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Applications of DTM in the Forest Service*

A variety of products derived from DTM are employed for land management.

(Abstract appears on following page)

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INTRODUCTION

THE FOREST SERVICE, U.S. Department of Agriculture, manages nearly 187 million acres (74,800,000 hectares) of land throughout the United States. Environmental concerns are of vital interest to managers and users alike. We must take advantage of as much data as possible when making decisions on how to manage any portion of this land. The fact that much of the terrain is mountainous and scenic further restricts the options available for productive use of the lands. Photogrammetry and the computer are two tools that are invaluable in collecting, processing, and displaying terrain data needed by land management planners.

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TOPAS, DTIS, MOSAIC/PHOTOMONTAGE are three systems currently being used by the Forest Service to generate graphic products from a Digital Terrain Data (DTD) base. The details of the execution of the programs within each system are beyond the scope of this paper. References listed at the conclusion of the text will provide the potential user with the necessary information for operation of these systems. The basic features of each system and types of output products are emphasized here.

SYSTEM DESCRIPTIONS

TOPAS

TOPAS is an acronym for TOPographic Analysis System. It is a code name given to a package of computer programs that have been developed for the collection, manipulation, and analysis of digital terrain data (DTD). The primary set of programs act on existing terrain data such as the digital terrain data tapes that the Defense Mapping Agency (DMA) has generated from U.S. Geological Survey (USGS) 1:250,000 scale topographic maps. The secondary set of programs coded DTIS is used in the generation of digital terrain data directly from existing topographic maps or from aerial photography. The output products are graphic plots that are used by land managers to evaluate impacts of alternate land uses on National Forest lands. TOPAS has been in use for approximately three years.

DTIS

DTIS is an acronym for Digital Terrain Information System. Although originally a part of TOPAS, DTIS has been enhanced to perform more detailed analysis on site-specific problems. Basically, DTIS is a group of programs

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ABSTRACT: *There are currently three systems in use within the Forest Service that use Digital Terrain Data (DTD) as source material. TOPAS (TOPographic Analysis System) was developed in-house in 1975 and is heavily used by resource managers to evaluate impacts of alternate land uses on National Forest lands. Digital Terrain Information System (DTIS) is a secondary set of programs within TOPAS that has been enhanced to handle more rigorous analyses related to site specific projects, often involving engineering reconnaissance and design. Method of Scenic Alternative Impacts by Computer (MOSAIC) was written under contract, and is a photomontage system that employs computer graphics to depict proposed landscape alterations to overlay on a terrestrial photograph of an existing area. The basic features of each system and the primary uses of output products are discussed.*

designed to take digitized terrain and resource data, manipulate and perform various calculations on the data, and output graphics that are useful for land use planners yet accurate enough for use in engineering applications. DTIS is still under development but has been used by field units in a test and demonstration mode for approximately two years.

MOSAIC

MOSAIC is an acronym for Method of Scenic Alternative Impacts by Computer. It was written under contract by Aerospace Corporation, El Segundo, California, and employs computer graphics to depict proposed landscape alterations to overlay on a photograph of an existing area. MOSAIC produces a computer graphic perspective view of the landscape alteration in exact registration with the photograph. Multiple perspective drawings from different viewing locations of the same landscape alteration can be produced. MOSAIC has been operational within the Forest Service for approximately six months.

All three systems are operational on a Univac 1100/42 computer at the USDA Fort Collins Computer Center. Programs are written in FORTRAN and may be accessed from any Forest Service office having low speed or batch processing capabilities. All graphic products are drafted using Cal Comp 900/1136 drum plotters.

SYSTEM APPLICATIONS

Although each system is dependent on DTD for source data, the applications of each are geared to a different clientele or user. Often products from each system may be required to support specific project analysis. The primary applications for each system are outlined below.

TOPAS

TOPAS was developed to support land managers for broad area planning applications. Graphic products depicting contours, slope and aspect, seen areas, and perspective views can be generated for entire watershed areas or planning units to provide a general overview of the terrain features that may effect land management decisions. Accuracy of DTD is not as critical as with site specific applications and generally DMA data tapes are sufficient for applications.

