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Evaluation of the AirLand Battle Management Advanced Technology Demonstration Prototype Version 1.2: Knowledge Base Assessment of the Avenue of Approach Generation Tool

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Field Unit at Fort Leavenworth, Kansas
Manpower and Personnel Research Division

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

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This report documents subject matter experts' (SMEs) assessments of the knowledge base of the Avenue of Approach (AA) Generation Tool, a module of the AirLand Battle Management (ALBM) Advanced Technology Demonstration (ATD) decision aid prototype, version 1.2. This is one of a series of assessments of the ALBM ATD prototype conducted during its development. The AA Generation Tool will generate an AA given an initial location, objective, and force template. It uses terrain data obtained from the Tactical Decision Aids terrain data base in generating the AA. In general, SMEs thought that the concept for automatic AA generation was good, but the current implementation was of marginal use. Specific recommendations for improvement are provided.

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Evaluation of the AirLand Battle Management Advanced Technology Demonstration Prototype Version 1.2: Knowledge Base Assessment of the Avenue of Approach Generation Tool

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FOREWORD

This document contains the results of an early assessment of the Avenue of Approach Generation Tool, a module of the AirLand Battle Management (ALBM) Advanced Technology Demonstration (ATD) prototype, version 1.2. ALBM ATD is a program to develop decision aid prototypes to support Army division-level tactical planning. This assessment is one of a series of life cycle assessments of ALBM ATD being conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) during the development of the system. The results will be used by the developer and government sponsors of ALBM ATD to guide further development of the system.

The research was conducted under the ARI research task entitled "Support for Command and Control Research." The assessment was in support of the Combined Arms Command (CAC), the program's user representative. A Memorandum of Agreement was in effect with the Combined Arms Combat Developments Activity, "Development and Implementation of the Future Battle Laboratory," dated 30 June 1989. The results of this review were briefed to personnel from the Battle Command Battle Laboratory, Combined Arms Command; Communications and Electronics Command; Lockheed; and MITRE on 7 January 1993. Brigadier General Anderson, Deputy Commanding General for Combat Developments, Combined Arms Center, was briefed on the findings presented in this report on 25 January 1993.

EDGAR M. JOHNSON
Director

EVALUATION OF THE AIRLAND BATTLE MANAGEMENT ADVANCED TECHNOLOGY DEMONSTRATION PROTOTYPE VERSION 1.2: KNOWLEDGE BASE ASSESSMENT OF THE AVENUE OF APPROACH GENERATION TOOL

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EVALUATION OF THE AIRLAND BATTLE MANAGEMENT ADVANCED TECHNOLOGY DEMONSTRATION PROTOTYPE VERSION 1.2: KNOWLEDGE BASE ASSESSMENT OF THE AVENUE OF APPROACH GENERATION TOOL

Summary

This study evaluated the completeness, accuracy, and adequacy of the knowledge base (i.e., procedures, data base, and algorithms) of the Avenue of Approach (AA) Generation Tool, a module of the AirLand Battle Management Advanced Technology Demonstration (ALBM ATD) version 1.2 prototype. The study was performed as part of the Army Research Institute's (ARI) support of the Battle Command Battle Laboratory (BCBL).

Six Subject Matter Experts (SMEs) participated in individual evaluation sessions. In the evaluation, the procedures, data base, parameters, and algorithms of the AA Generation Tool were briefed to each SME. Following the briefing, SMEs completed a written questionnaire. Throughout the briefing and while completing the questionnaire, each SME was encouraged to ask questions and make verbal comments.

Analysis of the data collected for the AA Generation Tool showed that the data base was "borderline adequate" to support AA generation. The data base lacked certain needed information, and the information contained was not sufficiently detailed. The AAs generated were not optimum due to artifacts caused by the algorithm. The SMEs felt the parameters used to control AA generation and the displays produced were "rather adequate" to "borderline adequate." They wanted a broader range of control and more detail in the displays was desired. The SMEs also felt that the AA Generation Tool was "rather compatible" to "borderline in compatibility" with Army doctrine regarding AAs. This was due to the simplification of the data base and the suboptimal paths generated for the AAs. In general, the SMEs thought the concept for automatic AA generation was good, but the current implementation was of marginal use. If suggested improvements would be made, automatic generation would be a useful tool at division and corps echelons, although the SMEs would regard the generated AAs as suggestions and guides to assist them in manually developing AAs.

It is concluded that the AA Generation Tool in the ALBM ATD version 1.2 prototype is not adequate for use at this time. If improvements are incorporated, the AA Generation Tool would be useful at division and corps echelons. It is recommended that the AA Generation Tool be improved before it is provided to units for operational use. The improvements suggested include expanding the goals for determining the path of an AA, including additional terrain data for determining the AA path, and including tactical considerations (e.g., boundaries, contamination areas) as constraints in generating an AA.

Introduction

Overview

The purpose of this report is to document the results of a knowledge base assessment of the AA Generation Tool, a module of ALBM ATD. This evaluation is one of six conducted by ARI of the Version 1.2 prototype of ALBM ATD. The assessments are part of a set of life cycle evaluations conducted on the ALBM ATD prototype during development. The purpose of life cycle evaluation is to provide user and subject matter expert feedback to the government sponsor and contractor developer in order to guide the design and development of the system and to provide information for management decisions. In this way, it is hoped that the final operational system will have capabilities that will improve user performance.

Assessments conducted on the version 1.2 prototype include knowledge base reviews of four tools, a human factors assessment of the interface, and a user and SME review of demonstrated prototype capabilities. In addition to this report, these assessments are documented in separate ARI reports (Flanagan, in preparation; McKeown, in preparation; Rappold & Flanagan, in preparation; Riedel, McKeown, Flanagan, & Adelman, in preparation).

The objectives of the evaluation described in this report were to assess the completeness, accuracy and acceptability of the AA Generation Tool algorithms, procedures and products, as reported by subject matter experts. The study involved obtaining, recording, and analyzing feedback from six SMEs on the current functionality of the AA Generation Tool. Therefore, the procedure for conducting the study centered on obtaining reactions to the existing tool, rather than on obtaining suggestions on how the AA Generation Tool should function. There was no attempt to elicit design suggestions, although some were volunteered and captured during the study. As a result, this study presents problems, deficiencies, and omissions in the functionality of the AA Generation Tool, without always presenting approaches for overcoming these problems. It is hoped that system engineers and system designers will be able to review the results contained herein, and develop appropriate enhancements or corrections to the current design of the Tool.

Description of ALBM ATD

ALBM ATD is a Training and Doctrine Command (TRADOC) and Army Materiel Command (AMC) program. The main purposes of ALBM ATD are to (1) define and refine operational requirements for automated decision aids for planning, (2) develop operational prototypes based on advanced technologies, and (3) facilitate transition of the decision aids to the Army Tactical Command and Control System (ATCCS). The decision aids are intended to support corps, division and brigade level commanders and their staffs in tactical planning operations. The Communications and

Electronics Command at Fort Monmouth is responsible for the overall management of the program; the Combined Arms Command, Combat Developments at Fort Leavenworth is the users' representative responsible for functional requirements, knowledge elicitation with SMEs, and the operational evaluations; and the Program Executive Office for Command and Control systems (PEO-CCS) is responsible for integration with the Army Tactical Command and Control System (ATCCS).

Two force level control (FLC) advisors are under development as part of the ALBM ATD system - MET 4 and FITE. MET 4 (Mission, Enemy, Terrain, Troops and Time Available Tools) is intended to aid commanders and their staffs from brigade through corps to analyze the area of operations and to assess the enemy and friendly capabilities. FITE (Force Interactive Tactical Evaluator) interacts with MET 4 to aid commanders and their staffs to develop, wargame, and compare courses of action.

MET4 has four basic components.

-Battlefield Area (BA) component assists commanders and staff to analyze the terrain and develop and analyze avenues of approach.

-The Enemy Situation and Capabilities (ESC) component interacts with the other MET 4 components to aid commanders and staffs to anticipate enemy operations. Its principal focus is on probable enemy courses of action.

-Friendly Situation and Capabilities (FSC) component interacts with other MET 4 components to assist commanders and staffs to analyze missions received from higher headquarters, to assess the friendly situation and to determine the general ability of the unit to accomplish its assigned mission. The focus is on projecting friendly unit readiness and capabilities.

-The Execution Monitor (EM) component interacts with ATCCS components, FITE, other MET 4 components, and other decision aids to aid commanders and staffs to monitor current operations. It alerts commanders and staffs when the current operation deviates from the operations order (OPORD). EM aids commanders and staffs to determine when orders should be issued to implement new phases or branches provided for in the current plan and when modifications of the current plan or replanning are necessary.

FITE interacts with MET 4 to aid commanders and staffs to develop, wargame, and compare courses of action (COAs). It also aids commanders and staffs to properly synchronize operations of subordinate and supporting units in order to concentrate combat power at the critical place and time to accomplish the commanders intent. Its principal focus is on COA development, preparation of the COA sketch, COA analysis (wargaming) and comparison, and on an execution synchronization matrix.

Description of the AA Generation Tool

This section provides a brief and simplified description of the ALBM ATD AA Generation Tool as it existed in November 1992, the time of this study. The AA Generation Tool automatically generates an AA given an initial location and objective. It will apply data obtained from Tactical Decision Aids, rules for doctrinal force frontages and terrain query capabilities to search for a satisfactory avenue of approach. The following descriptions of AA Generation components are provided in this section: (1) Cognitive Map structure, (2) unit templates, (3) disaggregation, (4) path deflection, (5), logic of AA path generation and (6) example of AA generation using the Cognitive Map. SMEs were briefed in these areas as part of the assessment and data collection session. The figures referenced in this section are all contained in Appendix A.

Cognitive Map Structure. The method of developing the Cognitive Map is explained in this section. The examples use a 1:250,000 scale map of a portion of Germany (see Figure A-1).

Cognitive Map is the name given to the computer representation of terrain that is used to automatically generate AAs. It is intended to represent the Combined Obstacles Overlay (i.e., GO, SLOW-GO, and NO-GO terrain) which is used manually to develop AAs.

The starting point for developing the Cognitive Map is the Engineering Topographic Laboratory (ETL) Cross-Country Mobility Tactical Decision Aid (TDA), which provides NO-GO, SLOW-GO, and GO data. An off-line software process analyzes this data to derive NO-GO polygons. This is done by determining the density of NO-GO data. If a small piece of NO-GO is isolated from other NO-GO data, it is ignored. If pieces of NO-GO are gathered in near proximity, a polygon is developed to include the NO-GO data. Figure A-2 shows the same terrain as Figure A-1, but with dark slanted lines depicting NO-GO terrain, and light slanted lines representing SLOW-GO terrain as provided by the ETL TDA. In Figure A-3, slanted lines represent the ETL TDA NO-GO data, and polygons enclosing the ETL TDA data are the developed NO-GO polygons. Because the source data only considers cross-country mobility, urban areas are not included. To cover this omission, Defense Mapping Agency (DMA) Interim Terrain Data (ITD) is used for its polygons representing built-up areas, which are designated as NO-GO. In Figure A-3, these are the large polygons with a small amount of slanted lines (i.e., ETL TDA data) within them.

Lines of shortest distance are drawn between each NO-GO polygon connecting with all other nearby NO-GO polygons, as long as a line does not itself cross an intervening NO-GO polygon. These lines are called "minimum gaps". The lines are then decluttered by finding all intersecting lines and removing the longer of the intersecting lines. The result is an allocation of the map area into NO-GO and GO (i.e., areas other than NO-GO) polygons. Figure A-4 shows the results of this process. Each GO polygon (i.e., areas other than NO-GO) is then described in terms of the percentage of the polygon that consists of SLOW-GO terrain as derived from the ETL TDA shown in Figure A-2.

The Cognitive Map shown in Figure A-4 consists of polygons of NO-GO terrain, and polygons of calculated percentages of SLOW-GO and GO terrain. These latter polygons are separated by minimum gap lines drawn between neighboring NO-GO polygons. The points, lines, and areas that make up this collection of polygons are stored as a "fully integrated topologically linked polygon network structure" (Burrough, 1990), to facilitate automated processing. This polygon network is the terrain representation used by the AA Generation algorithm to develop AA paths.

Unit templates. The various echelons have doctrinal minimum and maximum frontages (ST 100-9, The Command Estimate Process). Basically, an AA must be at least as wide as the minimum frontage for the desired echelon (i.e., the AA must pass between NO-GO areas that are no closer than the minimum frontage distance). The user can modify the minimum frontage width of the desired echelon through use of the Choke Factor. The Choke Factor is a distance in meters that the minimum frontage requirement can be relaxed to allow an AA to exist. For example, a brigade minimum frontage of 3 kilometers would not pass through a gap between NO-GO areas of 2.9 kilometers. A Choke Factor of 100 meters would allow the brigade to pass through the 2.9 km gap with no penalty.

