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This document is a manual to assist military and operations research analysts in the use of the COMMEL (communications-electronics) II Model and in the preparation of the input data base for the model. This manual was prepared by Evaluation Technologies, Incorporated (ETI) under contract to the US Army Concepts Analysis Agency (CAA) to document the COMMEL II Model, as improved by ETI; a CAA updating of the manual, where required, based on experience gained while using the model in early 1976 has been included in this edition of the—

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document. The COMMEL II Model was an element of the CAA study "Communications Operational Effectiveness Methodology." This study was an element of the Operational Effectiveness of Communications methodology development program sponsored by the Deputy Chief of Staff for Operations and Plans (DCSOPS). The COMMEL Model is a fully computerized combat simulation which includes dynamic interface between tactical operations and communications systems. The model output provides statistics on both communications system performance and combat outcome. The COMMEL Model simulates division-level combat with resolution to company level. Tactical and communications activities are represented by four interrelated submodels which periodically transmit event statistics to output files. The model is basically deterministic although message routing factors may be varied through use of a random number generator.

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VOLUME I - MODEL OVERVIEW

October 1976

Prepared by

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for

US Army Concepts Analysis Agency
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CHAPTER I
INTRODUCTION

1. Purpose and Background

a. This document contains the information required to enable non-ADP oriented military analysts and operations research analysts to utilize the COMMEL Model and to develop and formulate the required data to activate the model. It **does** not contain an indepth description of the theory used to develop the model or a description of the programing techniques contained in the model.

b. The descriptions and definitions contained herein concern the model as it exists and do not address any possible revisions that may be under consideration.

c. The basic text of this document was prepared by Evaluation Technologies Incorporated (ETI) in January 1976 under contract to the US Army Concepts Analysis Agency (CAA). The Concepts Analysis Agency has updated the text, where required, based on experience gained while using the model in early 1976.

2. Model Description

a. General

(1) The COMMEL Model, described in this manual, is a research tool for use by scientists, engineers, systems designers, and operations research personnel in the study analysis, organization, development, and implementation of future communications-electronics (C-E) concepts and systems for Army combat organizations (division level and below).

(2) The primary function of the model is to provide the user with a dynamic, ground combat environment in which the effect on division level combat of a proposed C-E concept can be observed in detail. The model can be used to explore the fundamental characteristics and qualities of combat communications phenomena in a variety of conditions.

(3) The model is a fully computerized, dynamic, two-sided, free-running model that depicts ground combat between two forces to division in size. The model is a tool that:

(a) Permits detailed observation of communications events in a combat environment, and

(b) Provides a means of measuring in terms of combat outcomes the merit of competing communications systems concepts.

(4) The model augments the usual war gaming methods available to the communications system designer by providing:

(a) Precise computation of effects of combat phenomena,

(b) Reports of actions that may be printed out in exhaustive detail, or be held directly available in computer language for statistical analysis by computer techniques,

(c) Consideration of combat details not usually played,

(d) An easy expansion capability to accommodate inclusion of models that are too complex for manual processing but are desired for study in detail, and

(e) The ability to repeat games that have small change parameters.

(5) The following tactical functions are played in detail for each of as many as 257 units into which the two combat forces can be organized.

(a) Close combat fires including attrition, splitting of fires from armor, infantry, and mechanized elements, and coordination between adjacent elements.

(b) Artillery fires including target selection and allocation of fires from both direct and general support batteries,

(c) Movement of front line units toward objectives with rear line units adjusting positions appropriately,

(d) Maneuver:

    <u>1</u>. Offense to include advance to contact, penetration, exploitation, and reconnaissance in force,

    <u>2</u>. Defense to include delaying action and withdrawal,

    <u>3</u>. Commitment and withdrawal of companies, commitment of reserve battalions and brigades, and allocation of artillery and other support from reserves,

    <u>4</u>. Selection of lines of departure, route, and objective, and

    <u>5</u>. Movement and deployment of General Outpost (GOPs), special units, rear echelon elements, and reserves.

(e) Communications of all types:

    <u>1</u>. Specific, tactically essential messages whose individual delivery affects the course of combat,

    <u>2</u>. General tactical and logistical messages whose aggregate performance is applied eventually as a coefficient of effectiveness to fires of front line units,

    <u>3</u>. Complete representation of the operational capabilities of any type communications system in a combat environment, (e.g., it suffers attrition, moves, can be jammed).

(f) Combat surveillance, target acquisition, and

(g) Route selection as a function of terrain and intelligence.

(6) The model consists of a large collection of small computer subroutines each of which represents some specific combat phenomenon and uses and operates independently on a common store of data. Hence any of

the data items may be changed by the analyst at will before a simulation run.

(7) The model is free-running. It proceeds from the start of an action to some designated conclusion without intervention. Since it is designed as a test environment for the analysis of communications systems performance, many elements of tactics such as the options available to the command/control decision programs are limited and are not sufficient for more sophisticated or advanced tactical studies. However, the basic programs that compute fire, attrition, movement rates, artillery damage, suppression and targeting, acquisition and dissemination of intelligence, and which control communications are considerably more sophisticated than the equivalent conventional activities. Furthermore, they operate at computer speed.

(8) The COMMEL model cannot be used to:

(a) Compare tactics

(b) Compare weapons systems

(c) Measure logistic requirements

(d) Compare logistic policies

(e) Provide absolute values or measures of effectiveness of a given C-E system.

b. Model Construction

(1) COMMEL consists of three submodels operating on a large set of data. The first of the submodels consists of a set of detailed mathematical and logical programs which simulate the course of a ground battle between two opposing forces, on a minute by minute basis. Factors represented include: movement, fire and attrition of front line, reserve, rear echelon and artillery units, acquisition and dissemination of intelligence, command decisions at each of three echelons (battalion, brigade and division), and the generation of explicit demands to transfer information.

(2) The second submodel, Communication Status Checks, (COMCHK), consists of another set of programs which periodically determine the current state of the communications system as a function of range, movement, attrition, reliability, or other factors as may be necessary to examine in detail.

(3) The third submodel, Traffic Processor, (TRAFIC), processes the demands for information transfer, which appear as "messages", through the communications system as it exists at the moment. It also determines length, encoding time, message center queues, interference, and switching time.

(4) The model is designed to portray the commitment of reserves, coordination of fires, selection of targets, effects of artillery, and movement of units as determined by the delivery of the associated messages. Thus a "good" communications system will permit the transfer of information at such a rate that the degradation of combat effectiveness due to the communications system will be negligible, while a "poor" system will impose delays on critical messages so that a significant reduction will occur in the ability of the force to fight.

(5) Currently the model does not contain a means of simulating air traffic control, air defense, tactical air, air mobile and other air operations. Also, no provision is made for explicit play of special (nuclear) weapons, CBR warfare, amphibious operations, guerrilla or counter-guerrilla, and other specialized military activities.

c. Model Operation

(1) The model provides a means to observe in detail the performance of military communications systems in dynamic combat environments, and a means to measure the relative contribution to combat of competing communications systems in terms of combat outcomes.

(2) To achieve the foregoing objectives, the model operates as two distinct elements:

(a) The tactical simulator generates the communications requirements for control of the tactical

action as a direct function of tactical situations, and responds to the performance of the communications system under test directly in terms of completion or failure of specific communications events.

1. The tactical element of the model can be thought of as loading the system under evaluation with realistic message communications demands, measuring the success of the tactical force in response to the performance of the communications system. The tactical simulator performs five fundamental functions. It moves combat elements on the battlefield in a realistic fashion. The simulator causes the personnel and materiel components of these elements to be damaged or destroyed by combat and non-combat factors. It generates requirements to transfer information in terms of the functions of the units and the state of the battle. The simulator responds to the success or failure of the communications system to satisfy the requirements for information transfer by assigning to each such "message" a specific tactical event or capability. It provides a measure of total communications system capability in terms of combat outcomes by providing detailed information on the strength, location, status, posture, and activity of every combat element every minute of combat time throughout the course of the battle. These data can be compared for different runs of the same battle, and from differences observed, judgments can be made about communications effectivenss of the system under test. In addition, a detailed listing of every communications event that occurs throughout the battle is available for analysis.

(b) The communications simulation processes demands for information transfer in terms of the specified capabilities and organization of the communications system under test. In other words, concurrent with the tactical simulation, the communications model simulates the flow of the messages generated by the tactical model and returns to the tactical model these messages and their content, where delivery is indicated. This tactical model in subsequent simulation acts on this information, and thus reflects the impact of the performance of the C-E system on the tactical operation. The communications portion of the model accepts the demands for

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information transfer, which appear as a large number of individual entries on a "message list," and then simulates the delivery of the message through the system described as a collection of "arcs" connecting communicating "nodes." The arcs may be unusable due to busy studies, wire outage, out-of-range, interference, lack of special messengers, etc., and the nodes may be incapable of handling the messages due to equipment failure, damage by enemy fire, long queues, nonavailability of encrypting equipment, (displacing), etc. When the message is delivered in time, it is assigned to the message in the list. Finally, when that time is reached by the clock keeping track of combat time, the action which is dependent on the delivery of the message is permitted to take place.

(3) During the play of a tactical simulation, the model outputs data that can be used to determine tactical progress, success or failure to gain objectives, casualties, equipment attrition, and combat time. In addition to tactical data output, data on the performance of the communications system are generated in the model output.

3. Simulation Procedures

a. Normal use of the simulation involves the following sequence of events:

(1) The problem area is established as one in which combat dynamics are an integral part of the measurement or evaluation process.

(2) A simulation is designed in the form of a combat action that will produce the events from which a judgment can be made.

(3) A scenario is written in the form of a battle between forces of suitable size and complexity (usually division level). Described in detail in the form of "input data" are the terrain of the battle area, the organization of the forces on each side, their deployment, strengths, rates of movement, objectives, lines of departure, the ranges, effectiveness and vulnerabilities of weapons, and the decision parameters.

(4) The communications system or concept under study is defined in terms of another set of "input data."

(5) The length (in simulated time) of the battle is determined.

(6) The model together with the "input data" is put into the computer, which then runs without intervention either to the termination of the battle or to some intermediate stopping point.

(7) At the end of the run, the detailed reports of the combat action and all associated communications events are examined, analyzed, and evaluated. Depending on the design of the experiment, the battle may be continued, restarted with a different set of initial conditions or system specifications, or the outputs subjected to more detailed or sophisticated statistical analysis.

b. These are the requirements used in the evaluation process of the communications system:

(1) All the pertinent attributes must be accurately representable in terms of combat. These attributes are commonly listed as mobility, flexibility, reliability, vulnerability, security, maintainability, and cost.

(2) The system must be usable in a large variety of combat missions and environments.

(3) The observations taken must be reducible to a common set of measurements.

(4) It must be possible to study trade-offs with other components of combat, such as weapons or vehicles.

(5) The method must be relatively inexpensive per application.

4. COMMEL Terminology

a. Unit. - A unit is any collection of men, material, functions, or equipment that for purposes of the study can be considered to be located at a single

point on the map during the battle, and which move as a single point. Communications equipment must be assigned to a unit, in which case the unit is also called a node. The Blue and Red forces are each divided into units, each of which is given an initial location, and assigned by function to a Pattern. An infantry battalion might be divided into 8 units: a Battalion Command Post, a Battalion Tactical Command Post, three rifle companies, and mortar, reconnaissance and engineer platoons.

b.   Pattern. - A pattern is a collection of units that ordinarily move together and maintain the same spatial relationships during the action. While in reserve, the units of the infantry battalion listed above might be assigned to one pattern. The movement of units in a pattern is determined by the movement of the pattern's assigned leader, which may be another pattern or a group. A pattern may move continuously, or by bounds. No more than 10 units can be in one pattern.

c.   Group. - A group is a collection of one or more front line units (usually an armor or infantry company) that move more or less together along a route, at a rate determined by the terrain, the suppression, and the enemy force. After commitment of a battalion, one or more of its companies become front line units and transfer from the pattern to form a group. Thereafter, these units move as a group along the route, and the remaining units in the pattern then follow the group. Front line units move in groups, whereas rear units move in patterns. No more than four units can be in one group.

d.   Route. - A series of straight lines connecting two points representing the line of departure and the objective, through the centers of grid squares which constitute the most desirable terrain for movement. Routes are selected automatically for groups at the beginning of the game, or when committed.

e.   Objective. - A piece of terrain, a unit, or an offset from the line of departure of a unit, defined in the scenario and selected to generate reasonable maneuver. All collections of forces which are in

groups will have objectives. These may be final positions in retrograde or defensive actions. (See Figure I-1)

f. Mode. - Groups are assigned modes initially or in the course of the game which determine how they will move. Uncommitted forces (those in patterns) are in the Reserve mode. Units in Attack mode move forward toward the objective as rapidly as possible consistent with terrain, mobility, and the intensity of enemy fire. Units in Yield mode move rearward as slowly as possible consistent with the same factors. Units in Hold mode do not move. Units in Withdraw mode move rearward at a rate consistent with terrain. Units in Leapfrog mode alternate between Hold and Withdraw modes. When all the units of a group have reached the end of the assigned route, the group simultaneously enters the Hold mode. Units in patterns moving to a new location, a line of departure, or to a blocking position, move in a straight line from the previous positions without reference to terrain. (See Table I-1)

g. Status Report. - A status report is a periodic message from a unit to its headquarters describing its current condition and location and any additional information needed by the commander to make decisions. Status report frequency from front line units (units in groups) depends on the amount of attrition, distance moved, and a specified time interval. Other status reports are sent at specified intervals unless fighting is heavy, in which case reports are sent as soon as the last one is received.

h. Coordination Message

(1) The effect of fire of adjacent front line units decreases along with the coordination level as time elapses after the completion of the last coordination message between the two units. Messages are sent between units in a group, not between groups.

(2) When a sufficient decrease in coordination level has occurred, a message is originated. When the message is completed, the effect of fire is set back to a maximum.

i. Arcs. - An arc is a connection between a pair of units by which messages can be transmitted. Characteristics of arcs are defined via input in data block ARCLOG (Chapter V). The various arcs can be divided into three broad classes according to means of transmission: radio arcs, wire arcs, and messenger arcs. Radio arcs may be further subtyped according to the following characteristics: voice/wirtten, FM/VHF/SSB/RATT, sole user/common user, telephone/teletype (applicable to wire arcs). A messenger arc is

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RELATIONSHIP OF PATTERN, GROUP, OBJECTIVE AND ROUTE

--- ENCLOSES THE UNITS (DENOTED BY ⊙) OF PATTERN 1.
THESE ARE THE COMBAT AND SUPPORT UNITS OF BN 1/1.

—— ENCLOSES THE UNITS OF GROUP 1.
THESE ARE THE LINE COMBAT UNITS OF BN 1/1.

⊠ DENOTES THE GROUP CENTER, INITIALLY ON THE LINE OF DEPARTURE.

ⓧ DENOTES OBJECTIVE OF GROUP 1.

⟶ DENOTES THE ROUTE OF GROUP 1.
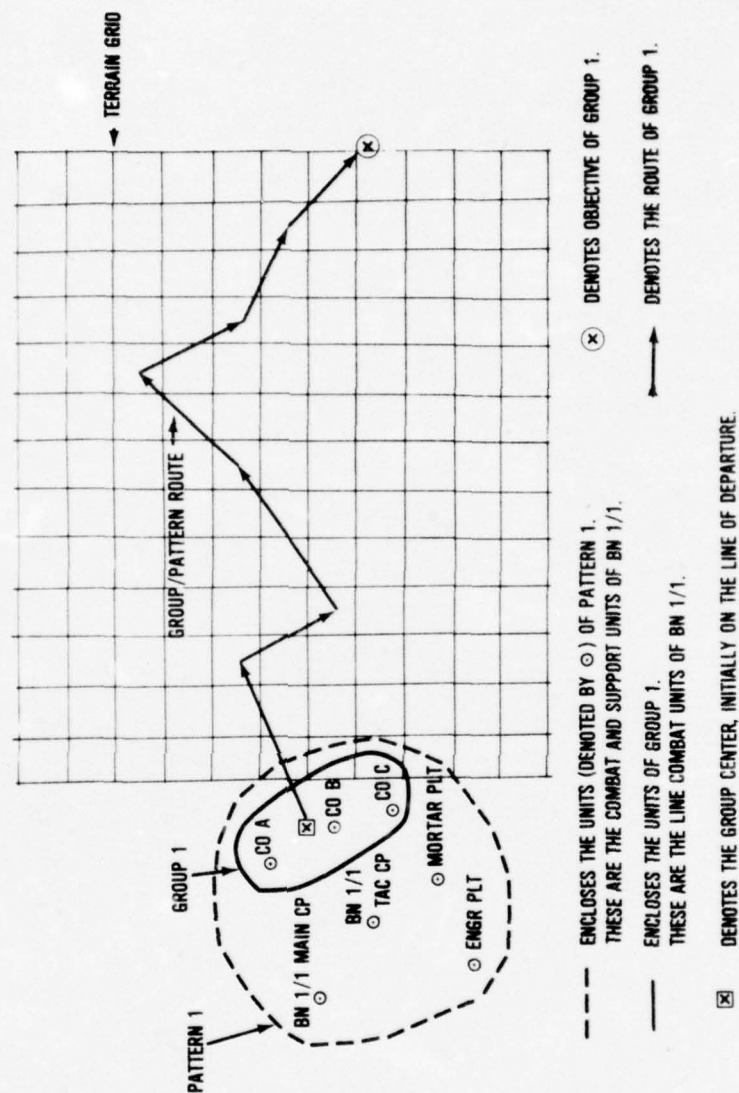
FIGURE I-1

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TABLE I-1, Group Move Modes

Group Mode	Response if Force Against is	
	High	Low
Reserve	No effect until bn is committed and changes mode.	No effect until bn is committed and changes mode.
Attack	Advance slows, may stop.	Advance progresses at high rate in proportion to force ratio.
Yield	Retrograde movement at high rate in proportion to force ratio.	Hold position and resist, or retrograde at low speed in proportion to force ratio.
Hold	Hold position (objective) and resist.	Hold position (objective) and resist.
Withdraw*	Retrograde movement at maximum speed.	Retrograde movement at maximum speed.
Leapfrog	Alternate hold/withdraw. Withdrawal more frequent.	Alternate hold/withdraw. Hold more frequent.

*Withdraw rate of movement is not dependent on force ratio.

a route between two units over which a messenger travels at specified and regular intervals.

j. Independent of the above transmission classes are the categories of simple arc and compound arc, applicable to all links. A simple arc represents a direct user-to-user route between two units. A compound arc connects two units, but transmissions between them are patched through one or more intermediary units (and implied equipments).

CHAPTER II
THE TACTICAL SIMULATION

SECTION 1
INTRODUCTION

1. Organization of the Discussion of the Tactical
Simulation

a. This chapter describes the tactical portion of
the simulation in terms of the various combat
phenomena. In general, it describes the functions of
combat in military terminology, and describes the
method by which the functions are simulated.

b. The simulation is designed to be used as an
experimental tool. Ordinarily the study will focus
upon the performance of a specified communications
system in a particular tactical environment, from which
the tactical inputs are determined.

2. Topics Covered by the Following Sections

a. Section 2 describes the method by which the
battlefield itself is defined. Once an area has been
selected, it is divided into "grid squares" and each
square is assigned four indices. From this data the
computer calculates two values, (1) the Terrain Index
which is used for route selection, and (2) the Terrain
Class which combines mobility, field of fire, cover and
concealment, and obstacles in a different way such that
move rates, and surveillance factors are stored to be
used by various tactical modules.

b. Section 3 discusses route selection. Since
combat implies movement of one or both forces toward
objectives or final positions, the scenario will
specify the expected flow of battle in terms of routes
between lines of departure and objectives. Some
routes, those of the initially committed forces, are
specified as inputs. Others, those of committable
reserves, are specified by their end points
(objectives) absolute or relative.

c.   Section 4 specifies the method by which the
actual forces engaged in the battle are located. These
are given explicit map locations in terms of a suitable
deployment relative to the initial lines of contact and
mission of the force as described in the scenario. The
objectives for Blue and the defensive posture for Red
(or vice versa, if desired) are established and
depicted on the map. The components are described in
terms of units, each representing some collection of
men, materiel, or functions which can be considered as
located at a single point for communication purposes.

        (1) In preparing the deployment, it is useful
to sketch in on the map the division, brigade,
battalion, and support command areas and then construct
the inventory of units, a list of the forces, unit by
unit, which will be given explicit unit indices and
locations. The units themselves are then located
suitably on the map, and the x, y coordinates read off
from the map and placed on the appropriate data sheets.

        (2) Finally, the units are collected into
patterns and groups (See Section 6) in preparation for
completion of input documents, and the sequence of
events is noted for use by the command decision
routines.

    d.   Section 5 discusses the method by which the
units themselves are defined for tactical purposes,
namely as a collection of weapons, by type and
quantity. The capabilities, ranges, firepower,
mobility, and vulnerability of the weapons are also
described with various miscellaneous constants
associated with close combat fire power. Artillery is
discussed in Section 11.

    e.   Section 6 describes the methods by which
movement of front line units and units in patterns are
simulated, and provides guidance for the proper
selection of the parameters and flags which are
required.

    f.   Section 7 develops the rules by which
attrition is computed, and describes how the basic

movement rate parameter, and the Force-Ratio (FR) are developed.

g.   Section 8 discusses the methods by which the model determines which units are in contact (that is, close enough to the enemy to have an opportunity to bring fire to bear), describes the selection of parameters, and provides limits used by the contact routines.

h.   Section 9 discusses the acquisition, interpretation, and dissemination of intelligence by front line and long-range surveillance units.

i.   Section 10 describes the basic module representing front line, close combat fires.

j.   Section 11 discusses the four artillery modules.

k.   Section 12 covers the modules which make the tactical decisions at battalion, brigade, and division headquarters, and the general outpost units.

l.   Finally, Section 13 describes the message generation procedure, including both tactical and sub-tactical (STM) (not tactically essential) messages, gathering together in one section information and descriptions which appear throughout the model.

SECTION 2
TERRAIN, ROUTES, AND OBJECTIVES

1. General

    a.   This section presents the process of laying
out the terrain to be simulated and of evaluating the
terrain features in such a way that they can be put
into the program. Also discussed are the ways in which
the terrain data are utilized internal to the computer
itself.

    b.   Some considerations, which are important when
studying map problems, are input into the computer only
by implication. Boundaries and objectives fall into
such a category. No specific data on these items is
supplied to the machine. However, the terminal point
of the route and the path itself that the attacker
takes can be determined only in the light of this
information. Hence, although only the terminal point
of a route is input, considerations about the
boundaries and objectives that lead to the
establishment of the terminal point are also discussed
in this chapter.

2. Terrain

    a.   General. - In combat, terrain affects
mobility, maneuver, fire, attrition, logistics, and
communications, and contributes to, or detracts from,
other combat factors. Hence, it is necessary that the
computer be informed of the basic terrain features of
the simulated battleground. This task is accomplished
by dividing the battlefield into an array of grid
squares and by providing several indices for each grid
square which describe the basic terrain features within
the square. In the evaluation of the terrain we
isolate those terrain characteristics that affect the
tactical action, such as contour and nature of the
ground, observation and field of fire, cover and
concealment, and obstacles. Of the original four
indices which are constructed, only two need to be
input into the simulation (see paragraph 2c, below).
The model uses these two indices to construct two

further indices which respond internal to the computer.
These internal indices describe the terrain
characteristics in a manner that enables the computer
to simulate properly the terrain effects on route
selection, movement, fire, attrition, surveillance, and
eventually, on communications.

b. Initial Preparation of the Terrain Map. - A
standard military map (1/50,000) is suitable for
terrain analysis. Indicate on the map the zone of
action by blocking out the simulation area. In this
area indicate unit boundaries, line of departure, objectives,
and the attacker and defender rear boundaries.