DTIS

DTIS has been enhanced to use DTD to support projects on a site-specific area. Both resource management and engineering analysis applications are possible with DTIS. Applications are a function of the accuracy of the DTD. Data to support road design efforts can be generated with DTIS. Both planimetric and topographic data can be input into the system and, through resection, output can be generated in either an orthogonal or perspective plot.

MOSAIC

MOSAIC was designed to provide the resource manager with a graphic representation of what a particular landscape would look like following specific alterations.

TABLE 1. DTD SOURCES FOR EACH SYSTEM.

SYSTEM NAME	DTD SOURCE		
	DMA TAPES	AERIAL PHOTOG.	TOPOG. SHEETS
TOPAS	X	x	x
DTIS		X	x
MOSAIC		x	X

TABLE 2. COMPARISON OF SYSTEM CHARACTERISTICS.

ITEM	TOPAS	DTIS	MOSAIC
DATA COLLECTION	NO	YES	NO
ACCURACY CHECK	NO	YES	NO
DTM FORMAT	GRID	GRID & RANDOM	GRID
MAX. FILE/APPLICATION	14,641 PTS.	39,000 PTS.	1000 × 1000 MATRIX
PLANIMETRIC FEATURES	NO	YES	SPECIFIC ONES
PHOTOMONTAGE	NO	AERIAL	TERRESTRIAL
OPERATIONAL	YES DOCUMENTED	YES DEVELOPMENTAL	YES DOCUMENTED
PRIMARY USE	GENERAL PLANNING	SITE SPECIFIC PLANNING/ DESIGN	LANDSCAPE ALTERATIONS

There are many landscape alteration applications currently available with the MOSAIC system. These include surface alterations such as fuel breaks, timber cuts and ski runs; topography alterations such as surface mines, spoil banks, road/railroad beds, man-made lakes, and earthen dams; and man-made structures such as power towers, tipple towers, cabins, water tanks, and smokestacks. Surface alterations are input as line segments of any size and shape, topography alterations are input as geometric features with specified cross-section templates, and man-made structures are preprogramed features.

SOURCES OF DIGITAL TERRAIN DATA (DTD)

DTD is collected from one of the following sources:

- Existing DTD tapes such as those generated by DMA from USGS 1:250,000 scale maps. These tapes are now available through the National Cartographic Information Center (NCIC) of the USGS.
- Existing topographic maps such as the 1:24,000 and 1:62,500 scale standard USGS quad maps. These maps can be digitized using either a grid or line method to provide numerical data of the terrain.
- Aerial Photography. Conventional photogrammetric mapping procedures can be used to create a three-dimensional optic model of the terrain that can be digitized to provide numerical data.

Table 1 summarizes the usual source(s) of DTD for each system. X indicates the primary source and x indicates secondary sources of DTD.

SYSTEM CHARACTERISTICS

As previously mentioned, the scope of this paper does not permit detailed explanation on the details required to operate these systems. However, several of the more important characteristics of each system are noted below for reference purposes.

TOPAS

- Application programs used gridded DTD. DTIS must be used to convert random DTD to gridded data.
- Maximum terrain file for application program is 14,641 points. Larger files must be joined.
- Contouring and perspective plots are Cal Comp routines and are proprietary.
- Only topographic data is used. No provision for handling planimetric features.
- System is fully operational with documented user's guide.
- Interactive option to aid less experienced personnel.
- Inexpensive to run.

DTIS

- Either gridded or random DTD may be input into system.

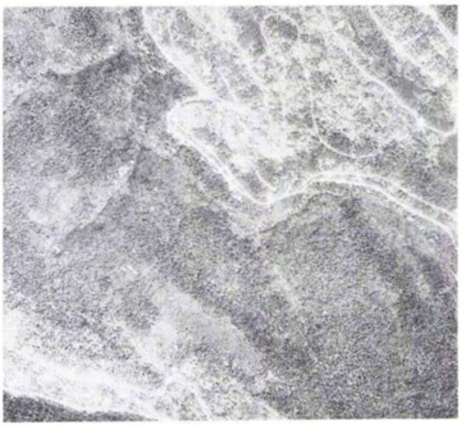

FIG. 1. Orthophoto base of project area.

