UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

RESEARCH, INVESTIGATIONS, AND TECHNICAL DEVELOPMENTS
NATIONAL MAPPING PROGRAM
1981

Open File Report 82-236

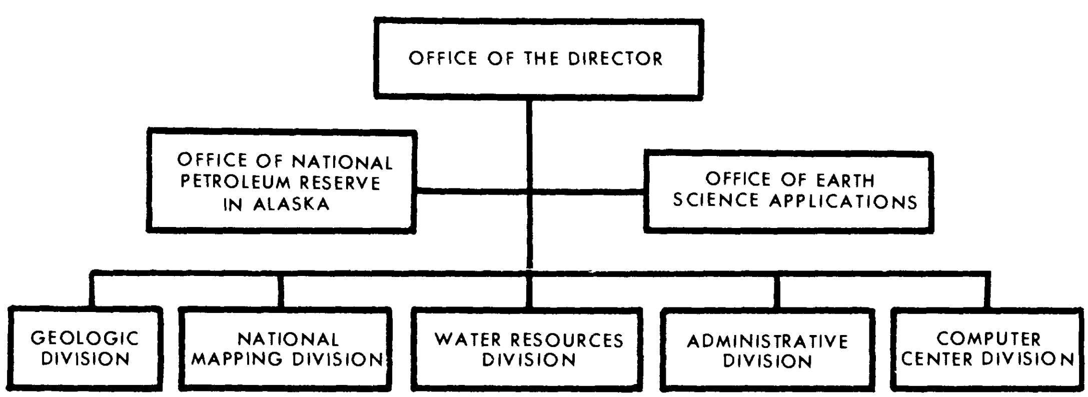
Reston, Virginia
1982

ORGANIZATION

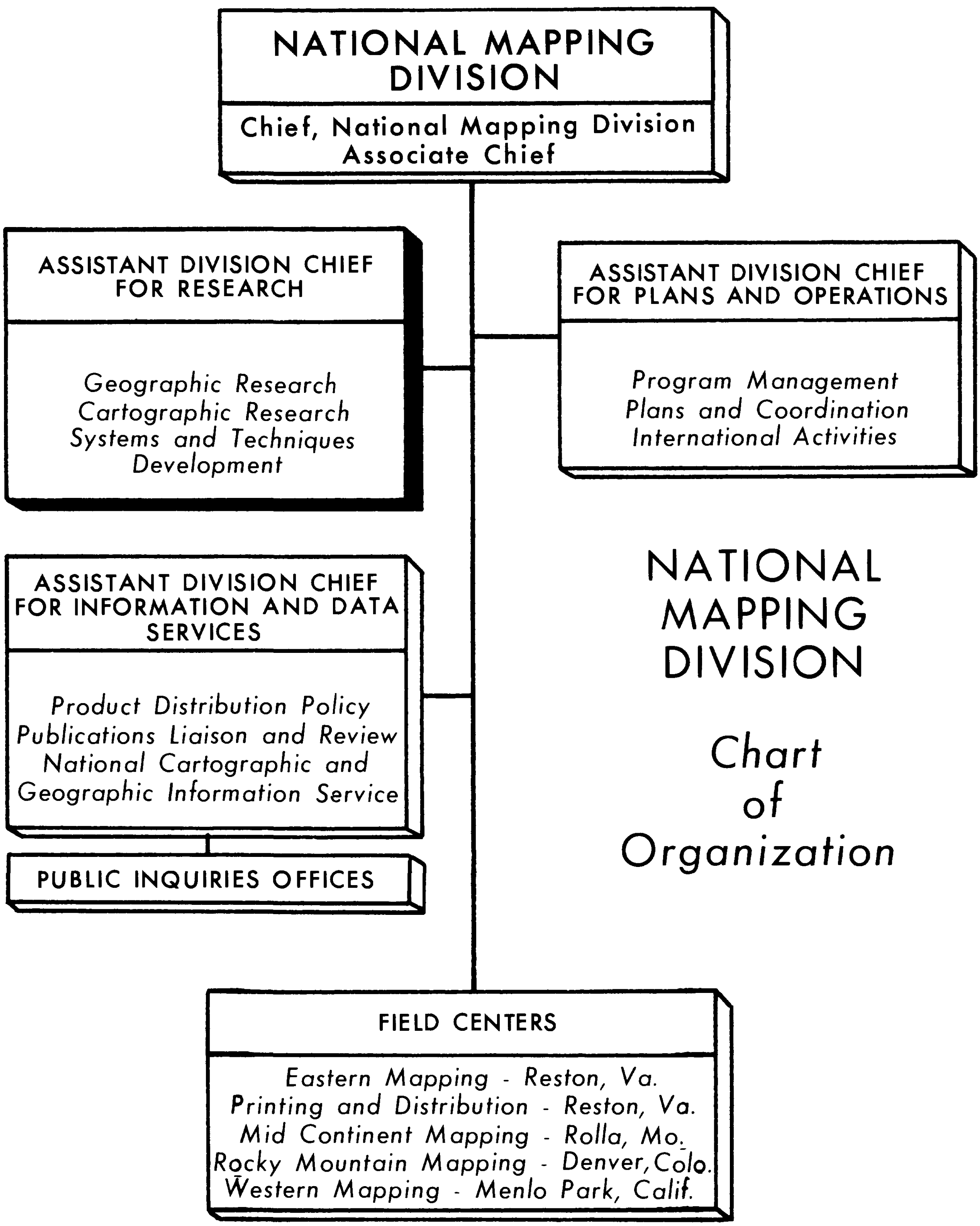
The U.S. Geological Survey Mission and Organization

The U.S. Geological Survey was established in 1879 and charged with the responsibility for the "classification of public lands and examination of the geological structure, mineral resources, and products of the national domain." Over the years the evolution of the earth sciences, the need to carefully manage the Nation's nonrenewable resources and to find new sources of critical energy and mineral commodities, and mounting concern over man's impact on the environment have added numerous other duties including geographic research, hazards studies, topographic and geologic mapping, and water resources assessments. The Survey is an impartial research agency that gathers, interprets, and distributes data in order to advance scientific knowledge of the Earth so that managerial decisions related to natural resources can be based on objective information.

The Geological Survey is headquartered at Reston, Va., and maintains a nationwide organization consisting of more than 200 offices located throughout the United States. The Survey is organized into three program Divisions (National Mapping, Geologic, and Water Resources), two major Offices (Earth Sciences Applications and National Petroleum Reserve in Alaska), and two support Divisions (Administrative and Computer Center), each reporting to the Director of the Survey. The Survey's field organization is made up of Regional Offices at Reston, Va., Denver, Colo., and Menlo Park, Calif., and a network of field and special-purpose offices. These offices coordinate and administer the work of the Survey's widely dispersed activities.

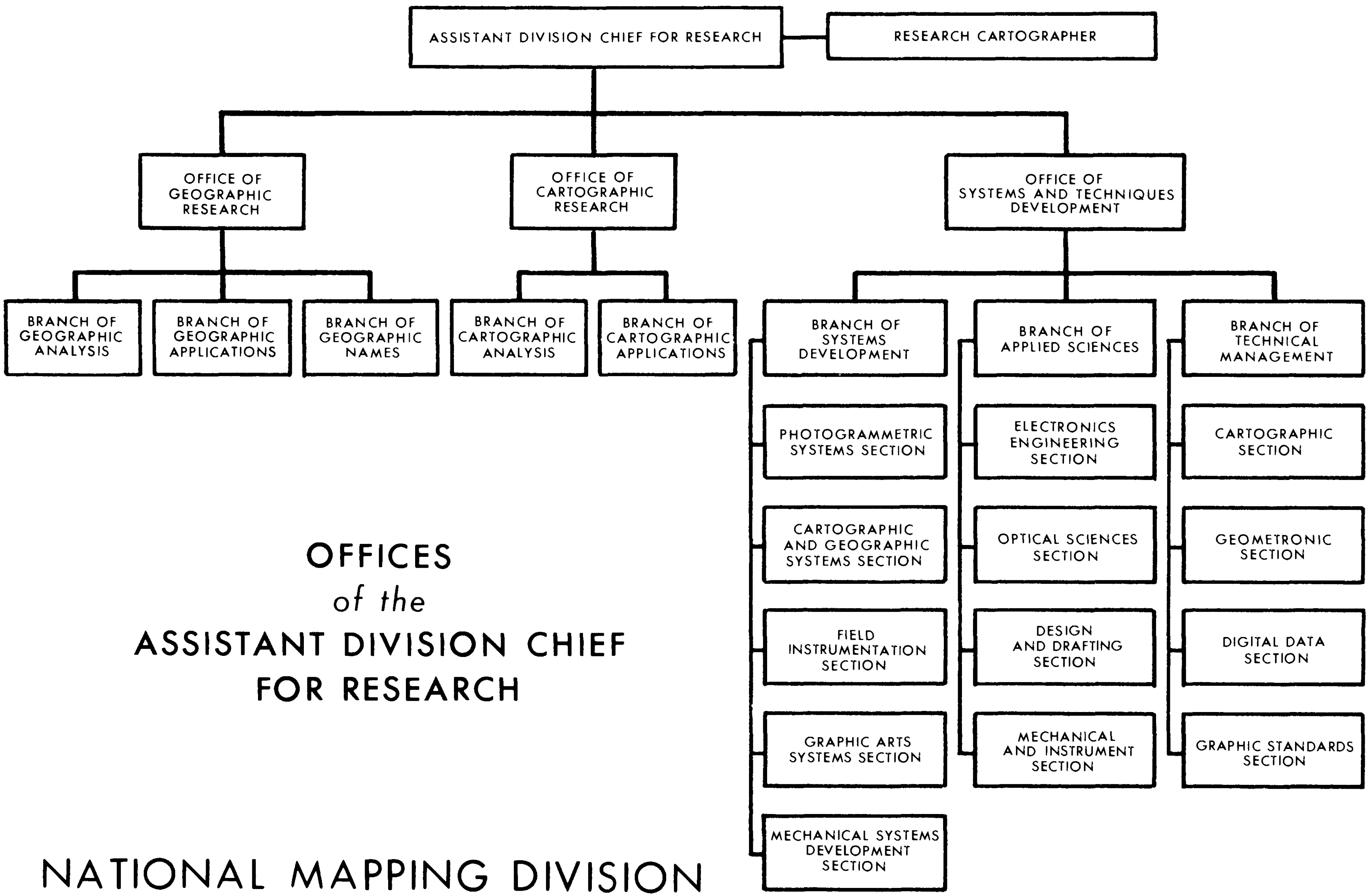


Organization of the U.S. Geological Survey as of March 31, 1982.



NATIONAL MAPPING DIVISION

Chart of Organization



OFFICES
of the
ASSISTANT DIVISION CHIEF FOR RESEARCH

NATIONAL MAPPING DIVISION

FOREWORD

In support of the Geological Survey's mission to provide information about the Earth and its physical resources, the National Mapping Division (NMD) provides geographic and cartographic information, maps, and technical assistance, and conducts related research responsive to national needs. The purpose of this document is to report research, investigations, and technical developments accomplished or currently being conducted in the NMD. The report covers projects undertaken by staff members in the Office of Research, by personnel in the five production centers, and through contracts.

Increasing demands for current and accurate cartographic and geographic data have encouraged many new technological developments in data acquisition, processing and display. Active research and development is conducted in NMD to improve the quality and efficiency of map production and to evolve new technology to support national earth science needs. Research continues in digital cartography and the related broad field of spatial data handling to support the development of a Digital Cartographic Data Base for the nation. Research to analyze these data in order to locate, predict, and plan for environmental changes or hazards should enable decisionmakers at all levels of government or the private sector to more fully utilize this information.

In order to complete nationwide large-scale map coverage by the late 1980's, the Division has developed technical standards and initiated an accelerated production program for Provisional Edition topographic maps. Provisional maps will be prepared for all remaining unmapped 7.5-minute quadrangle areas, including those currently covered by 15-minute maps and all unmapped 15-minute areas in Alaska.

In October 1980 the Geological Survey reorganized elements of the Publications Division, the Geography Program of the Land Information and Analysis Office, and the Topographic Division into the present National Mapping Division. An Assistant Division Chief for Research manages three Offices - Cartographic Research, Geographic Research, and Systems and Techniques Development.

This office structure was designed to enable each group to conduct specific tasks. Thus, the Offices of Cartographic Research and Geographic Research conduct basic and applied research in their disciplines and relate with such research carried on in the mapping centers. The Office of Systems and Techniques Development conducts research on hardware and software systems development for the Division, establishes and issues technical cartographic standards, and serves as the principal staff contact for technical problems faced by the Division.

To aid in the coordination, a research committee has been established within NMD to advise the Division Chief and the Director of the Geological Survey on major research and development activities. This committee will also serve as a clearinghouse for long-term, policy-related, or multi-center research projects. An advisory group, composed of representatives from other Federal agencies, academia, and the private sector, has also been proposed to broaden research coordination with the cartographic and geographic professional community.

This report, therefore, summarizes selected current and completed research and development activities carried on in the National Mapping Division during 1981. A complete listing of all projects and responsible Offices is included as an Appendix. A list of Selected References includes research reports and publications for the period 1978 through 1981.

Lowell E. Starr
Assistant Division Chief for Research

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CONVERSION TABLE

U. S. customary units used in this report may be expressed as metric units by the use of the following conversion factors.

Multiply	By	To Obtain
feet	0.3048	meters
statute miles	1.609	kilometers

U. S. metric units used in this report may be expressed as U. S. customary units by the use of the following conversion factors.

Multiply	By	To Obtain
meters	3.281	feet
kilometers	0.6214	statute miles

ABBREVIATIONS

DBMS	data base management system
DCDB	digital cartographic data base
DDES	digital data editing system
DEM	digital elevation model--an array of elevations for ground positions, usually spaced at regular intervals
DLG	digital line graph--line map information in digital form
GIRAS	Geographic Information Retrieval and Analysis System
GNIS	Geographic Names Information System
GPM-2	Gestalt Photo Mapper II
NASA	National Aeronautics and Space Administration
NMAS	National Map Accuracy Standards
NMD	National Mapping Division
RMSE	root mean square error
USGS	U. S. Geological Survey

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INTRODUCTION

This report reflects the major research activities within the National Mapping Division. The last report, published in 1977, covered cartographic research in the areas of field surveys, photogrammetry, orthophotomapping, and remote sensing, with a minor emphasis on hardware for digital cartographic applications. Since 1977 additional research areas have gained importance due to organizational changes, technological developments, and an increased emphasis on the mission of the Division to develop a digital cartographic data base. Therefore, this report includes digital cartography, with emphasis on several key areas on spatial data handling relating to both cartographic and geographic digital data, geographic analyses of land use and changes in land use, potential environmental hazard areas, and multidisciplinary studies.

Several special projects, undertaken in 1981, are highlighted. The eruption of Mount St. Helens in 1980 resulted in a series of special cartographic products. The System Alpha study, which reports on a three-phase strategy for the development and maintenance of the Digital Cartographic Data Base, was completed. A 1:2,000,000-scale data base, developed using source materials from the "National Atlas of the United State of America," will be completed in 1982. Standards for a new series of Provisional Edition topographic maps were prepared to meet the goal of completing nationwide large-scale map coverage by the end of the decade. In the area of remote sensing, a concept was developed and validated for an operational Earth resources mapping satellite--Mapsat.

The section on spatial data handling reflects the current major research thrust in the Division and covers a wide range of activities in the areas of manipulation, retrieval and analysis of digital cartographic and geographic data. Included here are projects such as the development of a prototype geographic information system for utilizing the digital products of the land use and land cover mapping program, and activities relating to the development of the Digital Cartographic Data Base. The section on cartographic and geographic studies covers basic and applied research in both disciplines, including topics which range from land use change to the development of new cartographic techniques. Research discussed in the section on remote sensing and space technology includes studies specifically related to Landsat, Seasat, and side-looking airborne radar. The treatment of digital data derived from space sensors for image mapping and geographic applications is also included. The systems and techniques research and development section emphasizes developments in digital applications hardware, and techniques for handling raster-formatted data. This section also covers studies in screenless lithography and automation of cartographic lettering. Associated activities such as the testing and calibration of aerial cameras, research in camera calibration, and information on resolution targets and the distribution of computer software are covered in the final section.

All illustrations in this report are reproduced in black and white. However, some of them actually depict experimental maps which were produced in color.

1981 HIGHLIGHTS

Mount St. Helens Mapping

The volcanic eruption of Mount St. Helens in 1980 resulted in a series of special cartographic products required by other USGS Divisions and land management agencies. All products required special procedures due to time, cartographic, and logistical constraints. The five major efforts involved 1:100,000-scale base maps, orthophotoquads, contouring sequential topographic changes, surveying and mapping along drainage basins, and generation of digital cartographic data.

The 1:100,000-scale base maps were the first products prepared in response to local planning requirements after the May 1980 eruption. Both pre- and post-eruption versions were made. This was a cooperative effort with the U.S. Forest Service and the State of Washington's Department of Natural Resources. Special symbols were used and the hazardous area received special editing treatment.

Post-eruption 1:24,000-scale orthophotoquads were also produced. These orthophotoquads were made from NASA 1:130,000-scale photos taken from a U2 aircraft in June 1980. Due to poor weather, this was one of the earliest sets of mapping photos flown after the eruption. Higher-resolution orthophotoquads were produced later from 1:40,000-scale photographs taken in September 1980.

A new series of 1:24,000-scale topographic maps was started with the discovery of the "bulge" in March 1980, prior to the major eruption in May 1980. The mapping was used to monitor the changes on the mountain. The earlier 15-minute map was compiled in 1952 at 1:48,000 scale. The first topographic map in the series was compiled from the 1952 photographs at 1:24,000 scale. As a basis for monitoring the "bulge," a 1:24,000-scale map was compiled from July 1979 photographs. Pre-eruption mapping was produced from photographs taken in April and May 1980, and post-eruption mapping was completed from photographs taken from June through October 1980. The photographs taken in September 1980 were used to compile the 1:24,000-scale map which was published. These maps were compiled in most cases within a few days of the flight day to assist others in their monitoring of the mountain and its surroundings. Two examples of topographic contouring are shown in figures 1 and 2.

The USGS Water Resources Division had an immediate requirement for large-scale (1:4,800) maps of drainage basins in the Mount St. Helens area for erosion monitoring and watershed analysis. Most of this mapping was done under contract. However, due to short-term needs in critical areas, the NMD produced some maps prior to the contract mapping. This effort required ground surveys and photogrammetric mapping at large-scale accuracy in an extremely short timeframe. Ground crews worked under difficult access and hazardous conditions, performing field surveys required for the photogrammetric work. Analytical aerotriangulation was used to extend field control, using accurate procedures which minimized the field requirements. The final products were compiled photogrammetrically at 1:4,800 scale with 4-foot contour intervals.

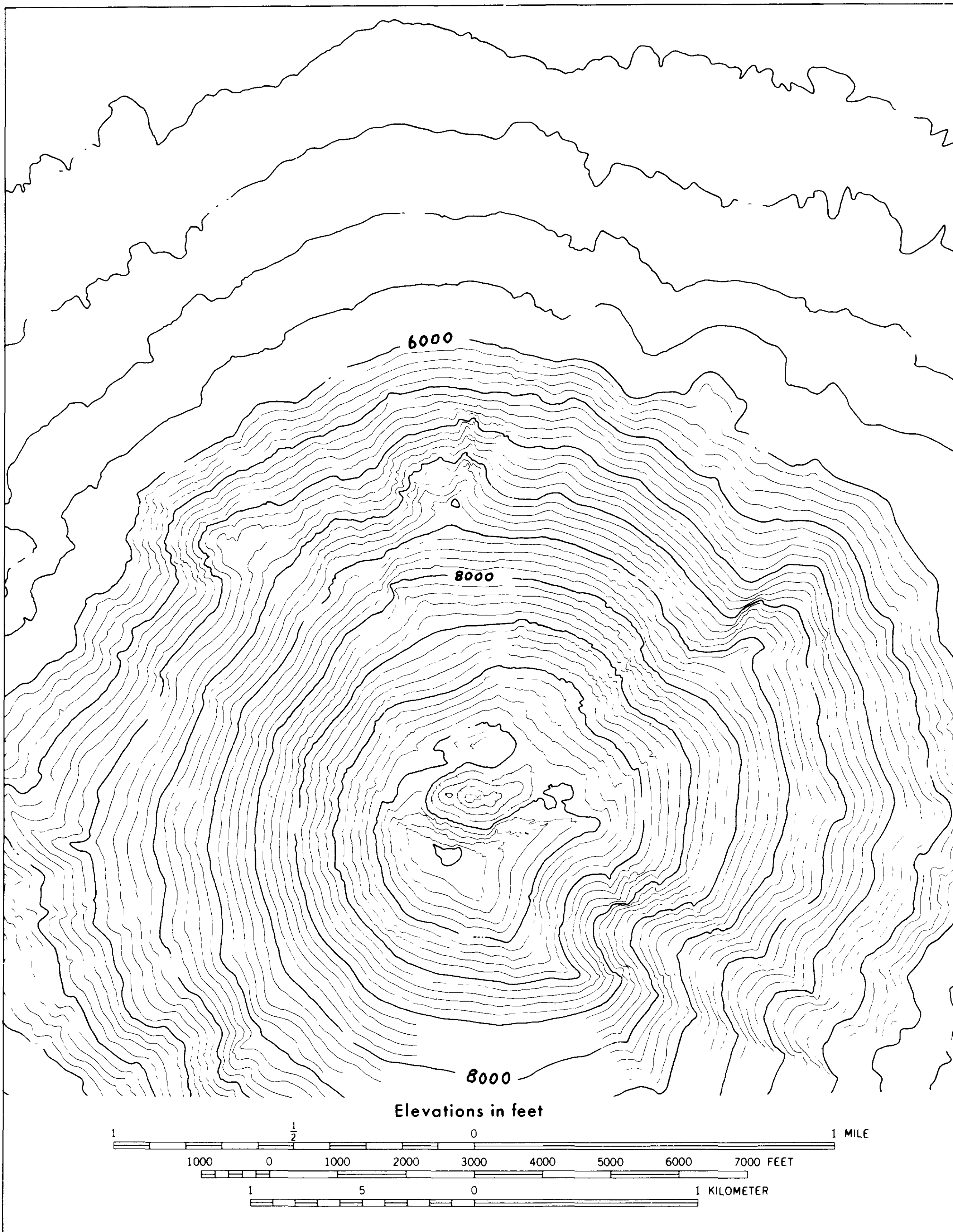

Figure 1. Topographic contours of Mount St. Helens compiled from April 12 1980 photographs (pre-eruption).