(1) At this time the simulation area is
divided into a regular array of grid squares.
Minimizing the number of grid squares reduces the
computer storage and running time. However, the grid
squares should be small enough that each square
contains terrain of essentially one type. A 1,000
meter x 1,000 meter military map grid square generally is
considered adequate.

(2) Consideration must be given to the fact
that all movement rates are defined in terms of grid
squares. For example, a movement rate of "5 grid
squares/hour" implies that the unit moves in one hour a
distance equivalent to five times the width of one grid
square.

(3) At this point, mark out clearly on the
military map in the area between the line of departure
and the line of objectives those terrain features that
are considered terrain obstacles for the type of force
under simulation. For example, when simulating a force
that is predominantly armor, such terrain features as
streams, bluffs, heavy woods, marshes, and defiles are
definite obstacles and should be so represented.
Another type of force may not consider these features
to be such serious obstacles.

c. The Four Terrain Description Indices. - Four
indices which describe the following four qualities of
the terrain are provided for each grid square:

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Mobility
Observation and field of fire
Cover and concealment
Terrain obstacles

The Observation and Field of Fire Index, and the Cover
and Concealment Index are very closely related to the
Mobility Index. Hence, for the purposes of the
simulator there is a one-to-one correspondence among
these three indices. Only the Mobility Index and the
Terrain Obstacles Index are input into the computer,
and then from the given value of the Mobility Index the
simulator supplies the corresponding values to the
Observation and Field of Fire Index and the Cover and
Concealment Index. Detailed information about the
latter two indices is given to the reader for two
reasons. First, in the construction of future games
using unusual types of forces advancing over extremely
unusual terrain, it may become necessary to alter or
dissolve completely the one-to-one correspondence that
has been established. Second, it was discovered that
when the Mobility Index is assigned to a grid square
without knowledge of the values of the other two
indices which this assignment implies, minor
inaccuracies in the terrain description often result.
Hence, the scenarist should assign values to the
Mobility Index, the Observation and Field of Fire
Index, and the Cover and Concealment Index
simultaneously in such a way that the three values as a
whole best describe the grid square under considera-
tion.

        (1)   Mobility Index. - Index each grid square
within the zone of action with the Mobility Index.
This index ranges over the integers from 1 to 5
according to the general terrain presented by the grid
square. The terrain in each grid square is classified
under one of five categories:

        Type 1 -   Generally flat, open terrain
                   with good maneuvering. May or
                   may not have roads. Mobility
                   Index is 1.

        Type 2 -   Moderately open, rolling
                   terrain. Good maneuverability.
                   Mobility Index is 2.

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Type 3 - Moderately closed terrain, one-third to one-half covered by heavy woods or steep grades. Tank movement restricted. Mobility Index is 3.

Type 4 - Close terrain, tank movement limited. Mobility Index is 4.

Type 5 - Rugged terrain. Tank movement limited to reconnoitered routes, and engineer assistance necessary. Mobility Index is 5.

The index decided upon is placed in the upper left hand corner of each grid square. Road nets and terrain obstacles do not influence this index. See Figure II-1.

     (2) Observation and Field of Fire Index. - Index each grid square within the zone of action with the Observation and Field of Fire Index according to Table II-2, Column 2. As explained above, this index follows directly from the Mobility Index. Thus, if we have indexed a grid square with a Mobility Index of 1 (open terrain), then this same grid square will carry an Observation and Field of Fire Index of .1. Low values for this index imply good fields of fire and high values imply poor ones. Place the index given in the table in the upper right hand corner of the grid square. See Figure II-1.

     (3) Cover and Concealment Index. - Index each grid square with the Cover and Concealment Index according to Table II-2, Column 3. As with the Observation and Field of Fire Index, this index follows directly from the Mobility Index. For example, a Mobility Index of 5 (rugged terrain) implies a Cover and Concealment value of .1. A low value implies good cover whereas a high value implies poor cover. Place the value decided upon in the lower right hand corner as in Figure II-1.

     (4) Terrain Obstacles Index. - Index each grid square with a Terrain Obstacles Index according to the severity and extent of the terrain obstacles present. The index ranges over all values (fractional

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as well as integral) from zero to 5. Grid squares with no obstacles receive an index of zero. Table II-1 should serve as a guide for the establishment of proper values for this index. The value for this index should be placed in the lower left hand corner of the grid square. (See Figure II-1)

(5) <u>Terrain Index</u>. - The Terrain Index, TI, is a single-valued function of the original four indices constructed in such a way that it represents the relative desirability of the grid square as a segment of an attack or withdrawal route. The Terrain Index is used exclusively in the route selection routine.

(6) <u>Terrain Class</u>. - The Terrain Class, KT, is an integer ranging from 1 to 15 combining together the information contained in the Mobility Index and the Terrain Obstacles Index. The internal conversion is performed in two steps. First, the Terrain Obstacles Index is converted from the range zero to 5 to an integer Q in accordance with the following table:

Value of Terrain Obstacles Index	Value of Q
0.0 to 2.6	1
2.6 to 3.7	2
3.7 to 5.0	3

Then the Terrain Class, KT, is computed by the following formula:

$$KT = 3M + Q - 3$$

where M = the Mobility Index.

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APPLICATION OF TERRAIN VALUES

NOTE: EACH GRID SQUARE IN THE ZONE OF ACTION IS SIMILARLY GIVEN A TERRAIN INDEX.

FIGURE II-1

TABLE II-1, Examples of Terrain Obstacle Weights

Obstacle	Maximum value	Fraction of grid square affected			
		1/4	1/2	3/4	Full
Marsh	5.0	1.2	2.5	3.7	5.0
Stream-fordable	2.5	0.6	1.2	1.8	2.5
Stream-bridge	3.7	0.9	1.8	2.8	3.7
Defile	1.2	0.3	0.6	0.9	1.2
Woods	3.7	0.9	1.8	2.8	3.7

NOTE: Table contains examples only

TABLE II-2, Mobility, Observation and Field
         of Fire, and Cover and Concealment
         Weights

Terrain type	Mobility value	Obs. and FF value	Cover and concealment value
A=1 open	1	.1	1.0
B=2 moderately open	2	.2	.6
C=3 moderately close	3	.2	.3
D=4 close	4	.6	.2
E=5 mountainous	5	1.0	.1

NOTE: Table contains examples only

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d. __Terrain Pseudo__. - It is important to recognize that, for the purposes of evaluating communications and tactical action, precision in developing the terrain indices is not important, for the very simple reason that the simulation is not restricted to working on some special part of the real world. If the data assigned are not precise, the operational effect is simply to portray a slightly different terrain than that covered by the map being coded. In fact, it may well be that for purposes of analysis some quite unrealistic terrain would be most desirable, since this would tend to stress the capabilities of the communications system to an extreme and thus spotlight possible shortcomings in the system under study in a way that a more reasonable battlefield would not.

e. __Terrain Factors in Movement Rates__

(1) In simulating the rate of advance, the tactical model consults the Terrain Class of the terrain over which the attacker advances. The Terrain Class of the grid square through which the attacker unit is moving determines a normal move rate for the unit in question as long as it is in that particular grid square. For front-line units the nominal move rate is modified by the "force against," thereby reflecting the enemy resistance encountered.

(2) The normal move rate for each Terrain Class (an array of information which is input into the computer) must be constructed by the following logic. First, a realistic movement rate should be established for each value of the Mobility Index on the basis that there are no obstacles present. On the basis of the movement rate established, the time required to cross a grid square in the absence of any obstacle should be calculated. Second, for each value of Q above, a delay in minutes is established. This delay should represent the average time necessary for the advancing unit to surmount the obstacle. The delay time is added to the passage time in the absence of obstacles. The sum represents the total time required for the unit to pass through the grid square and surmount the obstacle. Finally, on the basis of the total passage time a normal move rate should be calculated such that a unit moving at this rate crosses the entire grid square in the total time allotted. Recommended values for the time delays imposed by terrain obstacles are shown in Table II-3.

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f.   Terrain Factors in Route Selection. - A series
of tests in route selection over a variety of terrain,
using these values for terrain factors, indicate that
for armor these values give acceptable routes for the
purposes of this project. In a simulation involving a
force not predominantly armor, it might be necessary to
use other values for the four external indices.
However, the terrain types and factors as listed enable
the computer to properly utilize terrain for any type
of ground action.

TABLE II-3, Guide for Time Delays Imposed by Terrain
            Obstacles

Obstacle	Time delay (approximate)	Remarks
Stream:		
To bridge	2 hours a/	Per each MAB + Ribbon Bridge
To ford	1 hour b/	To prepare approaches
Marsh	2 hours b/	To lay corduroy
Woods	1 hour b/	To clear trees
Defile	20 minutes c/	To change formation

NOTE: These delays are intended as a general guide to
the delay that should be imposed on a column
negotiating obstacles of the nature shown in this
table.

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a/   From TM 101-10.

b/   No published data available. Based on professional
     military estimate.

c/   Based on time length of open column.

NOTE: Table contains examples only.

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TABLE II-4, Guide for Time Delays Imposed by
Defender-placed Obstacles

Obstacle	Time delay (approximate)	Remarks
Minefield	120 min	Deliberate clearance
Minefield	30 min	Hasty clearance
Road crater	60 min	To fill
Tank ditch	30 min	To fill
Tank ditch over 50ft	60 min	To bridge
Tank ditch under 50ft	10 min	Armored vehicle launched bridge
Road barricade	30 min	To demolish - clear
Abatis	30 min	To clear - per 100ft
Blow down	30 min	To clear - per 100ft

NOTE: Table contains examples only.

g.   Boundaries and Objectives

(1) Realistic boundaries are difficult to
program into the tactical simulation. Boundaries are
not always straight lines, often following terrain
features or other well-defined guides. Then too,
boundary control data must not be incorporated into
other terrain data. This means then that data must be
put into the computer (separate from the indexed
terrain data) that will keep each attack column within
its sector. This is accomplished by prescribing a
sector width for each attack column. Sector width is
the width of the possible route the group can follow.
The computer selected route cannot lead into grid
squares that lie more than one-half the sector width
away from the lines that connects a route starting point and

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the route objective. Sector widths are dependent upon the tactical layout of the simulation area and may be different for each column. These widths should be as wide as the tactical situation permits. For a battalion size Task Force the width should not be less than three grid squares. A value for the sector width is assigned for each group.

(2) Sector widths depend on the tactical disposition of the group and may be different for each attack column. However, the program permits only one sector width entry for a column, i.e., the sector width once prescribed for a group (attack or defense) cannot change during the simulation.

(3) Each group and associated battalion should have an objective assigned in the input data. If a group is not initially committed, it will not move toward its objective until it is committed. The objective of a battalion (represented by a group) may be a preestablished point (a terrain objective) or an offset from a unit. Most past applications of the model have utilized only preestablished objectives.

    h. Routes

(1) Terrain Attack and Withdrawal Routes. - The tactical model includes a routine that selects routes of advance for each attack column and, withdrawal routes for defender groups. This route selection routine utilizes the Terrain Index.

(a) There is a necessity for a route selection routine, particularly for attacker groups committed during the play of the combat action, because it cannot be determined in the initial layout of the problem when and where these reserve forces will be committed. When reserve forces are committed, the simulation must have the capability to move such attack forces toward the objectives over suitable terrain.

(b) In an exercise where brigade or division reserves will not be committed, the routes could be selected from the map and the information could be used as initial data input. This can be done in any situation where the locations of the attack positions and the objectives are initially known. However, in an exercise that may involve the commitment of brigade or division reserves, it is not initially known when and where the reserves are to be brought into play; hence, the program must have the capacity to accept reserves at any place and provide these reserves with routes to the objectives.

(c) In the tactical model the computer selects the routines for all attacker groups. The withdrawal routes for

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defender forces might also be selected by this same routine, or the routes can be designated by initial input data.

(d) The route selection routine operates on the Terrain Index, i.e., it selects the most appropriate terrain route to the objective. If terrain difficulty is treated as a form of "cost," the model generally selects a "least cost" route in each instance.

(e) To insure that the route selection routine moves the columns along tactically sound routes requires that the terrain data stored in the computer by the initial terrain evaluation include those terrain features the commander considers when selecting a route, and assign these items relative values comparable to the commander's evaluation. The computer route selection will then reflect the commander's evaluation and select routes based on sound terrain utilization.

(f) When providing terrain data for the route selection routine the type of force has a major bearing on the datum item values, particularly on the Mobility Index and the Terrain Obstacles Index.

(2) Changes in Attack Routes

(a) Some apprehension has been expressed concerning the combat validity of the computer selected attack routes, because the computer selects attack routes from initial input data and then simulates the action along these routes to the objective without change. It has been pointed out that in actual combat these routes might be changed by local commanders as the situation develops. However, for the purposes of this project, tactical simulations along initially selected attack routes are acceptable if the simulation fully develops the communications requirements. Simulating minor changes in the attack routes would not necessarily lead to a more valid tactical background or a more complete evaluation of communications requirements.

(b) The computer does introduce new routes into the simulation as the action progresses - when the tactical situation warrants. When brigade or

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division commits reserves, the computer selects routes
for those units. These routes are additions to the
routes the computer selected for the initial attack
columns. The routes of the newly committed forces
serve to deploy attacker units to fit the changing
tactical situation as the action develops. Similarly
for defender, the computer selects withdrawal routes
for those units initially in position. Additional
routes are selected for units ordered to counterattack.

(c) The routes the computer simulates,
for both attacker and defender, are sufficient to
create acceptable deployment at any time during the
action.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 3
ROUTE SELECTION

1. <u>General</u>. - This section contains a synopsis of the calculation of boundaries for route selection, and special types of routes.

2. <u>Boundaries</u>. - When a route is to be selected, generally the computer subroutine is furnished the starting point of the route and the final objective. These boundaries are points one-half a sector width on either side of the starting point and the final objective, and points on either side of the intermediate objective (if any) or middle of the route.

3. <u>Multiple Routes</u>. - There is a provision in the route selection routines to calculate several different routes and use the route with the least opposition.

4. <u>Parameters</u>

    a. <u>Sector Width</u>. - Sector width and objectives offer the only control over the location of a route. For a given objective, increasing the sector width causes less control over the route and increases the likelihood of the best possible route being selected. It also increases the probability that the route will coincide (at least in part) with some other route.

    b. <u>Avoiding or Seeking the Enemy</u>. - The model also contains factors which cause enemy-seeking or enemy-avoiding routes to be selected. These are currently programed as constants internal to one of the command decision routines.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 4
DEPLOYMENT

1. <u>Introduction</u>. - Any combat force is observed to occupy space and to consist of a large collection of small organizations whose functions differ, and which operate in an area whose center of mass is representable by a single point. A straightforward representation of this view is used in this simulation.

2. <u>Definition of a Unit</u>

a. The fundamental organizational entity in the model is called a <u>unit</u>. The combat forces on both sides are divided into units, and when listed and numbered consecutively, the number assigned to the unit is the <u>unit index</u>. Suppose that the two opposing military forces are divided into N units, of which M* are Blue Units and (N-M) are Red Units. The Blue units are numbered 1,2...., M, and the Red Units are numbered M+1, M+2, ..., N. The number of a unit is used to identify that unit.

b. A unit is any collection of men, material, equipment, or functions which for the purposes of the study being made can be thought of as located at a point. Since communications equipment can be located in the model only at units, if some communications complex cannot acceptably be considered as located at a single point, then the organization must be further divided into two or more units. If the combat qualities of a unit are so complex as to make their representation very difficult, the unit should be divided until each resulting unit can be handled with some degree of realism.

3. <u>Properties of a Unit</u>

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*"M" is not a set value but simply a shorthand means to describe where in the list of units the Blue list ends.

a. In general, the development of the list of units will follow the normal TOE for the force down to the level below which there exist no communications functions pertinent to the problem at hand. But since the unit is defined in the model by a fairly large collection of operations, any aggregation of people or functions for which these operations are realistic is an acceptable unit. (Actually this is the only way to define a unit explicitly.) Thus a unit:

(1) Has an initial location (X,Y) which is changed periodically according to the movement rules;

(2) Has a list of counts of "weapons" (the "Strength Vector") which when treated by the firesplitting (Section 10), attrition (Section 7), and artillery (Section 11) submodels are periodically attrited;

(3) Serves as the location for a collection of communications equipment;

(4) Is the originator or recipient of "messages";*

(5) Is represented by a number in all enemy intelligence logs, the number being the "coefficient of intelligence" as developed by the surveillance and other submodels;

(6) Provides targets for enemy artillery fire.

4. Lists Associated with Units

a. Information associated with each unit includes the following items:

(1) A counter representing cumulative attrition suffered, distance moved, and time;

(2) A measure of combat effectiveness reduction due to suppression by enemy artillery fire and the interval of time the reduction applies;

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* A unit cannot be both the origin and destination of any message played by the model, i.e., a unit cannot send a message to itself.

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(3) The unit index of the unit's own higher head-
quarters as the origin of displacement command messages;

(4) The unit's mode, (attack, defense), the
group or pattern of which it is a member, the type of
terrain it is in, and its function (artillery,
infantry, recon platoon, CP, etc.), is called unit type in the
model.

5. Types of Unit

a. Any combat element for which the above
qualities can be defined can be a unit. In other
words, the idea of a unit is abstract enough to provide
a vehicle for the representation of a large number of
possible combat components, although it may be
necessary to add further modules to the simulator to
handle special qualities of the unit such as movement
or vulnerability.

b. Examples of possible units which are not
currently played would be off-shore naval support,
helicopters, the persons of the various commanders as
distinct from the CP's, trucks, and manned bunkers.
Where such assignments are made, the lists of unit
types and modes must be increased if these units are to
be treated in a fashion different from those presently
considered.

c. Currently the model will play a total of 10
types of units.

6. Inventory of Units

a. All elements playing a part in the tactical or
communications simulation must be aggregated into these
combat units or listed as separate units. These units
and the data associated with them comprise the
"inventory of units". These units alone are played in
the model. Currently the model is sized to handle up
to 257 separate "units".

b. The purpose and tactical effect of the
aggregating technique must be kept in mind when
compiling the inventory of units, remembering that each

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aggregate becomes a numbered simulation unit used throughout the tactical simulation. Thereafter this number represents all activities assigned to that location. This is done primarily to facilitate the movement and deployment of signal equipment, but this technique also affects other tactical data, particularly weapon strength. NOTE: Command posts, unit trains, Op, etc., each count as one unit.

7. Empirical Factors

a. It is often necessary or desirable for purposes of simulation that units differ in strength and composition from TOE listings. In the simulation, units may be cross attached, some elements aggregated, and some activities detached. The initial composition of units and groups of units represents each force in its combat posture. The composition of units reflects the normal operational structure of each combatant for the tactical situation under study. Unusual dispositions and unrealistic groupings are to be avoided, unless such a tactical environment is desirable to place special stresses on the communications system.

b. Experience has shown that the simulator works best when units are formed using the following set of rules:

(1) Tank and infantry elements are integrated into teams at company level. These teams include artillery and mortar observers. All elements of a company size team are simulated as a single unit.

(2) A command post unit (company through division) includes all the staff, liaison, or support elements that normally operate at considerable distance from teams. Command posts are simulated as separate units.

(3) Units such as mortar, engineer, or reconnaissance platoons that may operate at considerable distance from teams or command posts are simulated as separate units.

(4) Direct support artillery is simulated at battalion level unless a battery is detached, in which case it is simulated as a separate unit. NOTE:

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Artillery is simulated in greater detail within the artillery model itself.

(5) For this model, division artillery includes all artillery units not assigned direct support missions. Division artillery is simulated by battalion units and is treated as general support artillery within the model.

(6) All elements of brigade trains are simulated as a single unit; major elements of division trains are simulated as separate units.

c. The sole purpose of the unit is to consolidate the locations of signal equipment, wherever such consolidation will not invalidate the deployment of the signal structure. Although not at the same point location, all this equipment is operated from the general location of a CP. For location purposes only, the communications model accepts the CP location as the location for any piece of signal equipment grouped at that location.

8. Patterns

a. Another technique used by the tactical simulator to reduce the data and programing load, computer storage, and running time is the use of tactical patterns. Tactical patterns are used in the simulation as an expedient for the movement of units during the combat action and to provide the initial input data required by the routines that comprise the tactical model. NOTE: No more than 40 patterns may be used.

b. In the tactical simulator all units are assigned a location in a pattern. Patterns are formed by logical grouping of units according to the operational doctrine, composition, and type of force. Patterns are a simulation expedient for movement and control, but they must not distort the tactically sound deployment of the combatants.

c. Tactical patterns must reflect the operational doctrine of the type force they represent and for the type action the simulation is playing. If by trial simulations these patterns do not create realistic deployment or otherwise fail to meet the requirements of the tactical simulation, then the patterns need

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adjustment. NOTE: A pattern cannot have more than 10 units assigned to it.

    d.   It might be questioned whether the use of these patterns so stereotypes the tactical action that deployment variations are lost. To a degree this is true, but for the purpose of evaluating signal systems this does not invalidate the tactical simulation if the attack patterns hold to tactical doctrine. The command post locations that result from these patterns are sufficiently realistic to present a valid communications deployment.

    e.   At task force level, the composition of units in attack patterns but not in groups (see paragraph 9 below) varies with the force ratio that develops against the forward elements of each column. The attack patterns used at brigade or division level are more stable but vary with the attack plan and also with the force ratio when it becomes necessary to commit brigade or division reserves.

9.   Groups

    a.   Some patterns have units that move out of their pattern location (but not their pattern) when contact is made and form groups. A group is a collection of one or more tank, infantry, or cavalry units (company size) that have been committed or could be committed to action. Groups are a simulation expedient for movement and control. NOTE: No more than 19 groups (total) may be used.

    b.   All units of a pattern which are front-line units (or could become front-line units when they are committed) are assigned to a group. All units assigned to one group must be members of the same pattern. In other words, the units of a group are a subset of the units in the associated pattern. NOTE: A group cannot have more than 4 assigned units.

    c.   The primary purpose of the concept of the group is to facilitate the movement of front-line units. Groups move toward and along routes which lead to objectives. A pattern with an associated group moves by following its own group. Other patterns which have no associated group move by following other groups or other patterns.

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10. Armor Attack Patterns

It is realized that the attack patterns and the variations when committing reserves do not cover all sound methods of employing armor or committing reserves. Assuming that the purpose of the tactical simulation does not go beyond creating a realistic dynamic combat environment and generating essential communications for evaluating the performance of supporting signal systems, it becomes apparent that a greater variety of deployment patterns is not a necessity. These patterns are sufficiently varied to bring into play the communications support that is necessary to commit and control the units. Similarly, the computer rules that go with these patterns are not sufficiently comprehensive to cover all the situations that confront units in combat. These rules limit command decisions to specific courses of action that are tactically realistic and whose execution requires the communications support that is to be brought into the communications simulation. The important point is that the simulation patterns create, with an acceptable degree of validity, dispersions and tactical maneuvers applicable to the force under simulation and its operational doctrine.