Disaggregation. The ST 100-9 also specifies a doctrinal maximum separation of subordinate units. If an AA cannot be found for a unit at a given echelon and the option to maintain subordinate unit proximities has been turned off, then an attempt is made to find separate AAs for the subordinate units. That is, gaps between NO-GO areas may not allow a brigade to pass, but it may be possible for subordinate battalions to pass through the gaps. If such AAs can be found, the paths for the subordinate AAs are averaged to present the AA for the echelon that was originally desired.

Path deflection. The user has the option to restrict the length of the AA being generated in relation to the straight-line distance from the starting point to the destination. Any deviation from a straight-line path is termed a path deflection. A path deflection of 50% would indicate the desire to limit the total AA length to no more than 50% greater than the straight-line distance. If no path exists that is shorter than allowed by the path deflection limit, then the lowest-cost (shortest time) path will be found regardless of the length.

Logic of AA path generation. The algorithm used to generate an AA path is shown and explained briefly in Figure A-5. The following paragraphs provide a more detailed explanation of the algorithm.

The user specifies starting and ending points for an AA. Also specified are the parameters discussed above, namely, force echelon, choke factor, subordinate unit proximity requirement, path deflection limit, and whether the AA path will be allowed to cross NO-GO terrain. The system attempts to find the shortest (i.e., in time) path from start to finish. The time is based on doctrinal unopposed daytime movement rates for mechanized forces over the terrain classes found in the cognitive map polygons.

The starting point of the first line segment of the AA path is the midpoint of a gap line that is long enough to allow passage of the user-specified echelon. If no gap line is of sufficient length (after allowing for the choke factor, if any), a determination is made whether or not the user required that subordinate unit proximities be maintained.

- If subordinate unit proximities are to be maintained, the search for the AA path fails, and the user is presented with a message that the AA search was unsuccessful.

- If subordinate unit proximities are not required to be maintained, the unit will disaggregate as described in the Disaggregation section, and the search for a sufficient gap line will be repeated using the smaller unit frontage.

There are three or more gap lines bounding each polygon. All gap lines of sufficient length are considered for use in the AA path, in terms of the movement time from start to finish. The path will be constructed using the gap line that provides the shortest total movement time.

The movement time can be calculated for the current polygon, since the percentages of SLOW-GO and GO terrain are known for that polygon. To arrive at the total time from start to finish (i.e., the goal is to find the shortest total time), the system assumes a straight-line path from the end of each of the current segments to the finish point, using SLOW-GO movement rates.

The end of the first segment is at the midpoint of a gap line that separates the starting polygon from an adjoining polygon. The path search continues by looking at all other gap lines of the new polygon (i.e., if at least two exist) to see if any are of sufficient length to allow passage of the specified echelon.

If only one gap line qualifies, it will be used by default.

If two or more gap lines qualify, then the one that provides the shortest total travel time will be used for the AA path, as described above. Although only the path that results in the shortest travel time is pursued into the next polygon, the calculated times for all other paths are kept (i.e., remembered). Thus, the travel time of the path being pursued is always compared to the travel times of the other remembered paths. The path with the shortest travel time is then pursued into its next polygon.

If no other gap line in the new polygon qualifies to allow passage of the echelon, then that path is a dead-end. The system examines all remembered paths (i.e., those that provided longer movement times than the one that led to the dead-end). The path chosen is the one that had the next shortest total travel time calculated as described above.

The process continues until a path is constructed to the finish, until all possible paths end in dead-ends, or until all possible paths exceed the specified deflection limit.

If no path is found, then adjustments are made to the search criteria as specified by the user, namely disaggregation of the echelon as described earlier. If the user had not allowed for disaggregation, then the search fails, and the user will be presented a message that the AA search was unsuccessful.

Example of AA Generation Using the Cognitive Map

Figure A-6 shows the centerline of an AA generated for a battalion force from point 1 to point 2. The first path attempted was directly towards the end point, but the gaps between NO-GO areas were too narrow at 3. Therefore, the algorithm pursued the path to the south. The somewhat wavering nature of the path at 4 is due to the algorithm passing through the midpoint of the gap lines. At 5, it would appear more direct to proceed to the east, rather than north to 6. The travel time calculated at 6, however, must have been shorter, if even by a small amount, than that proceeding to the gap line east of 5. At 7, the configuration of the polygon and the requirement to pass through the midpoint of the gap line, took the AA path markedly south, directly over a NO-GO polygon. Note that this is not an error, but a result of the requirement to draw the path between the midpoints of the gap lines. Also, the path made a subsequent move markedly north of a direct path at 8.

Method

Assessment Issues

This assessment addresses the following issues:

- Is the underlying data base an adequate representation of terrain from the standpoint of AA generation?
- Does the method of generating a path of an AA reliably result in an adequate AA?
- How much confidence does the user have in the generated AA?
- Do the parameters that control AA generation provide adequate ability for the user to represent his desires?
- Are the AA Generation products (i.e., displays) usable, in terms of information content and format?
- Is the AA Generation method compatible with doctrine (i.e., with the methods and procedures currently taught and used to generate AAs)?

Subject Matter Experts

Six subject matter experts participated in the assessment. The following is a summary of their backgrounds and experience.

- There are five Majors and one Lieutenant Colonel.
- Their length of service averages 15 years, ranging from 11½ to 19 years.
- All are graduates of the Command and General Staff Officers Course.
- Three are students in the School of Advanced Military Studies, two are observers/controllers of division and corps level G2 (Intelligence) activities for the Battle Command Training Program, and one is in the Treats Division of the Combined Arms Center
- Their tactically relevant experience averages 50 months per SME.
- The experience of five of the SMEs pertains to production of intelligence products, including terrain analysis and AA generation and the experience of one SME is in operations (i.e., the use of terrain analysis and AAs generated by intelligence planning activities).

Appendix D contains specific information about the military service, military education, and job experience of the six participating SMEs.

Documentation of Algorithms and Procedures

Descriptions of the AA Generation algorithms and procedures were obtained from Software User's Manual for the ALBM ATD Force Level Control Advisor System (Lockheed, 30 May 1992) and personal communications with Lockheed personnel.

Materials

The set of briefing materials used for each SME is included in Appendix B. The following topics are included:

- Explanation of the ALBM ATD program and the role of this study within the program
- Brief review of Army doctrine relating to AA generat
- Overview of the AA Generation process in ALBM ATD
- Description of the method used to construct the Cognitive Map
- Explanation of the parameters by which the user controls the ALBM *ATD AA Generation process*
- Description of the method used in AA Generation to search for the best AA path

To further illustrate the AA Generation process, color prints of the ALBM ATD workstation screen were obtained showing various aspects of the AA Generation Tool. Black and white versions of these prints are contained in Appendix A.

Color prints of the ALBM ATD workstation were used in lieu of the actual workstation. This was done to separate the soldier-machine interface function and system performance aspects of the ALBM ATD System from the underlying knowledge base (e.g., procedures, algorithms, and parameters) of ALBM ATD AA Generation. In this way, biases regarding other functional aspects of the ALBM ATD system would not influence the results of this study.

A questionnaire was developed based on the six key issues identified earlier. The questionnaire required ratings of the ALBM ATD AA Generation function for each of the six issues, and invited written comments on each issue. Also, a questionnaire was developed to obtain demographic information on each SME, and a release form was signed by each SME regarding video-taping of the session and participation in the study. These materials are contained in Appendix C.

Procedure

Two researchers, with backgrounds in Army division tactical decision making, conducted individual evaluation sessions. The sessions lasted approximately 1½ to 2 hours and were conducted at the ARI Field Unit Laboratory at Fort Leavenworth, Kansas.

This study was conducted immediately prior to an assessment of the ALBM ATD prototype module Location Analysis Applications (McKeown, in preparation). The AA Generation Tool and Location Analysis Tools are highly related in content. By conducting assessments of the two tools sequentially, duplicate briefing material was eliminated. The same SMEs participated in both assessments.

Following is a chronological listing of activities performed during each session.

- Release form (see Appendix C) regarding participation in the study and video-taping of the session administered.
- Demographic questionnaire (see Appendix C) administered
- Presentation of briefing (see Appendix B) explaining the study purpose, doctrinal background, and the knowledge base of AA Generation. Questions and comments are encouraged from the SME, and are recorded manually by the researcher.
- Presentation of color prints of an example AA Generation (Appendix B) which illustrates the knowledge base of AA Generation. Questions and comments are encouraged from the SME, and are recorded manually by the researcher.
- Questionnaire concerning the six research issues administered. Again, verbal questions and comments are encouraged from the SME, and are recorded manually by the researcher.

Data Analysis

Due to the limited number of qualified SMEs available for this study, no statistical analysis was performed on their ratings of the six research issues; instead, responses were examined to assess the SME's subjective appraisal of the AA Generation Tool.

The written and verbal comments made by the SMEs on the functionality of AA Generation in ALBM ATD were categorized according to the six research issues. Comments concerning the ALBM ATD program, or the AA Generation function as a whole, were assigned to a "General" category.

Verbal comments duplicating a written comment by the same SME were discarded. Verbal and written comments that exactly or closely replicated comments made by another SME were retained and categorized to indicate a degree of consensus on a topic.

The comments in each of the six research categories were then reviewed to discern common threads or topics. This allowed the researcher to discover the SME's major concerns and suggestions.

Results

This section presents results of written and verbal data collected from SMEs on the following research issues: Cognitive Map, AA Path Generation, SME Confidence in the AA, Parameters that Control AA Generation, Usability of Displays, Compatibility with Doctrine, and General Comments.

Cognitive Map

The SMEs were asked to provide a rating based upon the question "Is the cognitive map an adequate representation of terrain from the standpoint of AA generation?" In addition, the SMEs were asked to list any deficiencies and suggest changes. These detailed results are contained in Appendix E.

Number of SMEs giving the indicated ratings are the following:

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate
	1	3	2	

The written and verbal comments were categorized by topic, and are shown in Table 1. The following summarizes these comments:

- Additional terrain attributes should be considered in the cognitive map such as roads, rail nets, bridges, and hydrology (e.g., fords, unfordable places).

- SLOW-GO terrain should be explicitly considered. A big concern in generating AAs is maneuvering around SLOW-GO areas.

- Information is needed as to why an area is considered NO-GO. Edges of NO-GO areas may be unusable to certain forces. Certain types of NO-GO adjacent to a force may cause problems with exposed flanks, or coordination with adjacent forces.

- Tactical considerations (e.g., boundaries, phase lines, contamination areas) should be included. Cover and concealment should be considered. The effect of previous vehicle traffic on the mobility of the terrain should be considered.

- The use of non-German terrain and non-mechanized forces should be provided.

Table 1

SME Comments on the Cognitive Map

Topic	SMEs	Comments
Terrain attributes, other than GO, SLOW-GO, and NO-GO are not considered	5	The details of roads, rail, and hydrology are not considered. Depending on the type of operation you conduct, these items can be critical in determining an AA. Ignoring roads and actual waterway locations makes it difficult to relate this representation with reality. Account for road network and capacities, and actual waterway impact. Deals only with cross-country movement. Appears to allow forces to cross water obstacles at will. Add road and bridge data. The allure of existing road networks can not be ignored. Units consciously or unconsciously migrate toward them. The road network probably captures the path of least resistance or shortest distance. Weather has a major impact on determining GO, SLOW-GO, and NO-GO terrain.
SLOW-GO terrain not explicitly considered	2	SLOW-GO terrain is not specifically considered in the generation of the AA. Delineate the SLOW-GO terrain as compared to combining it with the GO terrain as a percentage. This representation is too general and looks at things from too much of a macro sense. While the need to reduce detail to accomplish calculations makes sense, generalizing SLOW-GO terrain into an entire polygon trivializes its effects. Make SLOW-GO areas specific polygons. GO and NO-GO areas are used. The biggest concern is how to maneuver around SLOW-GO areas.

Table 1 (continued)

Topic	SMEs	Comments
NO-GO information is not sufficiently detailed	3	It would be useful to know what attribute caused an area to be NO-GO. An AA for a flank force may need to avoid passing by certain types of NO-GO terrain that cause coordination problems, or expose a flank to attack. It's unclear how exact the distinction is between GO and NO-GO areas. Crossing into a NO-GO area guarantees NO-GO movement rates, when the edges of the areas may not really be NO-GO. An area defined as NO-GO in the cognitive map may not be NO-GO to the user (45% slope vice 44% slope). Knowing why an area is NO-GO would help the decision process. Need differentiation between built-up areas and other NO-GO terrain.
Tactical considerations are not included	5	Create an ability to modify the terrain as the operation progresses. Based upon amount and type of traffic that passes over a certain area in a given amount of time, the traffic of the terrain will most likely change. It is desirable to include selected control measures (boundaries, contamination areas, etc.) in the cognitive map. Does not consider cover/concealment factors. Allow for input of control measures. Adequate from a purely "academic" view of terrain, minus friendly and enemy situation and graphics. Both of these latter factors determine AAs. Friendly control measures (boundaries, phase lines, etc.) need to be considered along with terrain factors for friendly AAs.