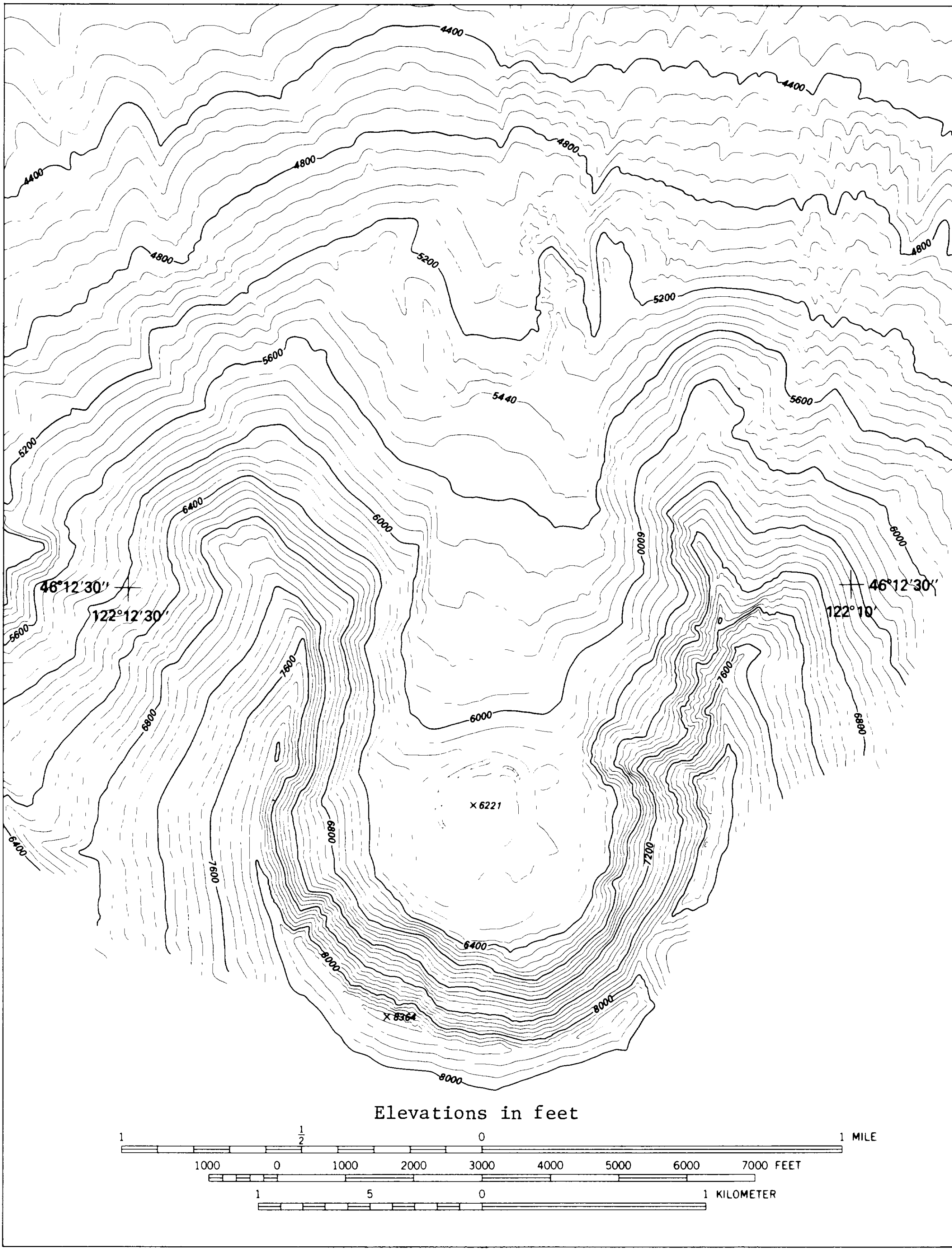

Figure 2. Topographic contours of Mount St. Helens compiled from July 1 1980 photographs (post-eruption).

Perhaps the most widely seen products of the mapping activities in the Mount St. Helens vicinity have been the pre- and post-eruption isometric views of the "mountain-volcano" (figures 3 and 4). These graphics were generated from digital elevation model (DEM) data of July 15 1979, and September 6 1980, photography, respectively.

The pre- and post-eruption DEM's were also used to project local ejecta deposition volume by algebraic subtraction of the two data sets. The resultant data set was used to produce a volumetric data isometric plot (figure 5). Additional products generated from the DEM data include a post-eruption contour plot and a contour plot indicating ejecta contours used for volumetric analysis. Plots made from DEM data are not standard USGS products. They are examples, however, of applications of DEM data which, in this case, met immediate needs of geologists and land management agencies.

System Alpha Study

The Department of the Interior has given the U.S. Geological Survey primary responsibility for the development and maintenance of the Digital Cartographic Data Base (DCDB), an undertaking which will produce the largest digital data base in the United States.

In February 1980, the NMD Digital Steering Committee recommended to the Division Chief that the Division adopt and implement a three-phase (Alpha, Beta, Gamma) digital data base development strategy that would provide an efficient, maintainable system meeting the majority of user needs by 1990. The Alpha phase was expressed as the collection of in-place hardware and software systems and techniques. Beta was seen as the Alpha system replacement 5 years from now, with Gamma projected to be realized after 1990 based on research conducted over the next 5 years.

Following these recommendations, the Division Chief requested that studies be undertaken to determine the necessary steps to implement the first recommendations of the Steering Committee and the Assistant Division Chief for Research appointed a System Alpha Review Team. The principal tasks of the Review Team were: (1) to examine the existing production capabilities for digital cartographic and geographic data in the NMD; (2) to determine the best use of existing facilities for data production and recommend any necessary enhancements; and (3) to recommend the most effective management strategy. Additional tasks were to develop an intermediate development plan for the growth of digital production and to identify specific tasks related to System Beta, the next phase.

The System Alpha Review Team study, completed in June 1981, represents the first comprehensive review of digital mapping software and hardware capabilities in the National Mapping Program. The study examined the various digital products of the Program, as well as the data capture, editing, and output systems. It proposed modifications to products and

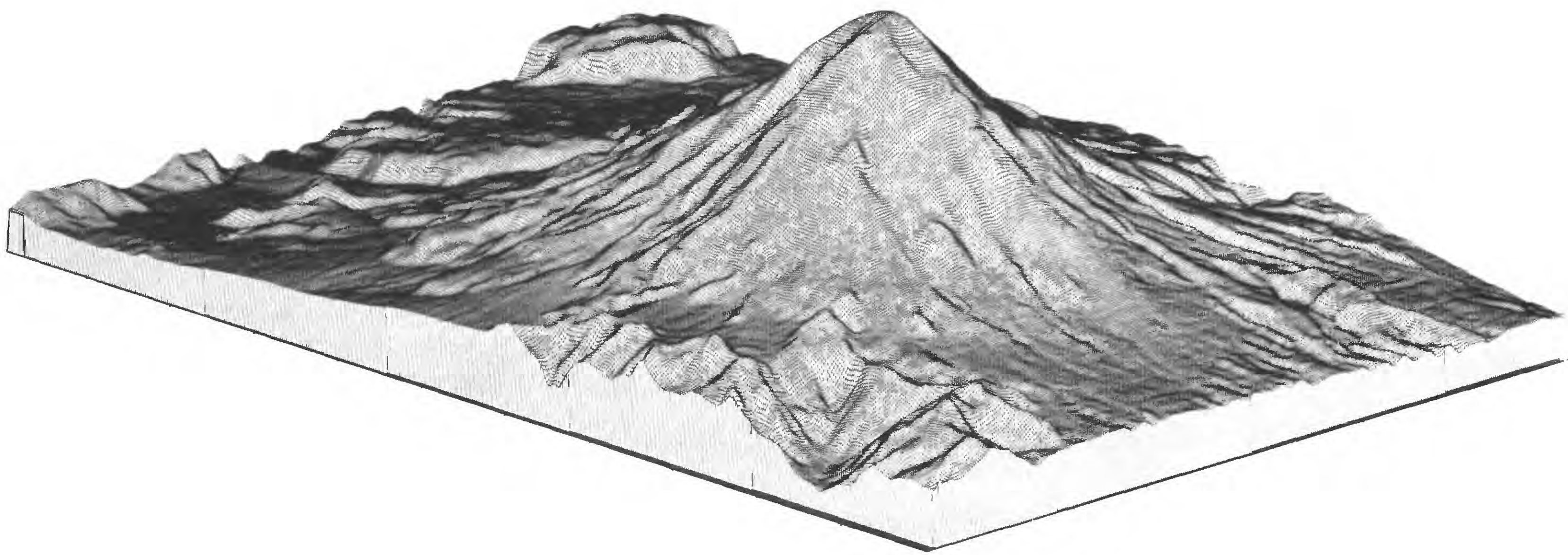

Figure 3. Pre-eruption isometric plot of Mount St. Helens generated from DEM data from July 15, 1979 photographs. View is from the northeast at a 45° altitude angle; vertical exaggeration is 3:1.

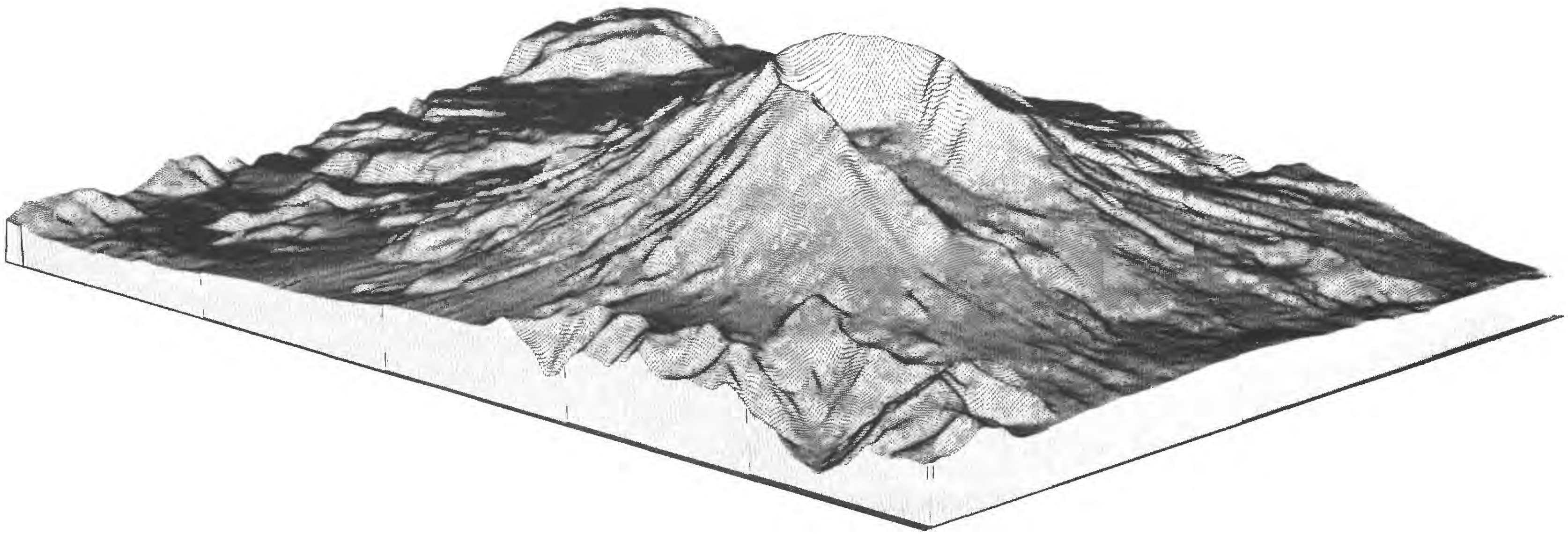

Figure 4. Pre-eruption isometric plot of Mount St. Helens generated from DEM data from September 6 1980 photographs. View is from the northeast at a 45° altitude angle; vertical exaggeration is 3:1.

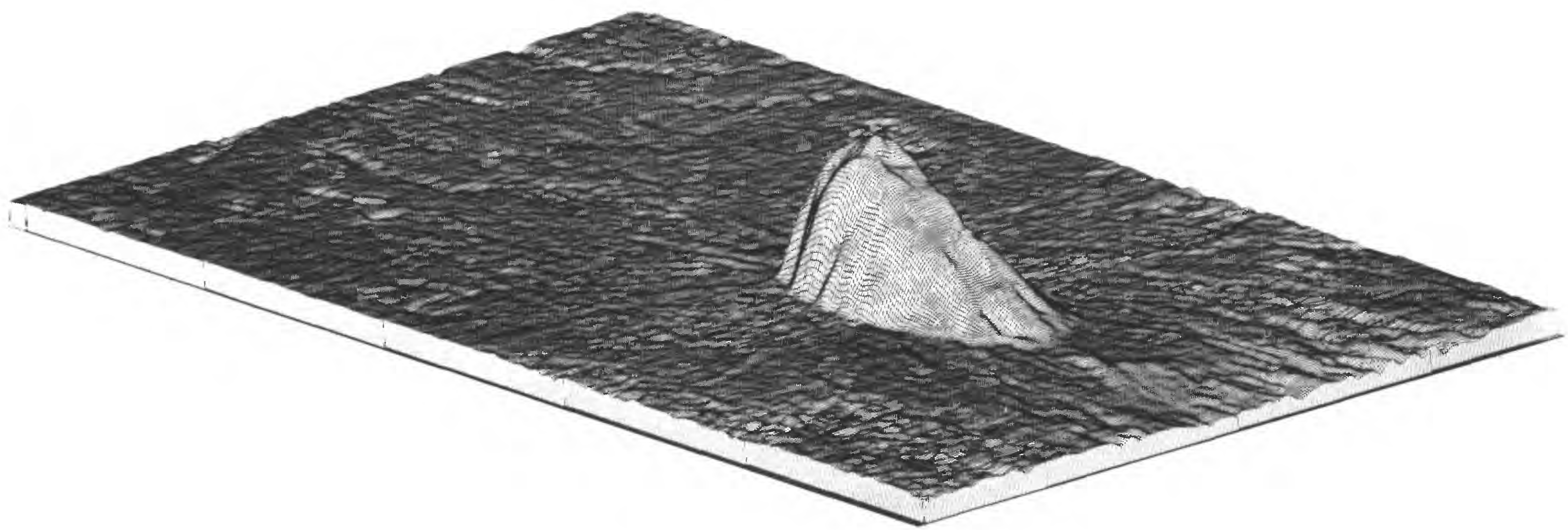

Figure 5. Isometric plot representing local ejecta volume from Mount St. Helens, generated by the algebraic subtraction of the pre- and post-eruption DEM data sets.

production systems, and identified the pertinent issues involved in further development of the DCDB. Collection processes for DLG and DEM data were examined and modifications identified to improve overall system speed and accuracy. Hardware and software systems were reviewed and improvements for documentation and maintenance procedures recommended. The study raises a number of developmental research issues involved in the creation of the next major Division digital system, System Beta, and presents recommendations for Division management to consider when planning program objectives, system operations, and future development and research. The report is currently serving as the principal Division document for the planning of the digital mapping program, which is expected to become the major Division activity in the years to come.

Provisional Map Standards Development

A primary goal of the NMD is to complete nationwide large-scale map coverage by the late 1980's. To provide a realistic means to meet this goal, the NMD has developed technical standards and has initiated an accelerated program for the production of Provisional Edition topographic maps. The provisional map standards modify certain conventional mapping procedures whereby significant reductions in map finishing operations and moderate modifications to standard field and photogrammetric operations are applied. These modifications permit provisional maps to be produced at approximately 20-25 percent less cost, and on a more timely basis than standard topographic maps. Provisional maps are prepared to NMAS, printed in four or five colors, and made available through normal distribution procedures. They generally contain the same level of information as shown on standard topographic maps but have a "provisional" rather than a finished map appearance (figure 6).

Provisional maps will be produced in three categories depending on the status of the individual maps or projects in the mapping cycle at the time the provisional mapping program was implemented: (1) category 1 maps for which map preparation materials have not been through field phases; (2) category 2 maps which have not been compiled, but for which map preparation materials have received advanced field interpretation; and (3) maps that have been through the field and compilation phases but not through the map-finishing (color separation) phases. Content, symbolization, and map-finishing procedures will differ somewhat for each category.

Copies of the compiled map manuscripts are used as the final drawings for lithographic printing of provisional maps. In general, standard compilation procedures apply, with the addition of separate manuscripts for water features, which are printed in blue, and public-land survey information, which is printed in red.

Map collars are generated either from master collars or directly on the DDES (except for grid and graticule values). The appearance of provisional maps is readily distinguishable from standard maps due to the

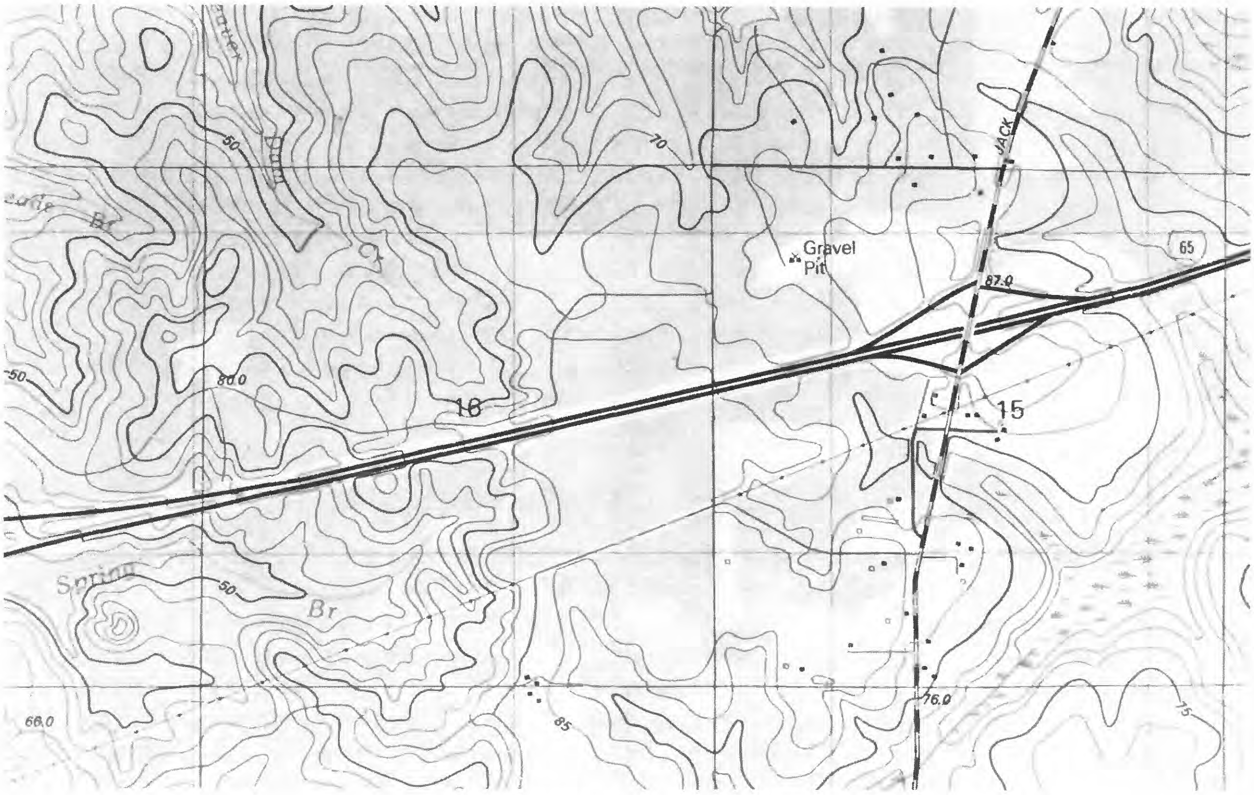

Figure 6a. Portion of a standard 1:24,000-scale topographic map.

