DIGITAL TERRAIN ANALYSIS STATION (DTAS)

CPT Michael R. Thompson
U.S. Army Engineer Topographic Laboratories
Ft. Belvoir, VA 22060

Robert M. Socher
IIT Research Institute
5100 Forbes Blvd.
Lanham, Maryland 20706

BIOGRAPHICAL SKETCHES

CPT Thompson received a B.S. degree from the United States Military Academy in 1973 and was commissioned as a military officer in the U.S. Army. He has served in infantry assignments in both Europe and the United States and is a graduate of the Infantry Officers Advanced Course. In 1981, CPT Thompson earned an M.S. in Photogrammetry and Geodesy from Purdue University and is currently assigned to the U.S. Army Engineer Topographic Laboratories as an R&D Coordinator.

Mr. Socher is a Senior Programmer/Analyst for the IIT Research Institute. He earned a B.A. in Mathematics from St. John's University at Collegeville, Minnesota in 1967. During his career, Mr. Socher has developed a broad base of knowledge in automated data processing for cartographic/terrain data. For the past five years, he has served as project manager guiding the design and development of interactive/batch graphics software on the Digital Terrain Analysis Station (DTAS) for the U.S. Army Engineer Topographic Laboratories.

ABSTRACT

Battlefield commanders in today's Army need timely, accurate terrain analyses. Modern tactical realities do not give the commander time for manual preparation of map overlays and other graphic products from varied and voluminous sources. The commander must have up-to-date graphic displays and overlays highlighting tactically vital terrain features and battle/combat advantages resulting from terrain configurations. These factors, combined with the advances in computer technology and data base management, indicate that a computer-assisted terrain analysis capability is feasible and needed by the Army.

The terrain analysis capabilities under development on the Digital Terrain Analysis Station (DTAS) at the U. S. Army Engineer Topographic Laboratories will be such a system. The terrain analysis capabilities of the DTAS produce graphic products that fall generally into two major areas: Intervisibility and Mobility. The products may be displayed on the DTAS viewing screens or drawn to scale on the DTAS plotter. They may stand alone or be used in compiling other products.

The intervisibility capabilities are used to determine areas that are visible, either optically or electronically, from a given site. These capabilities have the user-selectable option of including vegetation heights in the analysis. The mobility capabilities are used to evaluate the potential effects of terrain upon friendly and enemy operations.

INTRODUCTION

Today's modern Army, with greatly increased emphasis on mobility and quick reactions, is becoming more and more concerned with the problem of supplying information about the battlefield to the commanders who must direct high-speed maneuvers on what has come to be known as "the extended battlefield." The commonly projected short duration conflict in Central Europe is one example of a situation in which it is feared that conventional terrain analysis techniques might provide information to combat commanders that is "too little, too late". The recent British involvement in the Falkland Islands is another prime example. Major efforts were required to assimilate a wide variety of source data needed to update the few existing maps available and to provide meaningful terrain analysis products. All this had to be accomplished in the short time available as the British landing forces steamed southward toward the Falklands.

Given the present state-of-the-art, digital automation appears to offer the main hope.

OBJECTIVE

The primary objective of the DTAS effort is to provide the terrain analyst an automated tool so that he can better meet field commanders' terrain information needs in terms of response time, flexibility, and accuracy.

MANUAL VS. COMPUTER-ASSISTED

Manual methods in use today are labor intensive and require a considerable amount of skill and experience. Products are produced based upon the assumption of various terrain and weather conditions. To change any of the assumed parameters, such as season or vehicle type, in most cases requires a complete reconstruction of the required product. Accuracy is not only dependent on the analyst's source material, but upon his skill and experience as well.

By providing him with an automated tool, his production speed can be considerably enhanced. If input parameters change, new products can be generated with relative ease. While automated methods are still directly dependent upon the accuracy of the source material, products are generated by the system and are therefore not as susceptible to human error. This frees the analyst to concentrate more effort on updating and refining the data base and evaluating system products.

The first step in the manual method is to assimilate the source data into a series of transparent factor overlays, keyed to a particular map sheet. By visually correlating the factor overlays in a sequential process, the analyst next produces one or more factor complex maps. Applying basic analytical models, the factor complex maps are again visually correlated to produce a final product manuscript.