Table 1 (continued)

Topic	SMEs	Comments
Non-German terrain and non-mechanized force structures are not included	4	The standards for GO, SLOW-GO, and NO-GO terrain are based on German operations. The user may want to provide alternate parameters for other areas of the world. Dismounted operations and terrain in other parts of the world should be accommodated. SLOW-GO areas are vehicle dependent (M-1 versus 2½ ton truck). Need cognitive maps for different force types. G2/Terrain teams are required to project AA for both friendly and enemy forces, yet parameters set only for US.

AA Path Generation

The SMEs were asked to provide a rating based upon the question "Does the method of generating a path of an AA reliably result in an adequate AA?" In addition, the SMEs were asked to list any deficiencies and provide verbal comments. These detailed results are contained in Appendix F.

Number of SMEs giving the indicated ratings are the following:

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate
	2	2	2	

The written and verbal comments were categorized by topic, and are shown in Table 2. The following summarizes these comments:

- The path generated is not the most feasible. Placing the path at the mid-point between NO-GO areas generates a path that is adequate, but not necessarily optimum. The path should be generated to go more directly to the objective.
- Alternative paths should be presented. Or, the process could be made interactive to allow the user to override restrictions when significant deviations from a direct route are impending.
- Night movement rates are not considered.

Table 2

SME Comments on Path Generation

Topic	SME	Comments
An optimum path is not generated	6	Centering the path between NO-GO areas does not necessarily provide an avenue along the best terrain from the start point to the end point (one may, in fact, have an avenue drawn through SLOW-GO terrain when GO terrain is to either side). The example shown didn't provide the most feasible AA because the avenue went through NO-GO terrain when there was no need to, because of the center point and shortest time method of generating the AA. AA didn't make sense approximately 33% of the time. It went over NO-GO terrain and ignored logical mobility corridors. Placing the AA path at the mid-point between NO-GO areas skews the path. It appears to identify an adequate, but not necessarily optimum AA. Perhaps the path could be refined (smoothed) after it has initially been drawn. Projects AAs solely on terrain considerations that may be tactically infeasible. The speed and directness of generated AAs is questionable. Serpentine routes exposes forces for more time and requires soldier navigation tools. The system should take the force from A to B by the most direct route and report problems using that route, allowing user override. Use of mid-point between NO-GO polygons causes poor route selection. There is a fundamental flaw in the algorithm. After checking the mid-point of a gap between NO-GO polygons, it should look for a more direct path to the end point. As an alternative, draw a line form start to end and move the line as little as possible to obtain the most direct route. Perhaps the system should be interactive.

Table 2 (continued)

Topic	SME	Comments
Only one AA path is generated	2	Allow for consideration of alternative AAs early on. Calculating the route as you go, rather than using a decision tree of alternatives, results in a rough AA. Perhaps the system should be interactive and prompt the user at points where extreme changes of direction, or crossing of NO-GO terrain, occurs. The user could then override or guide the system as to the desired path.
Only daytime movement rates are used	1	Does not consider night movement.

SME Confidence in the AA

The SMEs were asked to provide a rating based upon the question "How much confidence do you have in an AA generated by ALBM?" In addition, the SMEs were asked to list any deficiencies and provide verbal comments. These detailed results are contained in Appendix G.

Number of SMEs giving the indicated ratings are the following:

Highly Confident	Rather Confident	Borderline	Somewhat Unconfident	Decidedly Unconfident
		5	1	

The comments of the SMEs are summarized as follows.

- Not sufficiently confident to use the generated AA directly. The AA would be reviewed, then an AA would be manually drawn.
- Showing alternative paths, or allowing interactive override of the generated path would provide more confidence.
- A 3-dimensional display of the AA would provide more information on the validity of the path, and allow the user to adjust the AA path to more reasonable areas.

Parameters That Control AA Generation

The SMEs were asked to provide a rating based upon the question "Do the parameters that control AA generation provide adequate ability for the user to represent his desires?" In addition, the SMEs were asked to list any deficiencies and provide verbal comments. These detailed results are contained in Appendix H.

Number of SMEs giving the indicated ratings are the following:

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate
	4	1	1	

The written and verbal comments were categorized by topic, and are shown in Table 3. The essence of these comments are as follows.

- In conjunction with the Choke Factor, allow the user the specify the distance he/she will allow the force to travel through a narrowly restricted area.

- Provide a threshold of deviation from a direct route which would allow the user to interactively guide or override the AA path.

- Automatically generate multiple paths using user controlled combinations of the parameters, and preserve the parameter set used with each AA to guide user selection of the desired AA.

- Add soil/path degradation factor corresponding to the number and type of vehicles traversing an area (modifies mobility class of terrain).

- Provide phase lines to allow specification of changes in movement formation.

- Forces normally move from assembly areas to objective areas. Perhaps multiple start points and multiple end points should be tried, since the path is highly dependent on the location of the start and end points.

Table 3

SME Comments on Parameters That Control AA Generation

Topic	SMEs	Comments
Additional parameters are needed to control AA path generation	6	Incorporate the distance that the user will allow the force to travel through constricted terrain as an additional facet of the Choke Factor parameter. Need ability to control illogical deviation, i.e., agree/disagree with major deviations from the logical path. Early comparisons of alternate AAs/MCs. Calculate the AA using all the possible parameters. The chosen parameters define, but also restrict, the AA. The user needs to have displayed, without asking, what alternatives are available by changing the parameters. This could increase confidence that the correct AA was selected and not unduly biased by a single parameter. The result of all possible parameter permutations should be available to the user to ensure parameters are defining, not restricting, the AA generation. G2/Terrain teams are required to project AA for both friendly and enemy forces, yet parameters set only for US. Parameters for friendly and enemy AAs should be different. Add time as a factor. A route could be chosen that is the shortest but traverses largely SLOW-GO terrain.
Additional parameters are needed to control use of the Cognitive Map	3	Add soil/path degradation factor, to describe the change in the condition of an area over time given numbers and types of vehicles planned to traverse the area (may change GO to SLOW-GO or NO-GO). There should be a threshold value for the "Avoid NO-GO" parameter, to allow a portion of the path to cross NO-GO terrain. Provide phase lines for variation in movement formation. Allow for cover and concealment requirements.

Usability of Displays

The SMEs were asked to provide a rating based on the question "Are the products (displays) usable, in terms of information content and format? In addition, the SMEs were asked to list any deficiencies in writing, and suggest changes. These detailed results are contained in Appendix I.

Number of SMEs giving the indicated ratings are the following:

Highly Usable	Rather Usable	Borderline	Somewhat Unusable	Decidedly Unusable
	3	3		

The comments of the SMEs are summarized below.

- Displaying NO-GO and SLOW-GO terrain, and hydrology, on the map makes visualizing and manually drawing AAs much easier.
- Display the AA as wide as the mobility corridor, rather than the doctrinal echelon frontage.
- Display time and distance from start to finish.
- For presentation and briefing purposes, provide large screen displays or color printouts.

Compatibility With Doctrine

The SMEs were asked to provide a rating based on the question "Is the AA generation method compatible with doctrine?" In addition, the SMEs were asked to list any deficiencies and provide verbal comments. These detailed results are contained in Appendix J.

Number of SMEs giving the indicated ratings are the following:

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate
	2	4		

The comments of the SMEs are summarized as follows.

- It's generally compatible, but too rudimentary and rigid.
- A big deficiency is ignorance of hydrology and roads.
- Viewing the terrain as a map is different than viewing it "on the ground." The AA generation process is too simple and structured to accommodate all necessary factors.

- Compatible, minus the ability to define friendly control measures. Boundaries must be considered to determine friendly AAs.

- In the real world, the G3 determines the area of operations and doesn't follow the rote procedure described in ST 100-9.

General Comments

During the course of the assessment session, the SMEs sometimes made comments that did not conveniently fall into one of the issue categories. These comments provide additional insight into the potential usability of the AA Generation Tool in the field. They also provide information for considering possible improvements and enhancements of the AA Generation function.

A summary of general comments are as follows (see Appendix K for the detailed comments).

- A similar capability is provided by the "Hawkeye", now renamed "Warrior", system, which was used in Desert Storm. The developer is PM-ASAS.

- If fixes can be made, automatic generation of AAs would be useful at division and corps to show major problems in the terrain, and allowing "what-if" analysis that can't typically be done at those echelons.

- Automatic calculation of AAs using "*school rules*" is very useful, although the user would probably draw his own AA after viewing the automatically generated AA.

- An ideal situation is an interactive system that prompts the user when a problem arises during AA generation.

Conclusions and Recommendations

Several themes emerged during the review of the ratings and comments made on the individual issues. These themes appear to be critical to achieving a feasible and usable automated AA generation capability. They are presented below as the key conclusions elicited from the study.

<u>AA Generation in its current form is of marginal usefulness, particularly considering the terrain display products available.</u>

The general consensus was that the cognitive map and the path generation algorithms were not sufficiently sophisticated to produce viable AAs. At the same time, the SMEs did like and appreciate the displays of terrain attributes and mobility characteristics. In current operations, this added information often is not readily available, and planners must rely solely on the map while generating AAs. When used in conjunction with the background map display (i.e., EMAP), the SMEs felt these terrain overlays provided information that would assist the planner in manually generating an AA, and that it would generally be superior to the automatically generated AA.

<u>Unless major fixes are made to AA Generation, the Tool will not be useful.</u>

Although the SMEs did not care for the current AA Generation function, they identified specific deficiencies, which if fixed, would improve the capability. It was not possible in this study to determine the acceptability of the Tool if these deficiencies were corrected. Without correction, however, the Tool would not be acceptable.

The major recommended fixes are summarized as follows (see the Results section of this report for details of the deficiencies).

- The Cognitive Map should include data on hydrology, roads, and bridges, and should provide specific information on SLOW-GO terrain, and the path generation algorithm should use this data.

- The option should be available to restrict AA paths within provided control measures (boundaries, phase lines), specify night or day movement, and to specify starting and ending areas.

- The AA path should be generated to proceed as directly as possible to the destination.

- An interactive way should be provided for a user to override certain critical (i.e., major deviations from a direct course) decisions made by the AA Generation algorithm.

- The AA should be displayed with the actual width of the mobility areas.

Recommendations

The following recommendations are the result of the synthesis of data from this study, the background research performed in order to understand the AA Generation function, and the evaluator's experience with division-level command group planning.

Reconsider the relationship of the AA Comparison Tool to AA Generation. In ALBM ATD, there are two tools involving AAs: AA Generation, which is the topic of this assessment, and the AA Comparison Tool (AACT). The latter tool allows the user to select two or more AAs for analytical comparison using the digitized terrain data available in ALBM ATD. The AAs being compared can be automatically generated using the AA Generation tool, or the user can manually draw them using the interactive graphics capabilities of ALBM ATD. The data used in AACT includes cover and concealment, obstacles, and roads -data that the SMEs indicated would contribute positively to the AA Generation function. Thus, in AA Generation AAs are automatically generated using basic, rudimentary data. These AAs are then compared and analyzed in a separate process using additional, more detailed data. The AAs are also compared and analyzed using a procedure that allows mission requirements and priorities to be associated with the terrain data. That is, the goals of the AA directly influence the outcome of the AACT process.

Observations of mission planning activities have shown that the process used by the planner in developing an AA is iterative - decisions regarding potential paths for the AA are made in conjunction with an analysis of the terrain attributes related to the potential alternative paths. Thus, based on the mission of the forces and tactical constraints, the first AA generated by the planner is usually the AA considered to be best.

Currently, AA Generation has a single goal: to have the shortest travel time from start to end of the AA. The AACT function allows specification of multiple goals. For example, certain missions may require that concealment be as important as travel duration. AA Generation uses only GO, SLOW-GO, and NO-GO terrain locations and mobility speeds for determining the paths of AAs. AACT uses a richer set of data to analyze the terrain attributes of an AA. The analysis data set used by AACT could be profitably used by AA Generation in generating the AAs.

Expand AA Generation to include data analysis and goal definition algorithms. This will allow for the generation of AAs that more accurately reflect the desires of the planner.

Allow the algorithms to exploit the data processing and calculation capabilities of automation. Include the user in the AA generation process to provide decisions and guidance that require cognitively complex integration of facts. That is, allow the computer to aid the user by rapidly processing large amounts of data that the user would be unable to handle, and allow the user to guide the computer operations, particularly in addressing unique, unforeseen tactical situations.

Implement the major fixes identified previously in this section.

Consider and evaluate for correction the other deficiencies identified by the SMEs, as documented in this section.

REFERENCES

Burrough, P. A. (1990). Principles of geographic information systems for land resource assessment. Washington, DC: Clarendon Press.

Command and General Staff College. (1992). The command estimate process. ST 100-9.