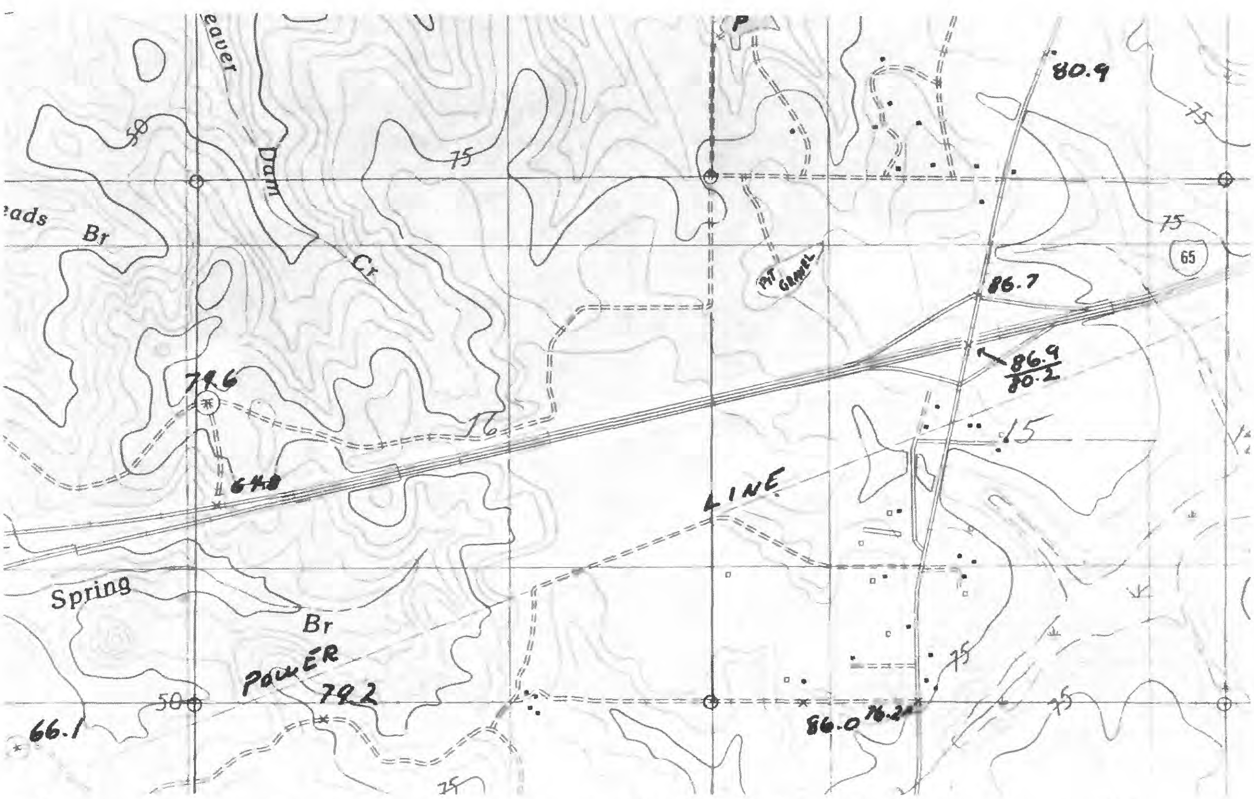

Figure 6b. Portion of a Provisional Edition 1:24,000-scale topographic map.

modified treatment and to the printing of all map collar information in brown. With minor exceptions, provisional maps will be prepared for all remaining unmapped 7.5-minute quadrangles (approximately 12,000), including those currently covered by 15-minute maps, and all unmapped Alaska 15-minute areas.

The 1:2,000,000-Scale Data Base

Most Federal programs are established on a nationwide basis and many of these require definitive information about the spatial relations of features routinely shown on base maps. Such feature data can be practically combined, manipulated, and analyzed only by digital means. To satisfy the expressed needs of both the USGS and other user agencies for a small-scale national data base, it was concluded that the data base had to contain cartographic information that was current, topologically structured, no smaller in scale than 1:2,000,000, and sufficiently flexible to permit the generation of smaller-scale derivative maps, thematic overlays, and other graphic products (figure 7). Existing cartographic data bases, related applications software, and data collection hardware systems were investigated, but all had limitations. After considerable study and planning, a series of tasks directed toward the generation of a comprehensive nationwide data base was defined.

The 1:2,000,000-scale general reference maps of the "National Atlas of the United States of America" were selected as the available source materials best able to meet the requirements. The resulting data are current to 1980, comprehensive, and available in two file organizations--one topologically structured and the other compatible with the Cartographic Automatic Mapping (CAM) Program. The data include political and Federal administrative boundaries, roads, railroads, streams, water bodies, and airports. The coding scheme allows maps to be generated with appropriate detail for a particular map scale and theme. The project will be finished in 1982, and the resulting data will be available to the public through the USGS National Cartographic and Information Center.

Mapsat

After 15 years of study and experimentation with cartographic applications of space technology the NMD developed a concept for a cost-effective earth resources mapping satellite called Mapsat (figure 8). In 1980 a contract was arranged to perform a feasibility study relative to the conceptual design of this new form of mapping satellite. The final report received during 1981 verified the validity of the concept and its cost-effective qualities. The several unique facets of the Mapsat system are the result of a USGS effort to define an operational Earth-sensing system based on Landsat technology which includes the following objectives:

- Global coverage on a continuous basis.
- Data dissemination in reasonable time and at reasonable cost.

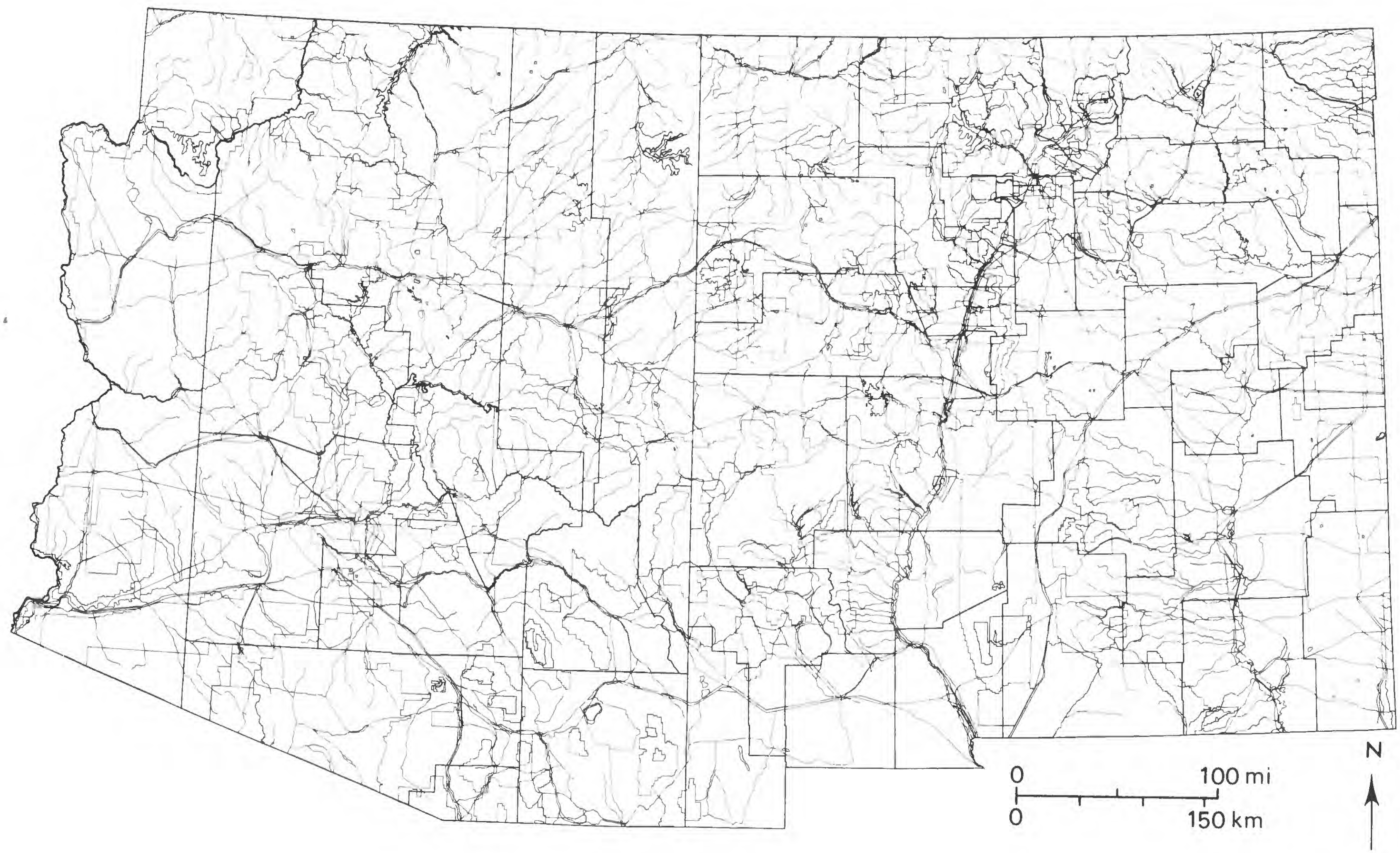

Figure 7. Plot showing 1:2,000,000-scale data for Arizona/New Mexico. Data include drainage, transportation, boundaries, and Federal lands. Plot is shown here at approximately 1:5,000,000 scale.

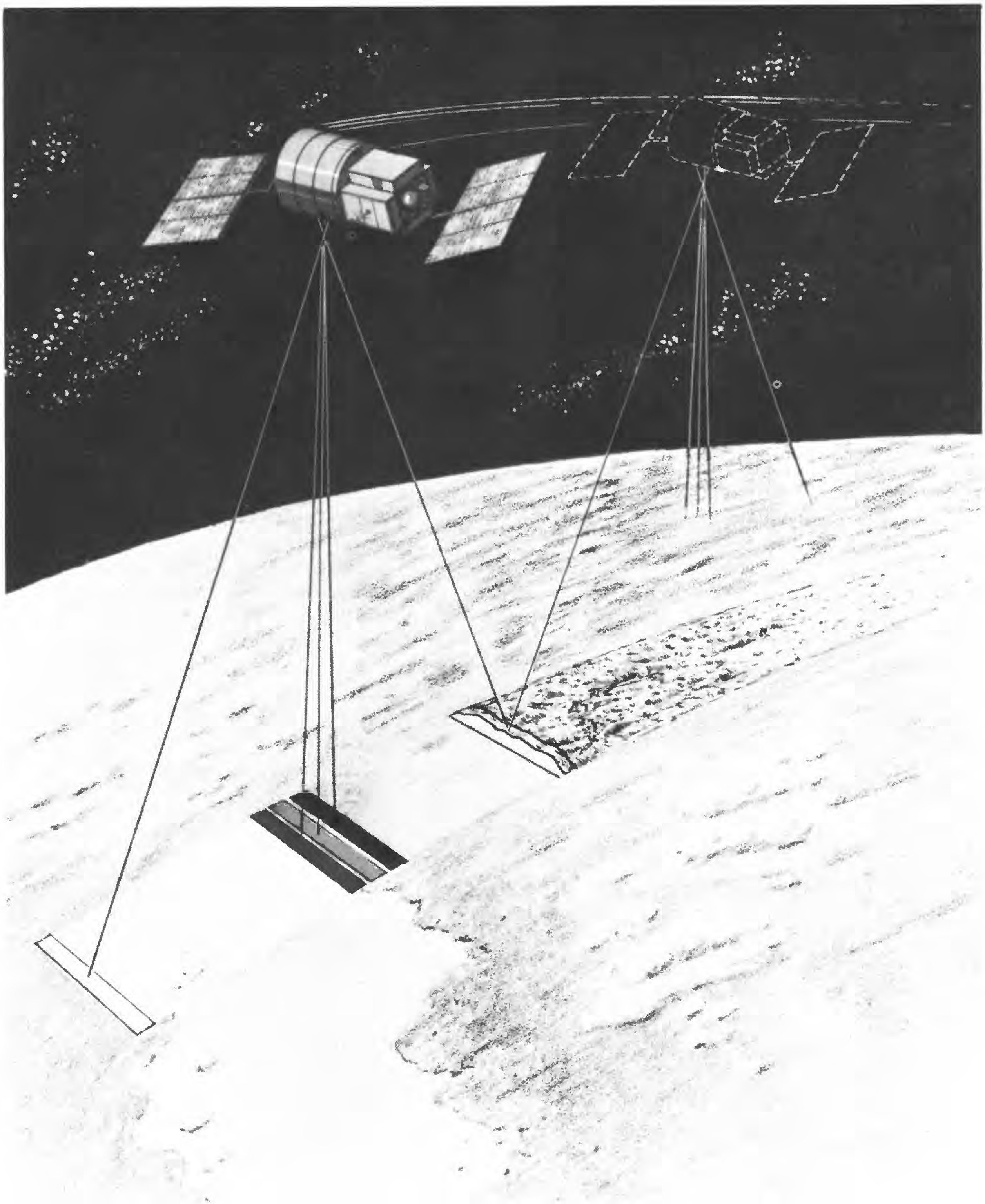

Figure 8. Mapsat viewing concept.

- Variable resolution (down to 10-m elements) and swath width, with stereoscopic and multispectral capabilities.
- Capability of image mapping at scales as large as 1:50,000 with contour intervals as small as 20 m.
- Continuity with respect to Landsats -1, -2, and -3, including the same orbit and basic data transmission and reception system.
- Cost effectiveness

Mapsat, as opposed to aerial photography, is a completely different concept for imaging the Earth's topography. It uses three sets of optics, two of which look fore and after of the satellite and the third which looks vertically.

Any two of the three optics view the Earth from two different positions as the satellite proceeds in its orbit (figure 9). The data are detected by thousands of solid state elements with one detector of one array (one optic) imaging the same line segment of the Earth as a corresponding detector on the other array (other optic). When such a line segment is imaged from two separate points in space, an epipolar condition exists. This results in the generation of one-dimensional data from each pair of imaging detectors. One-dimensional data processing is relatively simple and cost effective. Mapsat is multispectral as well as stereoscopic and thus has thematic as well as topographic mapping capabilities.

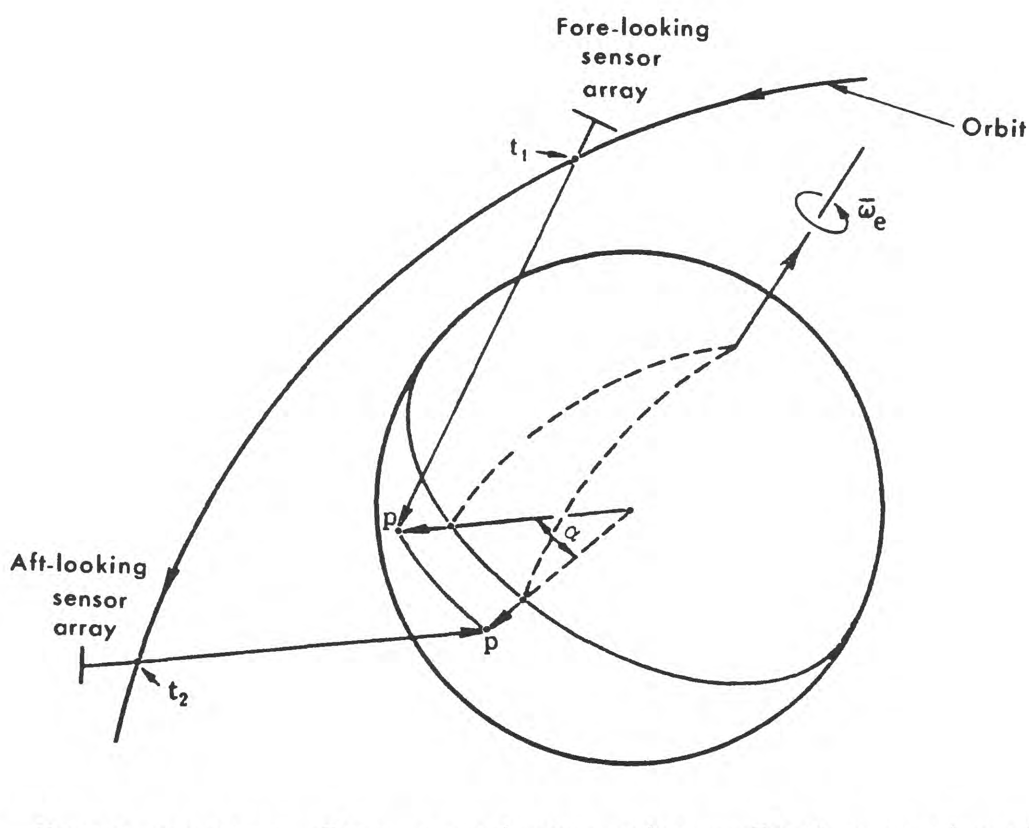

Figure 9. Mapsat geometry. Fore array images point on Earth p at time t1; aft array images same point at time t2. α is angle through which Earth has turned between t1 and t2. By controlling the yaw of the satellite, analogous detectors on the two arrays both look at point p.

High geometric fidelity is achieved by defining a spacecraft and sensor system having virtually no moving parts and very precise position and attitude determination. The sensor system is solid-state, the antenna is fixed, and solar panels are not actuated during periods of data acquisition.

Mapsat is designed for operations using three spectral bands at various resolutions and swath widths. The three bands selected for Mapsat are a blue-green (0.47 to 0.57 μm), a green-red (0.57 to 0.70 μm), and a near-infrared (0.76 to 1.05 μm). These selections are based on demonstrated practical uses of Landsat spectral bands and the need to limit data rates and achieve a high signal-to-noise ratio. The effective resolution element may be as small as 10 meters, and various spectral bands, stereo combinations and swath widths can be employed, depending on the areas of interest. However, the data transmission rate is limited to 48 megabits per second for reasons of economy. This data rate is achieved by relatively minor modifications to the existing Landsat receiving stations. The existing S-band Landsat transmission system or X-band defined for the Landsat D Thematic Mapper may be utilized.

The delineation of the Earth's surface in three dimensions is essential for many applications. Mapsat will provide two base-height ratios for the stereo mode. This mode provides for the automated production of contour maps and digital elevation data, which is a relatively new and powerful tool for defining and analyzing the Earth's terrain. A formal research project to further investigate the correlation of stereo data from a system such as Mapsat has been initiated.

A patent for Mapsat has been issued by the U.S. Patent Office.

AUTOMATED SPATIAL DATA HANDLING

Data Base Development

One of the major activities of the NMD is the development of the DCDB. Plans call for the data base to consist initially of the boundaries, public land net, streams and water bodies, and transportation features shown on 1:24,000-scale maps; of elevation data largely obtained concurrently with the orthophotoquad program; of planimetric features from the 1:2,000,000-scale sectional maps of the "National Atlas of the United States of America;" of elevation data obtained from the 1:250,000-scale map series; of land use and land cover data; and of geographic names. The potential size of the data base is extremely large; with complete coverage of the conterminous United States at 1:24,000-scale requiring nearly 54,000 maps, the data base would eventually contain several trillion bits of spatial data. For comparison, a typical type-written page contains about 25,000 bits.

In its configuration, the DCDB is a unified set of smaller generic data sets that are managed by the SYSTEM 2000 data base management system (DBMS). It is important to note that only the files are managed and not the coordinate and attribute data within the files.

There is, however, a standard file format for the map information managed by the DBMS. This format describes the parameters and characteristics of the individual map data files. General information such as map name, scale, projection, and data resolution is stored. In addition, data on the numbers of points, lines, and areas, as well as the attributes of these features, are specified for each map.

The purpose of the DBMS is to accept, catalog, and archive digital cartographic data files in a standard way and to access the files or report information about the files upon request. Certain file data, such as name, date, geographic coverage, data categories, and accuracy, are extracted and stored in the DCDB SYSTEM 2000 index. The DCDB system is also used to produce archival magnetic tapes, providing at least two backup copies of each file on high-density tape.

Research is being conducted to expand the DBMS from a file management system to a spatial data base management system that would enable the user to query the actual spatial data currently contained in individual files. To do so will require not only a greater understanding and formalization of the types of queries that are going to be placed upon the data base, but also a rigorous definition of the spatial operations that must be performed in order to answer a question. In such a configuration, the formal query will invoke a sequence of spatial operators to manipulate the required data sets and produce the desired output product.

DEM Editing Using a Polygon Scan-Conversion Process

One method the NMD uses to produce DEM's is with the GPM-2. The GPM-2 electronic image correlator derives a gridded array of elevations from stereophotographs. However, because of problems in automatic correlation on certain topographic features, such as large water bodies, elevation data derived for these features must be further edited. A polygon scan-conversion routine was developed on an interactive computer graphics system to edit GPM-2 elevation data for uncorrelated water bodies. DEM's in both the GPM-2 patch format and DCDB profile format can be edited using this routine. Complex polygon structures, such as multiple islands within a lake boundary, can be processed efficiently.