The primary focus of the DTAS effort is to automate the task of correlating the various factor maps, applying the analytical models, and producing the product manuscript (see Figure 1). The factor maps exist in digital form as the data base. Ideally, the data base will be produced by the Defense Mapping Agency and then further updated in the field on the DTAS, as required. Typical elements which are contained in the data base are slope, vegetation, soil, urban areas, roads, railroads, waterways, water bodies, and obstacles. A distinct advantage to automating this portion of the process is the flexibility provided to the analyst. For example, to produce a Cross-Country Movement product for two different types of vehicles manually would require considerable duplication of effort. With an automated system, the operator needs only to change the relevent vehicle parameters and the system can then duplicate the task more quickly and with greater accuracy. Final product manuscripts can be plotted automatically to any scale desired.

In addition, the operator can interactively update the data base itself. Common changes such as construction or destruction of roadways and bridges, the creation of obstacles, and large scale defoliation can drastically modify the complexion of the battlefield. These changes can be made to the data base quickly and easily on the DTAS. Hence, final analysis products can be produced which are current and are of greater value to the field commander and his staff.

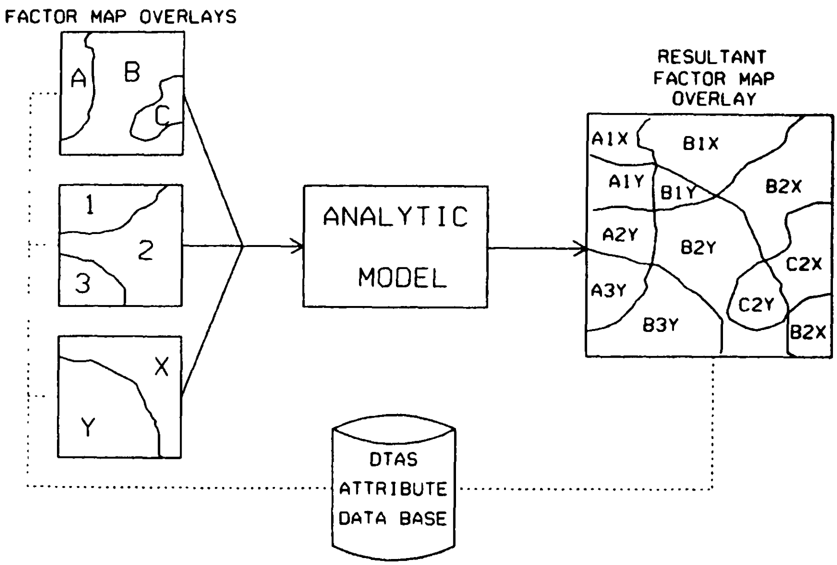

Figure 1. Computer-assisted terrain analysis schematic.

HARDWARE/SOFTWARE

Configuration

The DTAS operates on a PDP-11/70 minicomputer under the RSX-11M-PLUS operating system. The programming language is FORTRAN IV-PLUS. The graphics/data management capability is supplied by a turn-key interactive graphics design system. The graphics workstations have dual display screens, a digitizing table, a movable keyboard, a floating command menu, a multibutton cursor, and a built-in microprocessor.

Interaction

The DTAS is an integrated configuration of hardware and software which provides the means to compose original designs, encode existing drawings, modify designs, and store and retrieve designs under the interactive control of the user. The designs may be created either through direct user interaction at a workstation or through an applications program.

The data base management software is closely integrated within DTAS to provide the needed management of both graphic and associated nongraphic (attribute) data. The data base management software may be initiated through direct user interaction from a graphics workstation, through an alphanumeric terminal, or through an applications program.

Polygon Processor

A key feature of the DTAS is the capability to determine the spatial relationship between elements from two sets of polygons. Three boolean operations are supported: AND, OR, and NOT. The resultant set of polygons is stored in a design file and attribute values may be transferred from the original two sets to this resultant set in the form of read-only informational links. This capability is an integral component of the mobility models.

Data Base

Two data formats are currently used in the DTAS data base -- gridded data and graphic data. The gridded data is primarily used for intervisibility capabilities (Target Acquistion Model, Masked Area Plot, etc.) and the graphic data is used for the mobility capabilities (Cross-Country Movement, Concealment, etc.).

The current DTAS gridded data base consists of elevation and vegetation data and encompasses an area of over 4,000 square kilometers in Germany. It is designed for use with the Universal Transverse Mercator (UTM) coordinate system. The data was digitized using a grid mesh with a 125-meter spacing. The elevations were recorded at each grid lattice point. The most prominent vegetation type was recorded for each grid cell (125-meter by 125-meter square).