Lockheed Austin Division. (1992). Draft software user's manual for the AirLand Battle Management Advanced Technology Transition Demonstration Force Level Control (ALBM ATD FLC) advisor system, version 0.1. Austin, TX.

Flanagan, J. P. (In preparation). Evaluation of ALBM ATD prototype version 1.2: Review of the Trend Analysis and Projection Tool. ARI Research Product. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

McKeown, P. E. (In preparation). Evaluation of ALBM ATD prototype version 1.2: Knowledge base assessment of the Location Analysis Applications. ARI Research Product. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Rappold, V. A., & Flanagan, J. P. (In preparation). Evaluation of ALBM ATD prototype version 1.2: Human factors assessment of the Soldier Machine Interface. ARI Research Product. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Riedel, S. L., McKeown, P. E., Flanagan, J. P., & Adelman, L. (In preparation). Evaluation of ALBM ATD prototype version 1.2: Knowledge base assessment of the Avenue of Approach Comparison Tool. ARI Research Product. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

APPENDIX A

EXAMPLE OF AA GENERATION

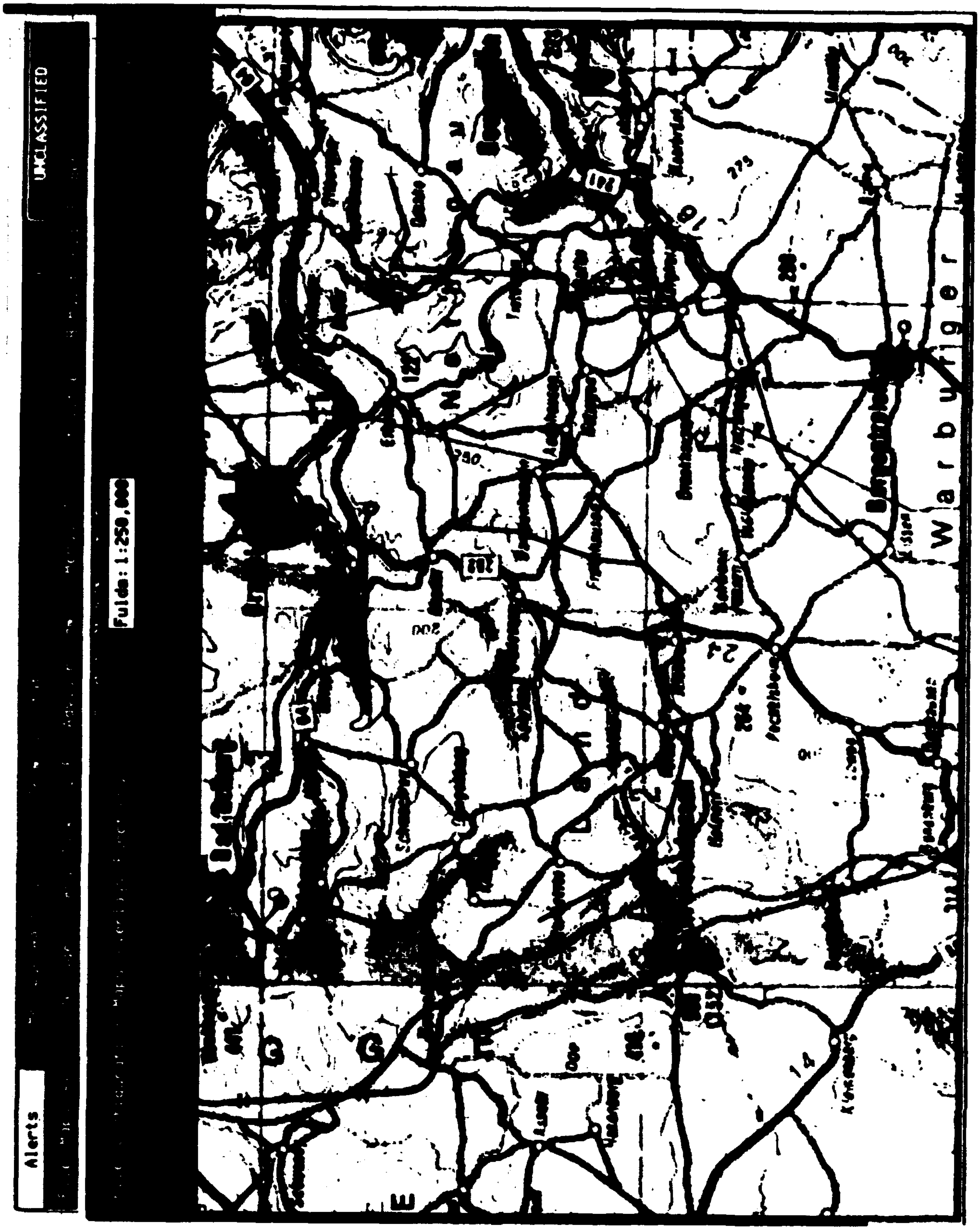


Figure A-1. Map Area Used for AA Generation.

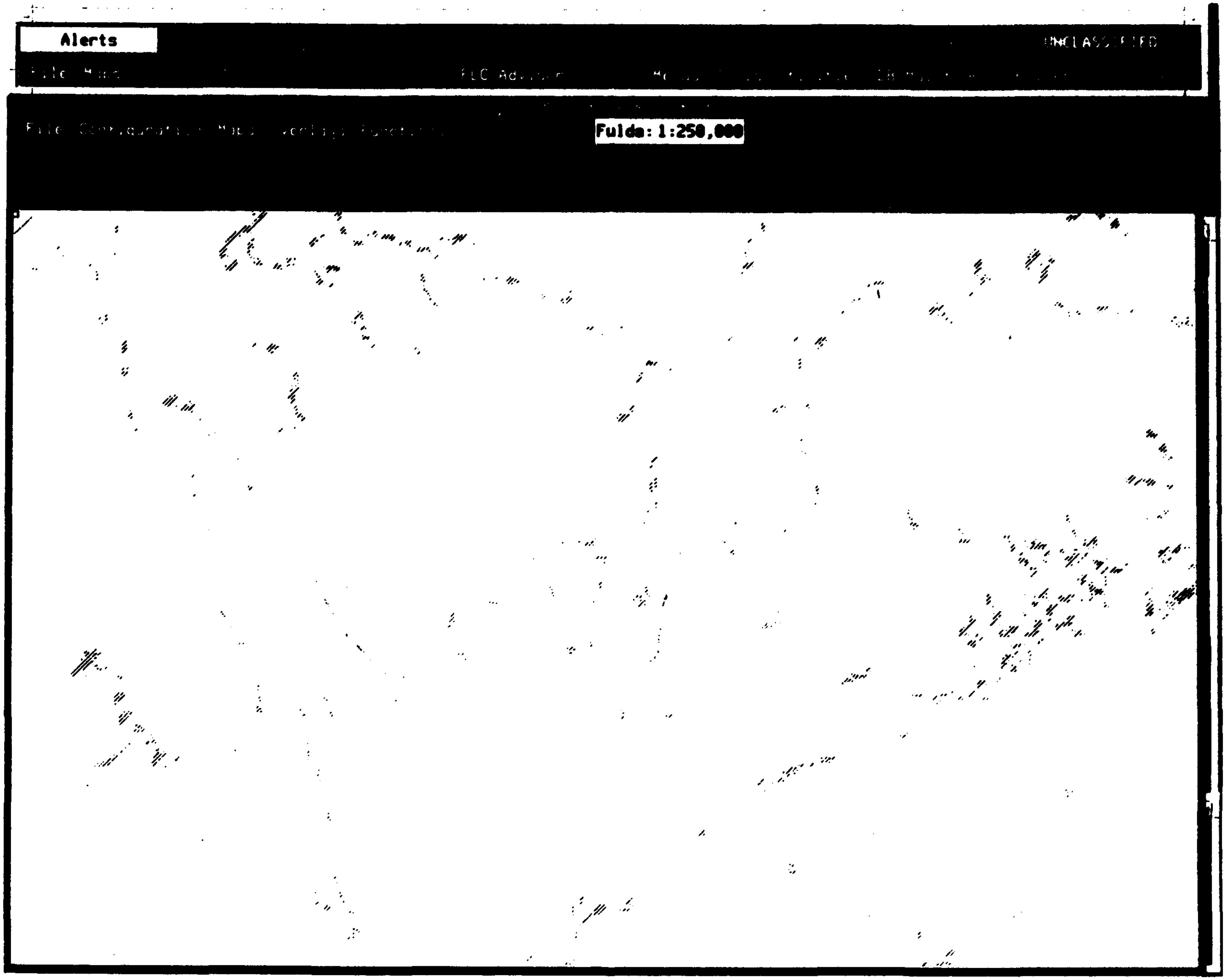


Figure A-2. Areas of NO-GO and SLOW-GO Terrain.

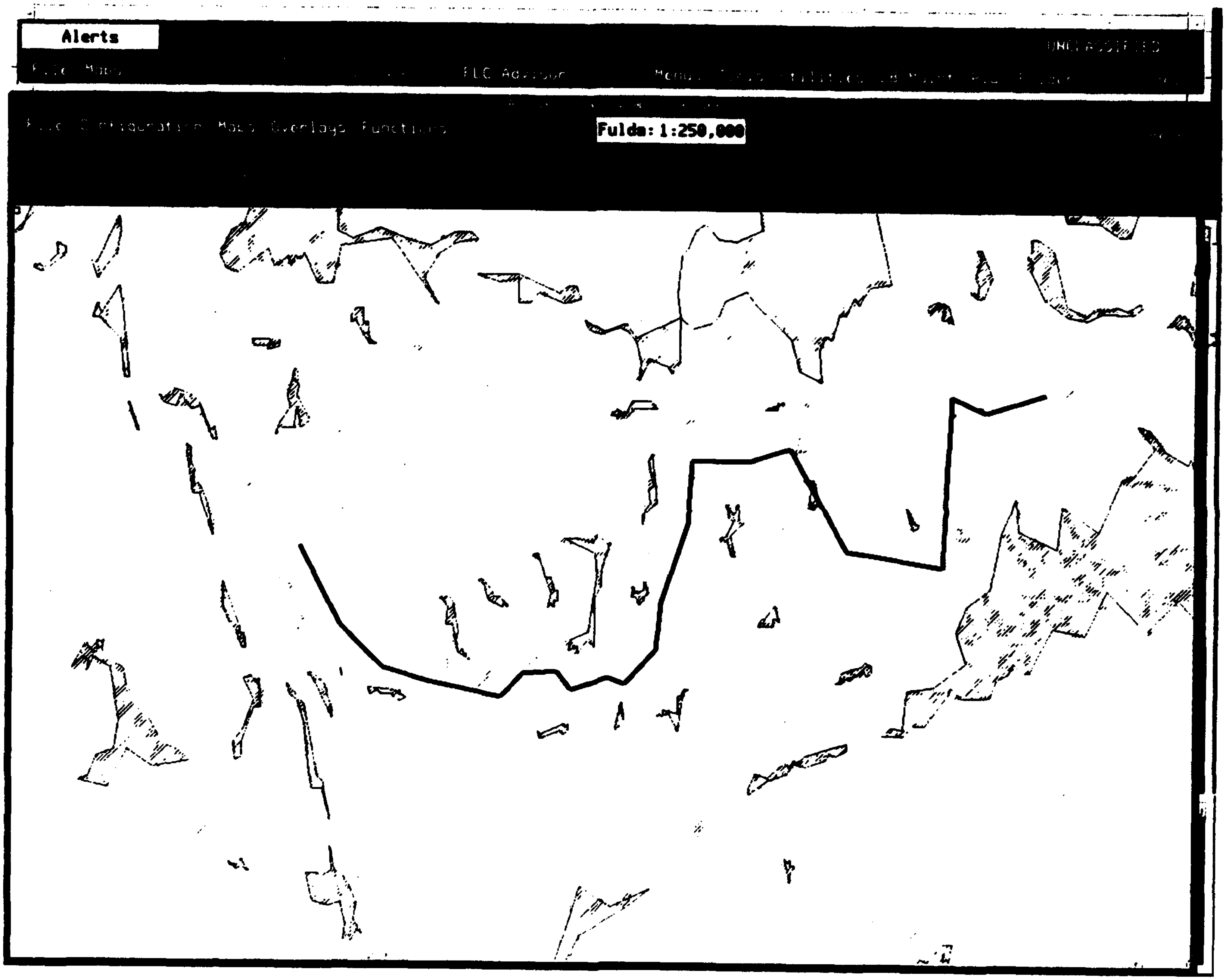


Figure A-3. Polygons Representing NO-GO Terrain.