The DEM for the Shadow Mountain, Colorado, quadrangle was selected for testing the edit software. A total of 22 edit polygons were digitized--2 large reservoirs, 6 ponds, and 14 islands. The digitizing and attribute tagging of the polygons took 1.5 hours and the polygon scan-conversion routine took 15 minutes. The output from the editing process is an edited DEM, captured on a magnetic tape, having the same logical and physical file layout as the input DEM. Relative accuracy tests on the unedited and edited DEM showed RMSE's of 17.75 meters and 11.95 meters respectively. Figure 10 shows isometric views of the DEM before and after being processed by the interactive water-body editing routines.

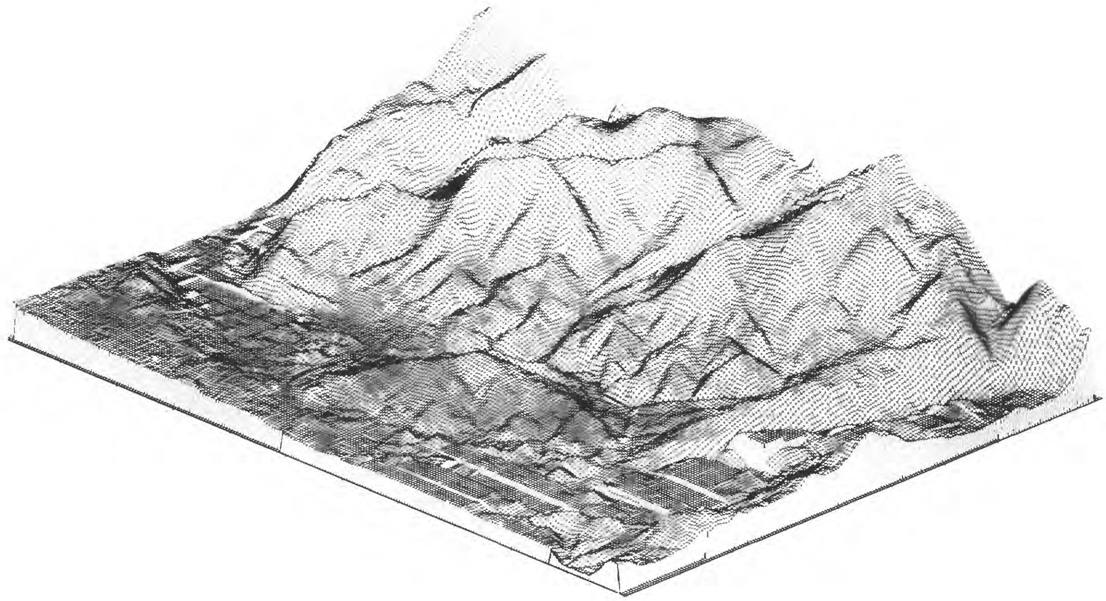

Figure 10a. Isometric view of unedited Shadow Mountain, Colorado, DEM. View is from the southeast at a 45° altitude angle; vertical exaggeration is 3:1.

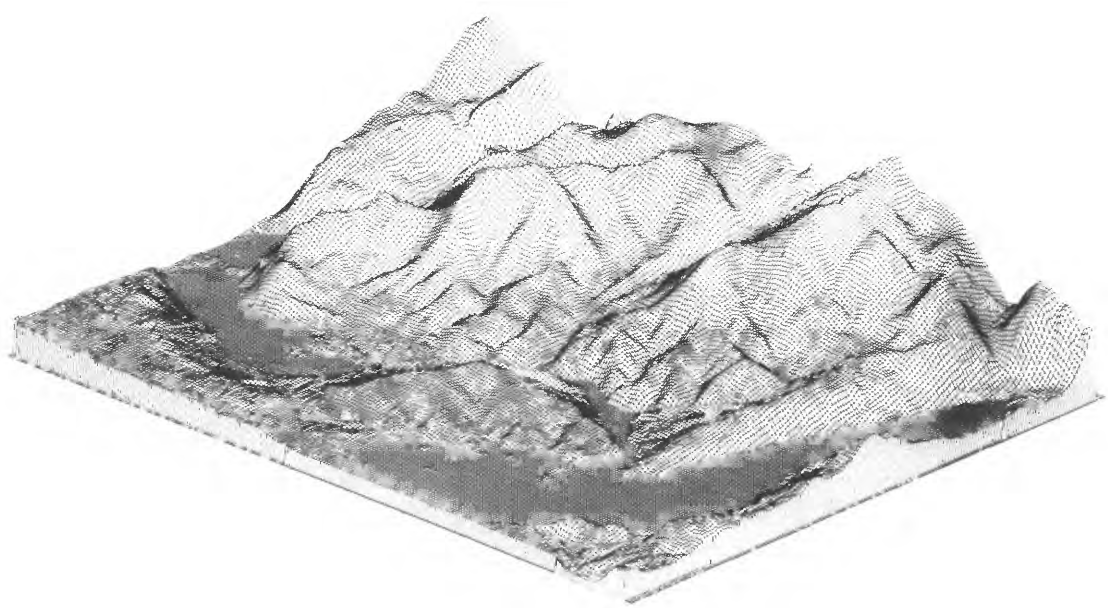

Figure 10b. Isometric view of Shadow Mountain, Colorado, DEM after being processed by the interactive water-body editing routine. View is from the southeast at a 45° altitude angle; vertical exaggeration is 3:1.

Automated Cartography

The use of the computer has been incorporated into nearly all computation phases of map production, and cartographers have taken advantage of this technology to enhance many of their production procedures. With the modern digital cartographic equipment now available, it is possible to utilize computer assisted techniques in many phases of map production to allow greater flexibility in mapping techniques and products.

In conventional map compilation operations, the map features are traced out on the stereoplotter tracing table, which is linked either mechanically or electronically to a pantograph or slave-plotter, which produces a drawing of the features on a Mylar manuscript. The manuscript is then usually manually scribed with proper symbology to produce the color separate guides.

In late 1977, research was initiated to test the feasibility and cost-effectiveness of capturing digital cartographic data directly from the stereoplotter. New equipment and techniques now permit the use of stereo-model digital-data capture, interactive editing, and cartographic machine-plotting techniques for the automated production of conventional map color separate guides. The corresponding digital data stored on magnetic tape or disks can be further processed to generate other products such as USGS standard DEM and DLG files, and to establish digital topographic data bases for revision.

Currently, four Kern PG-2 stereoplotters are dedicated to collecting digital data on a production basis. The stereoplotters are equipped with shaft-angle encoders, which output to an Altek AC/189 three-axis digitizer and tape unit. The digitizer captures X-Y movement of the plotter tracing table by either an incremental vector criterion (usually about 4-6 feet at ground scale) or through an angle-based hardware filter, which eliminates unnecessary vertices. Attribute codes are entered through an Interstate Voice Data Entry System (VDES) interfaced to the digitizer. The VDES, supported by a Data General Nova 2 minicomputer, allows the operator to enter attributes without breaking concentration or moving away from the stereoplotter. The VDES also reduces coding errors by prompting the operator to enter additional attributes as required for special features.

Processing of digital data is accomplished on a Perkin-Elmer (PE) 3220 System. Interactive editing capability is available on the DDES supported by a DEC PDP 11/70 computer. Verification plots are generated on a Versatec 8242A raster plotter, while color separation guides are photo-plotted on a Gerber 4477 flatbed plotter.

As a result of research in stereomodel digitization, the Digital Cartographic Software System (DCASS) was developed. DCASS is a system of programs used to collect, process, manipulate, and derive useful products from digital data obtained directly from the stereoplotter or digitizing table. All DCASS software utilizes a feature-indexed file structure for representation and storage of digital cartographic data. This commonality allows maximum flexibility as well as reduced software development costs, as many programs share the same routines for feature storage and manipulation.

The DCASS structure is vector-based and was designed to maximize the ease of performing cartographic manipulations, such as joining of features across photogrammetric models and resampling of contours for DEM production. Although the usual processing unit is one 7.5-minute quadrangle, it is self-defining and can represent maps of any scale within resolution limits. The DCASS structure consists of two files: an attribute file (DSA) and a coordinate file (DSB).

DCASS consists of six major subsystems. Each subsystem, comprised of one or more programs, exists for one of three primary functions. The subsystems can be categorized as: (1) manipulation (having the power to alter the contents, but not the structure; (2) application (using a read-only mode, to generate some other product); and (3) utility (reformatting/support functions).

DCASS is being used in a production mode. Test results show that the accuracy of DEM's produced using DCASS range between one-fourth and one-half the contour interval of the compiled quadrangles. DCASS is also being used to produce Provisional Edition 1:24,000-scale topographic maps. Approximately 50 of these maps have been completed and are now in the map-finishing stage. Initial results indicate a savings of about 20 hours per quadrangle for digitally produced maps.

Geographic Information System Development

Two primary goals of the digital mapping program are to: (1) "create, maintain, manage, and distribute the national cartographic and geographic digital data base for multi-purpose needs;" and (2) "implement digital techniques in cartographic and geographic operations." To accomplish both of these goals, capabilities in the areas of spatial data manipulation, retrieval, and analysis must be developed. Research to address these goals is being conducted to develop prototype geographic information systems components designed to utilize the digital products of the land use and land cover mapping program which are incorporated in the DCDB. The intended applications of the results of this project are two-fold: (1) to assist users, especially USGS personnel, in applying the land use and land cover and DCDB data to research and production tasks; and (2) to provide "feedback" mechanisms to the ongoing task of designing and developing the DCDB and the system to build and manage it.

One study is addressing the impact of spatial operators on data base management system design criteria. Spatial operators provide a common foundation for many different applications routines and perform the fundamental computations of locational, geometric, or topological attributes needed in spatial analysis. A survey of existing geographic information systems illustrates a high degree of commonality in types of capabilities. This would seem to suggest that a relatively small set of spatial operators could support a widely varying set of applications. The set of spatial operators would provide data base design criteria in terms of required data elements and structural elements that will need to be explicitly encoded or derived. The objectives of this research are to: identify a set of spatial operators; delineate the data requirements of the spatial operators; group like data requirements to define subschemas of archival data structures, and inspect the set of subschemas to provide data base management system design criteria.

Geographic Names Information System

Uniformity in the spelling and application of geographic names is essential at all levels of government, industry, and for those sciences that deal with the Earth and geographic location. Large amounts of interrelated data involving names and their application to specific features, places, and areas must be collected, processed, stored, retrieved, manipulated, and disseminated to a wide variety of users.

After several years of researching user needs and information systems, the USGS developed an automated Geographic Names Information System (GNIS) and is building a national geographic names data base. Although the system is operational, further research and analysis is being conducted in regard to methodology and the necessary expansion and development of the system. GNIS is presently capable of providing basic information for about 2 million names used in the United States and its Territories, and is designed for use at all levels of government, industry, educational institutions, and by the general public. Data from the system can be retrieved, manipulated, and arranged to meet the special needs and problems of users. Data collection is based mainly on the standard topographic map series published by the USGS but also includes names information derived from records of the Board on Geographic Names, U.S. National Ocean Survey charts, U.S. Forest Service maps, and reliable historical records as well as other reputable sources of name information.

GNIS was developed to meet national needs in the following six ways:

(1) to assist in establishing uniform name usage throughout the Federal Government in cooperation with the U.S. Board on Geographic Names, which works with State and local governments and the public;

(2) to provide an index of names found on Federal, State, and private maps;

(3) to eliminate duplication and the need to spend large amounts of money and time by government agencies, industry, and others to organize similar basic data files for their specific needs;

(4) to provide an interface to integrate data from other systems for multidisciplinary use;

(5) to provide for standardization of data elements and their coded representation for information exchange use within the information processing community; and

(6) to meet Federal public information requirements prescribed by law.

GNIS furnishes information to two types of users: (1) those who use the data for reference purposes; and (2) those who reformat the information for individual or specialized use. GNIS lists primary data for various kinds of features identified by a name. The information includes all named natural features (about 80 percent of the data base), and most major and minor civil divisions, dams and reservoirs, airports, and national and State parks. However, named streets, roads, and highways are not included at this time.

GNIS is capable of providing information on a number of data elements: official name, feature class, location of named feature (State, county, and geographical coordinates), variant names, USGS map sheet, and elevation. Information from the GNIS State name files is presently available in several ways: direct on-line access by an outside computer terminal; USGS computer products such as magnetic tapes, computer printouts, and microfiche; and printed and bound products such as alphabetical and topical lists.

Applications Software Development for Land Use and Land Cover Data

As a result of a 2-year demonstration project, software has been developed to support applications of digital land use and land cover data. The resultant software and procedures are rudiments of a spatial data base management subsystem which can be linked to existing software systems within the NMD.

To date, applications have largely utilized area data sets developed by the Geographic Information Retrieval and Analysis System (GIRAS) software. These data sets are efficiently handled through the use of a compact raster data format which reduces the volume of data for storage and processing. Spatial operations, such as compositing data sets, windowing an area, and merging data from adjacent map sheets, can be performed on the data in the compact raster format (Miller, 1980).

In addition, prototype methods for spatial retrieval have been developed for relating point and linear features in vector format to the areal data sets in the compact raster format. This allows radial and corridor searches of extensive data sets (Miller, 1980). To date, these radial and corridor search procedures have been utilized in several applications involving land use and land cover data sets. They could, however, be adopted to interrelate other raster and vector data developed from the national topographic map series. This would include DEM's in raster format and terrain data (such as water bodies) which could be converted from vector to raster format. These data sets can be interrelated with various line and point features from the maps, which are retained in vector format.

Automated Names Processing Research

The processing of geographic names constitutes a significant portion of the mapmaking process. Now that geographic names are available in digital form in the GNIS, and output devices are available that automatically generate high-quality type in the correct position, the process can be automated. In simplified sequence the name is first selected, then positioned on a draft, the type generated, and finally placed on the manuscript. Three research projects are underway to improve names handling techniques through automation using these new tools.

One research project is investigating the utilization of the DDES to prepare map lettering plates. Using DDES, the type in both the map collar and map interior are rapidly and accurately positioned on the screen. In most instances, the type style and size are automatically selected for the operator, thus eliminating many errors that occur in conventional type placement. When completed, the lettering is automatically plotted on film. Efforts are now being turned toward either locating or constructing additional type fonts to be installed on the DDES.

A second research project has been initiated to utilize the GNIS files for both the names selection process and input into the DDES for type generation. All names information within the map area will be automatically plotted on a proof map. This serves as the names worksheet upon which the cartographer indicates placement, type style, and size, plus any additional information. The worksheet will be used as a guide to interactively place names entered into the DDES from a GNIS-derived magnetic tape.

The Office of Cartographic Research is proceeding on a third project with contracted research in totally automated names selection and placement. The first phase of the research project involves building an experimental names data base by adding selection criteria to the GNIS such as population and administrative function. A program has been written to select point names from the data base and automatically plot them in the predefined areas. The project is currently working to automatically match names to the appropriate area and linear features contained in the DLG. The compatibility and accuracy of the GNIS and DLG files will also be addressed.

Algorithims for Generalization of Land Use and Land Cover Map Content

Computer algorithms for content generalization in scale reduction of digital land use and land cover data, with particular emphasis on reduction from 1:250,000 to 1:2,000,000, are being developed and tested. A frequency analysis of land use polygons, based upon seven representative 1-degree by 2-degree 1:250,000-scale quadrangles, explores the extent to which land use and land cover polygons and islands might be eliminated in a scale reduction because of small area or non-compact shape. Two conceptually independent shape indexes are warranted, one to measure boundary inefficiency (a ratio of the polygon's perimeter length to the square root of its area) and the other to indicate elongation of gross shape. Shape is related to area, but only moderately so. Through area, shape also affects land use and land cover. Absorbing small enclaves with a different aggregate attribute will not seriously dilute the "class purity" of most surrounding polygons. Marked patterns of topological nesting of landscape types are related to regional physiography.

CARTOGRAPHIC AND GEOGRAPHIC STUDIES

Map Projections

Map projection, the science of showing a sphere-like body, especially the Earth, on a flat surface with defined characteristics, has been researched with increased concentration by the USGS. The advent of space technology has led to a need for map projections which have not existed before. The generation of maps by computer has led to an increased need for mathematical formulas for projections and for more efficient computation of coordinates for high volume production. On the other hand, the computer permits easy handling and analysis of projections which previously were too complicated for routine manual use.

A direct space-age product is the Space Oblique Mercator (SOM) projection. For near-polar-orbiting satellites such as Landsat, there was no known projection which took into account the double motion of Earth rotation and satellite revolution to permit mapping of the imagery with the groundtrack continuously held true to scale. The existing Oblique Mercator projection only approximated this for a small portion of an orbit at a time. The SOM, which gives a true-to-scale groundtrack, was conceived and mathematically implemented by USGS personnel during the 1970's, and the complete derivation was published as USGS Bulletin 1518 (Snyder, 1978, 1981c). Another new series of projections, called Satellite-Tracking projections, was developed at the same time (Snyder, 1981a). These projections permit groundtracks to be shown as straight lines on conic and cylindrical projections with restricted distortion of land masses.

An expanded computer program to transform coordinates from one map projection to another was developed and tested under the name General Cartographic Transformation Package. It supersedes other projection packages used by the USGS. Figure 11 is an Oblique Mercator plot from the package. The package includes additional projections and both forward and inverse computations for all the projections contained. Another project generating considerable interest is the first detailed working manual describing all map projections used by the USGS (Snyder, 1982).

A computer program currently nearing satisfactory completion is intended to permit determination of the projection parameters such that data can be accurately transferred from one map to another. Over 20 paper maps have been tested using this program, and data transfer is generally accurate to within 1 mm.

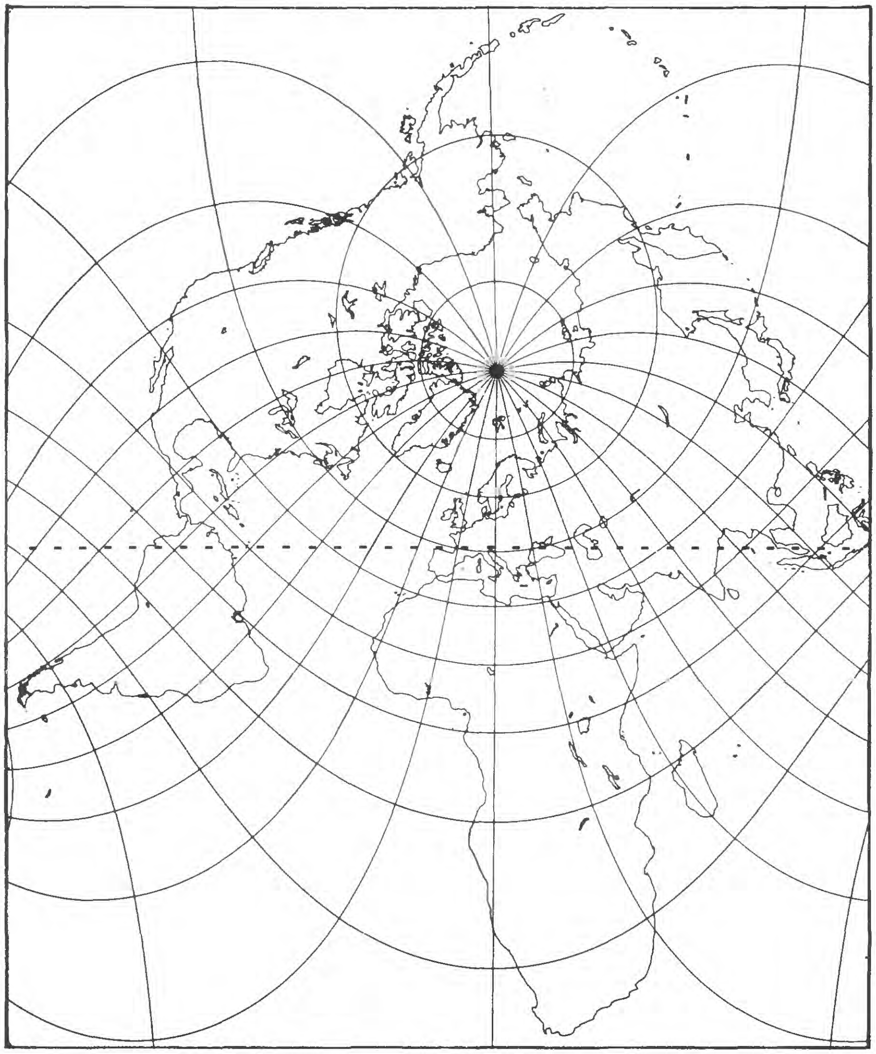

Figure 11. Oblique Mercator projection--an example of an outline map generated by computer using software incorporated into the General Cartographic Transformation Package. On this projection there is no distortion along the dashed line, which represents a chosen great circle path. The projection inspired the development of the Space Oblique Mercator projection, on which distortion is eliminated along a satellite groundtrack plotted as a curved rather than straight line.