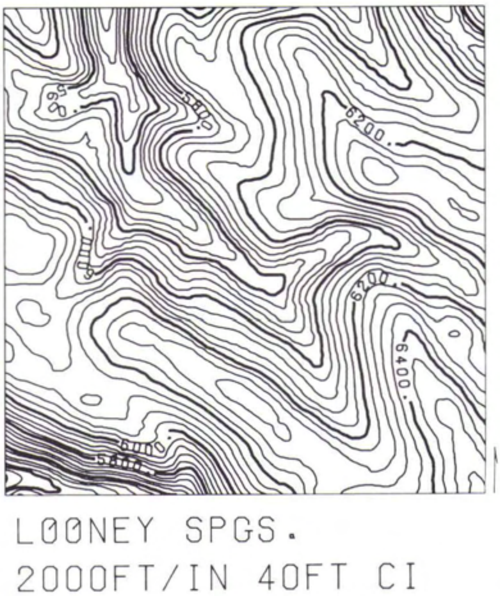

Fig. 2. Contour plot overlay.

Fig. 3. Slope zone plot overlay.

- Maximum terrain file for applications programs is 39,000 points.
- DTD accuracy check feature with Root Mean Square Error printout.
- In-house developed plot routines that use both gridded and random terrain points. Random points are weighted to give better contour definition on ridge and stream lines.
- Tie to Forest Service Road Design System. Alinement and cross-section lines interpolated from DTD.
- Planimetric features including resource overlay capabilities can be plotted.
- Orthogonal and perspective plot options.
- Orthophoto scan line profile option to support Gigas-Zeiss GZ-1 projector plates.
- Not fully documented—still in the development process.
- Tape base file system resulting in high data read in costs for each application.

MOSAIC

- Application programs use gridded DTD. Preprocessor program required for random data.
- Maximum terrain file size 1001 by 1001 nodes in x and y.
- Cal Comp perspective plot routines—proprietary.
- Standard symbology for feature plots. Orientation available for preprogramed man-made structures.
- Photomontage principle used to register landscape alterations to photo base.
- Terrestrial photo base most commonly used.
- Aerial obliques can also be used as photo base.
- System fully documented.
- Limited use to date since it is relatively new.

Table 2 compares the more important characteristics for each of the three systems. There is no current integrated tie between

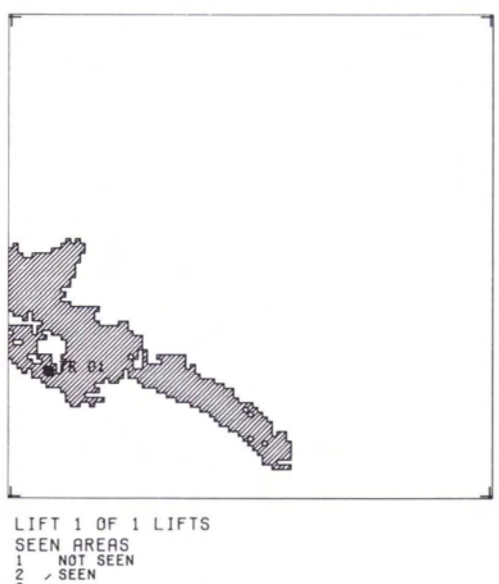

Fig. 4. Seen area plot overlay.