11. Division Attack Groupings

There are no fixed patterns for the division as a whole. All rear elements of the division are grouped into patterns, but the composition of the patterns and the relative location of units depend largely on the tactical situation.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 5
WEAPON STRENGTH

1.   Introduction. - In the model, as in real combat,
the strength of the combatants is a critical factor in
the determination of the combat outcome. The computer
accounts for the strength of each unit. This strength
is attrited; enters into the calculation of close
combat fires, intelligence acquisition, artillery
target values and movement rates; is involved in
command decisions; and can be a factor in route
selection.

2.   Inventory of Units

     a.   In Section 4, Deployment, the inventory of
units is discussed in detail. Associated with each
simulated unit is a list called the Strength Vector.
This list contains 15 items, the first 12 of which
contain counts of the different types of weapons the
unit has. NOTE: Red and Blue each can have up to 12
weapons and they need not be the same.

     b.   Artillery tubes are not included in the weapon
strength. Artillery (both DS and GS) is simulated by
separate artillery routines which select targets,
deliver fire, and compute attrition and suppression.

     c.   The tactical simulator is more sensitive to
changes in the communications simulator if all
artillery fire is simulated by concentration on targets
selected by surveillance. Thus, the effects of
artillery fire are computed separately - but its effect
on the combat action is included in the tactical
simulation.

3.   Applications of Strength

     a.   General. - The paragraphs below are not
intended to describe exhaustively the uses of the
Strength Vector in the model; instead, they are
intended to give the reader only a general idea of the
meaning of the Strength Vector.

b.   Firesplitting. - The calculation of the close combat fires that units are receiving is discussed in detail in Section 10, Close Combat Fires.

(1)   Distribution of Fire. - In real combat, when a unit is in contact with several enemy units, it generally will allocate some fire to each of these units.   Furthermore, it will try to allocate fire from different weapons in different ways.   For example, it will try to place more antitank gun fire against tank units than against infantry.   The model simulates this aspect of combat directly.   For a given unit in contact the model takes each of the 12 weapon categories and distributes fire from each of these on each enemy unit (within range) with which the given unit is in contact. Fire from weapons of a given category is distributed among enemy units in a way that depends on how far away each one is, how large its current combat value is, and the desirability of using this type of weapon against that type of unit.   Table II-5 contains an example of the type data used to represent the relative desirability of using the weapon types against three different types of units.

TABLE II-5, Relative Desirability of Firing Types of
Weapons Against Types of Units

Weapon category (Blue)	Red unit type		
	Armored infantry	Dismounted infantry	Armor
Tank	750	1	1000
Antitank	750	1	1000
Machinegun	750	1000	1
TOW	750	1	1000
4.2-inch mortar	500	1000	1
81mm mortar	500	1000	1
Dragon	500	1	1000
Hand weapons	500	1000	1

Data are based on professional military judgment and
have a range of 1 - 1000. NOTE: Table contains
examples only.

TABLE II-6, Effective Combat Value of Types of
Weapons Against Types of Units

Weapon category (Blue)	Red unit type		
	Armored infantry	Dismounted infantry	Armor
Tank	30.0	30.0	30.0
Antitank	20.0	10.0	20.0
Machinegun	8.0	8.0	4.0
TOW	25.0	12.5	25.0
4.2-inch mortar	15.0	15.0	7.5
81mm mortar	12.0	12.0	6.0
Dragon	10.0	5.0	10.0
Hand weapons	1.0	1.0	.5

Data are based on professional military judgment and have a range
of 1-30. NOTE: Table contains examples only.

(2) Vulnerability

(a) Not all types of units are equally
vulnerable to the fire of a given weapon. The model
reflects this fact by taking fire allocated as indi-
cated above and multiplying it by a factor which
represents the effective combat value of using the
weapon against the type of unit. Table II-6 is an
example of the type of data used to represent these
effective combat values.

(b) Such an effective combat value is
considered by the model to be the fire delivered from
the weapon on the unit. The sum of all such fire from
all weapons of all units in contact with a given unit
is the "force against" the unit and is stored in the
computer. Note that "force against" is calculated for
both attacker and defender units.

(c) This "force against" is used in many
ways in the model:

$\underline{1}$ In the calculation of movement
rates,

$\underline{2}$ In the calculation of attrition
rates, and

$\underline{3}$ In the determination of when to
commit and withdraw companies.

(d) The model expects "force against" to
be commensurate with unit total strengths.

c.   Short Range Surveillance

(1) The short range surveillance submodel is
covered in more detail in Section 9, Surveillance and
Intelligence. Both attacker and defender units use the
short range intelligence submodel every minute of play
to accumulate ground intelligence on enemy units with
which they are in contact.

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(2)   Consider a unit in contact. The model calculates a detection probability dependent on distance for each of the 15 strength categories. The ground intelligence increment the given unit picks up on the enemy unit is a weighted average of these probabilities modified by a terrain factor. The weights used in the average are the product of the number of items the enemy has in a given strength category and the detection value of the category. Note that categories 13-15, the visible object categories, are included in the short range surveillance calculations but not in the "force against" calculations discussed above. Table II-7 shows representative detection values.

d.   Artillery Target Value

(1)   In combat, artillery is selective of its targets. If faced with a choice between two potential targets of the same type, artillery may make its choice on the basis of variations in weapon strength between the two units.

(2)   The artillery submodel (Section 11, Artillery) selects direct and general support targets by calculating a target value for every enemy unit within range. This target value, among other things, determines which units are fired upon and by which batteries.

(3)   The target value depends on intelligence that the FDC has on the enemy unit, distance, its unit type, and how strong the unit is in each of its 15 strength categories. Specifically, the unit's entries in each of these categories are multiplied by weighting factors. The sum of these products is a factor in the target value. Table II-8 contains weights currently used.

(4) Inclusion of visible object categories in this calculation reflects the fact that low visibility is a valuable attribute of a target.
Furthermore, the inclusion of these categories helps solve the problem of generating counter-battery fire. This problem exists because, although an artillery unit is an exceptionally worthwhile target in real combat, it is difficult in the model to generate a high target value for an artillery unit, using just the first 12

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weapon categories and the other factors. Generally, an artillery unit is not particularly strong in the first 12 categories, and the fact that artillery is likely to be considerably farther away than other potential targets causes the distance and intelligence factors to be relatively weak.

TABLE II-7, Detection Value for Each Strength Category

Strength category	Detection value
Tank	15
Antitank	10
Machinegun	5
TOW	5
4.2-inch mortar	5
81mm mortar	5
Dragon	3
Hand weapons	1
High visibility objects	15
Medium visibility objects	8
Low visibility objects	5

Data are based on professional military judgment and have a range of 11 - 15. NOTE: Table contains examples only.

TABLE II-8. Target Value Weights for Types of
Weapons in Types of Units

Blue weapon category	Red unit type		
	Artillery	Dismounted infantry	Armor
Tank	.60	.20	.30
Antitank gun	.40	.13	.20
Machinegun	.16	.05	.08
TOW	.50	.17	.25
4.2-inch mortar	.30	.10	.15
81mm mortar	.24	.08	.12
Dragon	.20	.07	.10
Hand weapons	.02	.01	.01
High visibility objects	.00	.00	.00
Medium visibility objects	.00	.00	.00
Low visibility objects	.00	.00	.00

Data are based on professional military judgment and
have a value of 0.0 – 10. NOTE: Table contains
examples only.

TABLE II-9, Combat Value for Each Strength Category

Strength category	Combat value
Tank	30
Antitank gun	20
Machinegun	8
TOW	25
4.2-inch mortar	15
81mm mortar	12
Dragon	10
Hand weapons	1
High visibility objects	0
Medium visibility objects	0
Low visibility objects	0

Data are based on professional military judgment and have a range of 0.0 - 30.0. NOTE: Table contains examples only.

e.   Combat Value. - Aggregation is one of the model builder's most important tools. Aggregation results in avoidance of unnecessary detail, tends to conserve internal computer storage and computer time, and prevents significant results from being lost in a mass of output detail. There are several functions in this model for which consideration of individual weapon and visibility categories would contribute little or nothing to the purpose of the model. For these functions the categories are aggregated to represent the total strength or combat value of the unit.

(1) Calculation of Combat Value

(a) The total strength or combat value of a unit may be thought of as its total firepower. It is calculated by computing the unit's combat value in each of its weapon and visibility categories and then adding these values together. There is a list in the computer which contains the combat value of each category in each type of unit. (Table II-9 contains examples.)

(b)   When a unit is attrited, each entry
in its Strength Vector is reduced. Then the reduced
entries are used to recalculate the unit's new current
total strength.

(2)   Unit Force Ratio

(a)   In combat a unit's firepower,
relative to the fire it is receiving, is often a strong
factor in the unit's ability to move and its attrition
rate. In the model this is simulated by calculating
for each front-line unit, every minute of game time, a
unit force ratio which depends, among other things, on
the unit's current total strength.

(b)   The unit force ratio is a major
factor in determining the unit's movement rate, its
attrition rate, and the commitment and withdrawal of
units.

(3)   Brigade Force Ratio

The decision to commit a reserve
battalion is often strongly influenced by the progress
the committed battalions are making and by intelligence
on potential resistance. The model simulates this
process by having the commit decision, as well as the
frequency of status reports to division, depend on a
"brigade force ratio". This "brigade force ratio"
involves the current total strength of the brigade's
combat units in committed battalions and the brigade's
estimate of the current total strength of enemy units.
(See Section 12, Command Decisions.)

(4)   Long-Range Surveillance

In addition to depending on terrain,
distance, unit type, and surveillance device
characteristics, the intelligence acquisition rate in
the range surveillance model depends strongly on the
observed unit's total strength. (See Section 9,
Surveillance and Intelligence.)

estimate of the location and current total strength of enemy units. (See Section 2, Terrain, Routes, and Objectives.)

(6) Cumulative Attrition

Cumulative attrition often results in degraded performance in excess of that attributable to attrition alone. In other words, a unit which has suffered 10 percent attrition may have its combat effectiveness reduced by 15 or 20 percent attrition. The model simulates this by multiplying a unit's current total strength in firesplitting and unit force ratio calculations by an effectiveness factor which depends on the unit's cumulative attrition, i.e., its current total strength divided by its original total strength. (See Section 7, Attrition.)

CHAPTER II
THE TACTICAL SIMULATION

SECTION 6
MOVEMENT

1. Introduction

a. General Remarks on Movement

(1) The ability of opposing combat units (or groups of units) to advance or resist is determined by a comparison of their combat values. Combat value is firepower modified by terrain, intelligence, control, and logistics. Firepower is also modified by such factors as position effectiveness, unit performance, and weapons effectiveness. A comparison of the adjusted combat values determines the flow of the combat action.

(2) Two principal factors have separate and cumulative effects on the rates of advance. These are first, the terrain, and second, the amount of enemy resistance. Examples have been tabulated in reference to both of these factors. Other factors which have a bearing on rates of movement, such as morale, fatigue, extent of prior planning and reconnaissance, amount of preparation and briefing and similar items, although having important effects, are not simulated.

(3) In the tactical model the rate of advance is calculated primarily from the terrain and force-ratio (FR) factors. (FR measures the resistance.)

(4) Terrain data enable the computer to select routes for the attacking force. These routes represent the commander's decision based on information from reconnaissance or map studies. They provide the best mobility, cover, and fields of fire, and avoid major terrain obstacles to the objective.

(5) What the commander does not know at this point, or knows only partially, is the enemy resistance he will encounter along the route on which his force moves. The resistance consists of enemy units in his path of advance. Whatever the resistance, the model must have the rules, techniques, and data to simulate the rate of advance.

(6)   The attacker rate of advance is determined by his capability to negotiate the terrain over which the route leads him. The problem here is realistically to modify this terrain rate by the effects of the resistance encountered. The combination of the terrain and resistance gives us the combat rate of advance the attacker will achieve.

(7)   The movement routines are the heart of the tactical simulation. They manipulate the data that create the dynamics for the combat action under simulation. By combining the movement we get from these routines with the deployment and tactical aggregation, we enable the computer to print out unit and command post locations throughout the tactical simulation. These locations are a necessary element of information for the evaluation of the performance of the signal system.

(8)   To simulate the flow of the tactical action, the computer manipulates data that represent the comparative strength of the combatants along the routes the attacker has selected for the advance of his column. Terrain and resistance are the factors that provide the data for simulating the rate of advance along each attack route; terrain and intensity of attack affect the rate of retrograde movement of the defender along his routes.

(a)   Terrain

1   Each grid square in the simulation area receives a Terrain Index which depends on the Terrain Obstacle Index and Mobility Index for the square. The Terrain Obstacle Index and Mobility Index are supplied as inputs by the scenarist. The Terrain Index may be thought of as the cost of using the square for a route. It is used only for route selection.

2   Each grid square is also given a Terrain Class; this depends on the square's Terrain Obstacle Index and Mobility Index, too, but in a way different from the Terrain Index. The Terrain Class is

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used in determining movement rates, weapon ranges, rates of intelligence acquisition, etc.

(b) <u>Unit Force Ratio, Resistance, and Intensity of Attack</u>

<u>1</u>   In most war gaming a standard method of determining rates of advance for an attacker is by reference to his force ratio, i.e., the attacker's combat strength or value relative to the defender's. Force ratio is a method of measuring resistance: a high force ratio implies low resistance and results in a high rate of movement (ignoring terrain factors); a low force ratio implies high resistance and results in a low rate of movement.

<u>2</u>   But in actual combat resistance is determined by the fire a unit is receiving relative to its own firepower. This model calculates the fire each unit (attacker or defender) is receiving. Then for each unit a force ratio is calculated; this, of course, is different than that conventionally used because of the actual calculation of the fire received. This unit force ratio is the ratio of the unit's combat firepower to the close combat fires which it is receiving. The unit's combat value is modified by several factors; major among these are whether the unit is being suppressed by artillery fire and whether the unit has been attrited to the point that its effectiveness is seriously degraded.

<u>3</u>   In this model the resistance is measured by the attacker's force ratio, and the intensity of the attack is measured by the defender's force ratio.

b.   <u>Limitations</u>. - The current tactical simulator does not include the routines or data necessary to simulate the tactical effects of nuclear strikes, air strikes, or weather.

2. <u>Group</u>

a.   <u>Introduction</u>

(1) Movement and deployment are simulated in the model by a group movement submodel. One of the main motives in the construction of the model was to

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provide a tool which could compare signal communication systems by the differences in combat outcome they produced. One important measure of combat outcome is deployment. Thus, the part of the model which simulates movement, particularly the movement of front line units, is a very important one; understandably, it is a fairly detailed submodel.

(2) For the purposes of movement, a group is considered to be the set of front line units of a battalion. The group movement submodel endeavors to move groups along a relatively smooth course following a preselected route. Several different movement modes are possible to simulate battalion movement in different tactical situations, e.g., attack and defense. Within limits the units in a group are moved individually to reflect variables in the tactical situation, such as terrain, artillery suppression, cumulative casualties, and force ratio (fire power/direct fire received).

b. Group Movement Mode

(1) Withdrawal (Mode 1). - This mode, intended for defender groups, results in all units having the maximum move rate, M.

(2) Leapfrog (Mode 2)

(a) In this mode, intended for defender groups, all units may be committed initially, perhaps two up and one back. Each unit remains immobile until it either gets too far away from its aiming point or its force ratio drops below a pre-determined cutoff. In either case, the unit then starts leapfrogging.

(b) If all units in a group are leapfrogging, it is unlikely that any will stop until the end of the route is reached. To prevent this from happening, if all units are moving, of all those that are under fire, the one with the best force ratio is stopped.

(c) Delays are introduced at the start of movement to correspond to the degree of communications existing between the unit and its headquarters. The assumption is that, if the unit needs to move and is in contact with its headquarters,

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it will either be ordered to move or will request and receive prompt permission to move. If the unit is not in contact with its headquarters, it will not start moving as quickly.

(d)   When a group in the leapfrog mode reaches the end of its route, the associated pattern (the one containing this group's front line units) is changed to become a type zero pattern (continuous following this group with zero move rate). This causes the pattern to cease movement.

(3)   Reserve (Mode 3). - No units in a group of this mode are front line units; hence none should receive any movement rate. Instead, they are moved by the pattern movement routines.

(4)   Yield (Mode 4)

(a)   The model has three modes for defender groups, each of which results in a different type of movement. One, the hold mode, allows no movement; the second, the withdraw mode, allows movement only at full speed to the rear; the third, the yield mode, makes units stop if the force ratio is sufficiently good (high), move to the rear at full speed if the force ratio is sufficiently poor, and move at a rate proportional to the negative of the force ratio for intermediate values. It was anticipated that this mode, coupled with a battalion decision model which committed and withdrew in response to essentially the same force ratio, would allow defender units to move in a satisfactory fashion.

(b)   The model assumes that if a unit is in range of any of a certain class of weapons of an opposing unit it is within range of all the unit's weapons of this class and, except for fire split to other units, is receiving full fire from all those weapons. Thus, a change of a few meters in the separation of opposing units can cause a considerable change in the fire that these units receive and a consequent large variation in force ratio.

(5)   Mode 5. - Not used in model.

(6)   Static Defense (Mode 6). - For defender groups, this state is equivalent to the hold mode. Units in this mode do not move.

Also, when all units of a group are at the end of the route the group mode is changed to static defense. (There is no mode 5 in the current model.)

(7) Attack (Mode 7). - Units in this mode move forward at full speed if the force ratio is good, stop if the force ratio is poor, and move at a rate proportional to the force ratio for intermediate values. The group move rate is also dependent on whether movement is vehicular or dismounted.

c. Pattern Movement

(1) All movement is related to the movement of front-line units that are organized in groups and move along routes at a velocity determined by inherent mobility, terrain, force ratio (ratio of unit strength times combat effectiveness to enemy fire received) and amount of artillery suppression. The non-front-line units, which are organized into patterns, follow these groups, or other patterns which themselves follow groups. In retrograde movement, patterns are actually "pushed" to the rear by the retreating front-line units.

(2) A pattern may move continuously, that is, its location is adjusted every five minutes to maintain a constant distance from its leader, or it may move by bounds, remaining at a fixed location until its leader has moved to a specified distance from it, and then displacing to a new location another specified distance from it. Thus, four types of pattern movement are defined:

0 - Move continuously following a group
1 - Move by bounds following a group
2 - Move continuously following a pattern
3 - Move by bounds following a pattern.

Each pattern is assigned a type which remains constant throughout the exercise (except in the case of the commitment of a reserve battalion which ordinarily is type 2, but is shifted to type 1 until it reaches the line of departure and then is shifted to type 0 when it receives a route and its initial companies are committed to form a group).

(3) It is important to differentiate between a pattern and the units in the pattern. The pattern itself can be thought of as a collection of aiming points (destination or objective) toward which the units in the pattern are directed when the unit is not on its aiming point. This distinction of units and aiming points is necessary because of the difference between continuous and bounding movement, and because of the desirability to maintain the deployment of the units in some constant arrangement.

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CHAPTER II
THE TACTICAL SIMULATION

SECTION 7
ATTRITION

1. Types of Attrition

   a.   This tactical model simulates two types of
attrition:

        (1)   Attrition due to enemy action

        (2)   Attrition from non-combat causes.

   b.   According to the rates prescribed by initial
input data, attrition against each unit accumulates as
the action progresses.

   c.   Attrition for both attacker and defender is
necessary in this tactical simulation in order to keep
the combat value of units current. This is necessary
for the computation of force-ratios by which the
computer simulates the flow of the tactical action.
Attrition is also a factor used in comparison of
tactical outcomes. The equipment attrition is a factor
that has an application in the communications
simulation.

2. Combat Attrition

   a.   There are combat attrition rates for units of
division size based on a day of combat. These rates
are averages that can be expected. They depend
primarily on the type of division, the type of combat,
the intensity, and the terrain. The predicted combat
attrition rates are the basis for the attrition rates
used in this simulation.

   b.   Data have been obtained on average combat
casualty rates for prolonged combat for large units
(divisions) in terms of percent (of personnel) per combat
day. In general, the rates for the division vary between 3
percent per combat day for light combat and 15 percent
for heavy combat. The combat day is taken as 14 hours.
Since these are battle casualites, we assume for this
simulation that the rate is higher in the forward

units. Accordingly, the division area was divided into two zones from front to rear and the overall rates were adjusted to these zones. (Table II- 9.)

c. Since damage from artillery fire is assessed separately from attrition due to close combat fires, the rates used in the computer are adjusted downward from those shown in Table II-9. Furthermore, the rates used in the model are per minute of combat, rather than per combat day.

3. Non-combat Attrition

a. In addition to combat casualties, combat produces disease and injury attrition, and materiel attrition due to accident or lack of maintenance. These losses are distributed at a uniform rate over all units in the simulation, both attacker and defender.

b. A comparison of the "contact" figures in parentheses in Table II-9 with the "noncontact" figures shows that the effects of attrition from non-combat causes are inconsequential for short periods. However, for prolonged tactical actions the noncombat attrition rate becomes an influential factor in the computation of combat values. The overall noncombat attrition figure currently used in the model is about 2.4 percent per 14-hour combat day.

TABLE II-10 — COMBAT DAY ATTACKER ATTRITION PERCENTAGES

RESISTANCE	TYPE TERRAIN		TYPE ACTION	ARMOR		INFANTRY	OS ARTY.- HV. MORTAR		G S ARTILLERY		OTHERS
				TANKS	PERS	PERS	TUBES	PERS	TUBES	PERS	PERS
FR > 5:1 LIGHT	OPEN	A	ATTACK	(11.2)							
	MOD OPEN	B	"	(9.8)							
	MOD CLOSE	C	"	50 (8.4)	3.00	3.36	(8.3)	2.40	*	(2.40)	2.40
	CLOSE	D	"	(7.0)	(4.20)	(4.70)		(3.36)			(3.36)
	RUGGED	E	"	(5.6)							
4:1 < FR ≤ 5:1 MODERATE		A	ATTACK	(16.8)							
		B	"	(14.2)							
		C	"	50 (12.6)	3.00	3.36	(10.3)	2.40	*	(2.40)	2.40
		D	"	(10.5)	(7.98)	(9.00)		(3.36)			(3.36)
		E	"	(8.4)							
3:1 < FR ≤ 4:1 HEAVY		A	"	22.4							
		B	"	(19.6)							
		C	"	50 (16.8)	3.00	3.36	(12.4)	2.40	*	(2.40)	2.40
		D	"	(14.0)	(10.64)	(14.11)		(3.36)			(3.36)
		E	"	(11.2)							
2:1 < FR ≤ 3:1 (V HEAVY)		A	"	(28.0)							
		B	"	(24.5)							
		C	"	50 (21.0)	3.00	3.36	(16.6)	2.40	*	(2.40)	2.40
		D	"	(16.5)	(13.32)	15.00)		(3.36)			(3.36)
		E	"	(14.0)							
FR ≤ 2:1 (V HEAVY)		A	"	(28.0)							
		B	"	(24.5)							
		C	"	50 (21.0)	3.00	3.36	(16.6)	2.40	*	(2.40)	2.40
		D	"	(16.5)	(13.32)	(15.00)		(3.36)			(3.36)
		E	"	(14.0)							

*No entry required.

4. Effects of Attrition. - Unit performance is a
direct function of the amount of accumulated attrition
that the unit in question has received since the
beginning of the action. The unit performance for
various types of units versus the amount of accumulated
attrition that it has received is given in Table II-11.

        (1). To apply, multiply current combat value
by performance factor.

        (2). When performance factor reaches zero,
unit is ineffective; combat value = 0.