The current DTAS graphic data base consists of slope, soil, vegetation, water body, and urban area polygons and road, railroad, and waterway linear elements for the 1:50,000 Fulda, Germany map sheet, an area approximately 23 kilometers by 22 kilometers. This data was digitized on the DTAS from factor map overlays supplied by the Terrain Analysis Center at USAETL. Attribute values containing information about slope percentage, soil type, vegetation type, and other data were attached to these graphic elements. Attribute data may be retrieved and/or modified either through direct access or through an applications program.

EXISTING CAPABILITIES

The terrain analysis capabilities of the DTAS produce graphic products that fall generally into two major areas:

- Intervisibility
- Mobility.

The products may be displayed on the DTAS viewing screens or drawn to any scale on the DTAS plotter. They may stand alone or be used in compiling other products. For example, the combination of radar masking and cross-country movement produces a product that would be used by a terrain analyst in determining the least vulnerable avenue of approach.

Intervisibility

The intervisibility capabilities are used to determine areas that are visible, either optically or electronically, from a given site. These capabilities use the DTAS gridded data base and most have the user-selectable option of including vegetation heights in the analysis. The current DTAS capabilities in this area include:

- o Terrain Profile Model
- o Target Acquisition Model
- o Multiple Site Target Acquisition Model
- o Composite Target Acquisition Model
- o Masked Area Model
- o Perspective View Model
- o Path Loss/Line-of-Sight Model.

The Terrain Profile Model. This model displays the terrain profile along the great circle path between two user-selected points in a linear mode and in a 4/3-earth mode, showing a profile corrected for earth curvature and atmospheric refractivity.

The 4/3 earth plot is useful in checking optical or electronic visibility, i.e., in determining whether or not optical or electronic line-of-sight (LOS) exists between the profile endpoints.

When a profile is generated, the following options are available: the elevation of points along the profile may be interpolated from the four closest points in the data base or the nearest point may be used; the elevation of points along the profile (excluding the endpoints) may be augmented with average vegetation heights; and a table of elevations versus distance along the profile may be printed. The distance between the points along the profile, the antenna/observer heights at the profile endpoints, and the plot title are user selected.

The Target Acquisition Model. This model is used to determine the point at which an incoming target first becomes visible to an observer. One plot can be used to display the sighting contour for a number of altitudes for any observer sector from 0 to 360 degrees. This is done by retrieving the elevation (and associated vegetation heights if desired) of points emanating from the user-specified site in a pattern of equally spaced radial "spokes". Then a determination along each profile is made of the point that constitutes limiting line-of-sight and the distance from the site to this point. Once this is found, it is possible to determine the locations at which incoming targets are first detected for each user-requested altitude (either above sea level or above terrain). Finally the user-selected map projection is applied to these acquisition locations and a contour is drawn for each altitude.

Multiple Site Target Acquisition Model. Utilizing previously generated files from the Target Acquisition Model and a single, user-requested altitude, this model displays the acquisition contours for up to ten sites on one execution. These acquisition contours are drawn on separate levels in a design file, thus they may be displayed individually or in any combination.

Composite Target Acquisition Model. This model has the same input constraints as the Multiple Site Target Acquisition Model. The resultant plot, however, is a composite picture of all site acquisition contours for the given altitude. It is an outline plot, the logical sum of the individual acquisition contours, produced by eliminating any portion of a site's contour that falls within the bounds of another site's coverage. Thus it is possible to assess the cummulative detection capability of a number of sites operating in proximity to each other. Individual site markers are retained.

Masked Area Model. This model displays areas around a site in which a target at a user-specified height above ground level is shielded from the site (see Figure 2). The effects due to intervening vegetation is an option available to the user. All vegetation between the site and any point being analyzed is considered impenetrable.