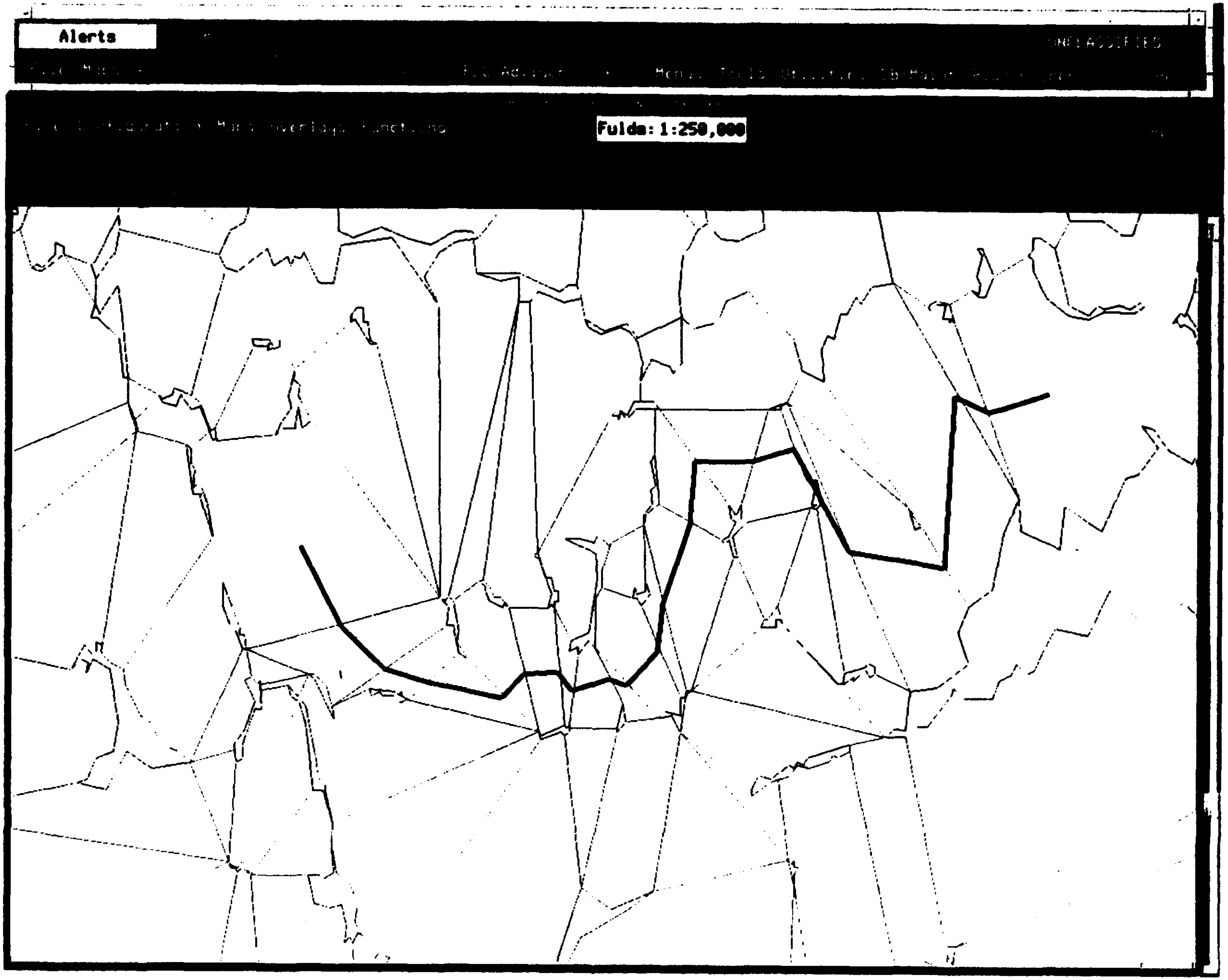


Figure A-4. Polygons Representing GO and SLOW-GO Terrain.

The Search For the Best AA Path

1	User specifies the AA start point, end point, and parameters.
2	System determines which of the gap lines qualify for the AA path (are long enough to allow passage of the desired echelon).
3	System computes time to travel in a straight-line segment from the start point to the mid-point of each qualifying gap line (using unopposed movement rates for mechanized forces over the terrain type found in the starting polygon).
4	System adds the time to move in a straight line from the end of each segment to the AA end point (using SLOW-GO movement rates).
5	The segment that provides the shortest overall travel time is selected.
6	The end of the first route segment becomes the start point of the second segment (in the neighboring polygon). Steps 2 - 5 are repeated for each polygon until the polygon containing the AA end point is reached.

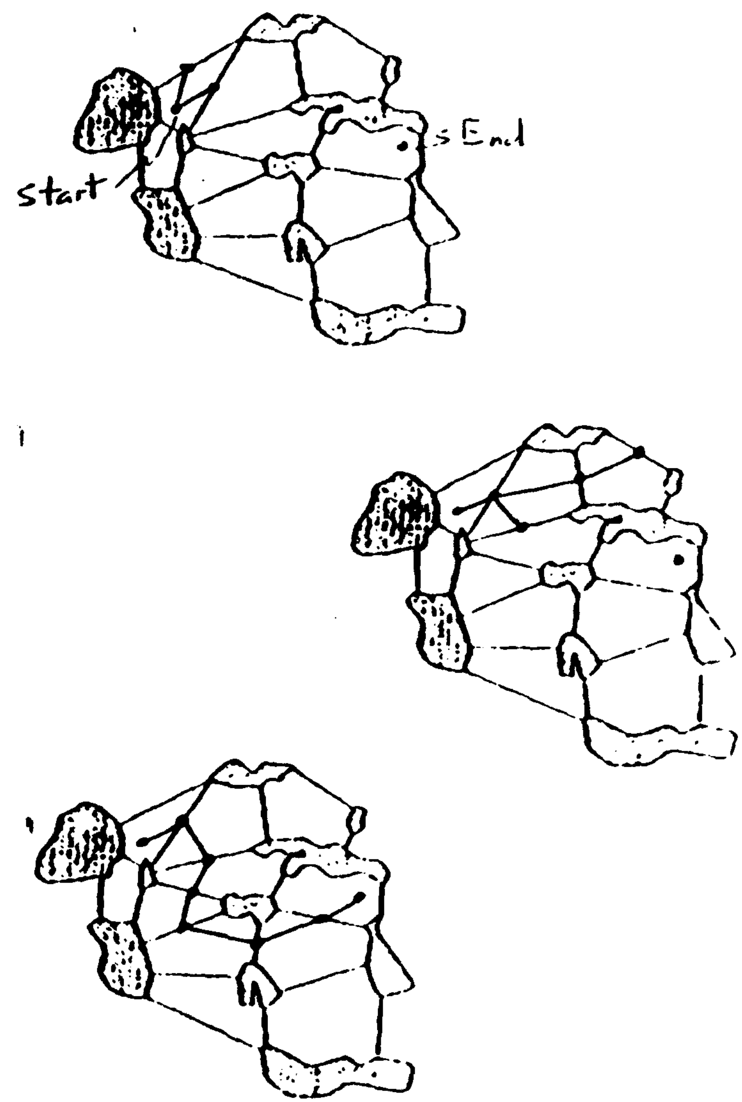


Figure A-5. The Logic of AA Path Generation

The Search For the Best AA Path, Continued

7	If no other qualifying gap lines exist, the system backs up to the next best travel-time segment.
8	If no path can be found, and the user did not require that subordinate unit proximities be maintained, then the process starts over looking for two AA paths for the next lower echelon.
9	If no path is found, the user is told "AA Search Unsuccessful". The user may alter any of the parameters and the start/end points as desired and try again.

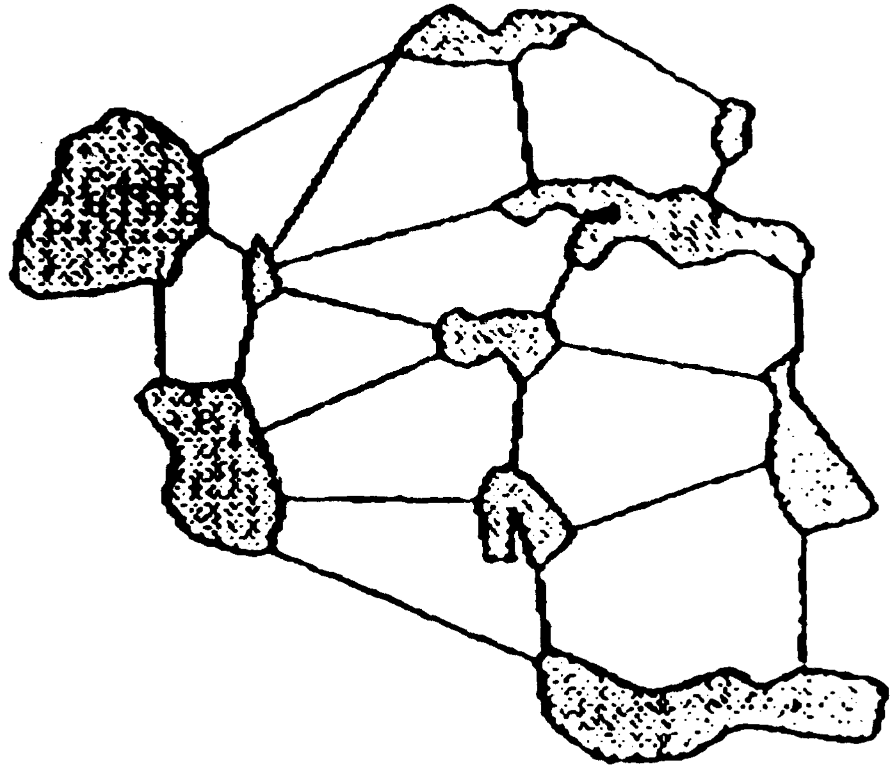


Figure A-5. The Logic of AA Path Generation (continued)

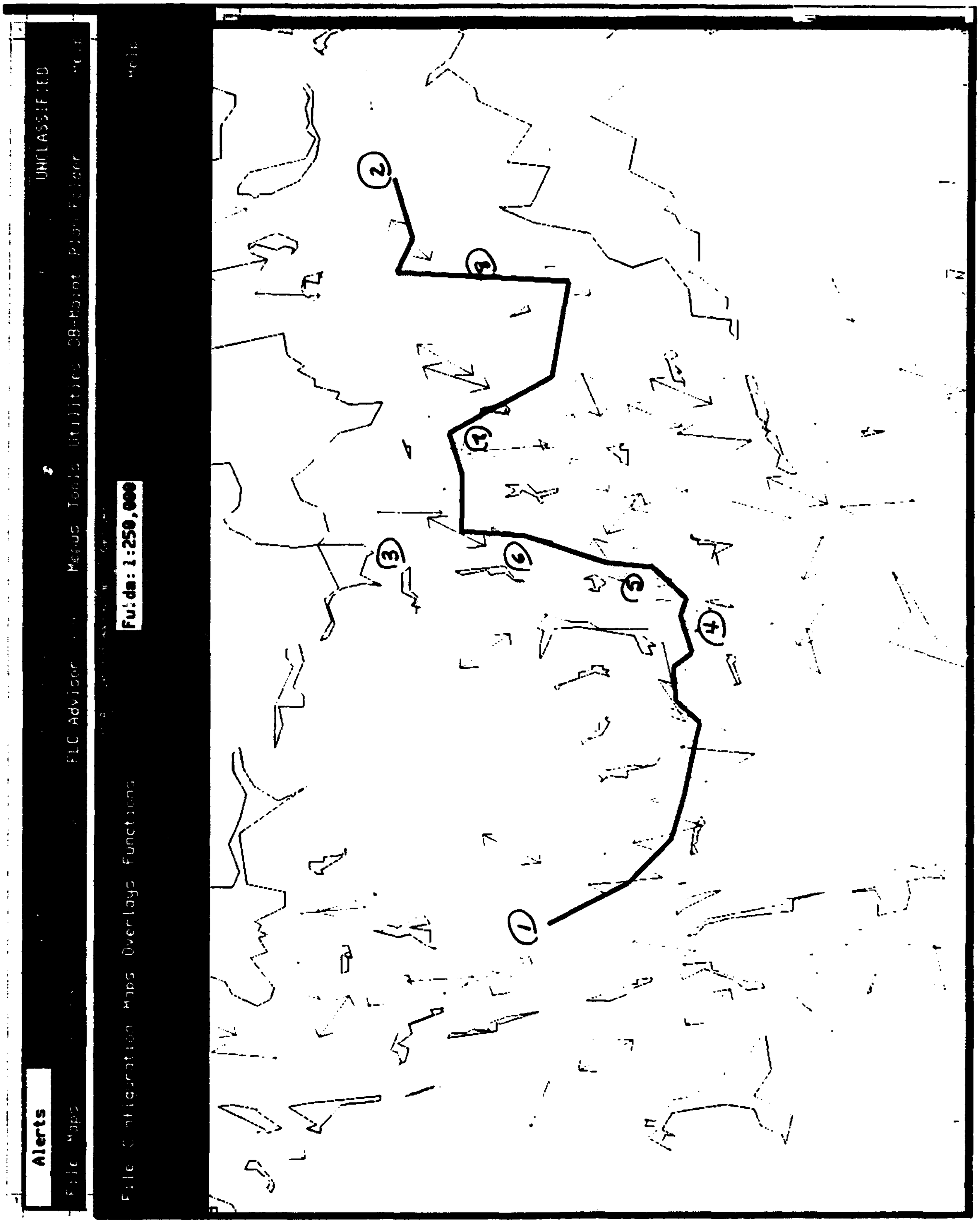


Figure A-6. Example of AA Generation.