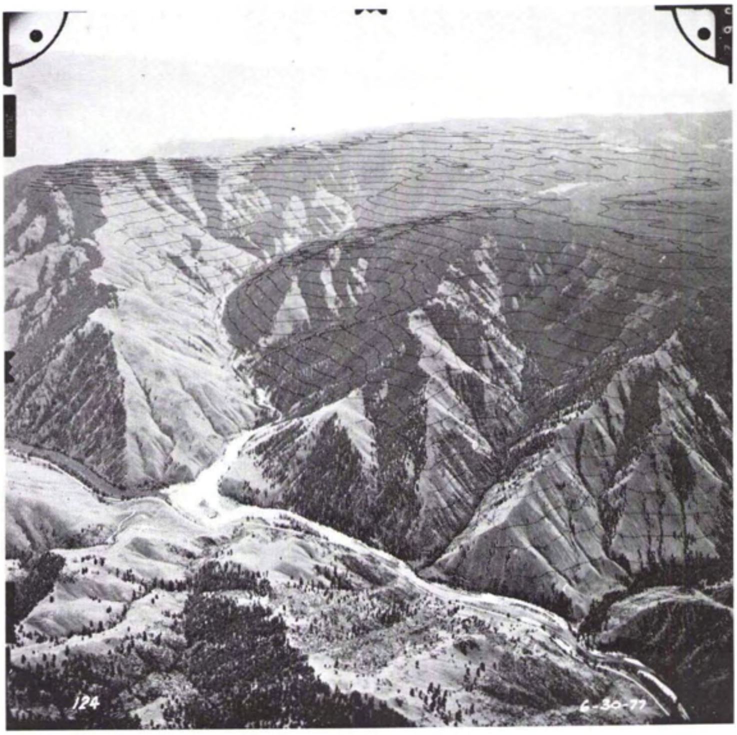

FIG. 5. High oblique photo of project area.

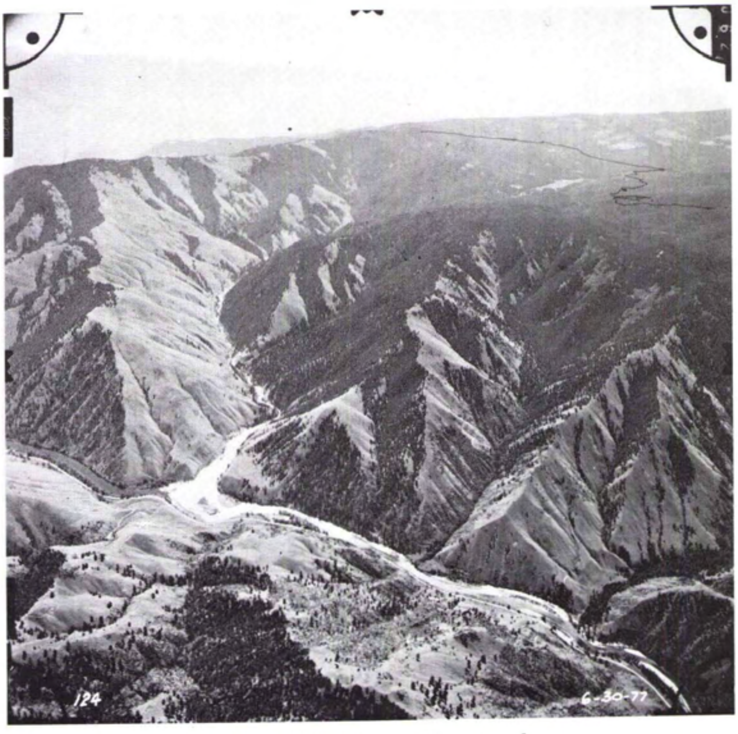

FIG. 6. Perspective contour overlay.

FIG. 7. Perspective land net and private land overlay.

these three systems which would afford maximum flexibility in their use. DTIS can be used to produce gridded data from random data for TOPAS applications. Integration of the systems is a priority item for future development work in the Forest Service.

OUTPUT PRODUCTS

The output products from these systems are graphics. Plot tapes are generated by the various output programs. Graphic plots are currently plotted on Cal Comp 900/1136 drum plotters located in each of the Forest Service's nine Regional Offices and the National Headquarters in Washington, D. C. Following is a list of various products available for each system.

TOPAS

- Contour plots at user-selected contour intervals with a variety of line weights and symbolization. Labels are optional.
- Isoslope lines at user specified intervals, i.e., 10, 20, 35 percent, etc. Isoslope lines are generated using the contouring program.
- Slope and aspect zones plotted at user-specified intervals. A maximum of 20 slope zones and 8 aspect zones can be shown. Slope and aspect are separate plots but can be superimposed to identify areas that fall within a certain slope and aspect zone.
- Perspective warped grid plots. Two options are available: (1) using every data point in the input elevation grid, and (2) using every other point in the elevation grid.
- Seen area plots to show all visible points within the data file from a specified view point. More than one view point may be specified for each plot, up to 50 points. View points may be either on or above actual terrain elevation. A line printer plot option is also available.
- Flight line plots to depict flight line ground profiles for each flight strip with camera height information annotated for alternate focal length cameras. The plots are stacked and each plot shows strip number, horizontal and vertical scale, and a horizontal and vertical graph.