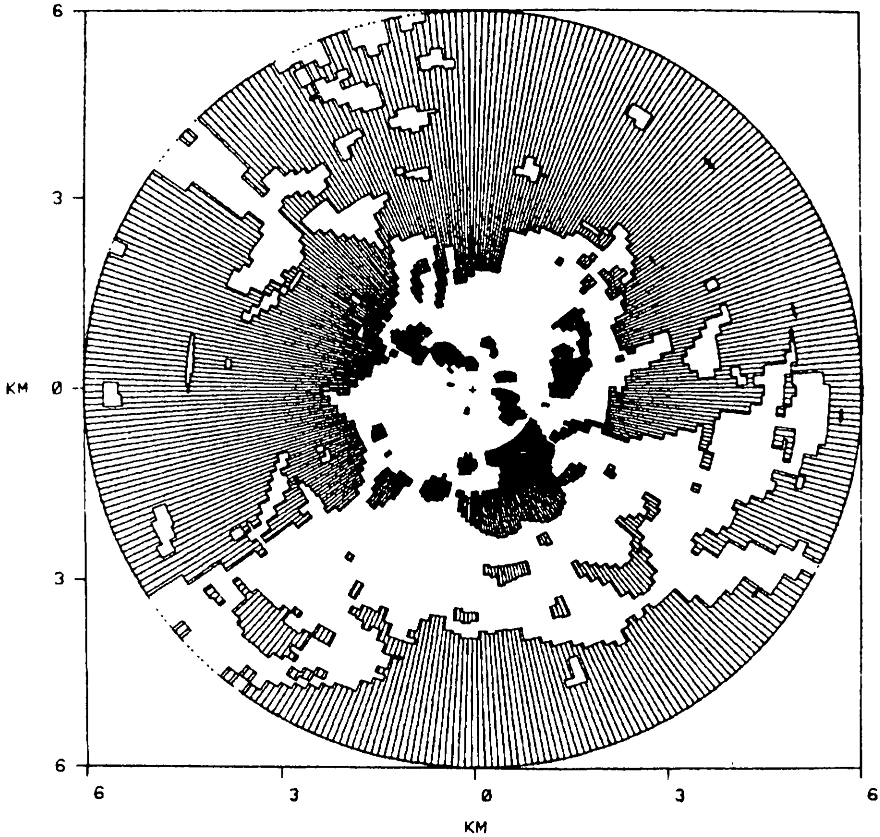

Figure 2. Masked Area Model Graphic Display.

Perspective View Model. This model provides the user a view of terrain in full perspective. The user has the flexibility to observe the terrain in any direction from any desired location and height above ground level or sea level. The terrain may be exaggerated vertically to aid in highlighting terrain features. Individual points on the surface may be flagged to aid in identifying significant features. Lines of equal distance from the observer may be superimposed on the surface to aid in the perception of distance. An overhead view of the area showing the observer's position, the limits of visibility, flagged feature spots, and range lines is displayed to aid in correlating the perspective view with map sheets of the area.

The perspective view consists of a grid of equally spaced lines following the changing elevations of the terrain. Those portions of lines which would be hidden by intervening terrain are removed. The resultant "fishnet" representation of the terrain (see Figure 3) provides the viewer with two important depth cues: the grid cells grow smaller as they become more distant, and the removal of hidden lines results in sharp edges outlining the tops of hills and mountains. The shapes of terrain features can also be discerned from the shading effect of the grid lines; areas which are almost parallel to the line-of-sight contain a greater density of grid lines and so appear darker than areas which are more perpendicular to the line-of-sight.

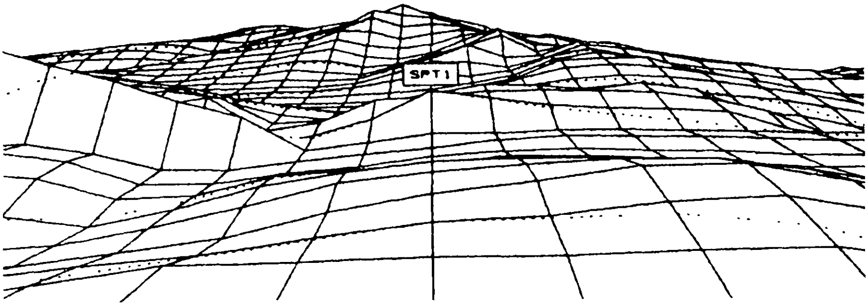

Figure 3. Perspective View Model Graphic Display.

Path Loss/Line-of-Sight Model. This model produces a display depicting path-loss-related calculations (power density, field strength, received signal, signal-to-noise ratio) or terrain shielding calculations relative to a specified site. The site may be located either inside or outside the coverage area.

Displays generated in the path-loss mode can be used to show base station transmitter coverage in terms of the signal produced at hypothetical receiver locations about the site. Base station receiver coverage with respect to hypothetical remote transmitter locations can also be depicted.

In the terrain shielding mode, displays can be used to define line-of-sight contours for radar and microwave installations, and optical line-of-sight for visual observation platforms.

Mobility

The mobility capabilities are used by terrain analysts to evaluate the potential effects of terrain upon friendly and enemy operations. The current DTAS capabilities in this area include:

- Local Relief Model
- Slope Model
- Cross-Country Movement Model
- Cover Model
- Concealment Model
- Key Terrain Model
- River Crossing Model.