APPENDIX B

BRIEFING MATERIALS

ALBM ATTD Knowledge Base Evaluation
Avenues of Approach Generation
Introduction

- Definitions
  - ALBM AirLand Battle Management
  - ATTD Advanced Technology Transition Demonstration

- ALBM ATTD Purpose
  - Define & refine operational requirements for automated decision aids for planning
  - Develop operational prototypes for Decision Aid Applications (DAAs)
  - Facilitate transition of DAAs to ATCCS

- Purpose of Operational Evaluation of ALBM ATTD
  - To ensure the needs of the user are considered in the development of the DAAs

- Types of Operational Evaluations of ALBM ATTD

  Range of Applicability
  Match of Requirements with DAA characteristics
  Requirements Validation
  Utility
  - Performance
  - Usability

  Knowledge Base - Procedures, algorithms, parameters
  - **Completeness**
  - **Accuracy**
  - **Adequacy**

ALBM ATTD Knowledge Base Evaluation

AAs in the Tactical Decisionmaking Process (ST 100-9)

Products In	Phase of Tact. Decisionmaking	Products Out	AA Activity
Mission from Higher	Mission Analysis	Intel Estimate Restated mission Analysis brief Commander's guidance	**Generate AAs** Compare AAs (to support analysis brief)
Intel Estimate Restated Mission Commander's Guidance	Course of Action Development	COA statements and sketches Intel Estimate update COA brief	**Generate AAs (to support alternative COAs)** Compare AAs
COA statements and sketches Intel Estimate update Commander's approval	Course of Action Analysis and Comparison	Wargame results Decision matrices COA decision brief	Use approved AAs
Commander's intent Wargame results	Decision and Execution	OPLAN/OPORD	Use approved AAs

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis - ST 100-9, 1992

General Process

- Identify gaps (missing) in terrain data
- Develop terrain factor overlays
- Integrate weather
- Combine overlays
- **Identify Avenues of Approach**
- Analyze Avenues of Approach

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis, continued

Identify gaps in terrain data
Fill gaps with data from other units, imagery, reconnaissance

Develop terrain factor overlays

- Tree spacing, stem diameter
- Stream width, banks, velocity, depth
- Canopy closure, vegetation density
- Soil types
- Height of vegetation and built-up areas
- Slopes

Integrate weather

ALBM ATTD Knowledge Base Evaluation
Terrain Analysis, continued

Combine overlays into GO, SLOW-GO, and NO-GO areas

Terrain Factor	NO-GO	SLOW-GO	GO
Man-made obstacles	Yes	No	No
Built-up areas	Over 500 meters wide, or not easily bypassed	Easily bypassed, or under 500 meters wide	Easily bypassed, or under 500 meters wide
Slope uphill	Over 45%	30 - 45%	Under 30%
Hard surface roads/trails (only if terrain is not open) **See Note below**	No road, and no more than 1 trail per km	Per km, 1 road, or 2 trails, or one of each	2 or more roads per km
Tree diameter and spacing	6-8 inches thick, and less than 20 ft spacing	2-6 inches thick, and less than 20 ft spacing	Under 2 inches thick, or over 20 ft spacing
Stream bank height	Over 4 ft	Under 4 ft	Under 4 ft
Stream attributes	Depth over 4 ft, or velocity over 5 ft/sec	Depth 2-4 ft	Depth under 2 ft
Elevation variation in one km	Over 200 meters	100-200 meters	Under 100 meters

Note: Except for Hard Surface Roads/Trails, if the terrain meets any of the criteria in the NO-GO column, then the terrain is NO-GO even if all other attributes are in the GO category. If the terrain is not open (e.g. restrictive tree diameter and spacing), then the existence of roads/trails may have the effect of raising the mobility of the terrain. For example, if two roads exist in an area, then restrictive tree diameter and spacing would not reduce the mobility to SLOW-GO or NO-GO.

Identify Avenues of Approach

- Determine mobility corridors

Corridors use GO terrain, avoid NO-GO areas, and occasionally use SLOW-GO terrain if necessary.

Mobility corridors are determined two echelons down from the planner's echelon.

Mobility corridors are non-directional unless slope dictates a direction.

Unit	Mob. Corr. Width
Division	6 km
Bde/Rgt	3 km
Bn	1.5 km
Co	.5 km

- Determine Avenues of Approach (AAs)

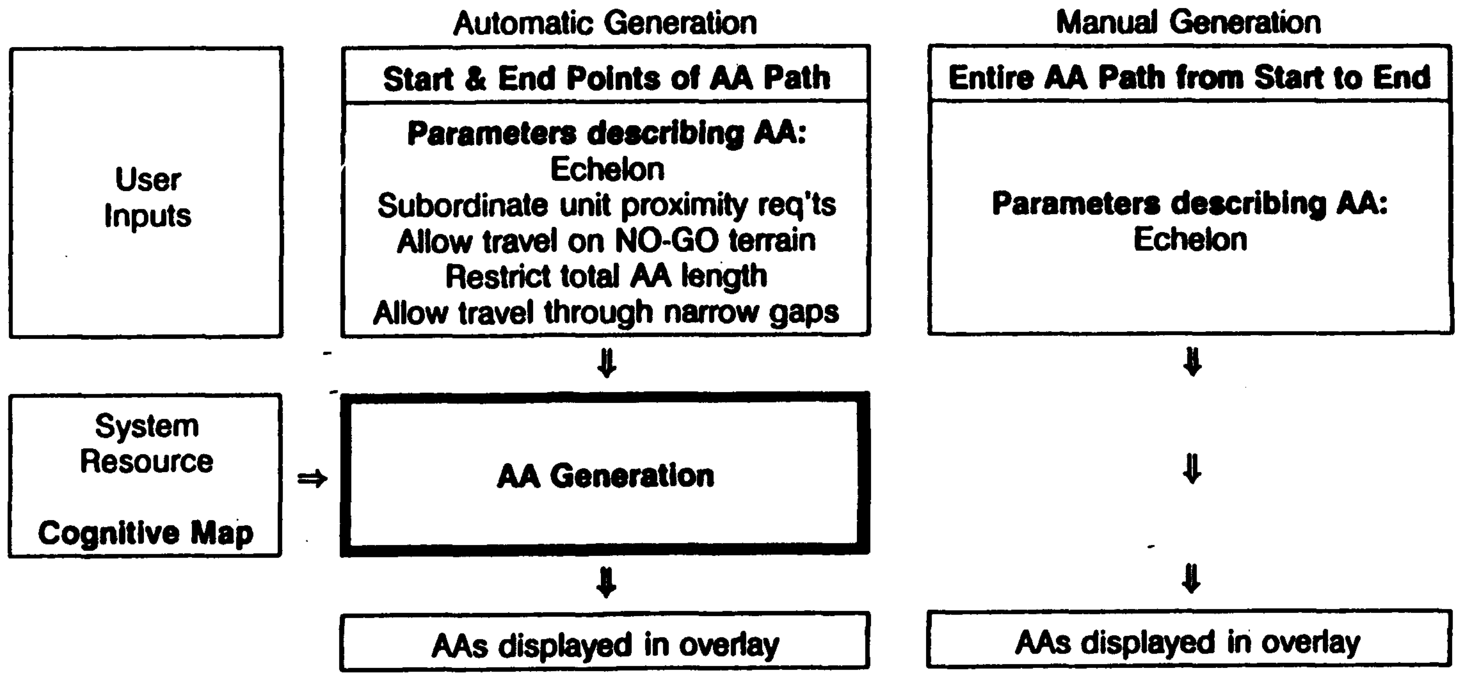
AAs are determined for the echelon below the planner, using two mobility corridors for the next subordinate echelon.

Echelon	AOA	Mob. Corridor
Corps	Division	Bde/Rgt
Division	Bde/Rgt	Bn

The two mobility corridors should not be too widely separated.

AOA	Mobility Corridor	Max. Separation
Division	Bde/Rgt	10 km
Bde/Rgt	Bn	6 km
Bn	Co	2 km

Overview of AA Generation Process



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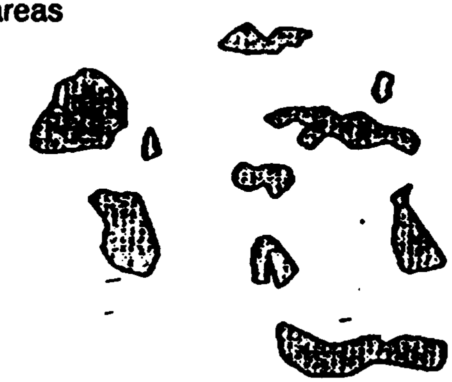
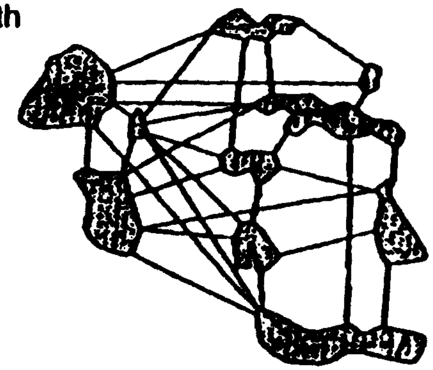
Cognitive Map Generation

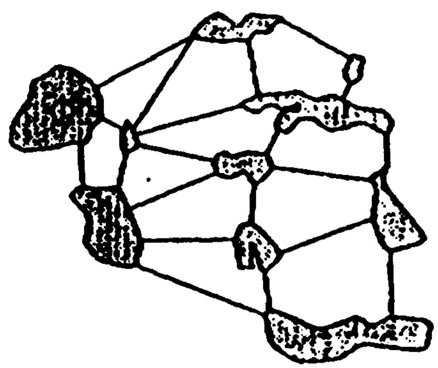
Begin with map of NO-GO areas



Join neighboring NO-GO areas with lines of minimum length



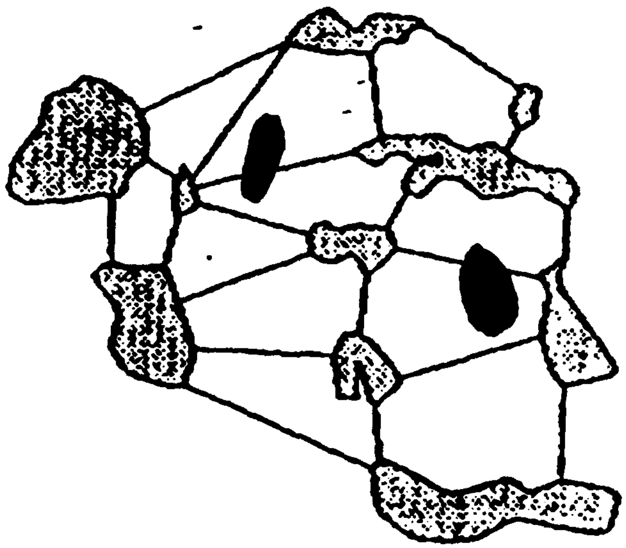
Remove intersecting lines (the longest ones)



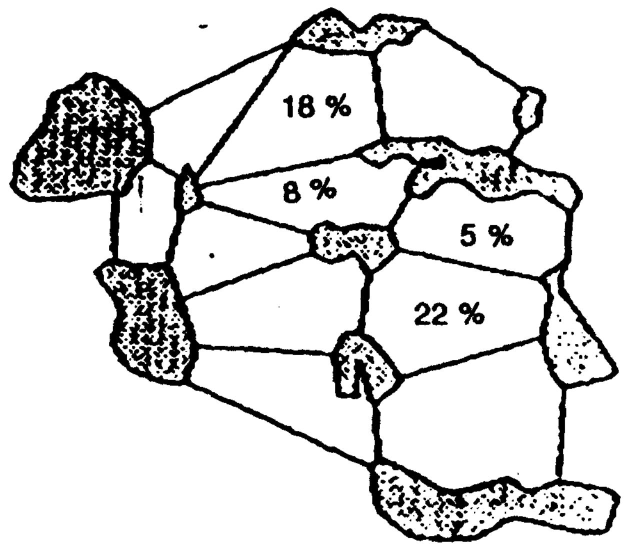
The result is a map made up of two types of polygons, NO-GO and "other than NO-GO"