Examples of several output products from TOPAS are shown in Figures 1 through 4.

DITS

- Contour plots to the scale or perspective of any document (photo, map, orthophoto, etc.) whose orientation constants have been computed and stored.
- Planimetric plots of point, line, and polygon data. Both cultural and resource features can be plotted (unsymbolized) on any

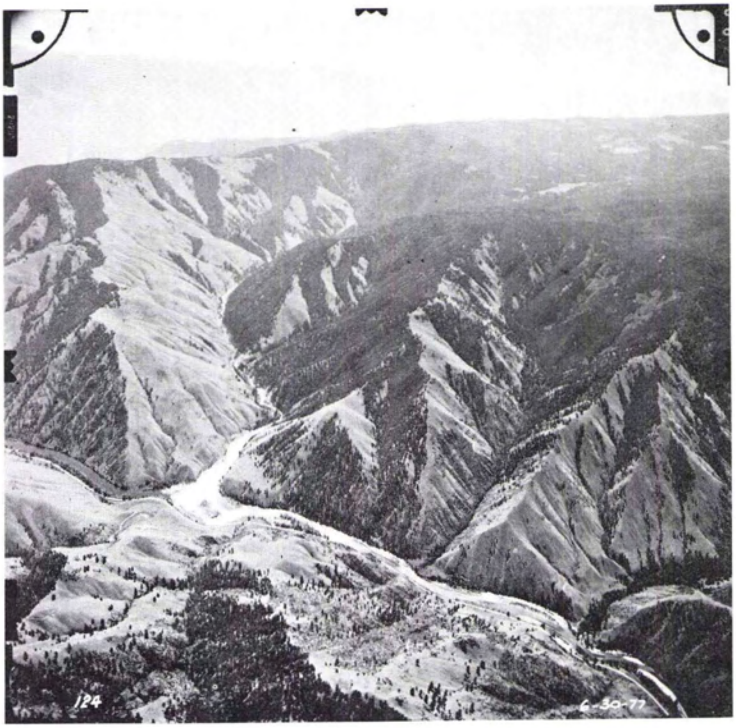

FIG. 8. Perspective road location overlay.

document whose orientation constants are known.

- Road geometry plots generated from computed alinement, profile, and cross-section data. Again, plots can be generated to any perspective with known orientation constants.
- Orthophoto profiles plotted to meet the scan plate requirements of the Gigas-Zeiss Orthophoto System (GZ-1).
- Attribute listings of resource features including areas of polygons and lengths of line features.
- Ground cross-section data files can be generated for input into the Forest Service Road Design System.

Examples of several output products from DTIS are shown in Figures 5 through 8.

MOSAIC

The final product of the MOSAIC/PHOTOMONTAGE system is a field photograph with a computer-assisted rendering of a landscape alteration overlayed upon it. The various considerations necessary to obtain this end product are discussed in this section. The initial step in the preparation of the photomontage display is the plotting of the overlay on a Cal Comp 1136 pen plotter. The software automatically produces the correct plot scale for overlay on the working print from the input of equivalent focal length. If other than a Cal Comp 1136 plotter is used, the scale factor must be adjusted on the hardware or in the software scale factor. The prints used in final display are usually color prints in a scale different (usually smaller) than the working print. Care must be exercised to insure the final graphic plot is reduced (or enlarged) to proper scale for the final display print. The final display photography can be color prints or transparencies of various formats limited only by the ability to enlarge or reduce the original negative of the field photography and graphic plot.

The simplest display is the photomontage produced by overlaying the final photography with the computer graphics plot. This overlay process can be accomplished by plotting or printing the plot on a sheet of transparent mylar. It can also be produced by cutting the vellum plot of the alteration and affixing it to the photograph. While the simple photomontage may be inexpensive and quick to prepare, it may lack adequate realism.