Local Relief Model. This model displays a user-selected area divided into five-kilometer squares, with the minumum and maximum elevations and the difference between these two values depicted for each square. The difference is the local relief value and is used to roughly categorize an area as plains, hills, or mountains.

Slope Model. This model determines the percent-of-slope for every gridded elevation data point in a given area and displays the areas that are within a user-specified range of slope percentages. This product is an important ingredient in many other products (e.g., cross-country movement, cover, etc.).

Cross-Country Movement Model. This model displays off-road speed capabilities based on the characteristics of a user-selected vehicle and the slope, vegetation, and soil that occur in a given area. Prevailing movement conditions are categorized as GO, SLOW-GO, and NO-GO.

This model is the most comprehensive of the all the models in terms of complexity and volume of graphic data that must be processed.

Slope is evaluated based on the maximum climb capabilities of the user-specified vehicle. Vegetation (stem spacing and diameter) is evaluated based on vehicle dimensions and override capabilities. Soil is evaluated in terms of the rating cone index for each soil type and the vehicle cone index.

The slope, vegetation, and soil polygons are merged by the system through a series of successive boolean AND operations to produce a final Cross-Country Movement graphic (see Figure 4). In addition, the resultant polygons retain the original attributes linked to them in the attribute data base.

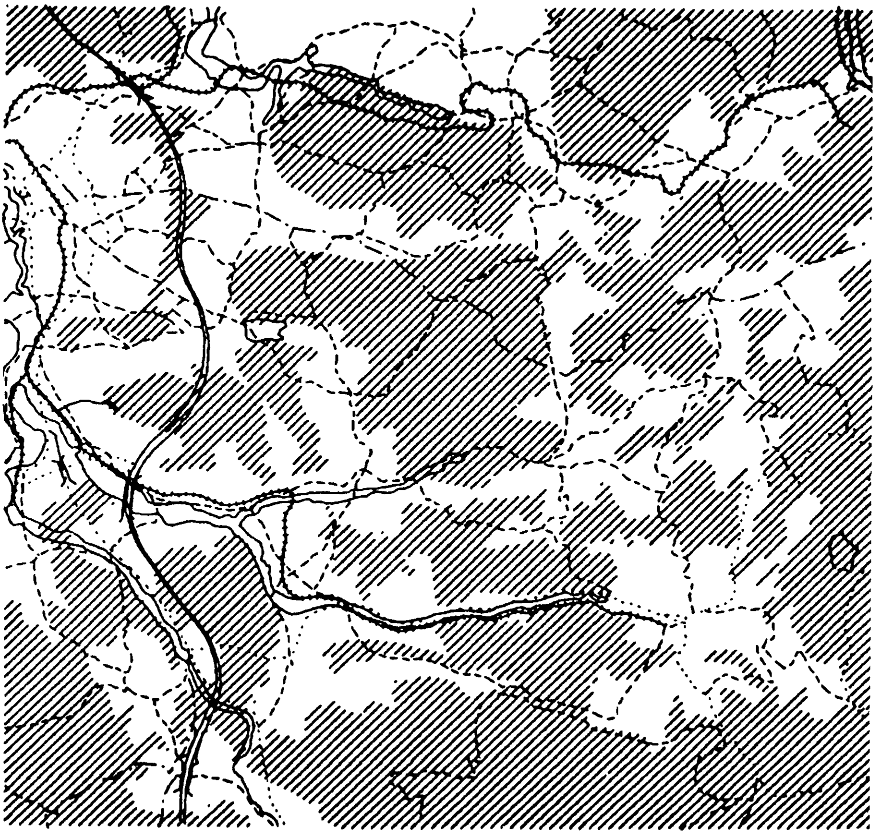

Figure 4. Cross-Country Movement Model Graphic Display of NO-GO areas and transportation network.

Cover Model. This model determines the amount of protection from flat-trajectory fire provided by vegetation, slope, and urban areas. The Cover display delineates areas that afford good, fair, or poor protection.

Concealment Model. This model determines the percentage of aerial concealment provided to a vehicle, man, or unit on the ground, based on the vegetation in the area of concern. The Concealment display delineates areas that provide concealment, graduated from the best areas (0-25% chance of being detected) through the poorest (75-100% chance of being detected).