        (3). This performance factor must not be
confused with combat value computations. This is a
factor that degrades computed current combat value, due
to lowering of the efficiency of the unit caused by the
loss of personnel and operations equipment necessary
for the delivery of the combat power that the unit has
available.

                TABLE II-11, Unit Performance Factors

% Accumulated	Armor		Infantry		Artillery	
attrition	Atk	Def	Atk	Def	Atk	Def
0-5	1.00	1.00	1.00	1.00	1.00	1.00
5-10	1.00	1.00	0.90	1.00	1.00	1.00
10-15	1.00	1.00	0.80	0.90	1.00	1.00
15-20	1.00	1.00	0.60	0.80	0.90	0.90
20-25	0.90	1.00	0.50	0.70	0.90	0.90
25-30	0.80	1.00	0.	0.60	0.80	0.80
30-35	0.70	0.90	0.	0.50	0.80	0.80
35-40	0.70	0.80	0.	0.40	0.80	0.80
40-45	0.60	0.70	0.	0.	0.60	0.60
45-50	0.60	0.60	0.	0.	0.60	0.60
50-55	0.50	0.50	0.	0.	0.50	0.50
55-60	0.50	0.50	0.	0.	0.50	0.50
60-65	0.	0.	0.	0.	0.	0.

        NOTE: Table contains examples only. Protect
decimal with zero when not preceded by another number.

5. Application of Attrition

a. Table II-10 provides the attrition data manipulated by the tactical model during the tactical simulation. Attrition starts at combat time zero (at the line of departure) and accumulates with combat time. Attrition varies with terrain and force-ratio. The attrition rate, both materiel and personnel, is determined at the beginning of each simulation time cycle by application of data derived from Table II-10. Casualties and damage are then computed and applied against the combat value of each unit.

b. Terrain classification for each five-minute cycle is taken as the terrain of the grid square in which the unit is located at the beginning of the cycle. This classification is simulated for the entire five minutes although the unit may enter another type terrain during this period.

c. The force-ratio for each time cycle is computed at the beginning of the cycle from current combat values and close combat fires received.

6. Attrition of Front Line Units

a. Two subroutines work together to simulate attrition and movement of front line units. One determines the more immediate results of the clash of opposing ground units by determining attrition and a current velocity for the unit. The second then finds a new location for the unit. Each minute the first subroutine computes for each company-sized front line unit: (1) its attrition rate, (2) its movement rate, and (3) as a result, computes for each unit its cumulative attrition, its move rate for the next minute, changes in status governing the generation of a message to the next higher headquarters, and its current total strength.

b. The first subroutine sweeps on a one-minute cycle all front line battalions or similar combat groups, and picks up all company-sized units in each group that are not in reserve status, and determines for each unit whether it is or has recently been under artillery fire. If so, the unit's combat effectiveness as affected by suppression from this fire is ascertained.

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c.   The unit is next tested for force against it.
If non-zero, the unit's current total strength or
combat value and effectiveness are looked up. Force-
ratio and attrition rate are computed.

7.   Attrition of Pattern Units

a.   A subroutine simulates the attrition of all
units which are not front line units from all causes
except artillery fire. It calculates current rates of
attrition on these units and revises their current
strength (combat value) accordingly.

b.   On a five-minute cycle the subroutine sweeps
each pattern and within each pattern sweeps each of its
units. If the unit is a front line unit, it is
ignored, since its attrition is accomplished by the
one-minute cycle. If the unit is not a front-line unit, the
noncombat attrition rates are applied.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 8
CONTACT

1. General Concepts

    a.   The simulation by the model of two very
important aspects of ground combat, direct fire and
intelligence acquisition by short-range surveillance
devices, depends on the determination of which pairs of
opposing units are in contact. Using a list of these
pairs, the firesplitting submodel allocates direct
fire, and the short-range surveillance submodel
acquires intelligence.

    b.   The contact submodel does not assume contact
to be symmetrical; i.e., unit A in contact with unit B
does not necessarily imply unit B in contact with unit
A. This means that the number of possible pairs is the
product of the number of attacker units and the number
of defender units. Examining each of these pairs to
determine which are in contact would be a rather time
consuming task even on a high-speed computer, so the
contact submodel was constructed in such a way as to
reduce the number of pairs which must be handled.

    c.   This reduction is accomplished by dividing
each side into sets of relatively small numbers of
units, determining which of these opposing sets are in
contact, and then examining pairs of units from pairs
of sets which are in contact. These sets are of two
types, groups and patterns.

2. Pattern-Group Contact

    a.   Pattern-group contact is determined once every
fifteen minutes of game time. A pattern-group pair is
considered to be in contact if the perimeters are
within range or could be within range with fifteen
minutes of movement.

    b.   Group centers are recalculated every minute of
the game as the center of gravity (average of the
coordinates of front line units in the groups). Thus,
if a group has only one unit up, the group center is

located at that unit; if it has two up, the center is
half way between the units; etc.

c.   The radii of patterns and groups are contained
in input lists. A group radius could be chosen as the
radius of the smallest circle capable of enclosing the
perimeters of all committed companies in the group when
the maximum number are committed. Pattern radius
should be chosen as the radius of the smallest circle
capable of enclosing the perimeters of all uncommitted
companies in the pattern when the minimum number are
committed. Figure II-2 represents pattern and group
deployments which determine radii. In many cases it
may be possible to locate pattern centers relatively
close to the front of the pattern and choose the radii
to enclose only the most forward elements of the
pattern on the grounds that the most remote elements
are unimportant from contact considerations.

ARTILLERY PATTERN AND RADIUS; BATTALION PATTERN AND GROUP
AND RADII, ONE COMPANY UP

BATTALION PATTERN AND GROUP WITH RADII, THREE COMPANIES UP
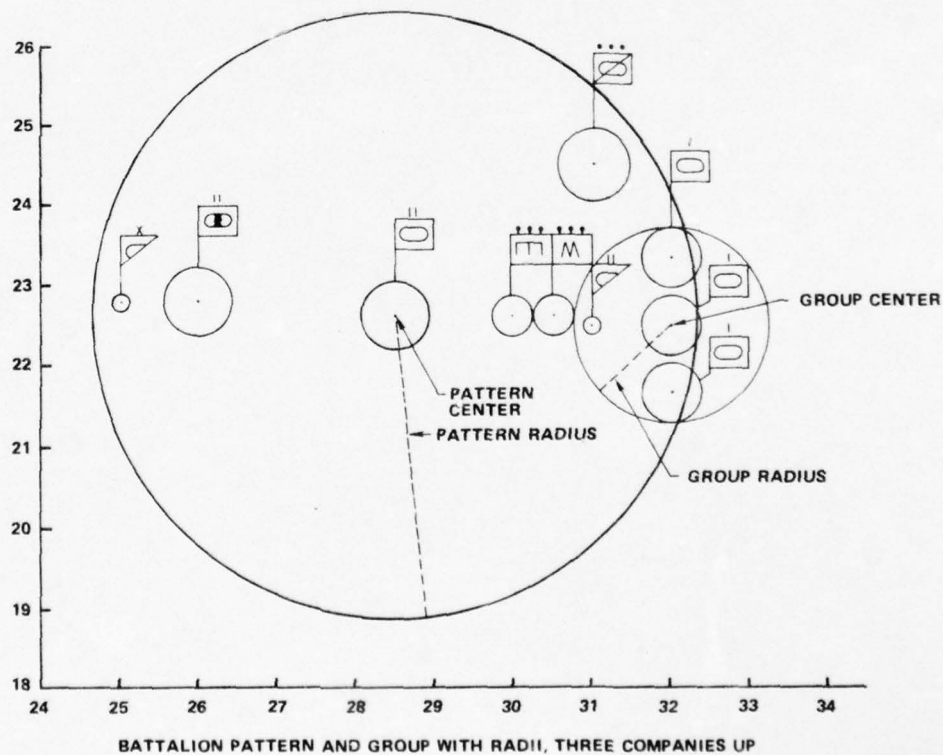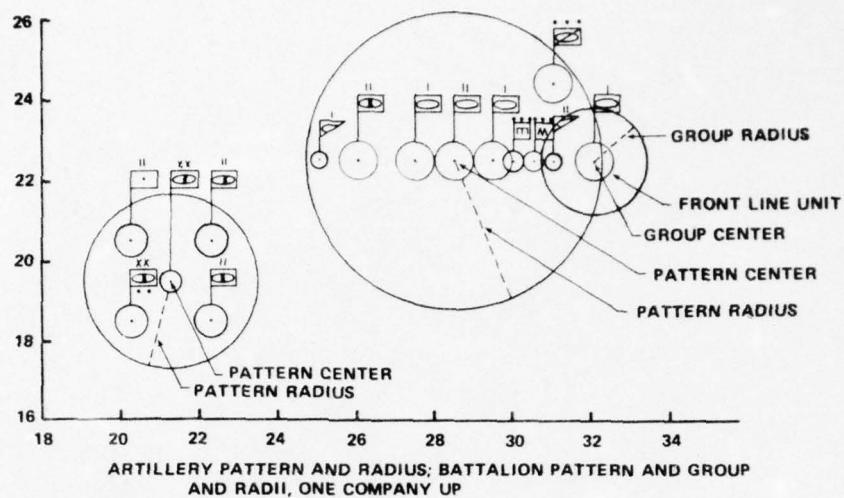
FIGURE II-2, Relationship of Pattern Radius to Group Radius

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d.   The distance a pattern or group could move in fifteen minutes is the maximum distance a continuously moving pattern could move in fifteen minutes. This seems to be an adequately large value, although it hasn't been studied in detail. The only case in which it would seem to be too small would be where the defender has units in bounding patterns which may occasionally get close to the front lines. If such a condition does exist, then it would seem advisable to increase this constant by the length of bound of these patterns.

e.   Figure II-3 is an illustration of pattern-group contact.

f.   For each group and pattern a list is kept, the contents of which are indices of other groups and patterns with which it is in contact. The list is symmetric in the sense that if A is in contact with B, then B is in contact with A. Stored with each index is a flag to indicate whether the index is for a group or a pattern, and the center-center distance.

g.   To conserve storage in the computer, it may be necessary to restrict the size of these lists. The possibility of some of these lists filling up complicates the contact algorithm, which otherwise would be trivially simple.

h.   When a group-pattern pair is found to be in contact, a check is made to determine whether the list for either is full. If so, the center-center distance for this pair is compared with the maximum such distance stored in the list. If the distance for this pair exceeds the maximum, this pair will be dropped from the contact lists. Otherwise it replaces the pair which had the maximum distance. In order to keep the lists symmetric, the other entry on the "bumped" pair is also removed. Processing of pairs is done in this order:

(1)   Attacker groups and defender groups

(2)   Attacker groups and defender patterns

(3)   Attacker patterns and defender groups

(4)   Attacker patterns and defender patterns.

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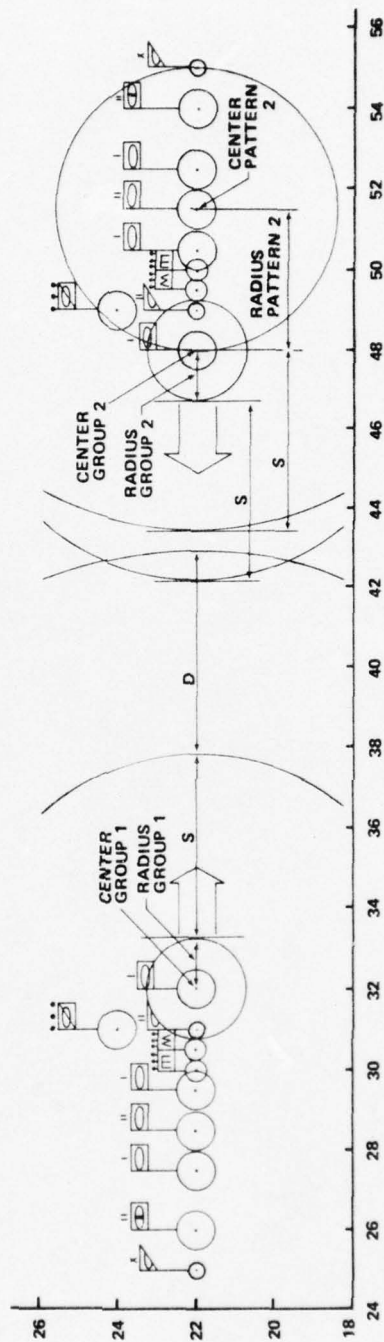
GROUP 1 WILL BE CONSIDERED BY THE MODEL AS IN CONTACT WITH GROUP 2, BUT NOT WITH PATTERN 2. S (DP15) IS THE DISTANCE A GROUP OR PATTERN CAN MOVE IN 15 MINUTES : D (PTRN) IS THE RANGE OF SHORT-RANGE SURVEILLANCE DEVICES OR DIRECT-FIRE WEAPONS.

FIGURE II-3, Test for Pattern-Group Contact

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3. Simulation Rules for Units in Contact

   a.   The leading task force of each attack column is in contact.

   b.   All units organic, attached, or in direct support of a task force in contact, are in contact.

   c.   All direct support artillery and heavy mortar units are in contact.

   d.   All units falling under the "contact" category of rules (a), (b), or (c) above absorb combat attrition. (See Table II-10, Section 7. Attrition rates within parentheses apply.)

   e.   All other units of the division absorb only non-combat attrition. (See Table II-10, Section 7. Attrition rates without parentheses apply.)

CHAPTER II
THE TACTICAL SIMULATION

SECTION 9
SURVEILLANCE AND INTELLIGENCE

1. Combat Surveillance Activities

    a.   Battlefield surveillance activities require
communications to transmit information to proper
headquarters for evaluation and action. To disseminate
the intelligence thus gathered generates more
communications requirements. The performance of the
signal system that transmits these messages is in turn
reflected in terms of tactical outcome by such factors
as timeliness of artillery fires, reserve movements,
warnings of enemy action, and other tactical actions
that depend on combat intelligence.

    b.   It is not a requirement of the tactical model
to simulate surveillance systems for purpose of
comparison or evaluation. To do so would require much
greater detail in input data and more comprehensive
simulation routines than are provided in the
surveillance and intelligence submodels. It is,
however, necessary to generate communications that
result from surveillance activities, and the tactical
model must have the capability to react to intelligence
the surveillance system provides.

    c.   The tactical model simulates short range and
long range combat surveillance. Each type of
surveillance is simulated by a separate set of
subroutines.

    d.   Short range surveillance is conducted by front
line units in contact with the enemy. These units are
given a surveillance index of 1. They observe from the
ground, using field glasses, BC scopes, etc. Artillery
and mortar FO are the chief source of information from
units with surveillance index 1.

    e.   Long range surveillance is simulated by two
subroutines. These subroutines extend the surveillance
deeper into the enemy territory by means of air
observers, ground OP with radars, and other equipment

and techniques that gather information on enemy locations that lie beyond short range surveillance capability.

    f.   Surveillance equipment is simulated as listed in the appropriate TOE. This equipment is deployed among the units of both combatants and assigned a surveillance index according to the surveillance capability that the equipment or activity represents. The deployment of this equipment, and in some cases the surveillance capability, is largely a matter of professional judgment.

2. The Simulation of Intelligence

    a.   The proper conduct of combat tactics depends strongly upon knowledge of the dispositions, strength, quality, and intentions of the enemy. Because its acquisition, interpretation, and dissemination rely heavily upon communications, these activities are represented in substantial detail in the simulator.

    b.   Intelligence can be treated effectively in terms of its end products, which are to increase the effectiveness of fire on the enemy and to permit the selection of tactically sound maneuver. No perceptible loss of tactical validity is incurred if the intermediate mental stages of information processing are simply assumed to occur in the minds of those combat personnel concerned. The model is restricted to the acquisition of information in a generalized sense, its transmission, and its direct application to fire and movement in some abstract numerical form. Thus, the specific interchange and interpretation of the voluminous minutiae of data which normally flow through channels, which are abstracted into concepts like the enemy order of battle, and which then become the basis for tactical decisions are avoided in the simulation and replaced by the following assumptions:

    (1)   The more that is known about the enemy as a target, the more likely he is to be fired on by artillery.

    (2)   The more that is known about the enemy, the more likely commanders are to act promptly.

c.   This list of uses of intelligence obviously does not exhaust the possibilities; for example, no use is made of intelligence in selection of lines of departure or intermediate objectives, nor in varying the sequence of commitments, all of which are formalized in this simulation in order to reduce variability which tends to obscure small effects in communications systems changes. The list is consistent, however, in that communications events interplay with tactics so that an improvement in the one causes a parallel improvement in the other. As long as there is at least one such phenomenon in the model, the objectives are satisfied.

d.   Since there is assumed a direct correlation between information about the enemy and tactical effectiveness, it suffices to treat intelligence and all its manifold associated activities as a dimensionless number between zero and one, which increases with acquisition of knowledge (or facts) about the enemy, and decreases with time as its pertinence declines, and to tie this number to an enemy unit and a friendly intelligence agency. Thus, if friendly CP(i) knows something about enemy unit (j), this knowledge is represented in (j's) column in the intelligence log of (i) as a number between 0 and 1. When those functions of (i) which depend on (i's) knowledge of (j) are more effectively or soundly carried out, the closer the value of the intelligence factor stored in (i's) log about (j) is to 1.

e.   Intelligence in this abstract numerical form originates at units in contact with the enemy or equipped with a surveillance capability. Set originally (at the game's beginning) at a level corresponding to the estimated level about the enemy that would be known at that time, the values are incremented with time, representing the fact that information about and understanding of the intentions of the enemy units tend to increase as the period of observation increases. Obviously, the more that is known about the enemy, the smaller will be the increment of new information gained in any unit of time, so that when "everything" is known, no amount of "new" information can be gained. We limit the intelligence factor to a range of 0 to 1.

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f.   The value of intelligence is not realized
tactically until the information is transferred to the
component which acts or functions as a result of the
intelligence, namely, the command decision personnel at
artillery FDC's and command posts. It is against this
requirement for the prompt and regular transmission of
intelligence messages that the performance of the
communications system is measured. Thus, the simulator
must reflect the development of needs to transfer this
information and the effects of the completion of the
transmission. As mentioned above, there exists in the
model a set of intelligence logs or other storage
locations, one for each intelligence-using element on
each side, and within each log a space assigned to each
enemy unit, in which the present level of the
intelligence on that enemy unit known by that user is
stored.

g.   If at any time intelligence level on any enemy
unit in one log (A) exceeds by a specified amount the
level in the appropriate successor log (B) (the one to
which A normally reports), then a message is generated
from A to B. When the message is delivered, all the
entries (i.e., for all enemy units) in B's log are set
to the higher of the two values.

h.   In this fashion the information flow from log
to log is simulated, with the result that under
conditions of perfect communications, no log about a
given enemy unit differs from another by more than the
difference specified, plus the amount one level may
have been decreased by the operation of one of the
"fading" routines since the last time the transfer
process was considered. The "fading" routines decrease the
value of stored intelligence as time elapses.

i.   When intelligence transfer messages are
received at the successor log, the difference between
the intelligence levels in each log can be considered
new data to the log containing the lowest value
and is therefore transferred directly across without
"merging". Where information is transferred up from
front line observers or long-range surveillance

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sections (drones, radar, air OP, etc.), a merging process is carried out.

j. The justification for reducing the increment by an amount representing that part of the increment already known is somewhat obscured by the fact that the sender will not ordinarily repeat himself, and further, that a repetition of information already transmitted constitutes a form of information in itself (e.g., "the enemy components are still in the area"). However, if we consider what occurs when this information arrives, we see that a "shaking down" or abstracting process takes place in the mind of the receiver. That is, the intelligence level, say at battalion, about a given enemy unit is numerically perhaps the same value as that at one or more F.O.'s or air OP's or at its company CP's. But it is obvious that if there is more than one source of information, the battalion value represents an enriched or broader view of the situation than either of the two direct observers can have independently. Therefore, although the increment received is all new data, its magnitude or significance at battalion is not as great as that at the observer, and therefore it is compressed or "merged" into the battalion log value.

k. Hardware or activities that are the raw material for intelligence messages do come into the simulation in terms of visibility and importance factors which determine how large the increment about a given unit will be during the observed time, given a specified surveillance capability, distance away, terrain and the like. Thus, a fourth tank in an open village will provide effective intelligence about a tank company every cycle time. As the intelligence level builds up, the added intelligence gets smaller, so that the fourth tank may be represented as the increment gained in the fourth cycle time. If the unit observed is large enough, the first periods of observation will provide steps which represent almost equal objects, so when it has a level of say .15 this can be said to represent 3 of a 20 tank company. During the fourth cycle time its level will be

$$.15 + .05 - (.05)(.15) = .1925$$

or an increment almost equal to the value of the first tank.

l.   To the observer this is an important item to be forwarded to his headquarters, but to the S-2 whose intelligence on the unit may be .65, the receipt of a message containing .0425 information, all of which is new to the observer, becomes

$$.65 + .0425 - (.65) (.0425) = .6649$$

or in effect the S-2 has only increased his own knowledge by .0149 about this unit.

m.   To avoid confusion, let it be restated here that information up from originators (F.O.'s, etc.) to logs depends on the increment in the F.O.'s own log. When information is transferred among logs, the amount transferred to the recipient is exactly the difference between the logs, provided the sender's level is greater than the recipient's. In the example above, if an FDC log had a level of .69 on the enemy unit, it might send a message to the battalion, in which case the battalion log would be stepped to .69. A diagram on the relationships is given as Figure 1.

n.   Fading, mentioned above, represents the obvious fact that the reliability of intelligence decreases with the passage of time. If at any time t , a level I(i,j) exists at unit i (or log i about enemy unit j), and if during an interval no further information is received, then at time t + t,

$$I(i,j,t+ t) = I(i,j,t) (F)^n \qquad (2)$$

where F = the fraction of the original still good after 1 minute,
            and

        n = the number of minutes between "fades".

o.   In some modules F is programmed as (1-G), where G is a small number (like .002). Otherwise F is a number close to 1 (like .998). In other cases, the value of F is pre-computed as H^m where H is the one-minute rate and m the cycle-time of the module. Then the program computes only the product.

p.   Different fade factors are used in various parts of the simulator representing the fact that the effective level or nature of the intelligence at the

various logs will vary. For example, the fade rate of intelligence at artillery FDC is greater than at division headquarters because the effectiveness of artillery is greatly dependent on a knowledge of location of the target. If the latter is moving irregularly, then an artillery barrage based on slightly aged information can miss the target completely. As it happens, the model simulates this phenomenon in a roundabout fashion, since an enemy unit must be considered a suitable target before a mission can be called. The suitability in turn depends on the intelligence level of the target unit at the appropriate FDC. Further, the damage brought on the target by the fire mission if the unit is fired on is proportional to the intelligence level.

q. In the case of the division CP, the information pertinent to larger scale tactical decisions does not lose its value as rapidly, so that the fading coefficient is closer to 1. On the other hand, information does not accrue so rapidly since the transfer differential cutoff is usually larger. In any event, all of these values are input parameters and may be adjusted to develop communications and tactical event patterns which meet standards of realism.

3. Contact Intelligence

a. It may be presumed legitimately that a unit close enough to an enemy to apply fire is also close enough to make some estimate of its strength, composition, role (or activity), and location. While the information gathered by observation may be sketchy at the first moment of contact, as the battle or fire-fight progresses, more and more information is gathered until at some time a fairly accurate description of the locally opposing force can be made. Included in the sources of intelligence at this level are artillery forward observers and outposts.

b. The intelligence (or more precisely the information) gathered at this level is ordinarily used in three ways:

(1) It serves as a basis for fire and maneuver of the front line unit itself.