The realism of the final photomontage display can be substantially improved by having an artist add the appropriate color and texture. Good quality color enlargement prints and clearly plotted computer graphics

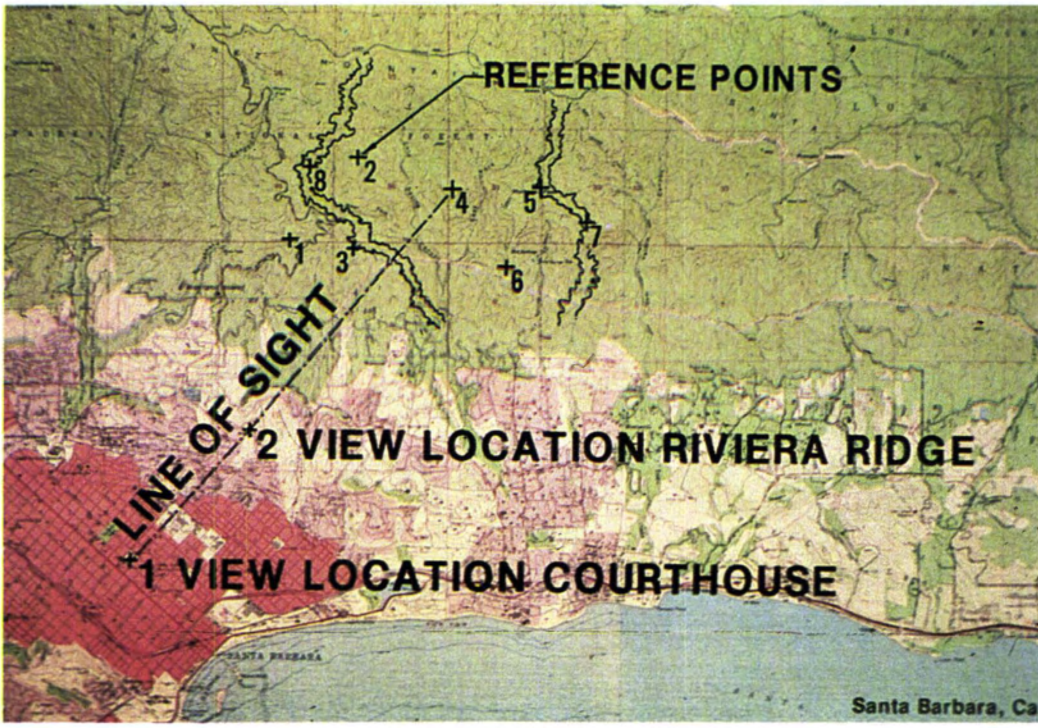

PLATE 1. Project area map.