Key Terrain Model. This model combines elevation data from the gridded data base with vegetation and slope data from the graphic data base to synthesize a display of suitable high ground areas within a user-specified region. Requirements for acceptable high ground are accessibility (i.e., slope <30%), reasonable concealment (i.e., canopy closure >50%), and prominent elevation relative to the surrounding area. The model offers a choice of summer or winter concealment conditions.

River Crossing Model. This model compares the characteristics of a user-chosen equipment against the features of each waterway segment to determine its potential as a crossing site. Some of the features used in the analysis are bank height and slope, bottom material, and water depth.

All of the above models have been developed and are resident on the DTAS. Exhaustive testing of each model will commence as format-compatible terrain data bases are loaded into the system.

CURRENT DEVELOPMENTS

Prototype DMA Data Bases

A major consideration in the development of DTAS is the data base required to feed such a system. To create the type of products mentioned thus far is relatively simple for a small geographic area or with simulated data. To be of value to the field Army however, the system must be capable of accepting large volumes of real data, data that is potentially obtainable for worldwide coverage. It is desirable to define a single data base capable of satisfying all digital terrain data requirements.

To this end, the Defense Mapping Agency has created two prototype data bases. Each prototype covers the same area of Fort Lewis and the Yakima Firing Center in the state of Washington. One prototype is in a gridded format and the other exists in a vector format. In the near future, these two prototypes will be evaluated using DTAS to reformat the data and to generate products. The output products will then be compared to manually produced products and ground truth. Input resolution will be traded-off against required quality.

New Models

Additional analytical capabilities currently being added to DTAS include:

- Air Avenues of Approach Model
- Drop Zone/Helicopter Landing Zone Model
- Barrier/Denial Model
- Infiltration Routes Identification Model
- Lines-of-Communication Model.

Air Avenues of Approach Model. This model will produce a graphic display of areas around radar sites in which an aircraft at a specified altitude above ground level cannot be detected. This display will be supplemented with areas from the Concealment Model that exhibit the least chance of being detected by ground forces. This can be a season-dependent input, either summer or winter. In addition, urban areas, transportation, and drainage will be shown as navigational aids. Obstacle data above a user-selected height may also be displayed.

Drop Zone/Helicopter Landing Zone Model. This model will produce a graphic display of areas suitable for drop zones and helicopter landing zones. The user will be able to indicate the minimum dimensions or the model will use default dimension values to select the areas. The display will be supplemented with areas from the Cover and Concealment Models that exhibit the least chance of being detected by enemy forces and areas from the Cross-Country Movement Model which indicate good off-road mobility. In addition, urban areas, drainage, obstacles, and transporation will be displayed at the user's option.

Barrier/Denial Model. This model will produce a graphic display of areas determined to be NO-GO areas and features whose attributes make them obstacles (e.g., wide, deep rivers and urban areas). This display will use the Cross-Country Movement Model to determine NO-GO areas. In addition, the user will be able to display data from the transportation and drainage overlays as well as from the Path Loss/Line-of-Sight Model at his option. Using these combined displays, the terrain analyst will be able to select and add various obstacles for display and plotting.

Infiltration Routes Identification Model. This model will produce a graphic display of areas not covered by enemy surveillance sites. This display will be supplemented with areas from the Cross-Country Movement Model that will allow off-road trafficability. Areas providing concealment from aerial observation will be shown along with areas providing cover from ground fire. This information will come from the Concealment Model and Cover Model, respectively. In addition, the user will be able to display data from the transportation, drainage, and/or obstacle overlays at his option.

Lines-of-Communication Model. This model will assist planners in conducting route analysis. Based on the size, weight, and speed capabilities of a unit's vehicles and the road networks contained in the data base, field commanders and their staffs can use this model to quickly analyze primary and alternate routes. This capability is especially critical to the concept of the "Active Defense", where a commander must consider numerous contingencies to redeploy his forces on a rapidly changing battlefield as well as to evaluate the enemies reinforcement capabilities.

CONCLUSION

Results thus far have proven very promising. The feasibility of providing the terrain analyst a usable, automated tool has been demonstrated. The next step is to take the capabilites of DTAS, demonstrated in a laboratory environment, and develop them into a fieldable Digital Topographic Support System. This includes the definition of the all important digital topographic data base, integration of militarized computer hardware that can withstand the rigors of a field environment, and the definition of interface requirements with other military systems. In addition, the models will be further analyzed and refined as necessary to insure they are tailored to the users' specific needs. These efforts have been initiated and are ongoing projects at the U.S. Army Engineer Topographic Laboratories.