Application of Linear Algebra to Computation of Gridded Data

Several mathematical studies have been considered the application of linear algebra to the computation of gridded data. A motivating force behind these studies is the desire to develop efficient algorithms for handling DEM's in which elevation values are assigned on a regular, horizontal rectangular-coordinate grid. These studies are preliminary, and work will continue.

One line of investigation has been into filtering and interpolation on perfectly spaced rectangular grids, on imperfectly spaced rectangular grids (i.e., where spacings vary slightly about a perfect spacing), and on grids for which some of the grid intersections may be absent. The analytical form of the solution is couched in terms of the direct or Kronecker product, a specific form of matrix multiplication. Normal equations are formed, and through identities a convenient solution algorithm is outlined.

A second line of investigation involves the sparse factorization of matrices with application to interpolation, filtering, and the fast Fourier transforms. The derivation of the sparse factorization is obtained in two steps: (1) simplifying the structure of the algebraic equations; and (2) defining matrix elements with the Kronecker delta symbol. For strictly computational purposes, the second step is unneccessary. The value of defining sparse matrices is that often the inverse or pseudo-inverse of a sparse matrix is itself sparse, and if so, it may be possible to factor these sparse matrices even further; although this possibility may not be evident from the straightforward algebraic equations.

The third line of investigation compares several techniques of solving the interpolation problem. The first technique is the direct method which requires n^6 multiplication where n is the dimension of a square matrix; a second is the so called array alegebra method which requires $2n^3$ multiplications; and a third is the tensor-product method, which also requires $2n^3$ multiplications. Two other methods investigated also require $2n^3$ multiplications. It is found that the array algebra technique is simply a notational device by which a user can express tensor products by multiple indices in a way which is consistent with the FORTRAN compiler.

Generalized Adjustment by Least Squares

The least-squares principle is the universally accepted basis for adjustment procedures in the allied fields of geodesy, photogrammetry, and surveying. A prototype software package for Generalized Adjustment by Least Squares (GALS) was recently developed. The package is designed to perform all least-squares related functions in a typical adjustment program. GALS is capable of supporting development of adjustment programs of any size or degree of complexity.

The impact of digital computers on the field of computational adjustment was recognized as early as the middle 1950's. During that decade, considerable progress was made toward effective formulation of the least-squares principle as it applied to photogrammetric triangulation problems.

During the 1960's, a large number of computer programs were written dealing with every aspect of adjustment in the mapping fields. Highly efficient algorithms were developed which made possible the practical adjustment of networks of observations containing tens of thousands of unknown parameters. Experimentation with various perceptions of the mathematical model of the mapping process was prevalent during this period.

The 1970's saw computational adjustment programs put into daily production. Attention was therefore focused on the operational aspect of these programs. Overall productivity became the goal. Data processing became more pertinent than mathematical or algorithmic questions in the evolution of computational adjustment. This trend is expected to continue for the foreseeable future.

GALS is a software system aimed at removing from the process of building adjustment programs all those mathematical and algorithmic aspects associated with application of the least-squares principle to the adjustment of linear mathematical models. It is intended to be the general tool that might lead to a standardization of least-squares operations in adjustment software.

GALS is a software subsystem which must be executed from a higher level program. It can be viewed as a subroutine package with somewhat involved interface requirements. Knowledge of the detailed internal operations of GALS is not essential for its use. It is possible to deal with GALS as a "black box" and still create very involved adjustment systems.

A prototype of GALS was built to operate on the USGS Amdahl computer. The prototype was written exclusively in FORTRAN, except for two small subroutines for bit manipulation which are written in Assembly language. GALS requires the services of a sort/merge software facility which is assumed to exist within the operating environment. The development of GALS is largely a software engineering project. As such, a prototype was needed to satisfy the important functions of: (1) System design verification for correctness and completeness; (2) Experimentation with the many possible design tradeoffs, under closely realistic conditions; and (3) Actual simulation of GALS in connection with various types of adjustment problems.

Because of the inability to access computer resources from within a FORTRAN environment, the prototype is configured as a sequence of six independent program tasks. This configuration will be changed in the second phase of GALS development by using PL/I programing language. This will make possible a single step, "black box" type of service. It will also provide for the automatic allocation of all necessary computing resources by GALS, depending on an assessment of actual needs.

Experimental 1:63,360-scale Orthophotoquad of Kodiak A-6 Quadrangle, Alaska

The NMD has been requested to prepare 1:63,360-scale orthophotoquads for the State of Alaska. The primary image sources for the project are the 1:120,000-scale photographs taken by NASA. By specification, up to 10 percent cloud cover is acceptable. New snow cover, film scratches, smoke, and density variations on the source photographs of Alaska will not be controlled to the same degree as photographs used for the standard USGS orthophotoquad program. A research project was undertaken to prepare a sample 1:63,360-scale orthophotoquad to present to the State of Alaska and interested government agencies for comment before embarking on the full-scale program. The Kodiak A-6 quadrangle was selected as a typical example of quadrangles having both clouds and new snow.

Two versions of the Kodiak A-6 orthophotoquad were prepared by different procedures for evaluation. The first version was prepared from stereomodels scanned on the GPM-2. Five stereomodel scans were mosaicked into a single negative at 1:63,360 scale. A collar was prepared and black-and-white prints were made, including one with a contour overprint. The main problem encountered by the GPM-2 was the loss of correlation in cloud and water areas.

The second version was prepared on the Wild OR-1 using a profile drive tape generated from Defense Mapping Agency DEM data derived from 1:250,000-scale maps. These are the only DEM data available in Alaska. Three OR-1 scans were mosaicked into a single negative at 1:63,360-scale, and composite prints were made. Extra effort was required to generate the profile tapes since formats and units of the DMA DEM tapes were not compatible with available software. The profile tapes provided uninterrupted scanning across snow, water, and cloud areas. Horizontal and vertical accuracy tests were applied to the resulting OR-1 stereomodel and orthophoto based on aerotriangulated test points. Preliminary test results indicate a good probability that DEM tapes can be used to produce 1:63,360-scale orthophotos that meet NMAS in areas of moderate relief.

Identifying Changes in Land Use and Land Cover

Since effective management of land resources requires current information on land use and land cover, maps that portray these data need to be updated periodically. In addition, data on land use and land cover change are of value to planners, land managers, and other decisionmakers in understanding and dealing with the varied and complex issues associated with the use of the Nation's lands. At the present time, we are studying ways to maintain the currency of USGS land use and land cover maps and associated digital data. Some of this research has focused on ways to both produce and use data on land use change in the updating process. Particular emphasis has been placed on identifying likely products that would provide information on land use changes for use in data analysis, modeling, and other land resources applications.

In one updating approach, spatial data on land use change are used to directly update existing land use maps and statistics (figure 12). To accomplish this, researchers compare the old land use map with new remotely sensed source materials and map only the areas of change between them. By then incorporating only the new polygon information, maps and digital data can be updated in an efficient and timely manner without the need for complete and costly remapping and redigitization of all polygon data (figure 13).

A variety of graphic products and formats could be used to portray the land use change data derived from this map-revision process. Such products could be produced quickly and inexpensively either by conventional cartography or as specialized products of a computerized geographic information system.

Figure 14 shows land use and land cover changes isolated and mapped on a separate overlay. A single overlay is produced to show both "from" and "to" categories. Each change is coded to identify the original Level II land use and land cover category (from the old map) and the new category (from the new photographic source). A separate polygon is delineated for every change in category and boundary that occurs.

In addition to graphic products, detailed statistics on land use change (see figure 15) can serve as useful aids for analyzing and interpreting land use and land cover and its changes over time. Statistical products can be generated from the computerized data in the form of standard area summary tabulations, charts and graphs, or as change category or land conversion matrices.

Land Use and Land Cover Statistics

The nationwide land use and land cover mapping program of the USGS began in 1975 and since that time approximately 53 percent of the United States (excluding Alaska) has been mapped. An important aspect of this mapping effort has been the development of digital data files which can be used to generate areal statistics of land use and land cover. Approximately 21 percent of the United States (excluding Alaska) has been digitized to date.

Current plans call for publishing reports of State acreages of land use and land cover, with breakdowns by county, hydrologic unit, and areas of Federal ownership. State reports will be issued after the data have been compiled, verified, and formatted for publication. In addition to the acreage data, each report will include written and graphic descriptions of land use and land cover patterns within the State. The States of Florida, Kansas, Pennsylvania, West Virginia, New Jersey, and Rhode Island are the first ones scheduled for publication.

An Assessment of the Accuracy of Land Use and Land Cover Maps

An advanced statistical technique for testing the accuracy of land use and land cover and other National Mapping Program thematic maps was completed and tested during the past year. The minimum sample size needed to validate the accuracy for each land use and land cover category with

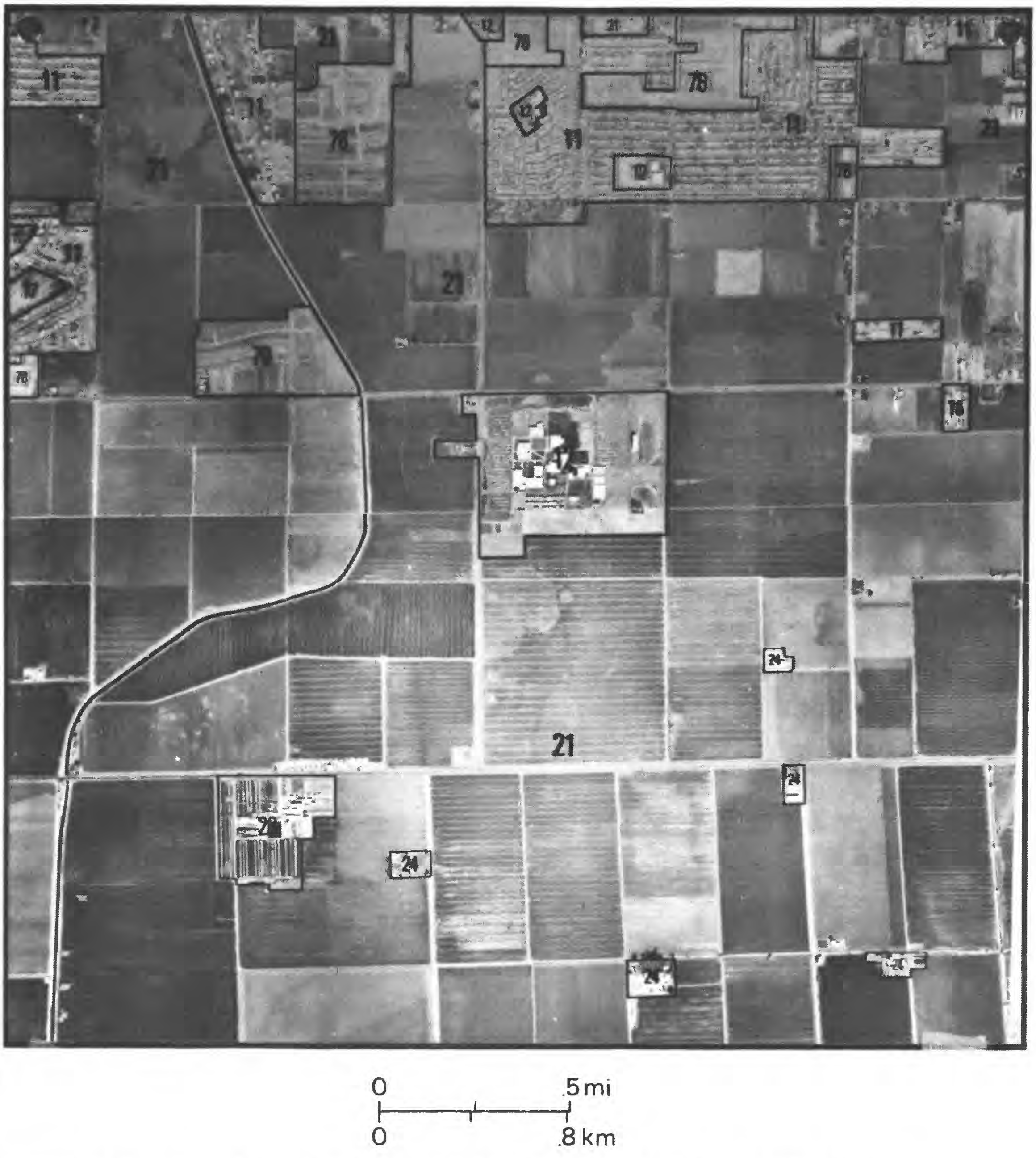

Figure 12. Overlay showing 1970 Level II land use and land cover categories for area southeast of Tempe, Arizona.

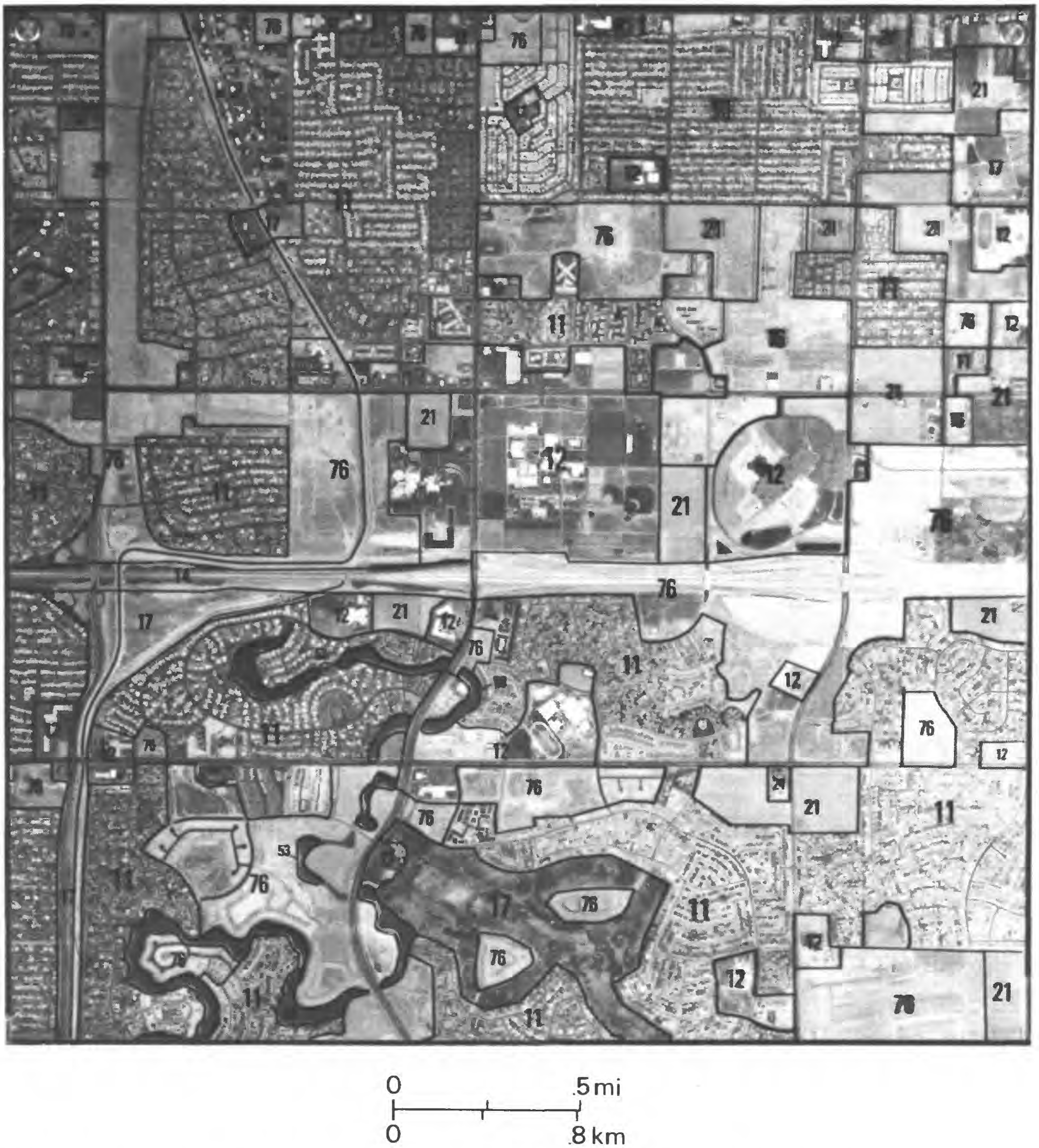

Figure 13. Overlay showing 1970 Level II land use and land cover categories for area southeast of Tempe, Arizona.

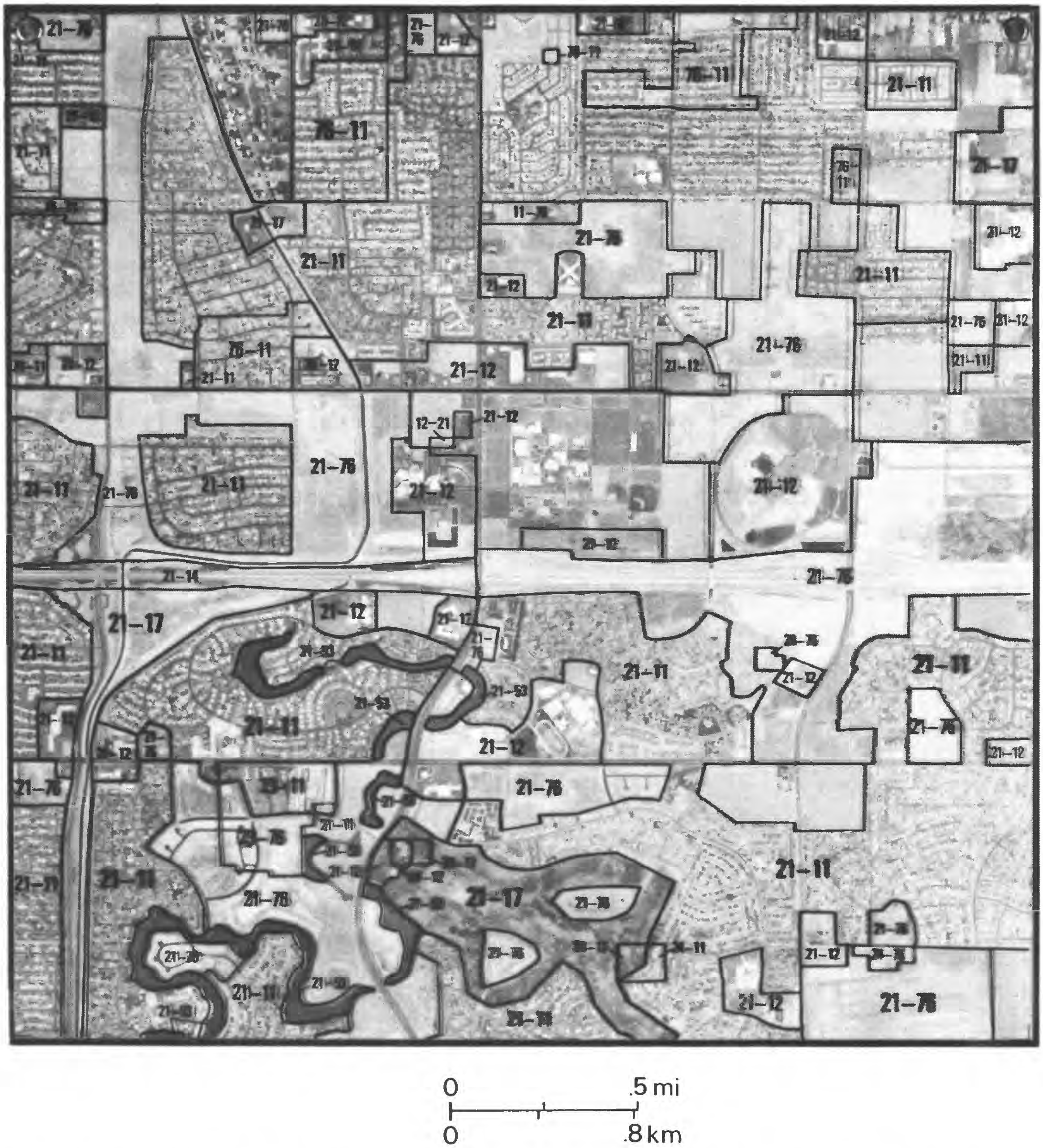

Figure 14. Overlay indicating changes in Level II land use and land cover categories, 1970-1979 for area southeast of Tempe, Arizon.