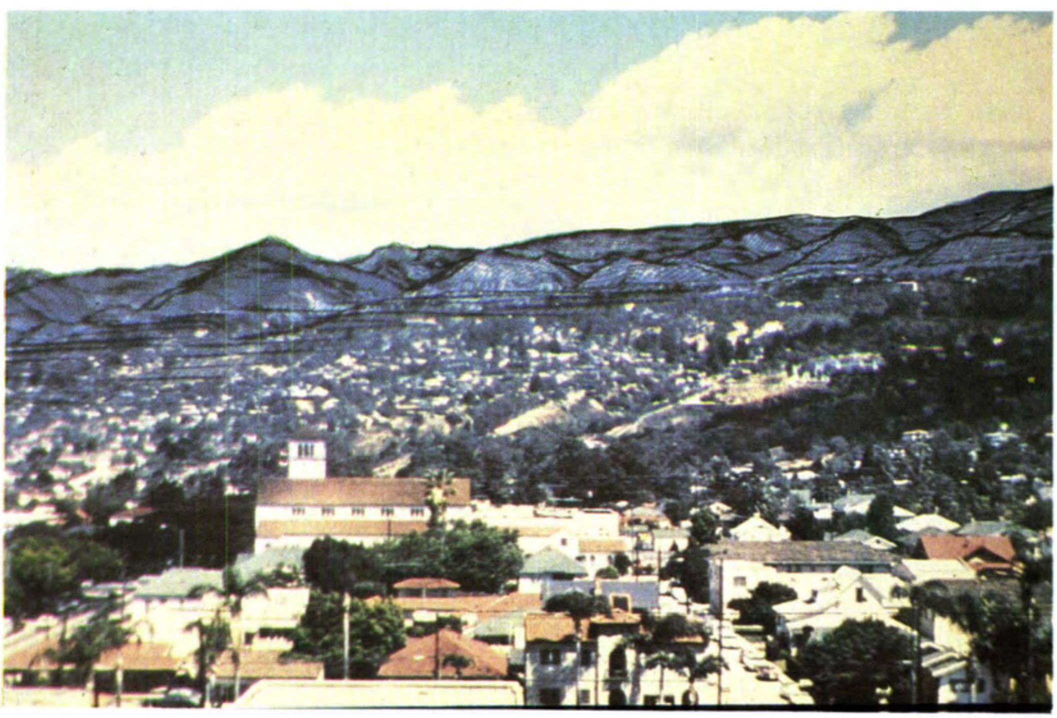

PLATE 2. Terrestrial photo (from Location 1) with terrain verification overlay.

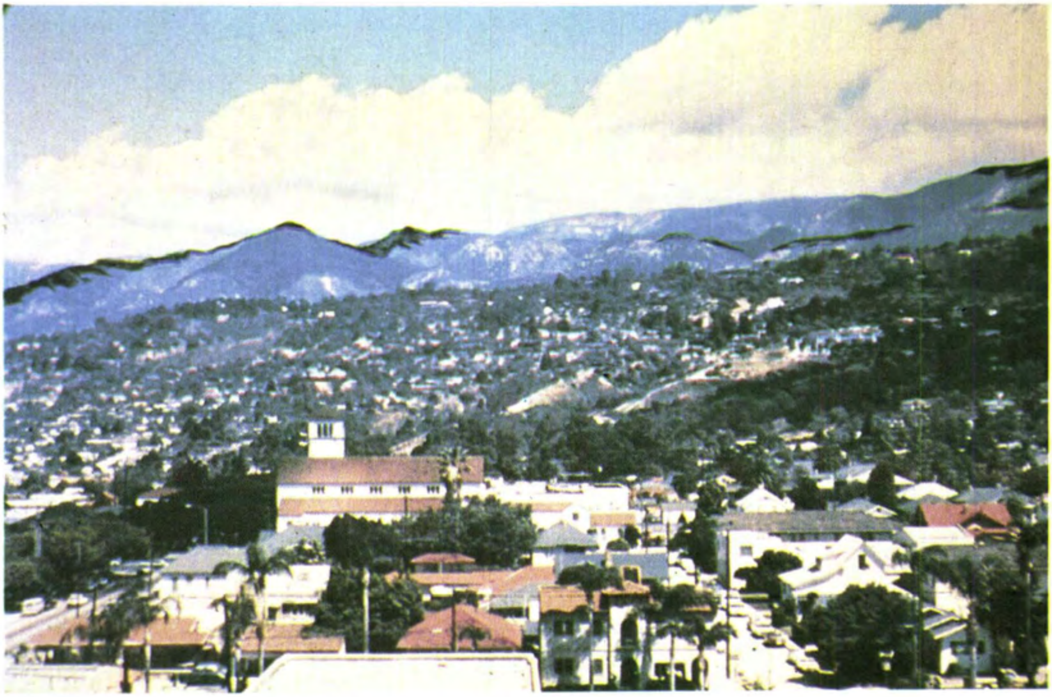

PLATE 3. Terrestrial photo with fuel break location overlay.