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(2) It is forwarded to battalion headquarters, where it is assimilated, interpreted, and used as a basis for battalion level decisions (at which point it can be said to become intelligence).

(3) It is forwarded to the appropriate FDC, where it constitutes the basis for fire mission decisions.

4. Long Range Surveillance

a. Two subroutines simulate the acquisition of intelligence about enemy units behind the line of contact. This information is gathered by surveillance radar and photo reconnaissance.

b. Each of the surveillance equipment types is defined by a set of values representing its ability to acquire useful information about enemy units. This acquisition rate is determined by the long range surveillance device capability as a function of observer type, e.g., radar, mortar locator, and as a function of range of the device, the terrain of the observer, the terrain of the object, the strength and type of the observed unit, and the distance apart.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 10
CLOSE COMBAT FIRES

1. Introduction

    a. In the tactical model the simulation program
includes techniques designed to distribute the fire
from direct fire weapons on enemy targets according to
range, strength, and target suitability. The purpose
of this distribution of fire (called fire splitting) is
to obtain greater combat realism in the comparison of
opposing force-ratios.

    b. Force-ratio is a basic factor in the
simulation for computing movement rates, attrition, and
deployment, and it enters many other aspects of the
tactical simulation. Without a realistic comparison of
opposing fire strengths, the computer will not create
an acceptable flow of combat action; and without a
combat-realistic distribution of fire, the computer
will not have realistic force-ratio data.

    c. The fire splitting routine distributes the
fire of the various type weapons of both combatants on
the available targets. By this routine, the computer
is enabled to simulate the distribution of fire over
the battle area in a manner that approximates the

2. The Fire Splitting Routine

    a. Fire splitting is a complicated computer
operation. It involves weapon ranges, proximity of
targets, suitability of targets, and characteristics of
weapons. These factors must be reduced to simulation
data and rules by which the computer distributes the
available fire onto the available targets. All of it
must be adapted to the fire splitting routine.

    b. When two forces meet in combat and begin to
shoot at each other, there is normally a matching of
the weapons on one side to the targets on the other.
This matching attempts to assign each target type the
weapon most likely to successfully destroy that target,

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so that the total damage to the enemy caused by all the weapons is maximized.

c.   The factors considered in this matching process are the number and types of weapons available, their ranges, and more particularly, the vulnerability of a given target to a given weapon. Thus, while anti-tank weapons can destroy infantry as well as tanks, light machine guns are not very effective against tanks, so ordinarily the antitank weapons would be applied to armored vehicles and machine guns to infantry.

d.   Further, if the enemy presents two targets of different types at different locations, the fire of the friendly side is divided proportionate to the threat posed by, and vulnerability of, the targets, and according to the desirability of the enemy unit as targets for each friendly weapon.

e.   This process of allocation is called fire splitting and is simulated by a subroutine. The output of the subroutine is a number for each unit, called AFOR, which describes quantitatively the amount of fire that the unit in question is receiving from all the enemy weapons with which it is in contact that appear in the enemy's strength vector. Fire from artillery is considered by another set of subroutines, (See Section 11, Artillery.)

f.   The value of AFOR is used in subsequent subroutines to determine attrition and force-ratio, which in turn determine move rate and indirectly, maneuver and command decisions.

3. General Description

a.   The first function of the subroutine, apportionment of fire among opposing units, reflects the ground combat observation that a unit armed with various types of weapons and confronted with two or more units within range will allocate a greater volume of fire against that enemy unit

(1) whose composition type offers the more remunerative targets for the firing unit's weapons (antitank weapons seek tanks, machine guns seek infantry, etc.),

(2) which is of greater strength (a larger unit presents a more attractive target and a greater potential danger), and

(3) which is nearer (threat increases with proximity).

b. That is, the volume of fire which a particular unit among others in range receives from a specific weapon in a given enemy unit is directly proportional to both the unit's target suitability for that weapon and its total strength, and inversely proportional to the distance between the unit and this enemy weapon.

c. After the proportions of the fire from the weapon of the given enemy unit have been calculated for each opposing unit in range of the weapon, the proportions are converted into combat values or firepower by multiplying by a constant which represents the combat value of the type of weapon against the type of unit and multiplying that by the number of weapons the enemy unit has of this type.

d. The effectiveness of this fire is influenced by a number of factors related to the attitude and the posture of the firing unit, suppression by artillery fire, and exposure and vulnerability while firing. The resultant of these factors is called "effectiveness" and is the product of:

(1) any suppression the firing unit may be undergoing as a result of artillery fire,

(2) its position effectiveness as a function of its unit mode, as attack or defense,

(3) its effectiveness as a function of the mode of its group, as hold, yield, etc.,

(4) its fighting efficiency as may be affected by casualties, and

(5) the degree of support the unit has received from rear echelon elements, in turn an indirect function of the performance of the communications system.

A0316

1.0   4.5   2.8   2.5
      5.0
      5.6   3.2   2.2
      6.3
            3.6
1.1   4.0   2.0

                  1.8

1.25   1.4   1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

e.   All the fire put out by each type of weapon of
a unit is multiplied by this unit's effectiveness.

f.   Similarly, each remaining weapon of the firing
unit may be taken in turn and the allocation of this
weapon's fire on opposing units within range
determined. The fire of each such weapon is
accumulated for each unit affected in a temporary list
called FCON until all weapons and all units in contact
have been processed. Thus, after the above process has
been completed, FCON contains for each unit in contact
a list of the units with which it is in contact and the
fire from each.

g.   The second function of the subroutine is to
combine the FCON entries for each unit to obtain the
total fire it is receiving. If there is no
coordination between the units firing on a given unit,
the entries are simply added to get the total fire.

h.   In combat it is generally true that the effect
of the combined fire of two units on an enemy unit is
heightened if the two units are coordinating their
fire. This is played in the model by coordination
messages between adjacent front line units of a
battalion. (NOTE: Coordination messages are only sent
between units in a single group, not between groups.)

i.   A list of coordinating pairs of units and of
coefficients indicating the degree of coordination is
maintained by the command decisions submodel.
Corresponding to this list of coordinating pairs is a
list of coordination coefficients indicating the degree
of coordination which exists between the units of a
pair. This latter list is updated during play.

j.   A coordination coefficient of zero is used to
indicate perfect coordination and one to indicate
complete lack of coordination. Subroutine INTCO
increments all coordination coefficients every minute;
when a coordination coefficient is first found to
exceed a cutoff, a message is generated between the
units. When the message is completed, the coordination
coefficient is reset to zero.

k.   Thus, the fire from a pair which has perfect
coordination will not be reduced at all; non-zero
coordination coefficients result in some reduction in

firepower.   (There would appear to be a minor flaw in
the logic at this point: a unit receiving fire from
flank units of two adjacent battalions will receive the
full effect of their fire, since coordination is only
played for units of the same battalion; on the other
hand, if the same unit should happen to be receiving
fire from two equivalent units in similar situations
but in the same group, this fire will be smaller,
having been degraded somewhat by the coordination
coefficient.   This would not appear to have any clear-
cut effect on the evaluation of signal systems, but it
might increase the model's variability somewhat.)

CHAPTER II
THE TACTICAL SIMULATION

SECTION 11
ARTILLERY

1. General Discussion

a.   Artillery receives a detailed simulation in
this tactical model. The reasons are discussed below.

b.   A tactical model is required that simulates
the tactical action of units in sufficient detail to
create a realistic combat environment. It is not the
purpose nor the intent to create a detailed war game,
except when tactical minutiae are essential to the
communications evaluation. Artillery, however, is of
such importance to ground combat that its simulation
must be in considerable detail.

c.   In ground combat it is the mission of
artillery to support, with fire, the action of the
forward combat elements and give depth to and isolate
the battlefield. To accomplish this mission requires
artillery units to acquire targets, communicate, shoot,
and move. To simulate with acceptable realism how
artillery units move and shoot during combat, and
generate the communications necessary to move and
shoot, is the purpose of the simulation routines that
comprise the artillery module of the tactical model.

d.   Artillery units are organic to all types of
divisions. Artillery weapons represent a major portion
of a division's fire power. Often the organic
artillery fire power is augmented by attaching
additional artillery units to divisions for a
particular action. Where this fire (artillery) is
placed, its timeliness, volume, and caliber are often
the deciding factors in the flow of a combat action.
With this in mind it is clear that continuous,
comprehensive artillery simulation is essential in the
tactical model.

e.   The model simulates two types of artillery:
(1) direct support; (2) general support. The
simulation unit is the battalion and the fire unit is

the battery. The model has the flexibility to simulate organic and additional artillery units of any caliber.

f. The artillery simulation routines are designed to bring into the tactical model a continuous, realistic play of artillery during the tactical action, and into the communications model the communications requirements necessary for the artillery to accomplish its tactical mission. Specifically, these routines are designed to simulate the acquisition of targets, the placement of fire on these targets, the assessment of the damage that results from this fire and, of primary importance, to generate into the communications model the communications links the artillery units need to accomplish their mission.

g. Much of the data required by the artillery simulation routines are available from officially published artillery documents. There are, for example, data available from the artillery school documents that list for the various weapons systems, the lethal areas, ranges, rates of fire, etc. Data are available that describe the capability of artillery surveillance equipment, and from the organization and employment of artillery units, data become available for communications requirements.

h. Following is a description of the way the model simulates how artillery shoots. In this section the description of target acquisition, communication, and movement is less detailed, since these functions are treated in depth in other sections.

2. Target Acquisition. - The artillery model has provisions for generating fire missions of two types: targets of opportunity and help missions.

a. Targets of Opportunity

(1) Intelligence

(a) Fire missions for targets of opportunity are generated from the intelligence log of the direct support FDC in the case of direct support artillery and from that of the Divarty FDC for general support artillery. The generation of intelligence is discussed in Section 9, Surveillance and Intelligence. A brief discussion of it will suffice here.

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(b)   Each intelligence log consists of
one number for each enemy unit. This number ranges
from zero (complete ignorance) to one (perfect
intelligence). There are three sources of intelligence
in the model: ground intelligence, intelligence from
long range surveillance devices, and exchange with
other logs.

1.   Ground Intelligence. - In
reality, artillery forward observers (FO's) are in
frequent communication with FDC's, aiding in target
selection, fire missions, fire adjustment, and
supplying intelligence. In the model the intelligence
function of the FO is simulated by having him
accumulate intelligence about enemy units with which he
is in visual (short range surveillance) contact. When
the intelligence he has on any of these units is
sufficiently great, he sends a message to the FDC.
Upon the completion of that message, all the FO's
intelligence accumulation is transferred to the FDC's
intelligence log. For reasons which will be more
apparent when target selection is discussed below, the
process of accumulating intelligence by the FO and
relaying it to the FDC may be regarded as simulating
the FO's target acquisition function.

2.   Intelligence from Long Range
Surveillance Devices. - Aerial observers and long range
surveillance devices are a source of targets and
intelligence for artillery, and in the model this is
simulated by having them represented as separate units,
each with an intelligence log with an entry for every
enemy unit. Associated with each such aerial observer
or long range surveillance device is an intelligence
log to which it reports. This intelligence log may be
(and frequently is) the log of an FDC. A subroutine
checks these surveillance logs, and when the in-
telligence on any unit is sufficiently great, a message
is sent from the unit which has the log to the unit
which has the log to which it reports. When the
message is complete, the intelligence is transferred to
this latter log.

3.   Exchange with Other Logs. - An
important function of a front line unit in combat is to
acquire intelligence for its battalion headquarters.
This function is simulated in the model by subroutine
GNDINF. Artillery liaison officers are maintained in

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supported headquarters where they keep their FDC's abreast of tactical developments, coordinate the artillery effort with the effort of the supported organization, and relay intelligence from the headquarters. Subroutine INTRAN simulates this last function. In addition, it simulates the flow of intelligence between direct support FDC's and Divarty. A pair of intelligence logs (from the ENTPR list) is selected. Then the routine examines the entries for each enemy unit. If there is a unit for which there is a sufficient difference in the entry for that unit in the intelligence logs, then a message is sent from the unit with the surplus to the other unit. When the message is completed, the intelligence from the log of the originating unit is transferred to the log of the other unit.

(2)   Target Selection

(a)   In reality, target selection is based on many considerations, such as need for artillery fire, suitability and availability of weapons and ammunition, range, etc. In the model, most of the important considerations enter directly or indirectly into the process of target selection.

(b)   Direct Support

1.   Selection of targets of opportunity for direct support artillery takes place in subroutine TARGET. Every minute of game time for every direct support FDC, the entry for each enemy unit in the FDC's intelligence log is checked. If the entry on a given unit is greater than zero, if no mission is currently in process against this unit from any of this FDC's batteries and if the time since this unit was last fired on by any of this FDC's batteries is greater than a cutoff, then the unit is considered a potential target, providing there is a forward observer in a position to observe this unit.

2.   The forward observer is regarded by the model as being with the unit which last sent a ground intelligence message to this FDC with intelligence about this unit. Note that if an FDC has received intelligence about an enemy unit only through long range surveillance or intelligence exchange, the unit will never be fired upon as a target of

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opportunity by this direct support artillery unit. If there is a forward observer, the distance from the forward observer to the potential target is calculated as the distance between the perimeters of the forward observer's unit and the potential target, unless the perimeters overlap, in which case the distance is taken to be zero.

_3_. This distance enters into the calculation of the target value of the unit. The target value of the unit is the product of three factors: the intelligence the FDC has on the potential target, a function of the distance mentioned above, and a weight function which depends on the type, composition, and strength of the potential target.

(c) General Support

_1_. In combat, Divarty may occasionally acquire enough intelligence on an enemy unit so that it will order its battalions to fire on the unit if they have an opportunity to do so in between more urgent fire missions. This is simulated in the model. For each Divarty, each enemy unit is checked to see if it is currently being fired on by any of Divarty's battalions or if it has recently been fired on by them. If not, it is examined to determine whether it might be a worthwhile target for at least one of Divarty's battalions.

_2_. For any battalion, if the unit is within maximum range of any of the battalion's batteries, if the target value of the unit exceeds the minimum requirements of any of the battalion's batteries (from the FDC list), and if the battalion has not recently been requested to fire on the unit, a message is sent from Divarty to the battalion and an entry is made on the battalion's help list.

_3_. The distance which is used in the range check is that from the perimeter of the battalion to the perimeter of the unit. This same distance is used in the calculation of target value, the formula for which is identical to that used for the direct support calculation, the intelligence value used being taken from the Divarty log. The help list entry has associated with it a relatively low priority.

_4._   Each battalion which is
emplaced, has batteries available, and has ammunition,
takes entries from its help list in order of decreasing
priority. If the battalion has not recently shot at
the unit and is now shooting at it, the target value of
the unit is calculated as above. If this value is
sufficiently large, the model attempts to select at
least one battery to fire on the unit.

b.   Help Requests

(1)   Direct Support

(a)   Frequently, direct support artillery
is requested to provide fire support to a particular
unit. Currently, the model has the capability to
process such "help" requests.

(b)   When a help request message is
completed, if the direct support FDC is emplaced and
has available batteries with ammunition, the model
obtains the index of the enemy unit which is delivering
the most fire on the unit for which aid was requested.
(This is obtained from the AFOR list.) If this enemy
unit is not currently under fire from this FDC and has
not been under fire from it recently, the model
attempts to select a battery to fire on the enemy unit.

(2)   General Support

(a)   One of the most important missions
of general support artillery is to provide reinforcing
fire for the direct support artillery.

(b)   In the model reinforcing fire is
provided in two ways.

(c)   Type 1. - As explained above, the
target value of a potential target is calculated in the
direct support routine, and in some cases the target
may be passed up to Divarty as a help request. If the
value exceeds a cutoff, the routine checks the
Divarty help list to determine whether there is already
a request for fire against this unit from this FDC. If
not, an entry is made in this help list, and a message
is sent from the FDC to Divarty. The entry contains
the index of the unit to be fired on, the message
number, and the priority which this request should

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have. The priority is also dependent on the FDC. (The
fact that the cutoff and the priority depend on the FDC
means that reinforcing fire can be allocated, to some
extent, to the main effort. This could be done by
making the cutoff for a main effort FDC relatively low
and the corresponding priority high.)

(d) Type 2. - If the target value of a
prospective direct support target is not high enough
for the unit to qualify as a Type 1 target, but the
value is higher than a second cutoff, which depends on
the FDC, and for some reason, such as range, batteries
being occupied, etc., the FDC can't fire on the unit,
then an entry will also be made in the Divarty help
list and a message sent, unless there is already such an
entry on the list.

3. Fire Missions

a. Selection

(1) General Support

(a) Battalion Selection

1. In selecting a battalion to
fire, first a nominal range is determined for each of
Divarty's battalions. This range is the *maximum range*
of any of the battalion's batteries. Next, the model
considers each entry in the Divarty help list for which
the message has been completed.

2. For a given help request,
Divarty examines each of its battalions to determine
which is best suited to handle the request. Battalions
are considered only if they are within range of the
target and have empty slots in the battalion help list.
For a given eligible battalion, its caliber is obtained
from an input list of general support battalion; then
the value of this type of unit as a target for this
type of battalion is obtained from an input list. The
eligible battalion for which this value is highest then
has an entry made on its battalion help list, and a
message is generated from Divarty to the battalion FDC.
Then, if no battalions are found, which can happen if
the only eligible battalions have zero values against
this type of unit, the entry is removed from the
Divarty help list.

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(b) Battery Selection

1. Given that a general support battalion is emplaced, has available batteries, and has ammunition, then the entry with highest priority is selected from its help list. If the message from Divarty to the battalion FDC is not complete, the entry is ignored and the one with next highest priority is taken. In any event, if a help request message has been completed, a check is made to determine whether a mission is currently in process against the target unit or if there has recently been one. If it has, or if an attempt to assign the target unit to a battery is unsuccessful, the request is eliminated.

2. The process of assigning the request to a battery involves calculating target value of the target and comparing this value with an input cutoff. If this is not a worthwhile target, i.e., if its value is less than the cutoff, no battery will be selected. Otherwise the model looks for a battery suitable for firing on this target. This is done by comparing battery weights with the target value. The battery weights are carried in an input list and are selected to prevent batteries from firing on unsuitable targets. Thus, an 8 inch battery might have a relatively high weight, a 105 battery a relatively low one. If a battery can be found with a sufficiently low weight so that it can fire on this target, and if the battery is available and in range of the target, then it is assigned the fire mission, and an entry is made for it on the battalion fire mission list. This entry includes the starting time of the mission, which is the current time plus the battalion's pre-mission delay (from FDC list). The completion time is the starting time plus the battalion's mission length (also from FDC list). After the fire mission has been assigned, the target value is reduced by the weight of the battery, and this new value is again compared with the cutoff. If the new value is still greater than this cutoff, an attempt is made to find another battery (available and in range) with a weight less than the value. If such a battery can be found, its contribution is added to the fire mission entry. This process is repeated until either the value is less than the cutoff or no suitable battery can be found.

(2) Direct Support Battery Selection

(a)　　Targets of Opportunity

　　　　　　　　　_1_.　　In the discussion that follows,
whenever a battery is referred to, the assumption is
that the battery is not currently firing a mission and
has not fired one recently.　("Recently" is defined by
a number in the FDC list and represents time between
missions.)

　　　　　　　　　_2_.　　For each unit that is
considered a potential target and has a value greater
than a cutoff, the model goes through a process
designed to assign the target to a battery and to
attempt to give every battery a target.

　　　　　　　　　_3_.　　This process is accomplished by
making tentative assignments of targets to batteries
and refining these assignments as more targets are
considered.　The batteries without tentative
assignments are examined one by one until one is found
which has a weight less than the value of the target
and a range greater than the distance to the target.
If one is found, the target is tentatively assigned to
that battery.　If not, the batteries are again examined
to determine if a battery in range of the target has a
tentative assignment of lower value than the target.
If one is found, it is replaced by the target and the
process is repeated with the replaced target.
Eventually a set of reassignments is found such that no
further reassignment can be made.　At this point, there
is a target which is unassigned.　Its value is compared
to determine whether it is suitable for a Type 2
request to Divarty for reinforcing fire as described
above.

　　　　　　　　　_4_.　　After all targets have been
processed, an entry is made on the fire mission list
for each battery against its tentative target, and a
fire mission message is generated from the forward
observer to the FDC.　As each mission is put on the
list, an attempt is made to generate a mission against
this target for some other battery which has no
tentative assignment.　This is done by subtracting the
weight of the battery from the value of the target to
obtain a new target value.　If this new value exceeds a
cutoff, the batteries without tentative assignments are
examined one by one, and the first one in range of the
target and with a weight less than the new target value

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is assigned a fire mission on this target. Again a new
target value for the unit is computed, and the process
is repeated until either the new target value is less
than the cutoff or there are no more suitable
batteries.

(b) Help Requests

<u>1</u>.   For an emplaced battalion, with
available batteries and ammunition, a subroutine takes
a help request (an entry from the FDC help list).
The request gives the unit index of the unit to be
helped. If this request is not already being acted
upon, the enemy unit giving the most fire to the unit
to be helped is determined (from AFOR list). If there
is not currently nor has there been recently a mission
from this FDC on that enemy unit, the target value of
the unit is calculated. The distance used is that from
the perimeter of the unit to be helped to the perimeter
of the enemy unit.

<u>2</u>.   Next, the FDC available
batteries are considered one by one, and the first one
in range of the target is given a mission against the
target. A message is generated from the FDC to the
unit at which there is a forward observer (obtained
from the FDC intelligence log).

<u>3</u>.   The target value is reduced by
the weight of the battery to which the mission was
assigned, and the new value is compared to an input
cutoff. If it exceeds the cutoff, an attempt is made
to find another battery as described above, and the
process continues until there are no more batteries or
the target value is finally reduced to less than the
cutoff. As additional batteries are selected, their
contribution is added to the fire mission (an entry on
FMIS list).

b. Firing

(1) General Support

(a) <u>Start of Mission</u>. - If a mission for
a given general support battalion should start the
current minute, the entry on the fire mission list
(FMIS) is modified to indicate that the mission is in
process, and an entry is made in the damage assessment

list. This entry includes the effective intelligence Divarty has on the target and the amount of fire to be delivered.

(b) <u>Mission in Process</u>. - If a mission is in process, an entry in the damage assessment list is made.

(c) <u>Mission Completed</u>. - If a mission was completed the previous minute, the damage assessment and fire mission entries are wiped out, and a list (FDC) is modified to reflect the next time that the batteries will be available (current time plus post-mission delay, the latter also being obtained from FDC list). Then the ammunition level of the battalion is reduced. The new level is the old less the rate of ammunition consumption.

(2) <u>Direct Support</u>. - Direct support fire missions are handled in the same way as those of general support, except that the effective intelligence is not degraded by the unobserved fire factor, since there are (in the model) observers for all direct fire support.

4. <u>Damage Assessment</u>

a. <u>Consolidation</u>

(1) If a unit is being hit by artillery fire from several different missions, the suppressive effect and the damage inflicted are essentially the same as if the fire were from one mission of equivalent firepower. The model simulates this by surveying the damage assessment list to find if there are any targets for which there is more than one entry in the list. If there is a duplication, the second entry is combined with the first and the list is again examined for further duplication, which, if found, results in the duplicate entry again being combined with the (new) first entry.

(2) A damage assessment entry contains (among other things) the intelligence the battalion had on the target at the time of firing and the amount of fire delivered.