LAND USE AND LAND COVER CHANGES BY CATEGORY		TO 1979 (ACRES)										1970		
		RESIDENTIAL 11	COMMERCIAL & SERVICES 12	TRANSPORT COMM UTILITIES 14	MIXED URBAN OR BUILT UP 16	OTHER URBAN OR BUILT UP 17	CROPLAND & PASTURE 21	CONFINED FEEDING OPERATIONS 23	OTHER AGRICULTURAL LAND 24	RESERVOIRS 53	TRANSITIONAL AREAS 76	LOSSES (–)	TOTAL AREA BY CATEGORY (ACRES)	TOTAL AREA BY CATEGORY (%)
FROM 1970 (ACRES)	RESIDENTIAL 11	–									10	–10	410	8.6
	COMMERCIAL & SERVICES 12		–				1					–1	151	3.2
	TRANSPORT COMM UTILITIES 14			–										
	MIXED URBAN OR BUILT UP 16				–								6	0.1
	OTHER URBAN OR BUILT UP 17					–							10	0.2
	CROPLAND & PASTURE 21	1624	444	55		248	–			68	1024	–3463	3931	82.3
	CONFINED FEEDING OPERATIONS 23	23						–			27	–50	50	1.0
	OTHER AGRICULTURAL LAND 24	4	2			7			–		8	–21	25	0.5
	RESERVOIRS 53									–				
	TRANSITIONAL AREAS 76	172	14								–	–186	197	4.1
1979	GAINS (+)	+1823	+460	+55		+255	+1			+68	+1069	3731		
	TOTAL AREA BY CATEGORY (ACRES)	2223	610	55	6	265	469		4	68	1080		4780	
	TOTAL AREA BY CATEGORY (%)	46.5	12.8	1.2	0.1	5.5	9.8		0.1	1.4	22.6			100

Figure 15. Matrix showing 1970-1979 land use and land cover changes by category for area southeast of Tempe, Arizona.

specified confidence is developed from the cumulative binomial distribution. The critical level, also developed from the cumulative binomial distribution, is used as the criterion to determine if the identification from remotely sensed data of a thematic category meets a specified accuracy. The algorithm for selecting a sample for thematic map accuracy testing is based on sampling from two statistical frames and uses: (1) a stratified systematic unaligned sampling technique based on the map as a whole; and (2) an additional random sample of points for under-represented categories from all points in that category.

A computer program compares the category classifications interpreted from remotely sensed data to the field identified classifications and lists the statistical and tabular results of this comparison. The estimated overall accuracy of the map, and the estimated accuracy for each category on the map are considered with associated confidence limits.

Further research determined a methodology for accuracy analysis of area data acquired in land use and land cover mapping experiments. Some techniques of nonparametric statistics are applicable to the analysis of area data in thematic mapping experiments: (1) for the analysis of multiple related samples--Kendall's coefficient of concordance test and Freedman's method of ranks test; and (2) for the analysis of paired samples--the Kendall tau statistic test and the Wilcoxon signed rank test. In each analysis, the two-test procedure is analogous to testing the shape of two curves and the distance between them, in order to determine if they are statistically identical.

In a multiple sample experiment of Level II land use and land cover classification at three scales (1:24,000, 1:100,000 and 1:250,000), the area of individual categories delineated at 1:250,000-scale was determined to be significantly different from the other two scales. Thus, the classification at 1:250,000 scale results in significantly smaller areas for more of the categories than the other two scales (1:24,000 and 1:100,000), as determined by area measurement.

Evaluation of the variables of thematic mapping experiments, such as scales, images, and algorithms, that affect classification by thematic categories was also undertaken to aid in developing specifications and techniques for producing thematic maps.

The data acquired for analyzing the accuracy of thematic mapping methods usually consist of the population of agreements and disagreements between the classifications based on field observations and the classifications interpreted from remotely sensed data, such as aerial photographs. These data are assumed to be binomially distributed. A weighted analysis of variance adjustment rigorously accommodates the different numbers of sample points that fall within each of the various thematic categories. A posteriori multiple range tests are tests applied to population means found to be significantly different in the analysis of variance table. An experiment showed evidence of a significant difference in accuracy among three scales of land use and land cover mapping (1:24,000, 1:100,000, and 1:250,000) using the data transformed by a weighted analysis of variance adjustment. Multiple range tests showed that all three scales are different for the arcsine transformed data.

Land Use and Land Cover Change Research--Allegheny County, Pennsylvania

In 1976, manuscript black and white sectional maps of land use and land cover for all six counties of the Greater Pittsburgh region, together with maps of land use change in Allegheny County, were compiled and placed on open-file at 1:50,000-scale by the USGS in cooperation with the Appalachian Regional Commission. The maps were prepared to help local and regional planners reduce possible future damage such as that caused by Hurricane Agnes in 1972. These maps form the basis for continuing research in land use change, map design and preparation, and spatial analysis of earth science data for use by urban planners. In 1980, the same land use and land cover information for the six-county Greater Pittsburgh region was lithoprinted in color in one map sheet (USGS Map I-1248). This experimental map, at a scale of 1:125,000, includes planimetric detail from the topographic map for the same area at the same scale.

The one-sheet land use map also contains several aids on its margins for analyzing and interpreting land use and land cover in the Pittsburgh metropolitan region and the changes over time. One of the aids is a table (table 1) showing land use and land cover, 1973 and 1969, for Allegheny County only; (this county includes most of the Pittsburgh Urbanized Area as defined by the U. S. Bureau of the Census in 1970 and 1980). The land use changes from 1969 to 1973 were inventoried by photointerpretation after inventory of the 1973 land use and land cover. Land use polygons believed to be changing in use or cover in 1973 were coded both as to prior use and "transitional." With 10 land use and land cover classes, there are 90 possible combinations of class-to-class changes between the two times.

Table 1. Land Use and Land Cover, 1973 and 1969, Allegheny County, Pennsylvania--number of hectares, and differences, by land use class.

Year, and Differences Hectares and Percent	Total	Land	Resi-dential 11+11a	Com., Serv. 12	Indus-trial 13	Extrac. Indus 14	Trans-port 15	Open, Other 19	Crop, Pasture 21	Other Agr 22/24	Forest-land 40	Water 50
1973 Hectares	192,254	188,626	49,004	11,255	3,159	5,861	5,541	4,928	27,244	528	81,106	3,628
Difference, Hectares	0	0	+1,037	+312	+21	+140	+284	−7	−551	−41	−1,195	0
1969 Hectares	192,254	188,626	47,967	10,943	3,138	5,721	5,257	4,935	27,795	569	82,301	3,628
Difference, Percent	0	0	+2.16	+2.85	+0.67	+2.45	+5.40	−0.14	−1.98	−7.21	−1.45	0

An additional aid is the matrix shown in figure 16, modified from Map I-1248. It is a land-conversion matrix which lists the land use classes in the same order in headings down the left side (1969) and across the top (1973). The matrix lists the Built-up Area classes first, then a Transitional class (mostly Extractive Industry in a strip-mining area), and then the Open Space classes. As the matrix shows, many changes, but not all, are from an Open Space class to a Built-up Area class. The 10 entries along the diagonal from upper left to lower right represent the amount of land where change was underway in 1973 but no new class was assigned. Besides urban expansion, other significant forces for change were the result of interstate highway construction and the resurgence of strip mining for coal as a result of the oil crisis.

The Pittsburgh map (I-1248) is one prototype product of experiments using remotely sensed data to inventory land use and land cover and to monitor changes. The text and tables on the map margins are examples of aids which planners could use to apply current data to environmental problems. If a user has 1980 Census data, the 1969 and 1973 land use data and map provides a basis for correlating a decade of land use change with corresponding changes in population and housing reported by the Census. The extent of changes suggests vitality in one major metropolitan center in northern Appalachia, elsewhere found to be undergoing economic decline and population migration. The Pittsburgh map itself also demonstrates other innovations in design of a thematic map. These include folding, use of color symbols, place name gazetteer using the Universal Transverse Mercator (UTM) rectangular coordinate system, the need and use of three different map Norths, and the use of area scales (as well as distance scales) in both English and metric units.

	Land Use Class	Built-up Area, 1973				Trans.	Open Space, 1973					Total Area Lost from 1969
		Resi-dential	Com. Serv.	Indus-trial	Trans-port	Extrac. Indus.	Open, other	Crop, Pasture	Other Agr.	Forest-land	Water	
	Class code	11, 11a	12	13	15	14	19	21	22–24	40	50	
Built-up, 1969	Residential	—			3	5	5			19		32
Built-up, 1969	Com., Services		10							4		4
Built-up, 1969	Industrial			—	12							12
Built-up, 1969	Transportation				19							0
Tr.	Extract. Ind.	4	23			173		12		155		194
Open Space, 1969	Open, Other	5	12				—					17
Open Space, 1969	Crop., Pasture	329	45	33	32	118	5	105		27		589
Open Space, 1969	Other Agr.							23	8	29		52
Open Space, 1969	Forestland	731	236		237	211		3	11	382		1,429
Open Space, 1969	Water										—	0
	Gained by 1973	1,069	316	33	284	334	10	38	11	234	0	2,329
	Lost from 1969	32	4	12	0	194	17	589	52	1,429	0	2,329
	Net difference	+1,037	+312	+21	+284	+140	−7	−551	−41	−1,195	0	0
	In Transition	—	10	—	19	173	—	105	8	382	—	697

Figure 16. Land Use and Land Cover Conversion, 1969-1973, Allegheny County, Pennsylvania, showing number of hectares by land use class.

Computer-Plotted Map of Land Use and Land Cover, Three Mile Island and Vicinity

The much publicized nuclear accident which occurred in March 1979 at the Three Mile Island powerplant on the Susquehanna River, 10 miles southeast of Pennsylvania's State capital at Harrisburg has raised questions about where such plants are located and what areas may be affected. A current land use and land cover map of the site and vicinity which is keyed to political units and census statistical areas is one tool which politicians, planners, and utility company personnel can use in decisionmaking.

An experimental 1:100,000-scale land use and land cover map with census information was constructed from a statewide digital data base completed in 1979 as a cooperative effort with Pennsylvania's Department of Environmental Resources. An unannotated version was drawn in a few hours by a USGS computer-driven plotter utilizing digital data from GIRAS. It overlies a USGS topographic base map at the same scale which provides other essential information such as roads, mountains, and drainage lines.

A separate legend, also prepared by computer, identifies 19 categories of Level II land use or land cover by color and shading pattern. After the base map was completed, concentric rings at 5-mile intervals were added. They allow decisionmakers to analyze, plan, and assess hazards impact (figure 17). Utilizing the computer-based GIRAS data, it is possible not only to prepare land use and land cover maps in a short time, but also to correlate land use area measurements with census and other data, update all data sets, and retrieve and analyze data. Therefore, GIRAS could be an important tool for decisionmakers who must determine land use trends and patterns to aid in resource analyses and hazards assessment as well as prepare emergency evacuation plans.

Computer Graphics Experiments and Techniques

Cartographic information can be collected, organized, and sorted in such a way that a single digital data base may serve a wide range of applications. One use of the data is graphic production. Computer graphics techniques applied to digital spatial data can produce cartographic products that would be difficult, time consuming, and, in some cases, impossible to produce by traditional methods. One example of this application is the preparation of thematic maps for color lithographic reproduction from digital spatial data.

The thematic map described here depicts the land use and land cover information of the type being collected by the USGS. A portion of a manually drafted map is shown in figure 18a. After compilation, the maps are digitized, the data edited, and incorporated into a data base.

The land use and land cover digital data are maintained in a topologically structured polygon/arc-segment format. In this format the arc segments are defined by a series of x,y coordinate pairs. The requirements of the device used to display these digital data as a color thematic map made it necessary to convert the data from their vector format to grid cells in a run-encoded raster format. The polygon-to-grid computer program was used to perform this conversion.

A grid cell size of 200 µm on a side, at a publication scale of 1:250,000, was chosen for this example. Each cell represents 0.25 ha in ground area.

To prepare the data for display (and ultimately printing) on this map, each Level II data category was assigned a color value. The Level II color values were chosen within Level I tint groupings. The colors were preselected from color printing charts prepared by the Geological Survey. Using these charts the map designer can choose colors with the assurance that the desired colors will appear identical in published form. The color chosen for each Level II data category is composed of a unique combination of transparent lithographic process ink colors (yellow, magenta, cyan, and black). Colors are developed by using various densities of dot screens for each ink. To minimize moire patterns these screens (120 lines per inch) are also angled separately from horizontal for each color, 60°, 75°, 105°, and 45°, respectively, for yellow, magenta, cyan, and black inks.

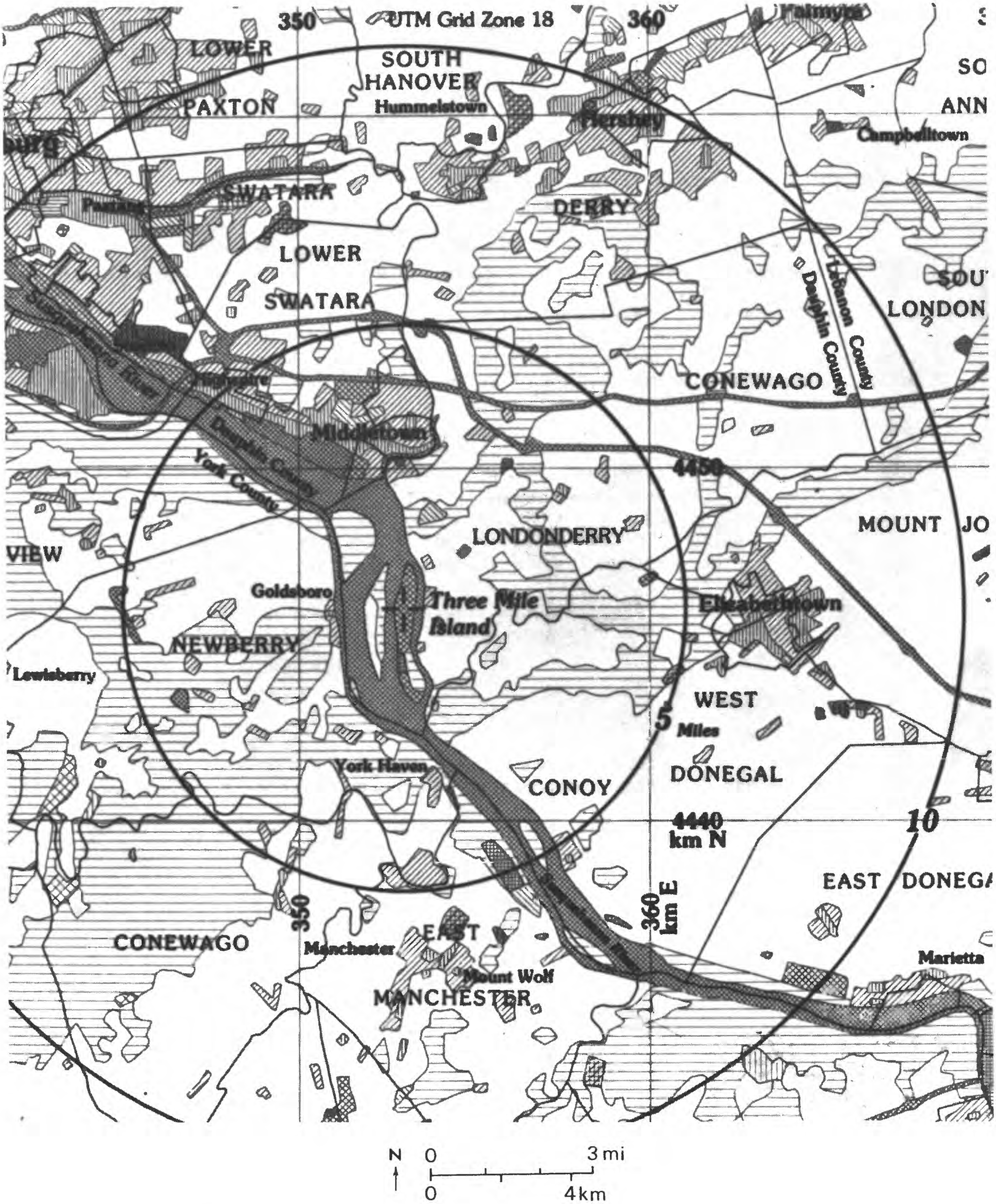

Figure 17. Portion of computer-plotted map of land use and land cover, Three Mile Island and vicinity.

This confidence in preselecting color values is deserved only if the tools are available to create from the digital data the required color separate materials. The Scitex Response 250 Cartographic System provides such a tool. The Scitex generates the desired dot screen (in terms of density, lines per inch, and angle) and assigns this screen pattern to the chosen input raster data elements, in this case land use data categories that create the image of the land use map. The laser plotter component of the system then permits the plotting, at publication size and scale, of the color separation films that are used directly to make printing plates.

For example, the red used to depict land use category 11 (Residential Land) is comprised of 39 percent yellow ink, 50 percent magenta, 0 percent cyan, and 0 percent black. In plotting the yellow separate, wherever the raster image contains data elements with category 11 the plotter would draw on film, within the 200-um x 200-um area covered by that raster element, a 120-line screen, angled at 60^{o}, with a density of 39 percent. This procedure is repeated for the other separates. When the separates are used for printing the color inks, the result is a color map (shown in black-and-white in figure 18b).

This entire process is very cost- and time-efficient. The conversion of the land use data from polygon/arc-segment format into raster format suitable for plotting requires less then 3 minutes of computer time. The four color separation films can be generated in less than 2 hours. Other computer-aided methods are at least an order of magnitude slower. Thus, the combination of digital spatial data bases with state-of-the-art computer software and hardware allows the rapid preparation of the materials necessary for the lithographic production of a color thematic map.

Barrier Islands Coastal Studies

Barrier islands, which occur from Maine to Texas, are the primary terrestrial/marine interface along the Atlantic and Gulf coasts. They are the product of a gradually rising sea level, ample quantities of sand supplied to the coast, and waves large enough to move the sand. A continually changing relationship among storms, waves, and moving sediments produces islands that are unstable. The estuaries and sounds that lie inland from barrier islands are among the richest and most productive ecosystems known, providing nurseries, shelter, and food for many species of fish, shellfish, and wildlife. Because of the aesthetic appeal and recreation potential of the islands, homes and commercial facilities are being constructed very close to the sea, and like the natural landscape, they too are unstable at times. Each year the wide range of landscape changes caused by natural processes takes its toll in human resources with costs measurable in millions of dollars.

Research has been conducted to summarize the current information on barrier-island dynamics, to develop a more detailed land use and land cover classification system to use in inventorying barrier islands, and to describe and evaluate some of the hazards associated with living on

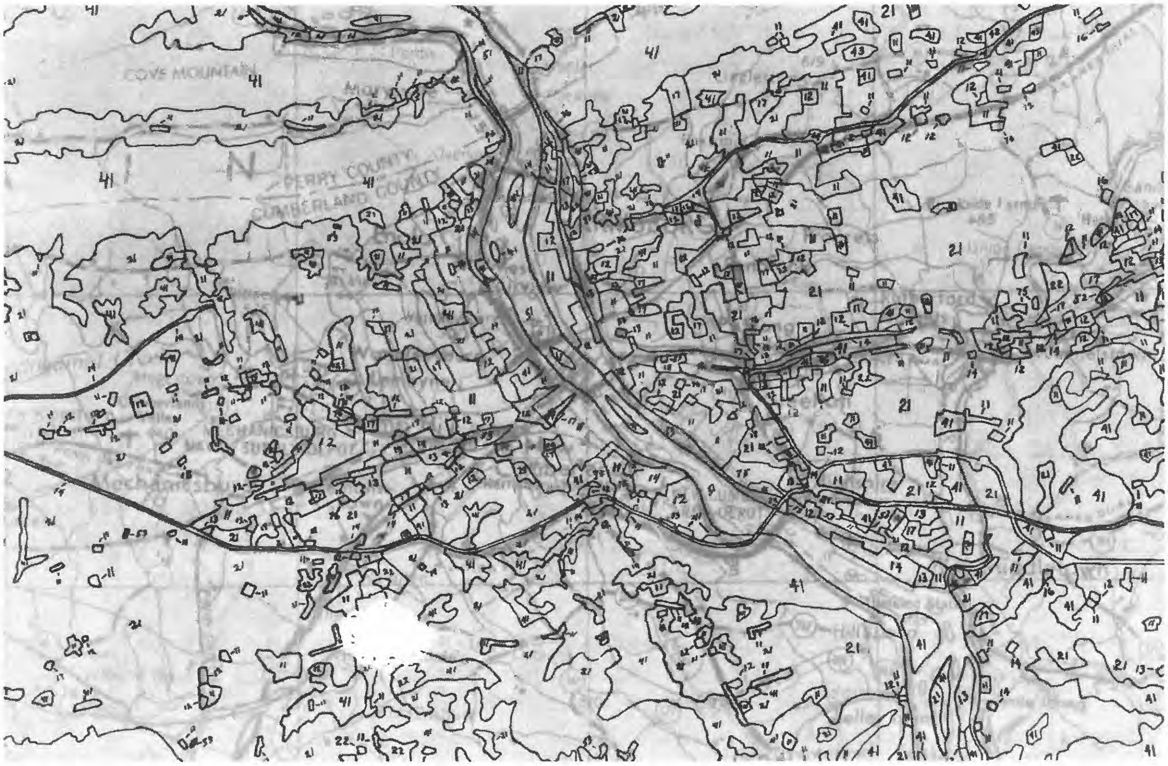

Figure 18a. Portion of manually drafted Harrisburg, Pennsylvania, Land Use and Land Cover Map, 1972 (original scale 1:250,000).