Cognitive Map Generation, Continued

SLOW-GO areas are investigated in relation to the "other the NO-GO" polygons



A percentage of SLOW-GO terrain is calculated for each polygon



Parameters Used For AA Generation

Basic Parameters	**Unit Template** (Echelon) (Frontage Requirement in km's)	Division: 6 km Frontage Brigade: 3 km Frontage Brigade (2 Bns): Two Routes of 1.5 km Frontage Each Battalion: 1.5 km Frontage Company: 0.5 km Frontage
	Maintain Proximities of Subordinate Units (Yes or No)	Division: Brigades Max. Separation of 10 km Brigade: Battalions Max. Separation of 6 km Battalion: Companies Max. Separation of 2 km
Augmenting Parameters	**Choke Factor** (meters)	The amount, in meters, that the frontage requirement is allowed to be relaxed to permit passage of a unit through a narrow gap
	Path Deflection (percent)	The amount, in percent, that the AA length is allowed to exceed the straight-line distance from start to end points
	Avoid NO-GO Terrain (Yes or No)	If Yes, allows AA path to cross NO-GO terrain polygons
	Allow Subordinate Units to Stop (Yes or No)	If Yes, and subordinate unit proximity is not maintained, subordinate units can pause to allow passage on the same AA path

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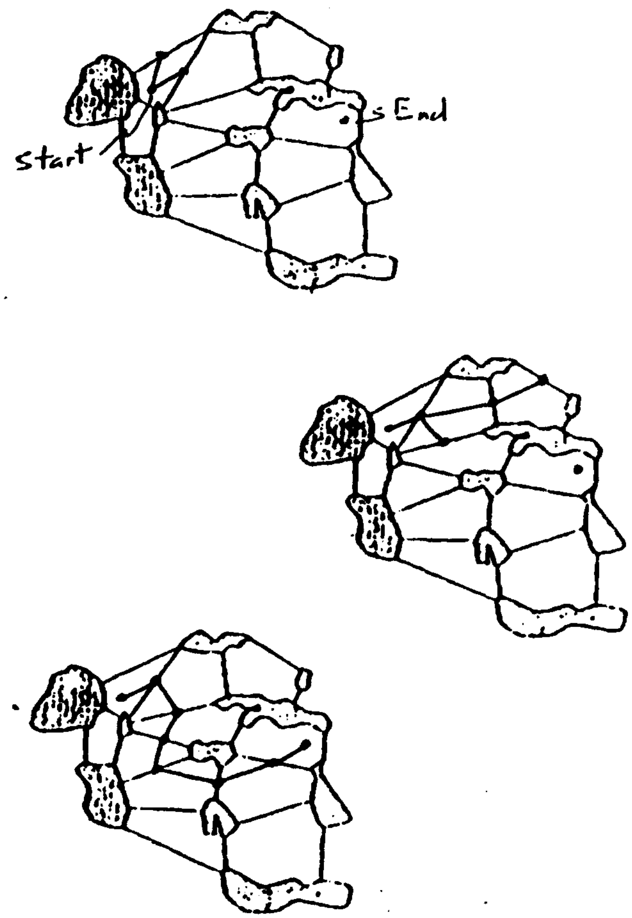
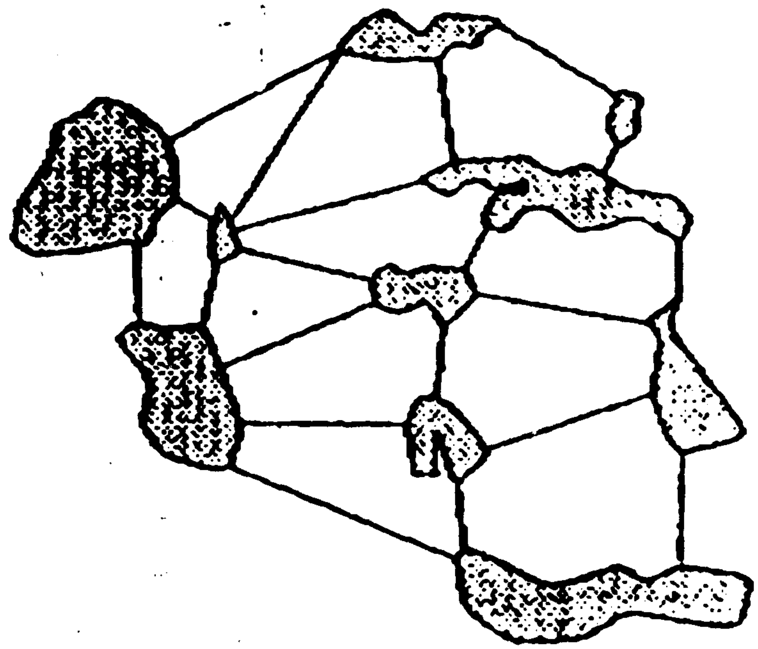
The Search For the Best AA Path

1	User specifies the AA start point, end point, and parameters.
2	System determines which of the gap lines qualify for the AA path (are long enough to allow passage of the desired echelon).
3	System computes time to travel in a straight-line segment from the start point to the mid-point of each qualifying gap line (using unopposed movement rates for mechanized forces over the terrain type found in the starting polygon).
4	System adds the time to move in a straight line from the end of each segment to the AA end point (using SLOW-GO movement rates).
5	The segment that provides the shortest overall travel time is selected.
6	The end of the first route segment becomes the start point of the second segment (in the neighboring polygon). Steps 2 - 5 are repeated for each polygon until the polygon containing the AA end point is reached.



The Search For the Best AA Path, Continued

7	If no other qualifying gap lines exist, the system backs up to the next best travel-time segment.
8	If no path can be found, and the user did not require that subordinate unit proximities be maintained, then the process starts over looking for two AA paths for the next lower echelon.
9	If no path is found, the user is told "AA Search Unsuccessful". The user may alter any of the parameters and the start/end points as desired and try again.



APPENDIX C

QUESTIONNAIRE AND RELEASE FORM

Cognitive Map

Is the cognitive map an adequate representation of terrain from the standpoint of AA generation?

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate

List any deficiencies

What changes would you make to the cognitive map to make it adequately represent the terrain for purposes of generating AAs?

AA Path Generation

Does the <u>method</u> of generating a path of an AA reliably result in an adequate AA?

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate

<u>List any deficiencies</u>

How much <u>confidence</u> do you have in an AA generated by ALBM?

Highly Confident	Rather Confident	Borderline	Somewhat Unconfident	Decidedly Unconfident

What steps would you take to increase your <u>confidence</u> in the generated AA?

User Interaction

Do the parameters that control AA generation provide adequate ability for the user to represent his desires?

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate

What other control mechanisms should be provided?

Are the products (displays) usable, in terms of information content and format?

Highly Usable	Rather Usable	Borderline	Somewhat Unusable	Decidedly Unusable

What other displays would be useful?

Compatibility with Doctrine

Is the AA generation method compatible with doctrine?

Highly Adequate	Rather Adequate	Borderline	Somewhat Inadequate	Decidedly Inadequate

List any discrepancies

WALK THROUGH QUESTIONNAIRE

Your Background

Date: ________

Grade: ______________________

Branch: ______________________

Time in Grade: ______________________

Time in Service: ______________________

Current Position: ______________________

Duties of Current Position: ______________________

____

Highest level of civilian education: ______________________

Area of study: ______________________

Please indicate year(s) of attendance for military schools completed:

Officer Basic Course: ______________________

Officer Advanced Course: ______________________

Combined Arms & Service Staff School (CAS 3):______________________

Command and General Staff Course (CGSOC or equivalent): ______________________

War College: ______________________

Other relevant military education: ______________________

Please indicate most significant tactical command or staff positions held:

Echelon	*Unit Type*	*Position*	*Months in Position*
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________

Which of the following best describes your experience and level of skill with computers?

Less than 1 year, relatively unfamiliar ______________

1 - 3 years, somewhat familiar ______________

More than 3 years, quite familiar ______________

Which of the following best describes how you now do tactical planning?:

Manually ________

Use Maneuver Control System (MCS) ________

Use other aided systems (please list) ______________________

VOLUNTEER AGREEMENT

I, ______________________________ (print name), hereby volunteer to participate in a study to evaluate the ALBM ATD prototype, FLCA 1.2, under the co-direction of Sharon Riedel from the Army Research Institute and MAJ M. C. Berwanger from the Battle Command Battle Laboratory, Ft. Leavenworth, KS.

The study has been explained to me and is described on the preceeding page, which I have signed. I have been given the opportunity to ask questions concerning this investigational study, and any such questions have been answered to my complete satisfaction.

I understand that I may at any time during the course of this study revoke my consent, and withdraw from the study without prejudice.

______________________ ______________
signature date

______________________ ______________
witness signature date

APPENDIX D

SUBJECT MATTER EXPERT BACKGROUND

Background Information

Information		SME A			SME B			SME C		
Service	Rank	MAJ			MAJ			MAJ		
	Time in Grade	2 months			1 year			2 years		
	Time in Service	11.5 years			12.5 years			17 years		
	Current Position	SAMS Student			SAMS Student			CAC - Threats		
	Current Duties	SAMS Student			SAMS Student			Ch, Theater Scenarios		
Education	Highest Military School	CGSOC			CGSOC			CGSOC		
Tactical Position	Echelon	Bde	Corps	Co	Bn	Trp		Corps	Div	Bn
	Unit Type	Inf	Hvy	MI	Cav	Cav		Abn	Inf	Inf
	Position	Asst S2	G2 Plans	Cmdr	S3	Cmdr		Plans Analyst	Dep G2	S2
	Months Service	24	18	15	12	19		18	12	12

Notes:

Abn	Airborne
Arm	Armor
Arty	Artillery
BCTP O/C	Battle Command Training Program Observer/Controller
Bde	Brigade
BICC	Battlefield Intelligence Coordination Center
Bn	Battalion
CAC	Combined Arms Center
Cav	Cavalry
CGSOC	Command and General Staff Officer Course
Co	Company
Div	Division
Hvy	Heavy
Inf	Infantry
MI	Military Intelligence
Plt	Platoon
SAMS	School of Advanced Military Studies

Information		SME D			SME E			SME F		
Service	Rank	MAJ			MAJ			LTC		
	Time in Grade	2 months			4 years			2 years		
	Time in Service	12 years			16 years			19 years		
	Current Position	SAMS Student			BCTP O/C			BCTP O/C		
	Current Duties	SAMS Student			Observe Corps Intell Staffs			Observe G2 Activities		
Education	Highest Military School	CGSOC			CGSOC			CGSOC		
Tactical Position	Echelon	Bn	Bn	Co	Div	Bn	Corps	Bde	Bn	Plt
	Unit Type	Arm	Arm	MI	Inf	Inf	Hvy	MI	Arty	Inf
	Position	S2	BICC	Cmdr	G2	S2	Dp G5	S3	S2	Cmd
	Months Service	26	12	22	24	36	25	24	6	6

Notes:

Abn	Airborne
Arm	Armor
Arty	Artillery
BCTP O/C	Battle Command Training Program Observor/Controller
Bde	Brigade
BICC	Battlefield Intelligence Coordination Center
Bn	Battalion
CAC	Combined Arms Center
Cav	Cavalry
CGSOC	Command and General Staff Officer Course
Co	Company
Div	Division
Hvy	Heavy
Inf	Infantry
MI	Military Intelligence
Plt	Platoon
SAMS	School of Advanced Military Studies

APPENDIX E

LOCATION ANALYSIS TOOLS RATINGS AND COMMENTS

AA Generation Questionnaire and Interview Results
Cognitive Map, Ordered by SME

SME	Is the cognitive map an adequate representation of terrain from the standpoint of AA generation?					List any deficiencies (written comment)	What changes would you make to the cognitive map to make it adequately represent the terrain for purposes of generating AAs? (written answer)	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate			
A				X		SLOW-GO terrain is not specifically considered in the generation of the AA. The details of roads, rail, and hydrology are not considered. Depending on the type of operation you conduct, these items can be critical in determining an AA.	Delineate the SLOW-GO terrain as compared to combining it with the GO terrain as a percentage. Create an ability to modify the terrain as the operation progresses. Based upon the amount and type of traffic that passes over a certain area in a given amount of time, the trafficability of the terrain will most likely change.	The standards for GO, SLOW-GO, and NO-GO terrain are based on German operations. The user may want to provide alternate parameters for other areas of the world. It would be useful to know what attribute caused an area to be NO-GO. An AA for a flank force may need to avoid passing by certain types of NO-GO terrain that cause coordination problems, or expose a flank to attack.
B				X		This representation is too general and looks at things from too much of a macro sense. While the need to reduce detail to accomplish calculations makes sense, generalizing SLOW-GO terrain into an entire polygon trivializes its effects. In addition, ignoring roads and actual waterway locations makes it difficult to relate this representation with reality.	Make SLOW-GO areas specific polygons. Account for road network and capacities, and actual waterway impact.	It is desirable to include selected control measures (boundaries, contamination areas, etc.) in the cognitive map. GO and NO-GO areas are used. The biggest concern is how to maneuver around SLOW-GO areas. Dismounted operations and terrain in other parts of the world should be accommodated.
C			X			Deals only with cross-country movement. Appears to allow forces to cross water obstacles at will. Does not consider cover/concealment factors.	Add road and bridge data. Allow for input of control measures.	