(3) The combined entry for fire consists of the sum of the amounts of fire of all the entries on a given target. The entry for intelligence weights the individual intelligence entries by the corresponding amount of fire.

b. **Damage**. - The damage inflicted by artillery depends on the accuracy of the fire, the amount of fire, and the vulnerability of the target. The level of damage is dependent upon the amount of intelligence on the target (from the damage assessment list), the amount of fire which is represented directly (also from the damage assessment list), and the target vulnerability which is directly proportional to the strength per unit area of the target and is influenced by the unit type and whether it is attacker or defender.

c. **Suppression**

(1) An important effect of artillery fire on a target unit is its suppressive effect on the unit's movement and firepower. This effect may persist for some time after a fire mission.

(2) In the model this effect is played by using a pair of numbers for each unit (the CEF list). These numbers are the suppression factor and the time applicable. They are applied against unit move rates, the direct fire allocated, and the artillery fire (for artillery units). If the time applicable exceeds the current game time, the suppression factor multiplies the move rate of the unit, the direct fire it delivers, and, if it is an artillery unit, the artillery fire it delivers.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 12
COMMAND DECISIONS

1. Introduction

a.   Command decisions are difficult to program
into a computer simulation. Decisions are continuous
at all levels of command during tactical operations and
involve many factors that must be reduced to computer
rules or mathematical formulas. However, decisions
activate the tactical simulation and therefore are a
part of the tactical model.

b.   The question then arises how tactical
decisions can be initiated and reflected in the
tactical simulation. These decisions must motivate the
tactical play, hold the action to operational
procedures, and create a tactical environment with
sufficient detail to meet requirements. To answer this
question we must examine the part which the tactical
simulation plays in the combat simulation model.

c.   A combat simulation model is not required that
permits evaluation of tactics or tactical decisions.
It requires a tactical simulation that permits
evaluation of the signal system. Its sole purpose is
to evaluate the performance of the signal system that
supports the tactical action. The tactical simulation
must bring into play the communications requirements
that each tactical situation requires.

d.   Communications are required to initiate the
need for a decision and, having made the decision,
communications are required to execute the decision.
The tactical simulation must bring into play these
communications requirements. For this purpose the
model uses computer techniques that stimulate and
direct the tactical action along sound tactical
courses. These simulation techniques must bring into
play the tactical actions that require communications
to execute. The decision itself is of no concern. It
must be tactically reasonable.

e.   Following this philosophy, the tactical
decisions can be very stereotyped. The personal

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characteristics of commanders are entirely erased. No element of choice enters the decision making process. All commanders react entirely according to the tactics of the combatants under simulation. The tactical situations, as they develop during the computer simulation, force all command decisions, according to rules that keep the tactical simulation within tactical capability. Command decisions, as such, are submerged in the movement, fire support, and force-ratio (FR) routines. The tactical simulation thus exploits each tactical situation according to the tactical capabilities of the opposing forces, and exposes the tactical situation to communications requirements and performance evaluation. Obviously this type of tactical simulation falls short of war gaming tactics, organization, weapons, and many other aspects of tactical operations, but it exposes for communications evaluation the performance of the signal system that supports a tactical operation.

f. Combat patterns, attack or defense, provide the computer with simulation techniques that give the combat action deployment and dynamics, and generate communications and command decisions. Each change in the combat patterns, manipulated according to fundamental rules of combat that fit the tactical situations as they arise during the simulation, reflects command decisions. Although the change in the combat pattern is initiated in the computer by the force ratio (FR), in the computer simulation the commander's decision is automatic, but it cannot be made until he is informed (by necessary communications,), nor can his decision be executed unless the necessary communications exist. Thus, changes in combat patterns generate communications and reflect command decisions. This simulation technique extends through all echelons of command and involves committing reserves, manipulating fire support, and acquiring intelligence.

2. Commitment of Reserves

a. In combat, decisions depend on many factors, some of which can be measured in terms of terrain, weapon strength, and combat intelligence, but there are also many intangibles.

b. In the tactical simulation the decision to commit reserves is achieved by manipulation of data in the decision routines. These data, manipulated according to the simulation routines, enable the computer to arrive at a force ratio comparison of the opposing forces, and again by comparison of this FR with other input data the computer arrives at a commit decision. The decision results entirely from the manipulation of input data. When the decision is made, the reserve reacts according to input data and simulation routines that move it to its desired location. Thereafter the unit reacts according to the regular movement routines.

c. In this tactical model reserves are committed at three (3) echelons of command:

    (1)   Battalion or task force level

    (2)   Brigade or regimental level and

    (3)   Division level.

3. Description

a. It usually becomes necessary for commanders to support the attack or defense by the commitment of reserves, to regain committed reserves once a local point of resistance is reduced, and to maintain close coordination with subordinate, adjacent and superior echelons of command through the transmission of status reports. The command decision package carries out these functions by simulating the actions and decisions of the commanders at battalion, brigade, and division level.

b. The decision routines are run in a sequence and cycle time. The routines function as pairs, the longer cycle routine making the decisions, the shorter cycle routine checking delivery of the generated messages and carrying out the decision when the appropriate messages are complete. Decisions at each echelon are generally dependent on the delivery of status reports from subordinate headquarters, so that significant leverage is applied to tactics by failure of communications.

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4. Decisions at the Battalion Level. - A routine simulates the decision of the battalion commander of a committed battalion to commit his reserve (if designated) on the basis of the battalion force-ratio, the timeliness of status reports from his companies, his mission, and his location.

5. Decisions at the Brigade Level

a. Decisions at the brigade level (BGE) follow generally the pattern at battalion level. The critical communications at brigade level that are related to this commitment are: the gathering of intelligence about the enemy, the receipt of status reports, notification for supporting elements of his actions and plans, and finally the command ordering commitment of the result.

b. The brigade decision package consists of two subroutines that perform the following functions:

(1) Keeps track of the condition of each battalion and generates status report messages from battalion to brigade, (a) continually if the battalion is in trouble and (b) otherwise periodically.

(2) Orders the reserve battalion into the attack by a commit message if the brigade is in the attack or, if the brigade is withdrawing, orders the reserve battalion into a blocking or counterattacking role if the attacker is approaching ground desired to be held.

(3) Selects a line of departure to a preassigned objective and arranges for the notification of subordinate units of the move to the line of departure by triggering another routine.

(4) Causes battalions in retrograde and attack to enter the hold mode when they have reached the end of their routes.

(5) Causes the selection of a route from the line of departure to the objective.

(6) Sets up the order of battle for the battalion elements, i.e., sequence for commitment of reserve battalions.

(7)   If a reserve brigade is under examination, accepts the commitment order from division and generates orders to his battalions to advance to the line of departure and enter the attack.

c.   The commitment rule for the attacker is one-dimensional. A check is made every 15 minutes of the resistance that the brigade is meeting in terms of its own strength and the strength of nearby and resisting enemy units about which sufficient intelligence has been acquired. When it becomes obvious that the resistance will cause the momentum of the attack to drop below an acceptable level, the commitment sequence is initiated. The condition of the brigade main attack is usually considered paramount, and in fact another battalion will not be committed unless the main effort battalion has committed all its companies, but the degree to which it and the supporting efforts are balanced is determined by an input weight allocated to each effort.

d.   The brigade commander considers each battalion in turn and, depending on whether he has had a status report recently enough, decides to commit his reserve. He then sends a message to the reserve battalion headquarters. When this message is received, the line of departure is calculated as an offset from the center of one of the fighting battalions, usually the main attack. A route is selected from the line of departure to the pre-established objective, usually a point near the brigade final objective.

e.   The response of the battalion commander when he receives the commit message is to notify his own subordinate units via standard move messages to move to the line of departure.

f.   The brigade decision package keeps track of the sequence of events and the units involved, and when the units have all reached the proper points around the line of departure, the module puts the leading company or companies in the attack mode, and from there on the battalion is handled by the battalion and company decision modules until it reaches the end of the route. At that point, a sub-routine changes the units in the battalion from attack mode to hold mode, representing the securing of the objective and organizing it to withstand a counterattack.

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g. The commitment rule for the defender is similiarly one-dimensional. When the attacker reaches a certain distance (the "commit radius") from the final objective, the defender acts to prevent its capture by committing the defender reserve battalion either to block or to counterattack. The selection or maneuver is an input. If a blocking role is to be taken, the objective is located very close to the line of departure. If a counterattack is planned, the objective is located farther away, presumably at some desirable terrain objective in the near rear of the attacking force. Different maneuvers can be simulated by selection of the commit radius, the line of departure offset, and the objective.

h.   Other than for the commit rule, the attacker and defender forces are treated identically.

i.   An important part of the brigade decisions routines is the generation of status reports. Status reports are sent at a fixed interval after the delivery of the last one, so that the time between reports varies with the effectiveness of communications. There is no explicit tactical significance to these reports, except that a reserve battalion may not be committed if status reports have not been received from all committed battalions within some specified period. Thus, the failure of one battalion to report its condition can prevent the commitment of the reserve at a crucial moment. These messages have an implied reciprocity, that is, when battalion is trying to call brigade, brigade is trying at the same time to call this battalion. This "lost" battalion effect emphasizes the fact that communications are most needed when they are most likely to be in bad shape, or when the brigade is in need of reinforcement.

6. Division Decisions

a.   The division decision module works with the brigade decision module to effect the commitment of the reserve brigade. Status reports are generated from brigade to division and make the commitment decision.

b.   The commitment process is best understood as two distinct sequences: the commitment of reserve battalions of a committed brigade, and the commitment

of the scheduled front line battalions of a reserve brigade. Actually, when the reserve brigage is committed, the assigned front line battalions are treated as if they were reserve battalions of a front line brigade and committed to lines of departure in the same way that reserve battalions of an original front line brigade are committed.

7.   Simulation of General Outpost Lines

a.   For computerized play, the initial manipulation of a battalion or similar combat group in the role of a general outpost or reconnaissance and security force is similar to any such group in the yield mode. The group and its associated pattern fight, move, gather intelligence, and are attrited by the standard subroutines. On the GOP group's approach to the FEBA, however, the subroutine takes over and moves the group to a position in rear of the FEBA.

b.   GOPOUT input list (GOPLST) contains a "within distance cutoff" equal to the range of the longest direct fire weapon of the FEBA plus the radius of a FEBA company unit, (thus simulating local security echelon).

When the distance from the GOP group center to the group final objective becomes equal to the "within distance cutoff," GOPOUT decommits the GOP group, and in effect converts the group and its associated pattern to a rear line pattern. For the pattern that the associated pattern has been following, GOPOUT now substitutes from the GOPOUT input list a new pattern in the rear, and for the pattern offsets of the former pattern it substitutes offsets measured from the new pattern center and of such magnitude as to place the GOP group in the desired rearward position. The pattern movement subroutines now move the GOP to its final position as a conventional pattern.

8. Status Reports from Front Line Units to Battalion

a.   For each unit an attrition distance time counter is maintained (ADTC). Entries in this list are incremented by the attrition routines, the movement routines, and a routine which increments it periodically.

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b.   The attrition routines increment the unit's attrition-distance-time counter by multiplying the unit's attrition rate by a constant and adding the product to the counter. Specifically, if the unit is a front line unit, the increment is (attrition rate) x (DAA), where DAA is an input constant. This is done every minute of game time.

c.   The movement routines increment the unit's attrition-distance-time counter by multiplying the unit's movement rate by a constant and adding the product to the counter. Specifically, if the unit is a front line unit, the increment is (distance moved in one minute) x (DAD), where DAD is an input constant. This is done every minute of game time by a subroutine.

d.   Every minute of game time, a subroutine increments the attrition distance time counter of every unit which is in a group by DAT, an input constant. The subroutine then checks to see if the unit has a status report in process. If so, it checks to see whether the message was completed the previous minute. If the message was completed, it is erased and the attrition-distance-time counter is set to zero. If the message is still in process, it is ignored. If the message is reported failed, it is regenerated. If there is no message in process, the attrition-distance-time counter is compared with CDAT, an input constant. If the counter is greater than or equal to CDAT, a message is generated.

CHAPTER II
THE TACTICAL SIMULATION

SECTION 13
MESSAGE GENERATION

1. Introduction. - During the combat action
commanders, staffs, units, and activities at all
echelons have a need to communicate. The signal system
that supports the tactical action provides the
facilities that accommodate these communications needs.
The tactical model generates the communications needs
(messages) that arise during the combat action.

2. Two Types of Messages

    a. Tactical Messages. - The tactical routines
have written into them the rules, criteria, and data
that enable them to arrive at message decisions, i.e.,
the routines indicate when a message requirement
exists, be it coordination between units, intelligence
exchange, move orders, fire requests, etc. In this
manner the tactical routines generate explicit messages
that stimulate the tactical action. Each message thus
generated is passed to the communications model for
processing.

    b. Other Messages. - In addition to the messages
generated by the tactical routines for specific events
as outlined above, there is a load of traffic that
arises from administrative and logistical activities.
This type traffic is not generated by the tactical
routines. However, it is necessary to include these
messages in the traffic load processed by the
communications model. Traffic of this nature is
brought into the communications model by use of service
routines that operate on computer storage data designed
to generate a representative load of subtactical
traffic.

    c. Deadline Interval (DLINE) and USAGE Lists

        (1) The DLINE and USAGE lists are a
compilation of data about the different types of
messages generated by the tactical model and, when
generated, passed to the communications model for
processing through the signal system. There are no
published data for lists of this nature. The message

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types listed and the accompanying usage data were prepared from studies of communications needs during ground combat.

(2) The DLINE and USAGE lists provide spaces for 200 different types of messages. Types 1-50 are used to describe tactically essential messages; types 51-200 are available for subtactical messages (the STM list). Each type message is assigned an index number and is further described by various items that instruct the communications model how the message is to be processed.

(3) Both DLINE and USAGE are one-dimensional lists, indexed by message type. Taken together they may be thought of as a single two-dimensional list, whose rows represent the various types of messages and whose columns represent the various characteristics of a given type of message. These characteristics include the following:

(a) Deadline interval, i.e., the time interval by which the message must be delivered to have value to the recipient.

(b) Security classification of this message type.

(c) Precedence of this message type in minutes.

(d) Mean length of messages of this type in minutes.

(e) Message mode; voice or written.

(f) Usage of this message type, i.e., the type of net which usually carries a message of this type.

(g) Information as to whether this type of message is to be sent by special messenger if ordinary means of transmission fail.

    d.   Tactically Essential Messages

(1) The DLINE and USAGE lists describe the non-textual qualities of messages the tactical model generates during the combat simulation. These characteristics are passed to the communications model by the tactical model. The data that follow each type number are used by the communications model routines that process the message through the signal system.

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(2)　It will be noted from the nature of the messages in the tactically essential part of the DLINE and USAGE lists, that these messages represent information transfer requirements that commanders, staffs, and activities of all echelons need to control the tactical operation.　When the communications links required by these messages are not available as needed, the failure or delay that results has an impact on the subsequent tactical action.　The nature or severity of this impact is reflected by the tactical routines as the action continues.　For example:　If front line units fail to coordinate, their fire effectiveness decreases; if artillery FO's cannot reach the FDC, the artillery cannot shoot; if front line reports do not reach the proper Hq, reserves are not committed, etc. From this it is apparent that the DLINE and USAGE lists of messages must be comprehensive and realistic, for it is primarily from the performance of these messages (through the signal system) that the tactical model can be used to rate the combat effectiveness of the signal system.

(3)　Type Number. - The DLINE and USAGE lists have space for 50 different types of tactical explicit messages.　At present all of these types are not utilized.

e.　Subtactical Messages

(1)　In addition to the tactically essential messages, i.e., the first 50 types in DLINE and USAGE, the combat signal system must accommodate a load of traffic that arises from administrative and logistical activities related to the tactical action.　These messages flow through the signal system concurrently with the tactically essential messages, and, although the failure or delay of these messages is not individually measured in direct tactical penalties, their presence in the communications load has an impact on the performance of the signal system.　This "subtactical" traffic, the STM traffic, is a separate part of the DLINE and USAGE lists, numbered upward from 51.

(2)　It is intended that from the nature of the messages included in the DLINE and USAGE lists, and the frequency of their occurrence, the tactical model will place on the communications model a realistic

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message load. Comparison of the computer outputs
(message count) for typical periods of combat with
available combat experience data, war games, or
professional estimates will indicate whether the
composition of these lists is acceptable.

3.   The Subtactical Message Package (STM). - The
explicit messages generated by the model in response to
specific tactical conditions which affect specific
tactical parameters travel among combat elements in the
forward portion of the division area and to CP's up to
division main. For this reason a sizable portion of
the division communications system is not exercised by
tactical explicit messages. While this portion
contributes less to the immediate tactical action than
do the battalion command nets, there is a long term and
accumulating effect on combat. It has a debilitating
effect if these subordinate and rear echelon elements
of the signal system do not function properly.
Therefore, the model includes a routine which generates
"subtactical messages" to load the communications
system.

   a.   Assumptions

      (1)   There is a collection of messages that
directly and immediately affect tactical action. By
this we mean some measure of the length of time it
takes from the appearance of the necessity to
communicate at the point of origin to the moment at
which the recipient is able to act on the content of
the message. This time includes the length of the
message itself, encrypting and decrypting time, waiting
for service on the arcs, and switching time through the
nodes in the circuit. Performance is defined
arbitrarily and quantitatively as the message length
divided by the time described in the previous sentence.
Performance can never be better than one, and could be
zero if the message were never delivered. Actually it
is never the latter, since provision is made for
messenger delivery if electronic means fail; the
delivery time is assumed to be roughly the distance
between sender and receiver divided by rate of travel
of messenger.

      (2)   There is a collection of messages whose
performance in aggregate eventually affects the
tactical action.

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(3)   There is a collection of messages which have no affect on tactics but do load the signal system in such a way as to compete with types (1) and (2) for service. We call these three classes (1) tactical explicit, (2) subtactical explicit, and (3) background.

b.   Background Traffic

(1)   There exists at any time between units A and B a steady flow of information which has no effect on battle. In spite of this fact, it still has a precedence and security distribution which causes it to interfere, to a certain extent, with the passage of other traffic. It may be important traffic. For example, a simplification in the simulation assumes one message to be sufficient to effect such important changes in the course of battle as commitment of a full brigade. The background represents all those messages associated with this commitment which are not played explicitly, plus the gathering of extraneous data.

(2)   The implicit content of this background will vary with time and circumstances, but its level is assumed to remain about constant. As battle conditions move from quiet to critical the content of the background moves from low-level to high-level staff coordination, but as long as a means to communicate is available, it will be used. In general, people will exercise enough self-control to set their own precedences in a reasonable fashion. Thus, the background should never rise to seriously restrict flow of important information, but never drop below some level.

(3)   Volume of background traffic is difficult to establish, being in large measure a product of intangible factors such as the degree and effectiveness of communications discipline, training, morale, and the tactical operation. It is furthermore essentially constant. Therefore, for purposes of the expected uses of this simulation, it is not considered. Traffic is restricted to explicit messages.

c.   Subtactical Explicit Traffic

(1)   There is a substantial amount of traffic in the division area whose performance affects combat in an indirect fashion over the long term. The farther

from the front and the less direct the functions of the
units communicating, the less significant are the
messages individually. On the other hand, as the
density of explicit tactical traffic drops off with
distance from the front, the density of subtactical
explicit traffic increases. Thus, an individual
message history is less important in the rear, but the
aggregate performance of these messages, since there
are so many of them, increases as the battle continues,
and a poor rear area system will eventually cut down
combat efficiency to a critical degree. The effect of
this process can be achieved by aggregating the
performance of individual messages into a coefficient
applied directly to the strength of the combat
elements.

      (2) Subtactical traffic applied on all arcs
is a method of measuring overall performance of the
division signal system in terms of combat outcome and a
practical method of observing performance of one part
of the system. While it is impossible to establish
precisely the aggregate load and importance of
subtactical traffic, which are inputs to the model, it
is equally impossible to assign a realistic tactical
effect to the performance of these messages if played
as tactical explicit traffic. The proper choice of
inputs is in either case a matter of judgment.

CHAPTER III
THE COMMUNICATIONS SIMULATION

SECTION 1
INTRODUCTION

1. General. - The communications simulator, taken together with the data on which the simulator operates, simulates two communications systems — one for each of two opposing military forces — and the operation of the two systems. The data describe two systems from the class of communications systems which can be simulated, certain aspects of the environment of each system, and the messages which are being processed by each system. It simulates changes in the systems, and the processing of messages. The simulator determines new values for some of the variables in the data. The new values describe the communications systems after the simulated changes, and the messages after the simulated processing.

The simulator permits alternate modes of operation where communications is simulated for no side or for one side only. If communications is not simulated for a side (i.e., perfect communications is assumed), no communications input data are required for that side. Due to computer storage constraints, communications cannot be simulated for both sides in one run on the UNIVAC 1108 system.

2. Section 2. - This section describes the concept of a communications system as used in this document and upon which the simulation is based. It defines terms used in the description of the system as used by the simulation. It sets the scenario and establishes a common understanding for analysts using the simulator.

3. Section 3. - This section describes the communications simulation as performed by the simulator. It explains the mechanics of establishing the simulation and provides the user with specifics on how the components of a communications system are treated by the simulator.

CHAPTER III
THE COMMUNICATIONS SIMULATION

SECTION 2
A COMMUNICATIONS SYSTEM

1. General

    a. A communications system consists of a complex of equipment
and personnel, distributed over a geographical area, designed for
the purpose of transmitting information between points in the area.
It is convenient to conceive of a communications system as con-
sisting of "units" and "arcs" - a unit being a concentration of
equipment and personnel, an arc being a communication link between
a pair of units.

    b. A unit is a concentration of equipment and personnel that
at any given time occupies a small area. Consequently, a unit can
be treated as a point and located in terms of a pair of coordinates.
Units do not merge or divide.

2. Arcs

    a. An arc is a connection between a pair of units by means of
which messages can be transmitted. Characteristics of arcs are
defined via input in data block ARCLOG (Chapter V). The various
transmission: radio arcs, wire arcs, and messenger arcs. Radio
arcs may be further subtyped according to the following character-
istics: voice/written, FM/VHF/SSB/RATT, sole user/common user,
telephone/teletype. The latter pair may also apply to wire arcs.
A messenger arc is a route between two units over which a messenger
travels at regular intervals.

    b. Independent of the above transmission classes are the
categories of simple arc and compound arc, applicable to all links.
A simple arc represents a direct user-to-user route between two
units. A compound arc connects two units, but transmissions between
the two are patched through one or more intermediary units (and
related equipments).

    c. An arc has certain properties that determine whether it is
suitable for use in the transmission of a given message type.

    (1) An arc may be inoperative for any number of reasons.
A radio arc is inoperative if the units on the ends of the arc are
out of range of one another. An arc may become inoperative if one

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of its end units is moving. Also, failed equipment (due to combat damage or "wear-and-tear") at a terminal will cause the associated arc to fail. Jamming may also temporarily block the transmission of messages. An inoperative arc becomes operative after the cause of failure is removed.

(2) An arc has a security classification. The security class of all messages transmitted over an arc must be no higher than that of the arc which carries them.

(3) An arc has a "mode" - voice or written. Some arcs are used for transmission of written messages. However, under certain conditions, the mode of a message is converted, i.e., a message that was originally written may be read over an arc intended for oral messages, and vice versa.

(4) An arc has a single usage (e.g., command, intelligence, operations, common-user). The usage of a message must exactly match the usage of the arc transmitting it. However, alternate usages may be specified (via input) for messages so that messages blocked in the original net may be switched for transmission over an alternate (hopefully open) net.