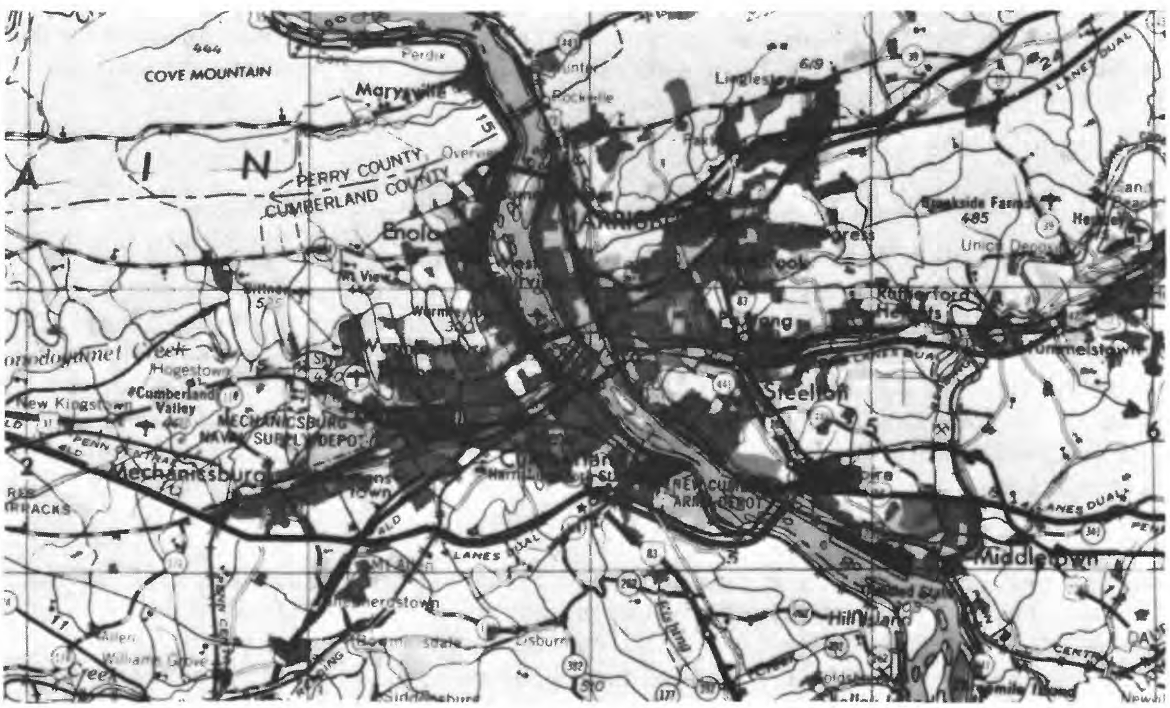

Figure 18b. Computer-generated color rendition (reproduced here in black and white) of a portion of Harrisburg, Pennsylvania, Land Use and Land Cover Map, 1972 (original scale 1:250,000).

barrier islands. Two recent reports--Geographical Analysis of Fenwick Island, Maryland, USGS Professional Paper 1177-A, and Patterns and Trends of Land Use and Land Cover on Atlantic and Gulf Coast Barrier Islands, USGS Professional Paper 1156, describe some of this research.

Level III Land Use and Land Cover Classification of the North Carolina Barrier Islands

In 1972, the USGS developed a two-level land use and land cover classification system for use with remotely sensed data. Level I of this system contains nine broad categories and Level II contains 37 more detailed categories. An even more refined Level III land use and land cover classification of the North Carolina barrier island system has been developed and tested by East Carolina University as a cooperative research project with USGS. The purpose of the project was to develop a classification system that would be responsive to the needs of planners, coastal zone managers, and others in North Carolina, and which also would serve as an example of Level III classification systems for others involved in similar coastal zone resource management work.

Preceding the development of the classification system a workshop was held involving Federal, State, and local agencies as well as universities and private organizations to determine information needs. After the classification system was developed, it was tested on Bogue Banks, N.C., and a Level III land use and land cover map at a scale of 1:12,000 was prepared from enlarged orthophotoquads. A selected group of users reviewed the work, and their comments constituted the basis for revision of the final Level III classification. The rationale for the Level III land use and land cover categories finally selected is based on the physical, environmental, cultural, and economic characteristics of North Carolina's barrier islands. Urban or Built-up categories reflect the dominance of a maritime environment; and the Barren Land categories reflect the importance of beaches and dunes to barrier islands.

Level III Land Use and Land Cover Mapping in Connecticut

The State of Connecticut requested Level III land use and land cover maps for the entire State which can be correlated effectively with water use and evapotranspiration coefficients to produce data for the Connecticut Water Use Information System and for developing water balance models for drainage basins in Connecticut. Therefore, the purpose of this research project is to develop a Level III land use and land cover classification system including definitions and mapping specifications and then to map the entire State of Connecticut using remotely sensed data and other source materials.

A preliminary Level III land use and land cover classification system has been developed with category definitions and mapping specifications established. A pilot study to compile a land use and land cover map of the area covering the Norwich 7.5-minute quadrangle is currently underway to test the proposed classifications and specifications. Statewide mapping is scheduled to begin when mosaicked orthophoto map bases become available in mid-1982 and should be completed within 1 year.

Land Use and Land Cover and Environmental Photographic Interpretation Keys: A Guide for Missouri

In 1975, the USGS initiated production of land use and land cover and associated maps for the United States. Documenting the land use categories shown on the maps and providing insight into the environmental effect of land use have been longstanding user requirements. These two requirements have been addressed in this a joint project by the USGS and the Environmental Protection Agency--production on a photointerpretation guide.

This prototype guide is designed to demonstrate the applicability of land use and environmental keys, to develop data acquisition techniques for compilation of the keys, and to indicate the potential effects of land use on the environment.

The guide is divided into seven sections dealing with: (1) the source materials; (2) selected types of remote sensors and their characteristics; (3) the background for the development of the land use and land cover classification system; (4) the techniques for compiling land use and land cover maps; (5) a general description of the potential adverse impact of some land uses on the environment; (6) photointerpretation keys for Missouri; and (7) Missouri land use statistical tabulations.

National Gazetteer Series

As part of its mapping program, the USGS began cataloging names as early as 1892. The Chief Geographer of the USGS at the time, Henry Gannett, stated that the USGS planned to produce a series of State gazetteers "...designed as an aid in finding any geographic feature upon the atlas sheets published by the Geological Survey." Under the direction of John Wesley Powell, the second Director of the USGS, Gannett compiled the initial gazetteers which were published as Geological Survey Bulletins between 1894 and 1906. This series of Bulletins covered 12 States, Puerto Rico, Cuba, Territory of Alaska, and Indian Territory (Oklahoma). Topographic mapping, however, is a slow process and inadequate map coverage restricted the gazetteer program.

Now the USGS has reinstated the gazetteer program and will publish the "National Gazetteer of the United States of America" on a State-by-State basis, with New Jersey being the first State. All volumes of the gazetteer will be published by State as parts of USGS Professional Paper 1200. Each entry will contain: official name (spelling and form), feature class (kind of place and feature named), official status of name, county in which it is located, geographic coordinates (with sources and mouths of rivers, streams, canyons, and valleys identified), elevation of place or feature, the name of the USGS topographic map or the number of the National Ocean Survey chart on which the feature is found.

Landsat Cartographic Research

The application of Landsat data to mapping has been a continuing research effort over the last decade. During 1981 investigations provided information which refined our knowledge of specific processing techniques and applications. These investigations include the exchange of technical information with foreign mapping agencies.

Analysis of the geometry, resolution, and radiometric qualities of Landsat-3 Return Beam Vidicon (RBV) imagery confirmed that the RBV on Landsat-3 is suitable for image map presentation at scales as large as 1:100,000. Tests indicate that one of the most common radiometric anomalies found in the standard RBV images, shading, can for the most part be removed by relatively simple analog processing.

New methods and techniques were developed for processing Landsat data to cartographic form as the result of experimental image map compilation. Experimental image maps of Cape Cod, Massachusetts, and Ikpikpuk River, Alaska, were prepared at 1:100,000- and 1:250,000-scale. In response to requests for technical assistance, areas in Saudi Arabia, Pakistan, Antarctica, and Africa were mapped to demonstrate these new techniques. Both digital and analog enhancement are involved, as well as the use of various new reproduction techniques, such as screenless printing.

Characteristics of Landsat data such as currency of images, repeating cycle of 18 days, simple enlargement without rectification, and the broad coverage of a single image render them advantageous for map revision. Experiments with RBV data have verified these advantages and demonstrated that RBV imagery can be used to update specific features such as woodland, new highways, and streams on maps at scales of 1:100,000 and smaller where conventional sources of revision data are absent.

Through contacts with other national mapping agencies it was also verified that Landsat multispectral scanner (MSS) and RBV data have been successfully applied to the revision of 1:250,000 and smaller scale line maps on an operational basis. We understand that Canada has also utilized Landsat as an inspection tool for their 1:50,000-scale mapping program to determine which quadrangles require revision and thus will require the acquisition of new aerial photography. The implementation of this procedure has resulted in substantial savings and is considered applicable to many other areas of the world.

As a result of the distribution of the Landsat image map of Berry Islands, The Bahamas, produced in cooperation with the Defense Mapping Agency from combined Landsat and hydrographic data, the value of MSS data for delineating shorelines and mapping shallow seas has become more widely known. Inquiries and requests for assistance from those concerned with island and shallow seas mapping programs have been received. During 1981 assistance was rendered to officials of Papua, New Guinea, which contributed to a new mapping program aimed at covering the extensive shallow seas north and east of the island country.

Combination of Unlike Data Sets

During 1979, the USGS initiated research in the combination of two unlike data sets of which one or both were Landsat records. The first resultant product was the stereocombination of Landsat MSS and aeromagnetic data. A Landsat stereomodel was created in which the apparent elevation differences or parallaxes were actually the differences in the strength of the magnetic field. This project was reported as USGS Open File Report 79-1527. During 1980, the EROS Data Center combined Landsat MSS and RBV data of the San Francisco and Washington, D.C. area. This work was reported in the March 1980 Landsat Data Users Notes and the combined color image of the San Francisco area was published in the October 6, 1980 issue of Aviation Week and Space Technology. This project demonstrated the feasibility and advantages of combining image data of different spatial resolutions into a multicolor image.

During 1980 and 1981, data from the Heat Capacity Mapping Mission (HCMM) were compared and correlated with Landsat MSS band 7 (near-infrared) data. Although the HCMM data were of 600 m resolution and the MSS of 80 m resolution, the two data sets were well correlated and permitted the extrapolation of the low resolution HCMM data set to the higher resolution MSS data set. This work was initially reported in USGS Open File Report 80-265. The University of Arizona, sponsored by the USGS, has prepared a formal paper on the correlation of HCMM and Landsat data and submitted it to Photogrammetric Engineering and Remote Sensing for publication during 1982.

Multispatial Data Acquisition and Processing

The term multispatial describes multispectral data taken simultaneously from the same platform but at different spatial resolutions in the different spectral bands. Concern about excessive data acquisition and transmission rates, especially with the latest generation of high spatial and radiometric resolution sensors such as multispectral linear arrays, the Thematic Mapper, and the Multispectral Resource Sampler, has triggered experiments in data compaction techniques.

When more than one spectral band is involved, considerable redundancy exists in the acquired data. Since the same boundaries (continuous spectral signature differences) are often recorded in more than one spectral band, it should be possible to record one dominant band at high resolution, for a reduction in data transmission without a corresponding loss of information. The USGS sponsored research at the University of Arizona to demonstrate that the multispatial principle applies to digital image data as well as to analog data.

Reconstruction of two lower resolution bands based on boundaries resolved in the higher resolution band yields significant improvement in radiometric quality and, by inference, in information content. The extent of this improvement will depend on the number of bands, their difference in resolution, the reconstruction method applied, and on the scene itself. It may be expected that for any multispectral sensor similar to the Thematic Mapper, or the linear arrays on the proposed Mapsat, that the proper application of the multispatial concept would result in an increase in information content per bit of data transmitted of at least 100 percent as compared to acquiring all data at the same resolution. This project indicates that for any general-purpose multispectral system on which a data rate limit is imposed or from which data costs are based on the number of bits, the multispatial concept has considerable advantage to make the system cost-effective.

Image Map Research

Image maps derived from Landsat, aerial photographs, radar, and computer-generated image data require new and different techniques and equipment from those used to produce standard line maps. The primary goal in image map research is to develop an ideal map tone curve (D log E curve) compatible with equipment, techniques, cost, and production considerations.

The selection of the midpoint in the tone curve is the most important factor in final image quality. The midpoint should be a transmission density of 0.86 ± 0.04 and the density range should not exceed 1.00 ± 0.05 with a transmission density minimum of 0.40 and maximum of 1.40 for conventionally processed photolithographic materials. Both halftone and screenless lithographic products reproduce on a predictable tone curve within these limitations. Computer-generated products such as those produced on graphic art scanners or digital raster-mode scanner/plotters can produce predictable tone curves that are reproducible with fidelity at up to 64 gray levels. However, the computer programer must limit the density range to 1.00 ± 0.05 for lithography with a density minimum above the base fog of the film. A "gray-scale" representative of the imagery is computer-generated along with the imagery for subsequent photographic/lithographic processing control and quality assurance.

Experimental image maps have been printed during the past few years for Saudi Arabia, Pakistan, Bangladesh, Nepal, Yemen, Ethiopia, Nigeria, Liberia, and Brazil, in addition to the NMD orthophotoquads, State Landsat maps, the Grand Canyon National Park Landsat map, and the map series of the Canadian/Mexican borders. Image map projects in progress include: (1) a duotone 1:2,000,000-scale halftone Landsat map of Saudi Arabia; (2) a series of 1:250,000-scale screenless duotone Landsat maps of Saudi Arabia; (3) a new series of 1:500,000-scale Saudi Arabia maps computer tone controlled and mosaicked by the Environmental Research Institute of Michigan; (4) various scale process-color Landsat maps for Mexico; and (5) duotone Alaskan radar maps.

Both screenless and halftone lithographic printing are used on these experimental and semi-production products. The latest pre-press development is to proof the screenless process color maps using relatively inexpensive photographic color paper. This new color proofing method is expected to significantly reduce costs and improve the quality of future image maps.

Mapping of Irrigated Cropland with Landsat Digital Data

The primary purpose of this research is to demonstrate the use of Landsat digital data to indirectly estimate water withdrawal from irrigated cropland acreage. The High Plains aquifer, covering parts of eight States, supplies water for one-quarter of the Nation's irrigated agriculture. That supply of water is being depleted rapidly with little natural recharge. A computerized hydrologic model which will assist in evaluating effects of future ground water pumpage is being constructed by staff members of the USGS High Plains Regional Aquifer Systems Analysis project.

The key model parameter is water pumpage, which is estimated from knowing the amount of land that is irrigated and how much water is used to irrigate an average acre. Landsat digital data were used to map irrigated cropland by analyzing 26 Landsat scenes from the 1978 crop season. After computer processing to establish spectral classes (classes where spectral reflectances in the four wavelength bands are similar) and through a process known as clustering, each scene was classified into spectral types based on the clustering results. An analyst then interpreted each spectral class to identify irrigated cropland and general land cover types. A 1-minute by 1-minute latitude/longitude grid was used to establish the percentage of irrigated cropland for each area from the classified scenes. These data, in turn, were aggregated into a mosaic showing intensity of irrigated agriculture on the High Plains and were used to produce a computer tape as input to the hydrologic model.

Although most of the irrigated cropland can be identified by using just one midsummer Landsat scene when crops are green, in some areas of the region a significant portion (more than 10 percent) of crop acreage was not mapped as irrigated land because some crops (mostly wheat) were not green during that time. For this reason, the central and southern portions of the High Plains aquifer required the interpretation of two, or sometimes three, seasonally related Landsat scenes. In areas where spring crops such as wheat are important, it is necessary to use spring as well as summer data. In the southern portion of the region, a late summer scene is needed to indicate the cotton crop which matures late in the season. In areas where both wheat and cotton are raised, scenes from spring, midsummer, and late summer are necessary.

Using 1980 Landsat data, a second analysis has been prepared to refine the estimate. In 1980, rather than clustering and classifying the data, the irrigated cropland acreage was identified by ratioing the red and infrared bands and establishing one ratio value per scene as a cut-off separating irrigated from non-irrigated land. Where two or three scenes were required, they were registered to one reference scene through a remapping procedure. Each scene was then analyzed separately and combined together with the others to produce a composite analysis of irrigated cropland. Just as with the 1978 data, aggregation of data to grid cells and generation of a tape for the hydrologic model completed the process.

Mapping Vegetation and Land Cover in Alaska with Landsat Digital Data

National Petroleum Reserve in Alaska

In 1981, work continued on completing a land cover classification of the National Petroleum Reserve in Alaska (NPR-A). The Landsat digital data were formatted into quadrangles, the data sets mosaicked, and photoprints of the result were scaled to topographic base maps. A map of vegetation and land cover at the scale of 1:500,000 has been compiled from 1975 data. After completion of the marginal information for the map, it will be placed on USGS Open File and a composite color map will be published. Digital tapes containing land cover classifications for areas mapped on the Barrow, Wainwright, Meade River, Teshekpuk, Harrison Bay, Utukok River, Lookout Ridge, Ikpikpuk River, Umiat, Misheguk Mountain, and Howard Pass 1:250,000-scale quadrangles will be released through the National Cartographic Information Center. The land cover digital data were combined with DEM data to help assess impacts in NPR-A lease areas. This work is described in more detail in USGS Open File Report 81-315 (Morrissey and Ennis, 1981).

Prudhoe Bay Region

Additional land cover mapping was done in the Prudhoe Bay region and south along the pipeline haul road into the Sagavanirktok quadrangle area. With the help of the U.S. Army Corps of Engineers Cold Regions Research and Engineering Lab, and their contractor, the Institute of Arctic and Alpine Research at the University of Colorado, an existing land cover classification prepared from Landsat data was evaluated, refined, and field-checked during the summer. Land cover in the Beechey Point and Sagavanirktok 1:250,000-scale quadrangles will be reclassified using information obtained during field investigations. Field sites for areas in the Dietrich and Bettles quadrangles also were selected and visited during the summer of 1981.

Land Cover of the Arctic National Wildlife Refuge Coastal Area

Late in 1981, efforts were focused on preparing a land cover map of the Arctic National Wildlife Refuge coastal plain for an environmental impact statement being prepared by the U.S. Fish and Wildlife Service with USGS support. Three Landsat scenes were selected for analysis. Knowledge of sites mapped in the field were used along with clustering techniques to establish spectral classes for the land classification. Results were then viewed on an interactive color display for verification with field reconnaissance notes and a description of vegetation associated with each category was compiled. The data were then geometrically corrected and mosaicked.

A laser plotter was then used to plot the land cover and vegetation data on plates for a four-color printing process of the map at a scale of 1:250,000. This unique thematic map depicts 12 land cover classes on a topographic base mosaic of the Barter Island, Flaxman Island, Demarcation Point, and Mt. Michelson quadrangles. Information printed on the map margin includes corresponding surface area measurements. This map will also be published in 1982 in the USGS Miscellaneous Investigations Series as Map I-1443.

Land Use and Land Cover Mapping in South-Central Alaska

In preparation for the 1:250,000-scale land use and land cover mapping of several quadrangles in south-central Alaska, a land use and land cover map of the Valdez B-6 1:63,360-scale quadrangle was prepared using August 1978 1:60,000-scale color infrared photographs. Land cover types in the region were correlated to the USGS land use and land cover classification system. Interpretation and classification problems were identified and category specifications and guidelines for compilation were developed. In October 1981 operational land use and land cover mapping of the Valdez 1:250,000-scale quadrangle was begun. Researchers found it difficult to make consistent interpretations of certain land cover categories when viewing the 1:20,000-scale black-and-white photographs in stereo or the 1:60,000-scale color infrared photographs without stereo. However, most of these problems were resolved by stereoscopic interpretation of the color infrared photographs.

Studies were also begun to compare the USGS classification system with selected land cover or vegetation classification systems being used in Alaska by other Federal or State agencies. This review may prompt possible modifications to the tundra categories in the USGS classification system for mapping in all regions of Alaska.

Mapping Perennial Snow and Ice in South-Central Alaska

In order to test imagery sources, approaches, procedures, and category specifications, perennial snow and ice, as defined in USGS land use and land cover mapping specifications, was mapped on the Valdez 1:250,000 quadrangle. Glaciers and perennial snowfields were successfully mapped using 1:60,000-scale color infrared photographs. Guidelines were prepared and tested to enable photointerpreters to apply category specifications in delineating glaciers and snow patches. Researchers found that spectral analysis of Landsat digital data did not separate snowfields from snow-covered glaciers, nor distinguish between debris-covered margins and snouts of glaciers and the rock debris of adjoining morainal features. However, visual interpretation of enhanced and enlarged Landsat multi-spectral scanner color composites was successful in mapping a combined snow and ice category at a degree of acceptable accuracy for the 1:250,000-scale maps.

