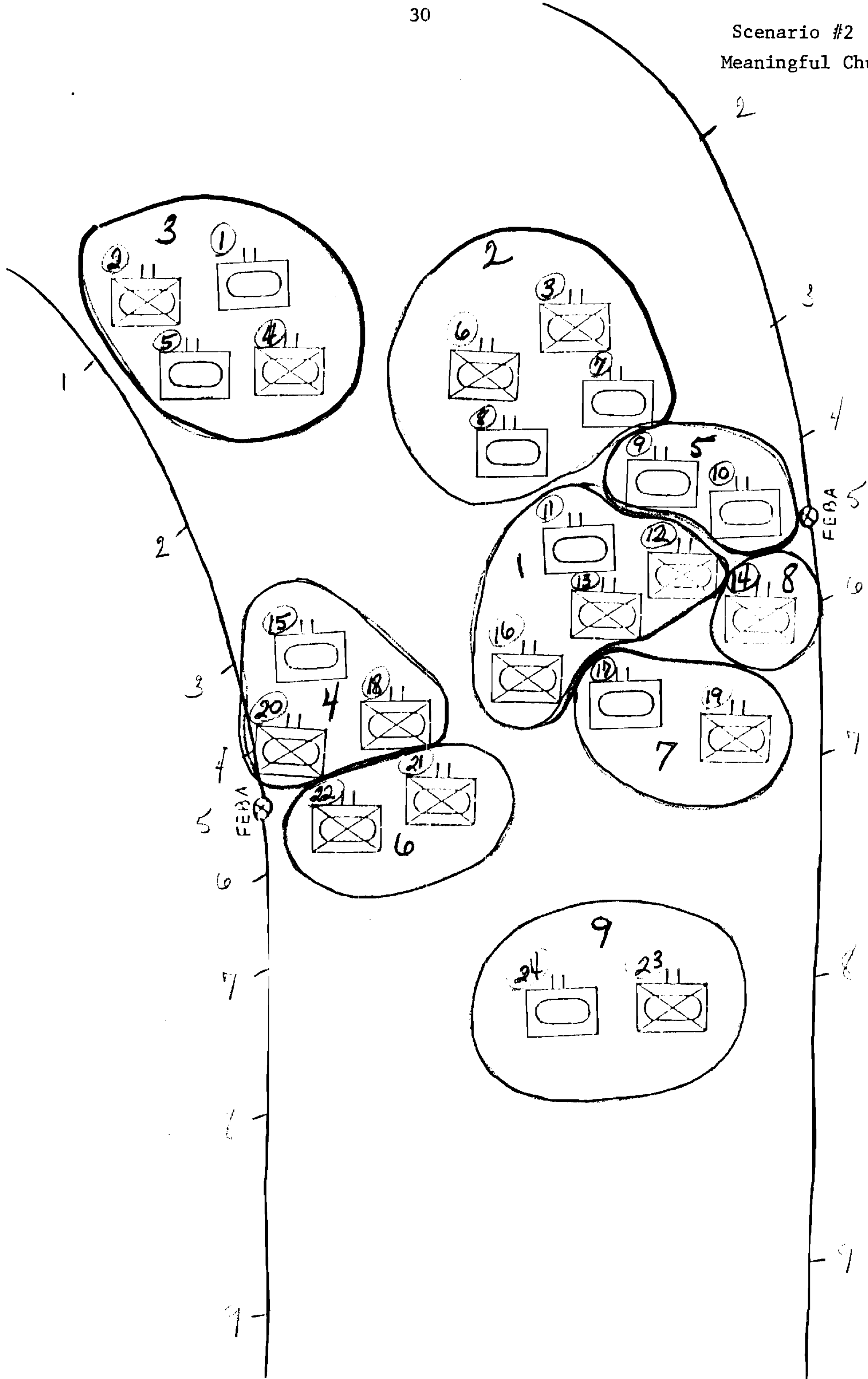
APPENDIX I

Scenario #1
Meaningful Chunks



Scenario #2
Meaningful Chunks



Scenario #3
Meaningful Chunks