(5) Some arcs are not "switchable." Suppose unit I and unit J are the two end units of an arc, and unit I can transmit messages along the arc. The arc is switchable with respect to unit I if, and only if, a message can be transmitted from (or through) unit I, along the arc, to unit J, and then along some arc that is available to unit J. If the arc is not switchable with respect to unit I, it can still be used for the transmission of messages to unit J, but not through unit J.

(6) Suppose that a message is to be transmitted from unit I to unit J, but there is no arc that has unit I at one end and unit J at the other. In addition, let us suppose that there is a pair of arcs, one from unit I to another unit, unit K, and the second from unit K to unit J. This pair of arcs may be used as the route for the message, but it is necessary that the pair of arcs be capable of being connected. Whether or not a given ordered pair of arcs is capable of being connected is described in the input data of the simulation.

(7) If an arc is to be used for the transmission of a message, it is necessary that the arc not be busy, or that the message be of sufficiently high precedence to cause another message to be "bumped." Message precedence is assigned via input for each message type.

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(8) If two arcs are equally acceptable for use by a message, with respect to the considerations mentioned above, one may still be preferred to the other for some reason which need not be specified. This is effected in the simulation by the use of "initial routing costs" for arcs, and "connecting costs" for pairs of arcs.

3. Channels and Circuits

a. A circuit is a connection between two or more units by means of which messages may be transmitted one at a time. A channel is a set of identical circuits - identical insofar as they connect the same units, and are the same with respect to all characteristics of arcs that are described in the data. It is apparent that the number of messages which can be in the process of transmission over a channel at any one time is the same as the number of circuits in the channel.

b. An arc is not necessarily a circuit or a channel. An arc is a part of a channel. The relation between the terms "arc," "circuit," and "channel" can be clarified by means of an example. Consider a part of a communications system which consists of three arcs. Suppose that these three arcs are all radio arcs, and that the same frequency is being used by all three for transmission. Suppose that one of these arcs connects units I and J, the second, units J and K, and the third, units I and K. Then these three arcs are parts of the same one-circuit channel. There is only one circuit, for, if an attempt were made to transmit more than one message at one time, interference would occur.

4. _Message Processing_. - The processing of a message by a communications system begins with the decision to send the message, and ends either when the message is in the possession of the addressee in a useable form (i.e., decoded or decrypted), or when the message fails (i.e., when attempts to transmit the message cease). During this time the message undergoes several stages of processing:

a. _Encoding_. - Whether or not a message requires encoding depends on the security classification of the message. In the simulation, three security classes of messages are distinguished: those that require encoding, those that require encrypting, and those that require neither encoding nor encrypting.

b. _Delivery_. - In general, equipment for sending oral messages is distributed throughout a unit, but equipment for sending written messages is centrally located, at the message center of a unit. Consequently, when a message is to be transmitted by telephone or voice radio, there is little delay for getting to a telephone or radio; there is usually one near to the person who is sending the message. But when a message is to be sent by teletype, a delay is incurred by the necessity for delivery of the message from the person sending the message to the message center of the sending unit.

c. _Selection of a Route_. - Some messages are transmitted by special messenger; a person is dispatched to hand-carry a single message directly from the sender to the addressee. For any other message, a sequence of arcs is selected — a route — over which the message is to be transmitted. The route which is selected for a message depends on characteristics of the message — the security, mode, and usage of the message — and on the characteristics of the arcs of the communications system. Sometimes an attempt to select a route for a message is not successful. What happens then depends upon the type of message and the previous history of the message. The different possibilities are the following:

(1) An attempt is made to select a route of an alternate usage.

(2)   An attempt is made to select a route of the other mode.

(3)   A special messenger is dispatched with the message.

(4)   The message waits, and later another attempt is made to select a route.

(5)   The message fails.

d.   Encrypting. - A message which requires encrypting may have to be encrypted before transmission starts.   Otherwise, encrypting takes place automatically during transmisssion.   Whether or not encrypting takes place automatically in a particular case is determined by the characteristics of the first arc of the route of the message.

e.   Connection of a Route. - The arcs of the route of a message are connected one at a time.   If it is time to connect an arc in the route of a message and that arc is busy, an attempt is made to connect a parallel arc.   If there are no parallel arcs, or the parallel arcs are also busy, consideration is given to "bumping" one of the messages that are causing the arc or a parallel arc to be busy.   Bumping occurs when an arc is busy because of a message of low precedence, and the arc is required for the transmission of a message of high precedence.   If a message cannot be transmitted because an arc in its route is busy, and the message is not of sufficiently high precedence to cause bumping, the message either waits for the arc to be freed, or fails, or another route is selected for the message, depending on the characteristics of the busy arc and the message.   The treatment of the message which is bumped is similar.

f.   Transmission. - When the route of a message is completely connected, the transmisssion of the message begins.   The length of time for which the message is "on the air" depends on the characteristics of the message and the condition of the route.   The length of time for which the message is "on the air" if the route is operating perfectly is one of the characteristics which make up the initial description of the message. If one of the arcs of the route is not operating

perfectly, the time for which the message is "on the air" is lengthened.

    g.   _Decrypting_. - Whether or not a message is decrypted automatically depends on the character of the last arc of the route.

    h.   _Delivery_. - Written messages require delivery from the message center of the unit of the addressee; oral messages do not.

    i.   _Decoding_. - If a message is encoded, it must be decoded before the information can be used by the addressee.

SECTION 3
THE SIMULATION

1. General. - The simulation of a communications
system consists of two parts: the simulator and the
data. The simulator is a function in the mathematical
sense; it is a rule of calculating which operates on
some of the data (the input variables), and determines
some of the data (the output variables).

2. Input Data. - A detailed description of the data on
which the simulator operates follows. The bulk of this
data describes the units, the arcs, and the messages:

    a.   General. - Each item of the data is labeled by
a letter in parentheses: (I) identifies an input
constant or a set of input constants; (T) identifies
data which are determined by the tactical model; (C)
identifies data which are determined by the
communications model. Initial values are assigned to
three kinds of input data. The values of the type (I)
data are not changed by the operation of either the
tactical o the communications models. The values of
type (T) data are changed by the operation of the
tactical model. The values of type (C) data are
changed by the operation of the communications model.

    b.   Data That Describe the Units. - Suppose that
the two opposing military forces are divided into n
units, of which m*are Blue units and (n-m) are Red
units. The Blue units are numbeRed 1,2,...,m, and the
Red units are numbered m + 1, m + 2, ..., n. The
number of a unit is used to identify that unit. (In
the computer program, the number of a unit is used as
an index for referring to the data which describe the
unit.) The data which describe the units consist of:

        (1) n, the number of units (I)

        (2) m, the number of Blue units (I) and

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*"m' is not a set value but simply a shorthand means to
describe where in the list of units the Blue list ends.

(3) A description of each unit.

c. <u>Data Changes</u>. - Certain data describing a unit change during the operation of the simulation. For example, the location of a unit changes. At any given time the description of a given unit consists of:

(1) The location of the unit (T)

(2) The attrition of the unit for the last five minutes (of simulated time) (T)

(3) A list of the arcs on which the unit can transmit (I)

(4) Indication of whether or not each of these arcs is switchable with respect to the unit (I)

(5) The "initial routing cost" for each of these arcs with respect to the unit (I)

(6) Indication of whether or not the unit has a crypto facility (I)

(7) If the unit has a crypto facility, a description of:

(a) The number of messages which can be processed by the crypto facility at any one time (I)

(b) A list of messages which are currently being processed by the crypto facility (C)

(c) A number that is multiplied by the length of a message to determine the time required to encrypt (or decrypt) the message (I).

(8) The activity of the unit is described. The data (T) enables classification of the activity of the unit as

(a) Moving,

(b) Preparing to move,

(c) Just now stopping at a new location or

(d)   Otherwise.

(9)   The data indicate the time at which the unit last stopped moving (C). When the unit is preparing to move, the data enable determination of the time at which it will begin to move (T).

d.   The Data That Describe the Messages. - When a message is generated by the tactical simulator, it is assigned a message number to identify it, and a description of the message is placed in the data on which the communications model operates (T). The description of the message, as generated by the tactical simulator, consists of the following items:

(1)   Sending unit identification.

(2)   Addressee unit identification.

(3) Security classification idenfification. Four security classes are permitted. A message of security class one is transmitted in the clear. The highest security is assigned to class four. Security class four requires off-line encryption.

(4)   The mode of the message is identified as oral (class zero) or written (class one).

(5)   The usage of the message is identified, e.g., FM command, SSB command, RATT opns/intelligence, or RATT admin/ logistics. The usage classes are numbered and the usage of a message is identified by the corresponding integer.

(6)   The message is assigned a precedence value, which is an integer between one and six. The larger this integer, the higher the precedence of the message.

(7)   The length of the message is specified in units of time. This time is the time for which the message will be on the air, if the route on which the message is transmitted is operating perfectly.

(8)   The origin time of the message, the time at which the decision is made to send the message, is specified.

(9)   The type of the message is specified by means of a "message type number" (also called a DLINE index).

(10) The data which describe the message contain three items which indicate the treatment that the message is to receive if difficulty is encountered in getting it transmitted:

(a)   One indicates whether or not the mode of the message is to be changed if there is no route available for the message in its original mode.

(b)   A second indicates whether or not a special messenger is to be dispatched with the message, if the "deadline time" of the message has elapsed and the message has not yet been transmitted.

(c)   The third is the "deadline time" of the message.   This is the time at which the message fails, or the time at which a special messenger is dispatched, depending on the preceding data item.

(11) Of the data items listed above, only one is changed by the operation of the communications simulator, namely, the "deadline time." If the deadline time is passed, and a special messenger is dispatched, the deadline time is changed to the time at which the messenger will arrive at the addressee.

e.   Data Added by the Simulator. - The following data (C) are added to the description of a message by the communications simulator — mostly at the start of the processing of the message — to be used and changed during the processing of the message:

(1)   The "message time" of the message.   This is the time at which the next stage in the processing of the message is to begin.   When a message is generated, the message time is the origin time of the message,

(2) A number of data items, each of which indicates whether or not one of the following statements is true:

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(a) The message has undergone no processing; i.e., it has just been generated.

(b) A special messenger has been dispatched with the message.

(c) The message arrives at the addressee by special messenger at the message time.

(d) The message has undergone mode conversion.

(e) The message is on the air.

(f) The message has failed.

(g) The message has been completed.

(h) The next step in the processing of the message is to attempt to select a route.

(i) The message is being encrypted.

(j) The message is encrypted.

(k) The message is waiting to be decrypted.

(l) The message is being decrypted.

(m) The message has undergone a delay for encrypting.

(n) The message has encountered a busy state and is delayed.

(o) The circuit carrying the message has failed.

(p) The message has been preempted by a message of higher precedence.

f. Message Routing Data. - When a message is generated, the following message route selection data are maintained.

(1) After a route has been selected for a message, the data include an ordered list of the arcs of the route.

(2)   After a route has been selected for a message, the data include indications of which of the arcs of the route have been connected, and which are to be connected next.

(3)   The data include a list of zero to six arcs to be avoided when a route is selected, these arcs having been found to be busy.

g.   The Data That Describe the Arcs and Channels. - Suppose that there are n arcs in a communications system that is to be simulated.   The arcs are numbered 1,2,...,n.   The description of a given arc at a given time consists of the following data:

(1)   The units at the two ends of the arc are identified (I).

(2)   The mode of the arc is identified, in the same way as is the mode of a message (I).

(3)   The usage of the arc is identified, in the same way as is the usage of a message (I).

(4)   The security of the arc if identified as being of class one, two, or three (I).   Arcs of security class one can only be used for the transmission of messages of security class one.   Arcs of security two can be used for messages of securities one and two.   Arcs of security three can be used for messages of securities one, two, and three,

(5)   Arcs of security three are divided into two classes: those that encrypt and decrypt messages automatically during transmission, and those that do not.   If a message of security three is to be transmitted over a route the first arc of which does not encrypt, then the message must be encrypted before transmission.   Similarly, if the last arc of the route does not decrypt, the message must be decrypted after transmission (I).

(6)   The data include an indication of whether or not each arc is currently operative, and, when an arc is inoperative, the time at which it will again become operative — provided, of course, that, at that time, there exists no other reason for the arc to be inoperative (C).

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(7) The data indicate whether each arc is a wire, radio, messenger, or compound arc (I).

(a) The data which describe a wire arc include:

1. The average number of failures per minute per kilometer (1)

2. The minimum repair time and the maximum repair time (I)

3. If the wire is inoperative, the time at which the wire will be repaired (C).

(b) The data which describe a messenger arc include:

1. The time that a messenger will next start along the arc if that time has been determined (C)

2. The time that a messenger will next finish travelling along the arc if that time has been determined (C)

3. Indications of whether or not each of these two times has been determined (C).

(c) The data which describe a radio arc include:

1. A "set type number" for each of the arcs (I)

2. Indications of whether or not the arc is jammable (I).

(d) The data which describe a compound arc include:

1. Identification of the units on each end of each link of the arc (I)

2. Identification of each link as a radio or a wire link (I)

3. Description of the equipment on each end of each link (I,C). (The description of the equipment on one end of a link of a compound arc is the same as the description of the same equipment on one end of a noncompound arc.)

4. For each end of each radio link, a "set type number" is included in the data.

5. The description of a wire link of a compound arc includes data analogous to that included in the description of a noncompound wire arc (I,C).

(8) The data include the "arc type number" of each ear (I). Examples of the different arc types are shown below; each type used in the simulation would be assigned an identifying number.

(a) Common user - VHF multichannel voice, out when moving.

(b) Sole user - VHF multichannel voice, out when moving.

(c) Common user - VHF multichannel teletype, out when moving.

(d) Common user cable voice (field wire), out when moving.

(e) Common user cable teletype (field wire), out when moving.

(f) Common user - VHF multichannel voice, in when moving.

(g) FM radio - voice/command, in when moving.

(h) HF/SSB voice - cav sqdn command, in when moving.

(i) HF/SSB RATT - opns/intell, in when moving.

(j) FM radio - voice admin/logistics, in when moving.

(k) HF/SSB RATT - admin/logistics, in when moving.

(l) Common user - VHF multichannel teletype, in when moving.

(m) Sole user - VHF multichannel voice, in when moving.

(9) In the determination of whether or not an arc can be connected to another arc, the ordered pair of arc type numbers is used, and, if they can be connected, the ordered pair of arc type numbers determines the "connecting cost" and "connecting delay." Also, the arc type number of an arc indicates whether or not the arc is inoperative when a unit using it is moving.

(10) The following data are not required in the description of a messenger arc, but are required in the description of all non-messenger arcs:

(a) The data include an "arc multiplier" for each arc (C). The arc multiplier is equal to one if the arc is operating perfectly, and greater than one otherwise. (Note: If the arc is operating at anything less than perfect then it is necessary that the arc multiplier be something greater than one to measure the delay. For example, if an arc is operating at one-half efficiency, the arc multiplier would be two since it would take twice as long to deliver the message.) The arc multipliers of the arcs of the route of a message are used in the determination of the length of time the message is "on the air."

(b) The data furnish whether or not there are any arcs parallel to a given arc (I), and, if there are, the data list the arcs that are parallel to the given arc (I).

(c) The data establish the "initial connecting delay" and the "terminal connecting delay" for each arc (I).

(d) The data identify the equipment on each end of each arc. The description of the equipment on one end of an arc consists of:

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<u>1</u>.   The probability of "failure" of the equipment during a five minute period (I)

<u>2</u>.   The number of components (e.g., teletypewriter, antennae, crypto device, etc.) of the equipment in each of eight vulnerability classes (I).

<u>3</u>.   An indication of whether the equipment components are arranged in parallel or series (I)

<u>4</u>.   The average repair time for the equipment after damage (I)

<u>5</u>.   An indication of whether or not the equipment is currently operative (C)

<u>6</u>.   If the equipment is inoperative, the time at which it will again become operative (C).

(e)   The description of an arc identifies the "channel" which contains the arc (I).

(11) As mentioned above, in the data which describe an arc, there is a number which identifies the channel which contains the arc. The description of a channel consists of:

(a)   The number of circuits in the channel (I)

(b)   A list of the messages that are currently using the channel (C)

(c)   An indication of whether messages queue on the channel (I).

h.   <u>Other Input Data</u>. - In addition to the data which describe units, messages, arcs, and channels, there are other data which are input to the communications model. These data are described below:

(1)   There are data which are used in the determination of whether a given ordered pair of arcs can be connected to form a route or part of a route for a message. These data are in the form of a list of

connectable ordered pairs of arc type numbers. When the model is finding a route for a message, and considering connecting a given ordered pair of arcs, the arc type numbers for the two arcs are determined. The resulting ordered pair of arc type numbers is compared to the list of connectable ordered pairs of arc type numbers; if it appears on the list, the arcs are connectable; if it does not, the arcs are not connectable (I).

(2) The data include a "connecting cost" and a "connecting delay" for each connectable ordered pair of arc type numbers (I).

(3) The data include a list of constants, one for each equipment vulnerability class, each indicative of the vulnerability of the corresponding class of equipment (I).

(4) The data include a list of (non-ordered) pairs of "set type numbers," each identifying a pair of types of radio sets. For each of these pairs of set types, the data include the nominal range (I).

(5) The data include a list of delivery delays, one for each of the possible values of message precedence (I). This table is used in the determination of the delivery delays which occur between the generation and completion of a written message of a given precedence.

(6) The data include a list of "arc emplacement delays" and a list of "arc displacement delays" (I). There is an emplacement delay and a displacement delay for each of the types of arcs which are "out when moving." An arc of one of these types is inoperative when a unit on it is moving, and for a time before the unit starts to move (the corresponding displacement delay), and for a time after it has stopped moving (the corresponding emplacement delay).

(7) The data include a table called the "message usage conversion" table (I). This table is used when the communications model cannot find a route for a message that is of the same usage as the message. The table indicates whether or not an attempt is to be made to find a route of an alternate usage, and, if so,

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lists the alternate usages in the order in which they are to be tried.

(8)   The data are used to keep track of the movement of scheduled messengers along messenger arcs (C). Messenger arcs are described in terms of sets, called "messenger routes." A messenger route is an ordered set of messenger arcs, the first arc from some unit, say unit I, to another unit, unit J, the second arc from unit J to another unit, unit K, the last arc returning to unit I. Messengers start out on the first arc of a route at regular intervals. The time required for a messenger to travel along an arc is determined from the distance between the end units of the arc. Five minutes after a messenger arrives at the far end of an arc, he starts out on the next arc of the route (unless the one that he just traveled along was the last arc of the messenger route). Special messengers do not require messenger arcs.

(9)   The data include the following constants:

(a)   The speed of a messenger (I). The distance between two units, divided by this constant, gives the time required for a messenger to travel between the two units.

(b)   A delay that occurs to messages that are sent by special messenger (I). When a message is sent by special messenger this constant, plus the time required for a messenger to travel from sender to addressee, gives the time required for transmission of the message.

(c)   A constant, which is multiplied by the length of a message of security two, to determine the delay required for encoding or decoding (I).

(d)   Two constants used in the determination of whether or not two radio sets are within range of one another (I).

(e)   A constant which indicates which of two communications systems are being simulated (I). There are four possibilities: Red only, Blue only, neither, and both.

3. Output Data. - Much of the input data, which are described above, can also be considered to be output

data — namely, that which is labeled as "generated by the communications simulator" (by the notation, "(C)"). Much of this data are written on output files during the operation of the computer program, and later printed or further processed. Output data that are not described above, as input data, consist of the following:

    a.   The number of completed messages

    b.   The number of failed messages

    c.   If the communications model has determined that a message is or will be completed, the output data include the time at which it is completed — i.e., the time at which it is available to the addressee in a useable form (i.e., decoded or decrypted).

    d.   If a message has failed, the output data include the time at which the decision was made that the message had failed.

4.   Processing of Messages

    a.   Message Initiation

    (1)   After a message has been generated, the processing of the message is simulated by the communications simulator. In the course of processing a message, the communications simulator operates on the message at several different times. At each of these times, the simulator determines the nature of the next step of the processing of the message, and the time required for the next step; then the communications simulator refiles the message, to be processed further, after the required time has elapsed — i.e., at the new "message time" of the message.

    (2)   The simulation would be simpler, if, instead of simulating the processing of a message piecemeal, it were to simulate all of the processing of a message the first time it encountered the message. But this is not possible, for, at the time when one step of the processing of a message begins, it is often not possible to determine how much time a later step will require, and, in some cases, it is not even possible to determine whether a later step will take place at all. For example, if a message is to be

encoded before transmission, then, at the time that
encoding begins, it is not possible to determine
whether the route will be busy when the message has
been encoded and is ready to be transmitted.
Consequently, the message that is selected as next to
be processed by the communications model is the message
with the smallest "message time." The processing of the
message is simulated as far as it can be at this time.
Then, if the processing of the message is not
determined to completion or failure, the message is
refiled, to be processed further by the communcations
simulator at a new, later "message time." When a
message is generated by the tactical simulator, the
"message time" is the time at which someone decides to
send the message (called the origin time). When the
communications simulator processes any message, it
either determines the time at which the message is
completed or failed, or it determines a new "message
time" at which the next step of the processing of the
message is to begin.

        (3)   When the communications simulator has
selected the next message to be processed, the
processing of the message begins with a sequence of
tests which determine what the next step of the
processing is.   These tests place any message in one of
the following categories:

        (a)   The message has undergone no
processing; it has just been generated.

        (b)   The next step of the processing of
the message is the selection of a route.

        (c)   The message is next to be encrypted.

        (d)   The message has just finished being
encrypted.

        (e)   The route of the message is being
connected.

        (f)   The message has just gone off the
air.

        (g)   The message is next to be decrypted.

(h) The message has just finished being decrypted.

(i) The message has just arrived at the addressee by special messenger.

(4) The initial processing that this message undergoes at this time depends on which of these categories the message is placed in, and the current state of the communications system. The STM messages are treated by the simulator in the same way as tactically essential messages and are, in fact, distinguishable only by their DLINE index, i.e., own message type number.

b. Message Handling

(1) When the communications simulator first encounters a message, the message is marked as having undergone no processing, and the "message time" of the message is the time at which the message is generated (the origin time of the message).

(2) The processing of the message begins with a determination of whether the message is to undergo a simplified type of processing. An input constant indicates whether the simplified processing is to be applied to messages between Blue units only, to messages between Red units only, to neither, or to both. The simplified processing consists of marking the message as completed, calculating the completion time of the message as the origin time plus the length, and, then, refiling the message. Simplified processing is used to simulate "perfect" communications.

(3) If a message is not to undergo this simplified processing, then the communications simulator examines the usage, security, and precedence of the message.

(4) If the message is not of usage 8, or is neither of precedence 6 nor security 2, then the communications simulator next determines if the message requires encoding, delivery, or both before it is transmitted. Encoding is required if the message is of security 2. The time required for encoding is an input constant times the length of the message. Delivery is

necessary if the message is written. The time required for delivery is determined from the precedence of the message, using a table of input constants, which lists a delivery delay for each of the possible values of precedence. If neither encoding nor delivery is required, the message is marked as next to have a route selected, and the processing of the message continues. If either encoding or delivery or both are required, the message is, in most cases, refiled to be processed again by the communications simulator after the corresponding delay has elapsed, but first the new "message time" is compared to the "deadline time" of the message.