SME	Is the *cognitive map* an adequate representation of terrain from the standpoint of AA generation?					List any deficiencies (written comment)	What changes would you make to the cognitive map to make it adequately represent the terrain for purposes of generating AAs? (written answer)	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate			
D			X			It's unclear how exact the distinction is between GO and NO-GO areas. Crossing into a NO-GO area guarantees NO-GO movement rates, when the edges of the areas may not really be NO-GO. The allure of existing road networks can not be ignored. Units consciously or unconsciously migrate toward them. The road network probably captures the path of least resistance or shortest distance.		An area defined as NO-GO in the cognitive map may not be NO-GO to the user (45% slope vice 44% slope). Knowing why an area is NO-GO would help the decision process.
E			X			Adequate from a purely "academic" view of terrain, minus friendly and enemy situation and graphics. Both of these latter factors determine AAs.		Weather has a major impact on determining GO, SLOW-GO, and NO-GO terrain. Friendly control measures (boundaries, phase lines, etc.) need to be considered along with terrain factors for friendly AAs.
F		X				Need differentiation between built-up areas and other NO-GO terrain.		SLOW-GO areas are vehicle dependent (M-1 versus 2½ ton truck). Need cognitive maps for different force types.

APPENDIX F

GLOSSARY OF ACRONYMNS AND ABBREVIATIONS

AA Generation Questionnaire and Interview Results
Path Generation, Ordered by SME

SME	Does the method of generating a path of an AA reliably result in an adequate AA?					List any deficiencies (written comment)	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate		
A			X			Centering the path between NO-GO areas does not necessarily provide an avenue along the best terrain from the start point to the end point (one may, in fact, have an avenue drawn through SLOW-GO terrain when GO terrain is to either side). The example shown didn't provide the most feasible AA because the avenue went through NO-GO terrain when there was no need to, because of the center point and shortest time method of generating the AA.	
B				X		AA didn't make sense approximately 33% of the time. It went over NO-GO terrain and ignored logical mobility corridors.	Calculating the route as you go, rather than using a decision tree of alternatives, results in a rough AA. Perhaps the system should be interactive and prompt the user at points where extreme changes of direction, or crossing of NO-GO terrain, occurs. The user could then override or guide the system as to the desired path. Perhaps the path could be refined (smoothed) after it has initially been drawn.
C		X				Does not consider night movement. Allow for consideration of alternative AAs early on.	
D		X				Placing the AA path at the mid-point between NO-GO areas skews the path. It appears to identify an adequate, but not necessarily optimum AA.	
E				X		Projects AAs solely on terrain considerations, that may be tactically infeasible.	The speed and directness of generated AAs is questionable. Serpentine routes exposes forces for more time and requires soldier navigation tools. The system needs to take the force from A to B by the most direct route and reports problems with using that route, allowing user override.

SME	Does the method of generating a path of an AA reliably result in an adequate AA?					List any deficiencies (written comment)	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate		
F			X			Use of mid-point between NO-GO polygons causes poor route selection.	There is a fundamental flaw in the algorithm. After checking the mid-point of a gap between NO-GO polygons, it should look for a more direct path to the end-point. As an alternative, draw a line form start to end and move the line as little as possible to obtain the most direct route. Perhaps the system should be interactive.

APPENDIX G

RESULTS OF CONFIDENCE IN GENERATED AA

AA Generation Questionnaire and Interview Results
Confidence in the Generated AA, by SME

SME	How much confidence do you have in an AA generated by ALBM?					What steps would you take to increase your confidence in the generated AA? (written comment)	Verbal Comment
	Highly Confident	Rather Confident	Border line	Somewhat Unconfident	Decidedly Unconfident		
A			X			As it is now, I would look at the computer generated AA, erase it, and draw my own. It's a good start point for determining AA but I don't think I would *trust it, as is, because of the deficiencies listed* previously.	
B			X			Show alternate AAs. Give the user a choice in questionable situations.	
C			X			Incorporate changes suggested for the cognitive map.	
D			X			A 3-dimensional travel path display might instill greater confidence that the AA is adequate, if not optimal. It might also allow the user to adjust the path toward the more likely traveled point on the ground, thereby changing the AA selected by the algorithm.	
E				X			I question whether the generated AA is really good. It may be fine for peacetime/administrative moves, but not for wartime where time and directness are critical.
F			X			Make AA generation interactive.	I would not follow the path automatically generated.

APPENDIX H

RESULTS OF PARAMETER USE

AA Generation Questionnaire and Interview Results
Parameters That Control AA Generation

SME	Do the parameters that control AA generation provide adequate ability for the user to represent his desires?					What other control mechanisms should be provided? (written comment)	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate		
A		X				Incorporate the distance that the user will allow the force to travel through constricted terrain as an additional facet of the Choke Factor parameter. Add soil/path degradation factor, to describe the change in the condition of an area over time given numbers and types of vehicles planned to traverse the area (may change GO to SLOW-GO or NO-GO).	
B		X				Need ability to control illogical deviation, i.e. agree/disagree with major deviations from the logical path.	There should be a threshold value for the "Avoid NO-GO" parameter, to allow a portion of the path to cross NO-GO terrain.
C		X				Early comparisons of alternate AAs/MCs. Provide phase lines for variation in movement formation. Allow for cover and concealment requirements.	
D			X			Calculate the AA using all the possible parameters. The chosen parameters define, but also restrict, the AA. The user needs to have displayed, without asking, what alternatives are available by changing the parameters. This could increase confidence that the correct AA was selected and not unduly biased *by a single parameter. The result of all possible* parameter permutations should be available to the user to ensure parameters are defining, not *restricting*, the AA generation.	
E				X		G2/Terrain teams are required to project AA for both friendly and enemy forces, yet parameters set only for US.	Parameters for friendly and enemy AAs should be different.
F		X				Add time as a factor. A route could be chosen that is the shortest but traverses largely SLOW-GO terrain.	

APPENDIX I

USABILITY OF DISPLAY RESULTS

AA Generation Questionnaire and Interview Results
Usability of Displays

SME	Are the products (displays) usable, in terms of information content and format?					What other displays would be useful? *(written comment)*	Verbal Comment
	Highly Adequate	Rather Adequate	Border line	Somewhat Inadequate	Decidedly Inadequate		
A		X				I like the idea of graphically depicting NO-GO and SLOW-GO terrain; it's much easier to visualize AAs once this is done. I would like to see the hydrology depicted separately from the SLOW-GO or NO-GO terrain.	
B			X			Display mobility corridor width, based on actual width of the corridor, not unit echelon.	
C			X			Graphics should be consistent with manually generated graphics. Time and distance from start to end points should be displayed.	
D		X				A 3-dimensional product would definitely be desirable.	
E			X			At division or corps level, the screen presentation may be too small to adequately portray AAs to a decision maker. May have to re-plot AA (if accepted) on a "acetate" overlay on regular scale map. The issue is how much time is saved.	With the cognitive map display (GO, SLOW-GO, NO-GO terrain) you could manually draw the AA. Need a way to display products to the commander, such as a color printer or large screen display.
F		X				Scaling or grid lines are necessary in overlays. Color code NO-GO and SLOW-GO terrain using standard map colors, for example, built-up areas (NO-GO) cross-hatched in black, and forests/mountains (SLOW-GO) hatched in brown.	

APPENDIX J

COMPATIBILITY WITH DOCTRINE RESULTS

AA Generation Questionnaire and Interview Results
Compatibility with Doctrine

	Is the AA generation method compatible with doctrine?					List any deficiencies (written comment)	Verbal Comment
	Highly Compatible	Rather Compatible	Border line	Somewhat Incompatible	Decidedly Incompatible		
A			X			It's rudimentary approach to determining AAs is compatible with the general procedure delineated in FM 34-130, Intelligence Preparation of the Battlefield. The methodology is too rigid as it stands now in this specific software. The mid-point criteria for determining the AA needs refinement.	
B			X			Ignorance of waterways, etc., is greatest deficiency.	
C			X			Doesn't consider night movement rates.	
D		X				The generation process tries to codify the way we look at terrain through a map. Seeing the terrain on the ground can be quite different than seeing it through a map. Terrain can be manipulated by the visionary military commander. Selecting an AA is a manifestation of that vision. Some will always do it better that others. This AA generation process does not begin to capture this essence of military genius.	
E			X			Compatible, minus the ability to define area with friendly graphics. First step in wargaming is G3 provided area of operations (i.e., boundaries). These must be considered to determine friendly AAs.	ST 100-9 is not a doctrinal manual. Some FMs may have different values for parameters, such as frontages. In the real world, the G3 determines the area of operations and doesn't follow the rote procedure described in ST 100-9. Seldom will a Brigade commander be told an AA to follow. He will be given the general area and will determine the AA with his S2.
F		X				Use standard map colors for terrain overlays (black for built-up areas and brown for forests/mountains).	

APPENDIX K

AA GENERATION QUESTIONNAIRE AND INTERVIEW RESULTS GENERAL COMMENTS

AA Generation Questionnaire and Interview Results
General Comments

Subject Matter Expert	Comment
A	1. FM 34-130 is the manual for IPB and goes into greater detail than ST 100-9. Is the developer using this manual? 2. The system is oriented towards Mid-/High-Intensity, and mechanized forces. What about low-intensity and light forces? 3. The concept is good, but need to allow changing of the parameters that define cross-country mobility, allow degradation of terrain, and explicitly provide for SLOW-GO in the cognitive map. 4. Some IEW systems do this same task. "Hawkeye" was used during Desert Storm. Similar functions may be incorporated into ASAS (JPL is contractor). Perhaps coordination should be performed with PEO IEW. 5. Once the cross-country mobility and the other terrain overlays are available with the E-Map, anyone could draw the AAs. 6. The upper limit of length for division AAs is 100 km.
B	1. My perspective is that of "operations" (G3), rather than G2 or terrain analysis. 2. There are disconnects between ST 100-9 and FM 34-130 in terms of defining GO, SLOW-GO, and NO-GO terrain. 3. The parameters used by "soviet" forces for AAs is different than for friendly forces. It appears that the system is using soviet parameters. 4. If fixes can be made, automatic generation of AAs would be useful at division and corps to show major problems in the terrain, and allowing "what-if" analysis that can't typically be done at those echelons.
C	1. The system constructs paths from start point to end point, but forces normally move from assembly areas to objectives (also areas). Moving the start or end points could have a large impact on the calculated route. Perhaps the system could use three start points in the assemble area, and three end points in the objective, and calculate three alternative AAs. 2. Automatic calculation of AAs using "school rules" is very useful, although the user would probably draw his own AA after viewing the automatically generated AA. 3. The system should be able to generate AAs for "Soviet" divisions of at least 30 km in length.
D	(None)

AA Generation Questionnaire and Interview Results
General Comments

E	1. The system should be able to handle AAs of a length of at least 25 km, up to 50 km. 2. Given the terrain analysis products able to be displayed on the map, the value added of automatic AA generation is very small.
F	1. Automatic AA generation is of some value, since manually drawing an AA might ignore narrow NO-GO gaps. Ideal situation is an interactive system that prompts the user when a problem arises during AA generation. 2. The system should support AAs of at least 100 km at division level. 3. The "Hawkeye", now renamed "Warrior" system provides terrain analysis products. The developer is PM-ASAS. The contractor is MYSTECH at Bailey's Crossroads in Virginia.

APPENDIX L

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

APPENDIX L

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AA	Avenue of Approach
AACT	Avenue of Approach Comparison Tool
ALBM	AirLand Battle Management
AMC	Army Materiel Command
ARI	Army Research Institute
ATCCS	Army Tactical Command and Control System
ATD	Advanced Technology Demonstration
BA	Battlefield Area
BCBL	Battle Command Battle Laboratory
C&C	Cover and Concealment
CAC	Combined Arms Command
CECOM	Communications and Electronics Command
COA	Course of Action
DMA	Defense Mapping Agency
EM	Execution Monitor
ESC	Enemy and Situation Capabilities
ETL	Engineering Topographic Laboratory
FITE	Force Interactive Tactical Evaluator
FLC	Force Level Control
FM	Field Manual
FSC	Friendly and Situation Capabilities
ITD	Interim Terrain Data
LAT	Location Analysis Tools
LOS	Line of Sight
MAUA	Multi-Attribute Utility Analysis
MCOO	Modified Combined Obstacle Overlay
MET4	Mission, Enemy, Terrain, Troops and Time Available Tools
OCOKA	Observation and Fire, Cover and Concealment, Obstacles, Key Terrain, Adequacy of Maneuver Space
OPORD	Operations Order
PEO-CCS	Program Executive Office for Command and Control Systems
PM-ASAS	Program Manager, All Source Analysis System
SD	Standard Deviation
SME	Subject Matter Expert
TDA	Tactical Decision Aid
TRADOC	Training and Doctrine Command