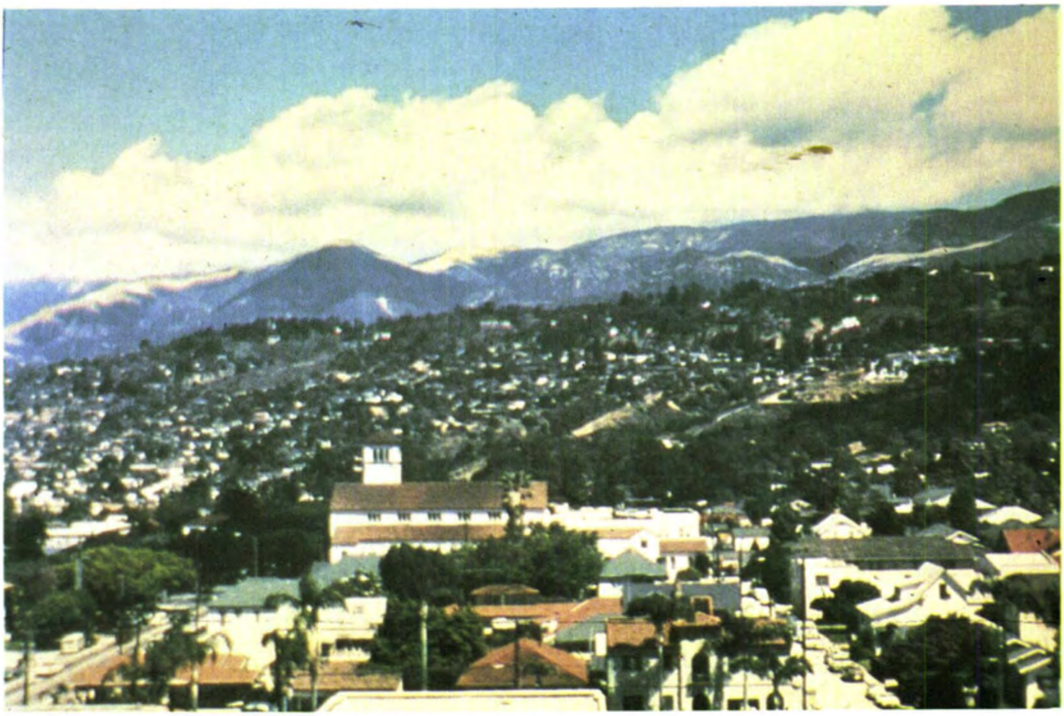

PLATE 4. Terrestrial photo with artist enhanced fuel break locations.

in the proper scale are required. The plot graphic can be transferred onto the photograph by either tracing the outline on the vellum overlay with a stylus to produce an indentation outline on the photograph, or by using a light table to project the graphic outline through the color print.

The addition of color and texture to the graphic outline on the color photograph can be accomplished using opaque water color applied with fine sable brushes. Examples of several output products from MOSAIC are shown in Plates 1 through 4.

SUMMARY

The Forest Service has been actively using products generated from a Digital Terrain Model (DTM) for over three years. The product varieties available through the computational power of the computer make the DTM a vital part of planning and design activities for both resource and engineering disciplines.

Development of additional application programs and the building of an interface program to tie the TOPAS, DTIS, and MOSAIC systems together are high-priority items for our Geometronics Development Group. Efforts are already underway to further enhance DTIS to include the capability to computer volumes between two surface layers in support of surface mining and mining area rehabilitation projects.

As better terrain data become available, applications will continue to increase. The Forest Service actively supports continued development of DTM technology and its application to land management problems.

REFERENCES

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Carey, J. B., G. W. Harju, A. E. Stevenson, *MOSAIC/Photomontage User's Manual,* Forest Service, PSW Grants No. 20 and 21, June 1976

Carey, J. B., F. M. Perkins, E. B. Turner, *MOSAIC/Photomontage Programers' Handbook,* Forest Service, PSW Grants No. 20 and 21, June 1976.

DTIS User's Manual, (Draft Copy), USDA, Forest Service, 1978.

Pelletier, R. T., *The MOSAIC/PHOTOMONTAGE System,* USDA, Forest Service, February 1978.

TOPAS User's Guide, USDA, Forest Service, January 1976.

Schedule of Meetings
Society of Photographic Scientists and Engineers

January 15-17, 1979	Symposium on Photographic Technology Institute for Defense Analyses Washington, D.C. Chairman: David Peek
January 23-26	Symposium on Optical Data Acquisition and Storage Orlando, Florida General Chairman: Dr. R. G. Zech
May 13-18, 1979	SPSE 32nd Annual Conference Park Plaza Hotel, Boston General Chairman: W. Kelly Papers Chairman: E. Guthoff
November 4-7, 1979	Business Graphics Symposium Washington, D.C. Chairman: S. L. Hou Committee: K. Shimazu, Dr. J. Gaynor, and S. L. Hou