(5) Associated with each message is a "deadline time." In the above case, and in all of those cases which follow, in which a message is about to be refiled to await further processing by the communications simulator at a new "message time," the new "message time" is compared to the "deadline time." If the new "message time" is less than the "deadline time," the message is simply refiled to await further processing; otherwise, what happens to the message depends on which, if any, of the following conditions is observed:

(a) The message is on the air, or being decrypted, or waiting to be decrypted.

(b) The message has been dispatched by special messenger.

(c) The message is to be dispatched by special messenger if it has not been transmitted by its "deadline time."

(6) If condition (a) is observed, the message is simply refiled to await further processing. If condition (a) is not observed, but condition (b) is, then the message will arrive by special messenger at the "deadline time," and attempts to send it by any other means now cease. If neither condition (a) nor condition (b) is observed, but condition (c) is, then the message is marked as dispatched by special messenger, and the "deadline time" is changed to the time at which the special messenger will arrive at the addressee. Attempts that are being made to send the message by another means continue until the new

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"deadline time." If none of the three conditions is observed, the message fails; attempts to transmit the message cease even though the message has not been transmitted; the message is marked as failed and refiled to be processed and then erased by the tactical model.

    c.   <u>Message Routing</u>

        (1) When the communications simulator selects the message next to be processed, and finds that the next step in the processing of the message is the selection of a route for the message, it proceeds to attempt to select a route. A route for a message from unit I to unit J is an ordered set of arcs , the first arc from unit I to some other unit, unit K, the second arc from unit K to some other unit, unit L, the last arc to unit J. In order to be a route, the ordered set of arcs must have the following properties:

            (a) Unit I must be able to transmit on the first arc; unit K must be able to transmit on the second arc; etc.

            (b) Each of the arcs, except the last, must be switchable with respect to the unit from which it starts. (E.g., the second arc must be switchable with respect to unit K.)

            (c) Each of the arcs must be operative.

            (d) Each of the arcs must be of sufficient security, as determined by the security of the message.

            (e) Each of the arcs must be of the same mode as the message.

            (f) Each of the arcs must be of the same usage as the message.

            (g) Each consecutive pair of arcs must be capable of being connected.

        (2) If there is more than one route for a message, the communications simulator selects the cheapest one. The cost of a route is the sum of an "initial routing cost", and a number of "connecting

costs", one for each junction of a pair of arcs in the route. The initial routing cost of a route is determined, given the identity of the sending unit and the first arc of the route. The connecting cost for the joining of a pair of arcs is determined, given the ordered pair of arc type numbers.

(3) If a route is selected for a message, the processing of the message continues. If a route is not selected, the treatment that the message receives depends on whether the communications simulator was attempting to select a "primary" or an "alternate" route. If some arc of that route is busy, and the message is not of sufficiently high precedence to cause bumping, then either the message waits for the busy arc to be freed, or an attempt is made to select another route — an alternate route — that does not contain the busy arc. The message waits for the busy arc to be freed if the busy arc is part of what is labeled by the input data as a queuing channel; otherwise, an alternate route is selected. If an alternate route is selected, and it is also busy, the message waits or an attempt is made to select a second alternate route — a route which does not contain either of the two busy arcs. As many as six alternate routes may be tried. If all the alternate routes are busy, or if there are no alternate routes, then a primary route is again selected, after a delay. The primary route selected at that time is the same as the primary route originally selected, except in certain cases where an arc changes from operative to inoperative, or vice versa, during the interval between the two times at which primary routes are selected.

(4) The distinction between primary routes and alternate routes amounts to this. If there is no primary route than can be used for a message, then there is no route that can be used for the message; but if an attempt to select an alternate route for a message fails, then there may still be a route that has been tried earlier and found to be busy with relatively high precedence traffic. When no route can be selected for a message, the message is refiled, to be processed again by the communications simulator at a new message time. At that time, an attempt will be made to select a primary route for the message. When the communications simulator attempts to select a primary route for a message and fails, an attempt is made to

select a route of a usage alternate to that of the
message. If a route of an alternate usage is selected,
the processing of the message continues. If there is
no alternate usage or the attempt to select a route of
an alternate usage fails, then the message is refiled;
another attempt to select a route will be made at a new
message time (assuming that the new message time is
less than the "deadline time"). Before the message is
refiled, consideration is given to changing the mode of
the message — i.e., to changing the message from
written to oral, or vice versa. (Data included in the
original description of the message indicate whether or
not the message undergoes mode conversion under these
conditions.)

    d.   <u>Encrypting</u>

      (1) After the communications simulator has
selected a route for a message, it determines whether
the message requires encrypting. Encrypting is
required if the message is of security 3. If the
message is not of security 3, the communications
simulator next begins to connect the route of the
message. If the message is of security 3, the first
arc of the route of the message is examined; if the arc
is described by the input data as being of a type that
encrypts messages automatically during transmission,
then the message is marked as having been encrypted and
the communications model begins to connect the route;
if the first arc does not encrypt, the message must be
encrypted by the crypto facility of the unit that is
sending the message before the route is connected.

      (2) A crypto facility consists of a number of
"circuits," this number being the number of messages
that the crypto facility can be processing (i.e.,
encrypting or decrypting) at any time. The number of
circuits in a crypto facility and a list of the
messages currently being processed by the crypto
facility are contained in the data. When a message,
message M, is to be encrypted by a crypto facility, the
communications simulator determines whether the crypto
facility can begin to encrypt the messages now; it can
if there is a circuit that is not in use, or if one of
the circuits is being used by a message of lower
precedence than message M; otherwise, message M must
wait for a circuit of the crypto facility to be freed.

(a) If message M must wait, it is refiled to be processed again by the communications simulator at the time that a circuit of the crypto facility will next be free.

(b) If the encrypting of message M can begin now, then the message is marked as being encrypted and refiled to be processed again by the communications simulator after a delay for encrypting has elapsed. This delay is the length of the message times a multiplier. The multiplier is included in the data that describe the crypto facility.

(c) If all of the circuits of the crypto facility are in use, but at least one is in use by a message of lower precedence than message M, then a message is bumped from the crypto facility — namely, the message of those using the crypto facility that has the lowest precedence. The encrypting or decrypting of the bumped message is interrupted, to begin again when the crypto facility is no longer busy.

(3) When the message selected as next to be processed by the communications model is marked "being encrypted," then the message time of the message (i.e., current time) is the time at which the crypto facility of the sending unit finishes encrypting the message. Accordingly, the message is marked encrypted, a circuit of the crypto facility is freed, and an attempt is made to begin to connect the route of the message. It is assumed that encrypting by a crypto facility results in hard copy of the encrypted message that eliminates the necessity for encrypting the message again if transmission is interrupted. Accordingly, the message is marked "delayed for encrypting"; this tag is examined if transmission is interrupted.

e. Establishing Communications

(1) The arcs of the route of a message are connected one at a time. When the communications simulator selects the next message to be processed, if it finds that the message is next to have an arc of its route connected, it determines which of the arcs of the route is next to be connected, and then determines whether or not the arc can be connected now. If it can, a delay for the connection is determined, and the message is refiled, to be processed again after the

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delay has elapsed; if it cannot, the message is refiled so that after a delay either another attempt is made to connect the arc, or an attempt is made to select a differect route. When the last arc of the route of a message is connected, the message is marked on the air, and refiled to be processed again at the time when it goes off the air - i.e., at the time when it has been completely transmitted.

(2) When the communications simulator is to connect an arc in the route of a message, it first determines whether the arc is operative. (It may have become inoperative after the route was selected.) If the arc is not operative, any arcs of the route that have been connected (i.e. seized) for the transmission of the message are unloaded (i.e., the corresponding channels are freed for use by other messages); then, the message is refiled to have a different route selected after a delay.

(3) If the arc to be connected is operative and a messenger arc, the communications simulator compares the "start time" of the messenger arc to current time.

(a) If the start time is equal to current time, a scheduled messenger is now starting out along the arc. In this case, the time at which the messenger will arrive at the other end of the arc has been determined. The message time is changed to this completion time, and the message is refiled to be processed again by the communications model at that time. At the new message time, an attempt will be made to connect the next arc of the route of the message, if there is a next arc; if there is no next arc, then the new message time is the time at which the message arrives at the addressee.

(b) If the start time is greater than current time, then it is the time at which a messenger will next start out along the arc. The message is refiled, to be processed again at the start time of the messenger arc. At that time there will be another attempt to connect the arc.

(c) If the start time is less than current time, then the time at which the next messenger starts out along the arc has not yet been determined.

However, it is known that no messenger will start out during the next five minutes. Accordingly, the message time is increased by five minutes, and the message is refiled.

(4) If the arc to be connected is operative and not a messenger arc, the communications simulator determines whether the arc can be connected now. It can if there is a circuit of the corresponding channel, or a parallel channel, that is not in use, or if such a circuit is being used by a message of lower precedence.

(a) Suppose that the arc to be connected cannot be connected now, because the channel and all parallel channels are being used by messages, none of which is of lower precedence. The treatment of the message that was to be connected depends on the character of the channel that was to be connected; if the channel is a queuing channel, the message waits for a circuit of the channel to be freed; if the channel is not a queuing channel, an attempt is made to select another route for the message after a delay.

(b) Suppose that the channel and all parallel channels are busy, but at least one of the messages using these channels is of lower precedence; then a message is bumped — in particular a message that is of the lowest precedence of those that are using these channels. The bumped message waits for the channel to be freed, or an attempt is made after a delay to select another route, depending on whether the channel is a queuing or a non-queuing channel.

(c) Suppose that the arc to be connected can be connected, with or without bumping:

<u>1</u>. If the arc is not the last arc of the route, then an attempt will be made to connect the next arc of the route after a delay. The delay is the "initial connecting delay" of the arc being connected, if the arc being connected is the first arc of the route; otherwise, it is an "intermediate connecting delay," which is determined by the types of the arc begin connected and the arc that precedes this arc in the route of the message.

<u>2</u>. If the arc that is being connected is the last arc of the route, the message is

marked "on the air" and refiled to be processed again
by the communications simulator after a delay. The
delay is the sum of three components:

a.   The length of the message
times the arc multiplier of the last arc of the route

b.   The "terminal connecting
delay" of the last arc of the route and

c.   An "intermediate
connecting delay" or an "initial connecting delay" -
the latter if there is only the arc in the route.

f.   End of Transmission. - When the message
selected as next to be processed by the communications
simulator is marked "on the air," then the message time
of the message (i.e., current time) is the time at
which the message goes "off the air" - i.e. the time at
which transmission of the message is completed.
Accordingly, the message is marked as no longer being
on the air, and any channels that have been used for
the transmission of the message are freed for use by
other messages. The message is now ready to be
decrypted, decoded, or delivered from the message
center of the addressee unit to the person who is to
receive the message. If decrypting of the message is
necessary (i.e., if the message is of security 3 and
the last arc of the route of the message does not
decrypt), then the processing of the message continues.
If decrypting is not necessary, the message is marked
"completed" and a completion time is determined. The
completion time is current time plus a delay for
decoding or delivery or both, if such processing is
necessary. (After the completion time has elapsed, the
message will be processed, and then erased by the
tactical simulator.)

g.   Decrypting. - When the message selected as
next to be processed by the communications simulator is
marked "waiting to be decrypted," then the message time
of the message (i.e., current time) is the time at
which an attempt is next to be made to begin to decrypt
the message. Decrypting can begin now if the crypto
facility of the addressee unit is not busy, or if it is
busy because of the processing of a lower precedence
message. The message to be decrypted waits, or
decrypting begins, with or without bumping.

(1)   The message waits if the crypto facility is busy, and none of the circuits is in use by a message of lower precedence. The message is refiled to be processed again by the communications model when a circuit of the crypto facility will be free.

(2)   Decrypting begins now if the crypto facility is not busy, or if one of the circuits is in use by a message of lower precedence. The message is marked "being decrypted," a delay for decrypting is determined, and the message is refiled to be processed again by the communications simulator after this delay has elapsed.   (The delay is the length of the message times the crypto facility multiplier.)

(3)   Bumping occurs if the crypto facility is busy, but one of the circuits of the crypto facility is in use by a message of lower precedence. The decrypting or encrypting of the bumped message is interrupted, to begin again when the crypto facility is no longer busy.

(4)   When the message selected as next to be processed by the communications simulator is marked "being decrypted," then the message time is the time at which the addressee unit finishes decrypting the message. A circuit of the crypto facility is freed, and the message is marked completed and assigned a completion time. The completion time is current time, plus a delay for delivery, if the message is written. (After the completion time has elapsed, the message will be processed and then erased by the tactical simulator.)

h.   Special Messenger. - When the message selected is marked "to arrive at the addressee by special messenger," then the message arrives at the specified time at the addressee. It is marked completed; the completion time is current time (i.e., the message time); the message is refiled to await processing and erasure by the tactical simulator.

5. Changes in the Communications System Status

a.   The input data provide the description of the initial status of a communications system which is simulated. The communications status check (COMCHK) submodel simulates changes in the communication system

by changing the appropriate data in the model file during the course of a simulation run. Two types of changes of the communications system are simulated:

(1) The movement of messengers and

(2) Changes in the state of the arcs of the communications system between the three possible states:

(a) Operating perfectly

(b) Operating imperfectly

(c) Inoperative.

b. The Movement of Messengers

(1) There are two kinds of messengers that are simulated:

(a) A "special messenger" may be dispatched with a single message, when either the nature of the message indicates that it is to be transmitted by special messenger, or when attempts to send the message by other means fail. Messenger arcs are not needed to link units by special messenger.

(b) "Regular messengers" travel at intervals around "messenger routes," pausing at points along their routes to pick up messages that have been waiting for them, and to deliver messages they have been carrying. Regular messengers must travel on messenger arcs.

(2) The simulation of the movement of special messengers has already been described. The part of the model that simulates the movement of regular messengers is described here.

(3) Each regular messenger travels along a "messenger route," which is an ordered set of "messenger arcs," the first arc from some unit, unit I, to another unit, unit J, the second arc from unit J to another unit, unit K, the last arc of the route returning to unit I. Messenger arcs have two characteristics that make them somewhat unusual:

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(a) All messenger arcs are one-way; of the two units on a messenger arc, one can only transmit messages, and the other can only receive.

(b) A messenger arc is never busy; it is assumed that a messenger is never carrying so many messages that he cannot carry one more.

(4) Messengers start out on a messenger route at intervals. A messenger moves along the first arc of his route, then along the second arc of his route, etc., and eventually back to the unit at which the route starts. The time required for a messenger to travel along an arc of his route depends upon the length of the arc. When a messenger arrives at the unit at the end of an arc (other than the last arc of the route), there is a short delay before he starts out on the next arc of his route. This delay corresponds to picking up and leaving messages at the message center of the unit.

c. Changes in the State of the Arc

(1) At any given time each of the arcs of the communications system is in one of three states:

(a) Operating perfectly

(b) Operating imperfectly

(c) Inoperative.

(2) Initially, all of the arcs are operating perfectly. As time progresses conditions change (e.g., equipment is damaged), and the arcs begin to operate imperfectly or to be inoperative. Later, conditions change further (e.g., equipment is repaired), and arcs return to the state of operating perfectly.

(3) At five minute intervals, the data which describe the communications system are examined, and changes in the states of the arcs are simulated. The operations that are performed by this part of the communications simulator are described in the following paragraphs, in the order in which they are performed at a given time.

(a) <u>Restoration of Arcs to the Operative State</u>. - In the paragraphs that follow, it will be noted that, whenever the communications simulator marks an arc inoperative, it determines and stores a "time next to be checked" for the arc; this is the time that the condition that causes the arc to be inoperative will cease to exist. For example, when damage to equipment causes an arc to be inoperative, the time at which the condition that causes the arc to be inoperative will cease to exist is the time at which the equipment will be repaired or replaced, and this time can be anticipated at the time the damage occurs. However, the arc will not necessarily become operative again at that time, for, in the meantime, some other condition may have come into existence (e.g., additional damage) that causes the arc to remain inoperative.

(b) <u>The Effect of the Movement of Units</u>

<u>1</u>. If an arc is one of a number of types — those with arc type numbers less than eleven — it will be inoperative when a unit on it is moving, and for short periods before and after the movement of a unit on it. The periods before and after movement during which such an arc is inoperative correspond to packing up equipment before a move (the displacement delay), and to setting up equipment after a move (the emplacement delay). The lengths of the emplacement and displacement delay are different for different types of arcs.

<u>2</u>. Every five minutes (immediately after directional antenna adjustment) the communications simulator examines all operative arcs that have arc type numbers less than eleven. For each such arc, the communications simulator determines if any unit on the arc:

<u>a</u>. Is moving, or

<u>b</u>. Will start to move within the corresponding displacement delay, or

<u>c</u>. Has stopped moving within the corresponding emplacement delay.

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<u>3</u>.   If one of these three
conditions is observed, the arc is marked inoperative
and the "time next to be checked" is set.

(c) <u>Damage, Failure, and Repair of the</u>
<u>Equipment at the Ends of Arcs and Links</u>

<u>1</u>.   At each end of each arc, and at
each end of each link of each compound arc, there is an
equipment complex. In the case of a wire arc, the
equipment complex may consist of a switchboard, several
telephones, and connecting wiring. In the case of a
radio arc, the "equipment complex" may be simply a set
for receiving and transmitting oral messages. Each of
these equipment complexes is to some extent susceptible
to damage from enemy action and to "failure".

<u>2</u>.   In the input data of the
communications simulator each equipment complex is
described as consisting of a number of components, and
each component of an equipment complex is identified as
belonging to a certain one of eight vulnerability
classes. The components of an equipment complex are
arranged either in parallel or in series. If the
components are in series, the complex becomes
inoperative if any one of the components becomes
inoperative; if the components are in parallel, the
complex becomes inoperative only if all of its
components become inoperative.

<u>3</u>.   At five minute intervals the
communications simulator simulates damage, failure, and
repair of equipment complexes during the preceding five
minutes. The equipment complexes are examined one at a
time. The operations that are performed for a given
equipment complex are as follows:

<u>a</u>.   The communications
simulator determines whether during the last five
minutes the equipment complex has sustained sufficient
damage to cause it to be inoperative. If so, a repair
time is determined, and the equipment complex is marked
as inoperative due to damage. (This determination is
made whether or not the equipment complex was operative
during the preceding five minutes.)

<u>b</u>.   If the equipment complex
was operative and undamaged during the last five

minutes, the communications simulator determines
whether or not the equipment now fails. If so, it is
marked inoperative due to failure.

c. If the equipment complex
was inoperative and undamaged during the last five
minutes, the communications simulator determines
whether the equipment complex is now repaired. If so,
it is marked as operative.

4. The three changes in the state
of an equipment complex — damage, failure, and repair —
are described in more detail in the following
paragraphs.

a. Damage. - At five minute
intervals the communications simulator assesses the
damage to each equipment complex. If the components of
an equipment complex are arranged in series then the
probability, P, that the equipment complex has, during
the last five minutes, sustained sufficient damage to
cause it to be inoperative is determined by a formula.

b. Failure. - If an equipment
complex was not damaged during the last five minutes,
and it was operative, then it may now fail. The
probability, P, that a given equipment complex fails
during a five minute period is included in the input
data that describes the equipment complex. The
communications simulator decides whether or not a given
complex has failed by comparing the probability, P, to
a random number. When an equipment complex fails, it
is marked as inoperative due to failure, and the time
at which it will be repaired is set to current time
plus five minutes.

c. Repair. - If an equipment
complex was not damaged during the last five minutes,
and it was inoperative, then it may now be repaired.
It is, if the repair time is not greater than the
current time.

(d) Conditions Under Which Arcs Become
Inoperative

1. At five minute intervals, after
the simulated damage, failure, and repair of equipment
complexes, the communications simulator examines each

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of the arcs that are marked as operative (except
messenger arcs which are never inoperative), and checks
for the existence of conditions which would cause an
arc to be inoperative. There are three conditions which
cause a wire to be inoperative.

a. A wire arc with an arc
type number less than eleven is inoperative when the
unit at either end is moving, and for periods preceding
and following the movement of such a unit. The
simulation of the effect of movement of a unit occurs
at an earlier part of the simulator.

b. A wire arc is inoperative
when the equipment complex at either end is
inoperative, due to damage or failure that is not yet
repaired. When the communications simulator finds that
this is the case for a wire arc, the arc is marked
inoperative and the time that the arc is next to be
checked is set to the repair time of the inoperative
equipment complex.

c. A wire arc becomes
inoperative when there has been a failure of the wire
which extends between the two ends of the arc. Every
five minutes the communications simulator checks for
wire failures during the preceding five minutes. When
one occurs, the arc is marked inoperative, a repair
time is determined, and the time the arc is next to be
checked is set to this repair time.

2. There are three conditions
that can cause a radio arc to be inoperative:

a. Current, recent, or near
future movement of the unit at either end

b. Failure or damage of the
equipment complex at either end of the arc

c. The distance between the
units at the ends of the arc exceeds the range of the
pair of radio sets at the ends of the arc.

3. A compound arc consists of
radio links and wire links. A compound arc is
inoperative if any of its links is inoperative. The
conditions that cause a wire link to be inoperative are

the same as those that cause a wire arc to be
inoperative. The conditions for a radio link are the
same as those for a radio arc.

    <u>4</u>.   Every five minutes the
communications simulator determines whether each wire
arc is operative for the next five minutes. The
simulator tests for the existence of each of the three
conditions that cause wire arcs to be inoperative. If
a wire arc is not inoperative:

    <u>a</u>.   Because of the movement of
a unit, or

    <u>b</u>.   Because of damage or
failure of an equipment complex at either end of the
arc, or

    <u>c</u>.   Because of a previous wire
failure that has not yet been repaired, then the
communications simulator determines whether a wire
failure has occurred during the preceding five minutes.

    (e)   <u>The Effect of Radio Range</u>

    <u>1</u>.   Every five minutes the
communications simulator determines whether each radio
arc is operative for the next five minutes. First, the
simulator determines if a radio arc is inoperative due
to the movement of a unit, or due to damage or failure
of the equipment at either end of the arc. If not, the
model next determines whether the two ends of the arc
are out of range.

    <u>2</u>.   The input data include a list
of nominal ranges, one for each of the different pairs
of radio set types. The input data that describe a
radio arc include a pair of "set type numbers," one for
each end of the arc, identifying the types of radio
sets on each end of the arc. The range of a particular
radio arc at a particular time is not the nominal range
for the given pair of set types; it is a random
variable that depends on other variables between the two ends of
the arc. However, the probability that the two ends of an arc
are out of range:

a. Is zero if the two ends of the arc are
very close together.

            b. Rises as the distance between the two
ends of the arc approaches the nominal range.

            c. Approaches one as the distance becomes
very large.

            3. The communications simulator determines
whether the two ends of a radio arc are out of range by determin-
ing the probability, P, and then comparing this probability to a
random number. When the ends of a radio arc are out of range, the
arc is marked as inoperative.

            (f) The Imperfect Operations of Arcs. The effect of
imperfect operation of an arc is that it takes a longer time than
usual to transmit a message along the arc. The time required to
transmit a message over an arc is the length of the message times
the arc multiplier of the arc. The arc multiplier is one if the
arc is operating perfectly, greater than one if the arc is
operating imperfectly.

            (g) Jamming. - The program has the capability of
jamming arcs based on options read in at program execution time.
(See Appendix C) A certain percentage of those nets that contain
specified arcs, one end of which has been emplaced a minimum time,
will be jammed for a specified number of minutes. The arc types
jammed, the percentage jammed, the minimum emplacement time, and
the duration of jamming are all user input.