Radar Studies

The USGS is participating in a project to acquire and evaluate side-looking airborne radar (SLAR) imagery. As a result of legislative directives, the USGS initiated the SLAR program in January 1980. The SLAR program required three major tasks: (1) the purchase of existing SLAR imagery of the conterminous United States acquired by two distinctly different radar systems--synthetic-aperture and real-aperture; (2) acquisition of new imagery by the two radar systems in Alaska; and (3) the initiation of research projects in the National Mapping and Geologic Divisions. Most of the research has involved the evaluation of real-aperture imagery acquired by the Motorola Aerial Remote Sensing System (MARS) and synthetic-aperture imagery acquired by the Goodyear Electronic Mapping System (GEMS).

Comparison of SLAR and DEM Shaded Relief Imagery

Shaded-relief imagery is useful for the interpretation of geologic information. Radar images, which simulate shaded-relief images in appearance, are used for this purpose. Because shaded-relief images can also be generated by computer from DEM data, a comparison was made between GEMS synthetic-aperture SLAR imagery and shaded-relief imagery produced from DEM data. A portion of the Butte, Montana, quadrangle (figure 19a), for which DEM data and a 1:250,000-scale radar mosaic were available, was chosen for the test. Shaded relief imagery was generated by digitally mosaicking the twelve 1:24,000-scale DEM's that comprise the test area. A sun elevation angle of 30° and a sun azimuth of 90° were selected to simulate the look and depression angles of the radar beam. The portion of the Butte radar mosaic corresponding to the test area was printed for comparison with the DEM shaded relief image. The two images, shown in figures 19b and 19c, were compared for utility, information content, accuracy, and cost.

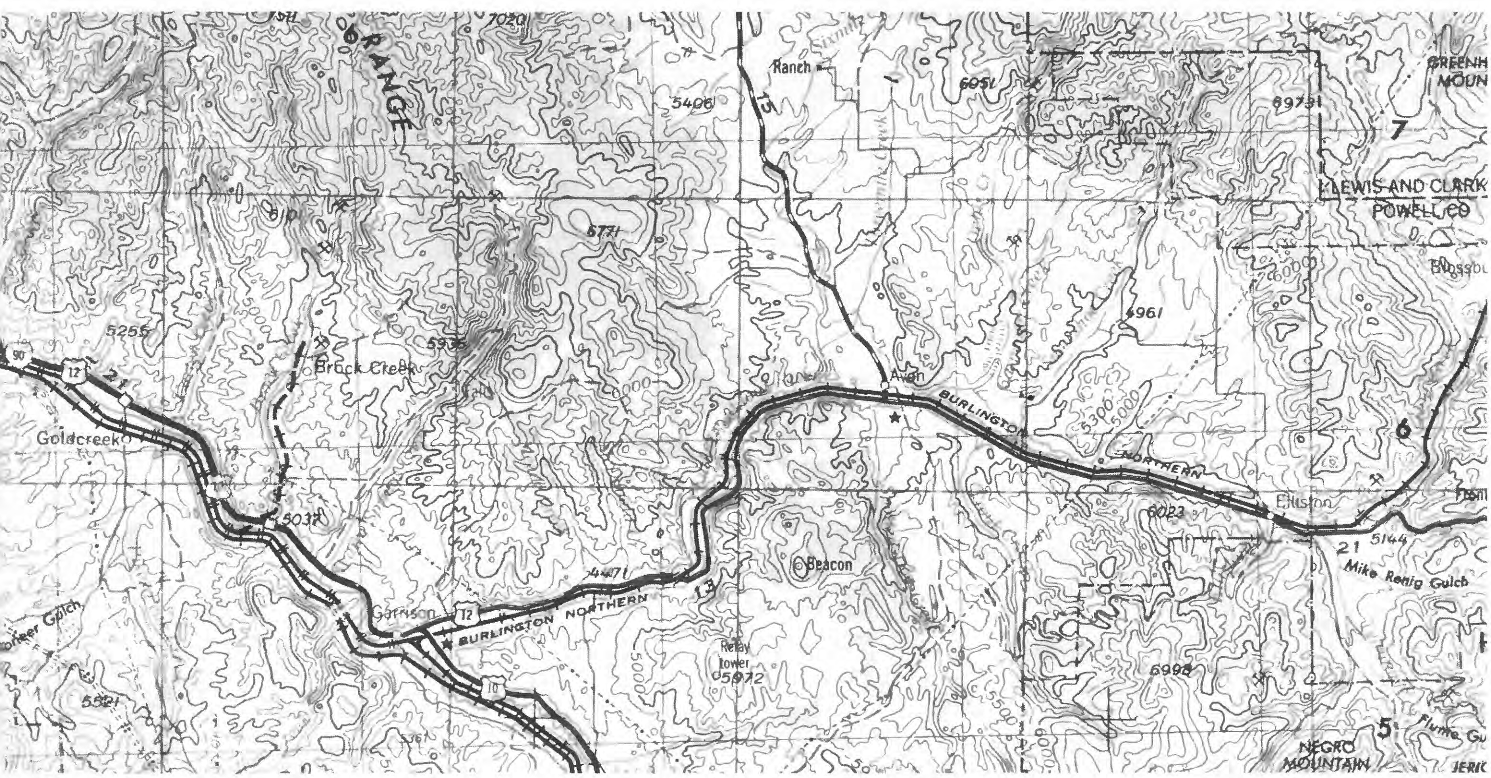

Figure 19a. Portion of Butte, Montana, 1:250,000-scale topographic map showing test area.

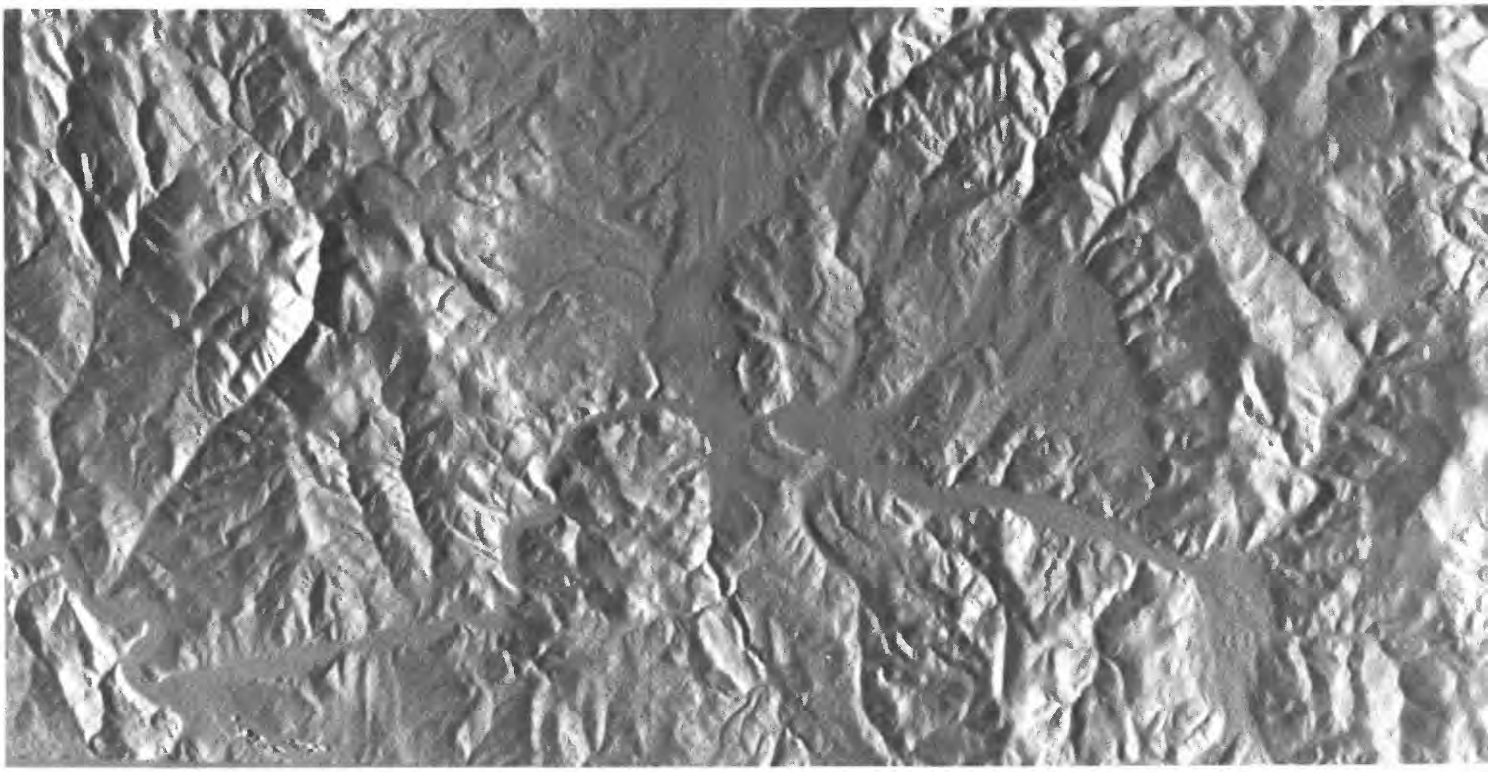

Figure 19b. Shaded relief image of Butte, Montana test area generated at 1:250,000-scale from DEM data.

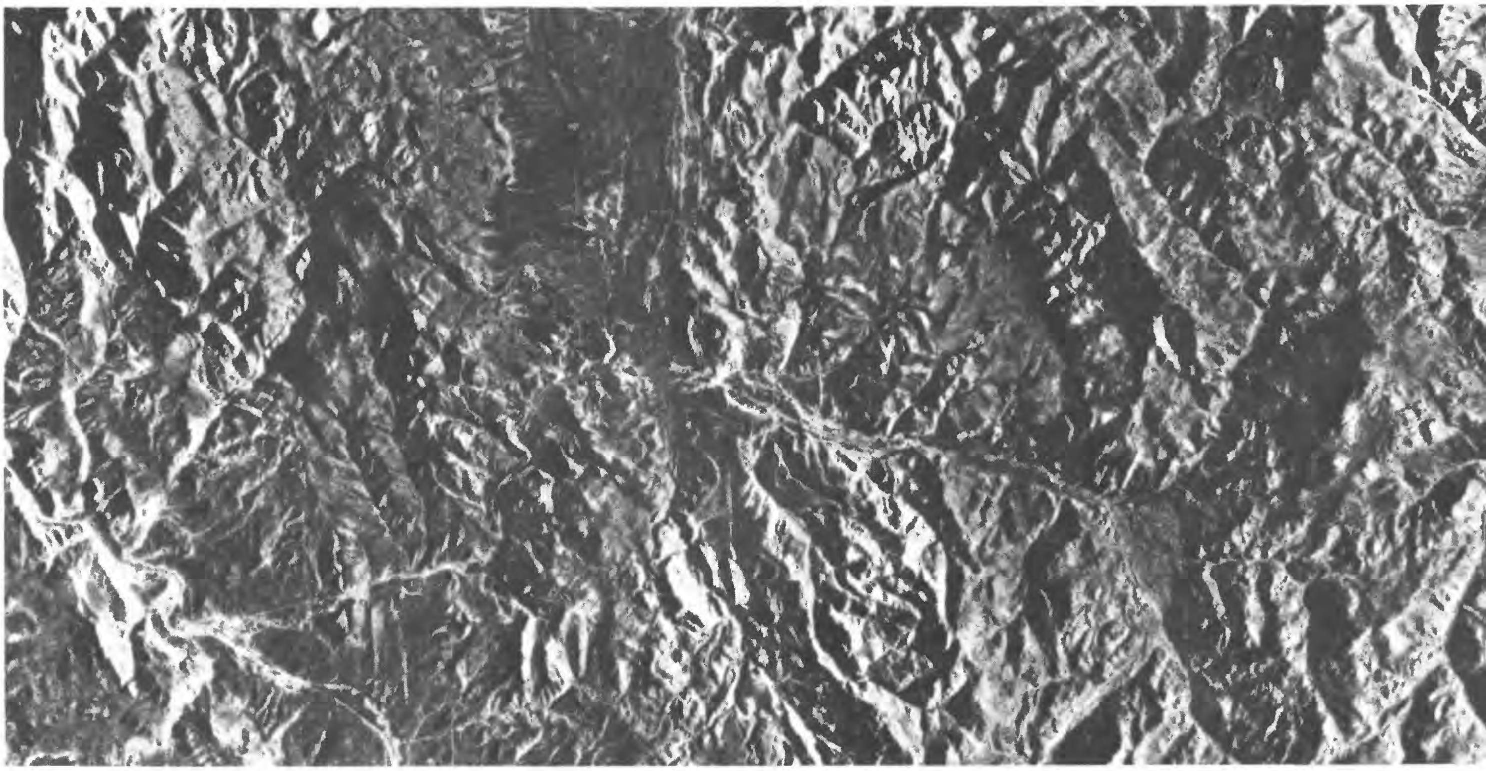

Figure 19c. Portion of Butte, Montana 1:250,000-scale GEMS radar image mosaic.

The DEM shaded-relief imagery minimizes surface features such as streams, roads, and towns which appear on the radar imagery and which may be a distraction to the analysis of structural detail such as lineaments. It has been advocated that at least two orthogonal radar looks are needed in order to detect all ground structure. However, this entails reflying each area at a considerable increase in cost. Using DEM data, it is quite simple and economical to generate shaded-relief images with multiple look and depression angles. DEM shaded-relief images have the added advantage of not being subjected to radar shadowing which can be detrimental to interpretation. Geometrically, a more accurate product results from the DEM shaded-relief image. Radar imagery is less accurate because of characteristic such as radar layover, and DEM collection procedures are more precise than those for radar imaging.

Control Extension Using Stereo Radar Strip Imagery

One of the uses of radar imagery is to make radar mosaics in 1:250,000-scale quadrangle format. The production of controlled mosaics requires geodetic control points. If the number of field-determined control points can be decreased, mosaic cost is also decreased. One of the potential uses of SLAR data that has been investigated is the extension of ground control based on stereo radar strips. Radar imagery from both realand synthetic-aperture systems was evaluated. Due to the radical geometric differences between radar imagery and photographic imagery, the computational procedures are quite different from those used in phototriangulation. The geographic area used as the test area is a portion of the Ugashik 1:250,000-scale quadrangle on the Alaskan Peninsula.

The control-extension process was divided into three general phases: interior orientation, exterior orientation, and pass-point intersection. The techniques used involved performing a space resection of each image strip individually and then intersecting common image rays of pass points based on the geometry shown in figure 20. Constant aircraft altitude and straight flight lines were assumed. Computation of planimetric positions did not present any computational difficulty. However, due to poor image geometry, elevations proved impossible to compute accurately. The GEMS synthetic aperture system achieved a slightly lower RMSE for planimetric point position than the MARS real-aperture system (GEMS RMSE = 90.4 m vs MARS RMSE = 102.2 m).

The relatively high planimetric RMSE's and the inability of either system to provide data which would permit reasonable elevation computations can be attributed to several sources of error. Ground control was obtained from existing 1:63,360-scale maps. Since there are only a few cultural features, identifiable image points were limited primarily to water features. Such features are likely to change shape with time. No data such as output from the inertial navigation system and gyro compasses were available to determine sensor position and attitude. Because registration marks were lacking, corrections for film deformation were limited to an overall correction for a variety of errors. For example, a non-orthogonality correction accounted for non-orthogonality due to image deformation as well as azimuthal errors in the radar. In addition, the imagery was acquired at low depression angles.

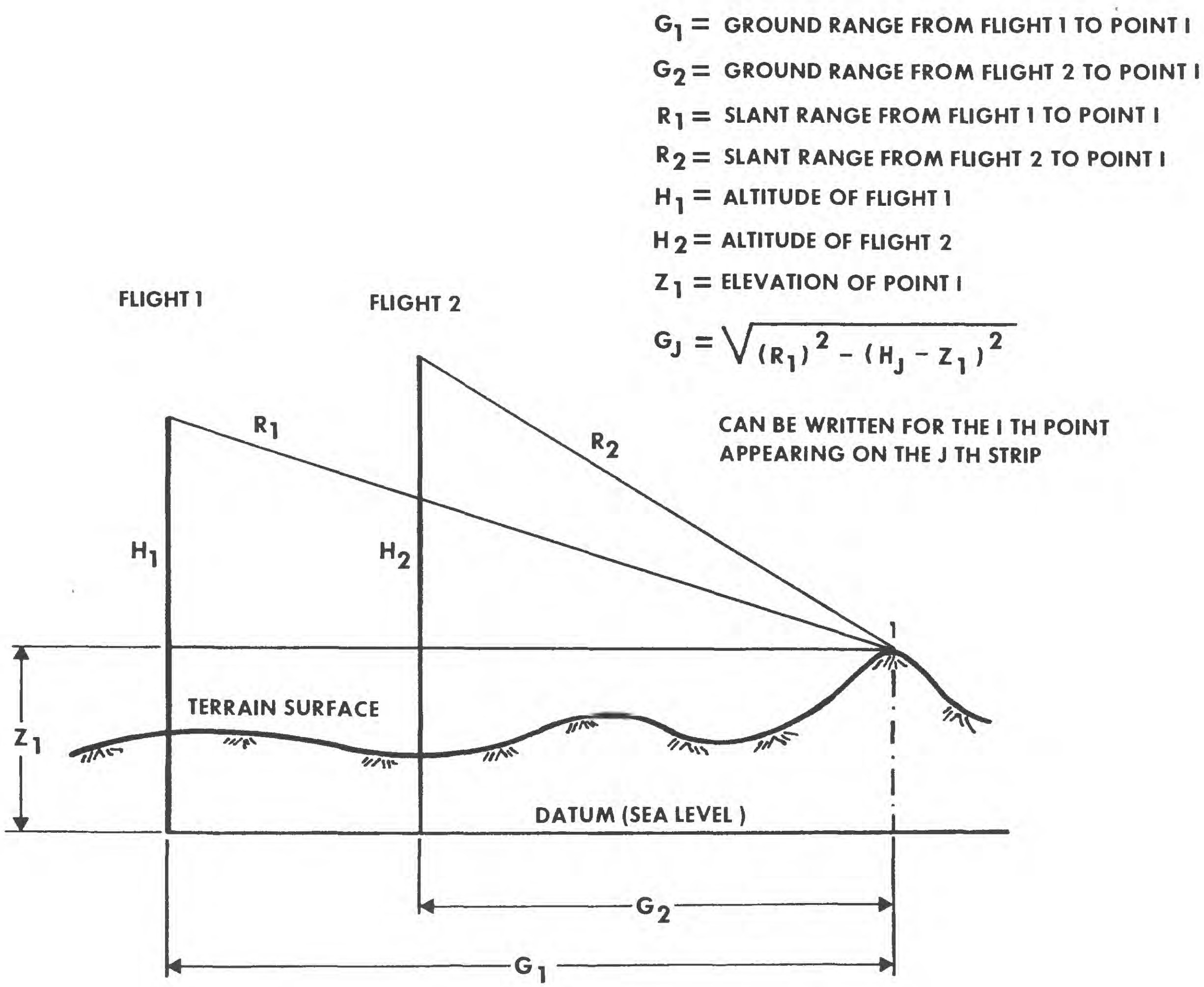

Figure 20. Generalized geometry of stereo radar imagery.

The low depression angles, imprecise knowledge of sensor position and attitude, and the use of same-side imagery results in very poor intersections, especially for elevation determinations. It is unlikely that SLAR imagery can be used for control extension until sensor position and attitude data are made available for radar images acquired at steeper depression angles in areas containing more identifiable image control points.

Detection of Forested Wetlands and Perennial Snow or Ice Using SLAR Imagery

Investigations were conducted concerning the value of X-band airborne radar imagery in detecting either Forested Wetland areas or areas of Perennial Snow or Ice. These are categories shown on USGS maps of land cover and commonly on topographic maps; however, they are often difficult to detect on aerial photographs because of concealing tree canopies in the case of wetlands and prevailing summer cloud cover in the case of perennial snow. Radar may be able to penetrate such concealment and to permit interpretation of hydrologic conditions. Tests showed the necessity of tailoring the radar collection to a specific type of investigation and for having ground investigators to collect hydrologic data at time of overflight of the radar aircraft. Nevertheless, it was found that an airborne synthetic-aperture radar image obtained in wintertime could assist the discrimination of frozen wetland from surrounding areas of dry forest and snow-covered rangeland in western Montana. Efforts were also made to delineate snow or ice fields in the Olympic Mountains of Washington as seen in a real-aperture radar image; however, strong radar reflection from mountainous terrain saturated the image and obscured the snowfield boundaries.

Screenless Lithographic Printing of 1:250,000-Scale SLAR Imagery

Experimental maps of real- and synthetic-aperture SLAR imagery have been printed in different hues and colors by the screenless printing process, which is currently the best cost-effective method of reproducing SLAR imagery. A 1:250,000-scale mosaicked radar quadrangle of Seattle, Washington, furnished by MARS, was printed by the screenless process in a single mixed black-brown ink. The screenless process results in an effect of two-color printing without the cost and time of making two impressions with two ink colors on the press. A collar was designed which specifies the pertinent data concerning the radar images and diagrams the flight strips that comprise the mosaic. A fitted UTM grid was generated by measuring control points on the mosaic and on the corresponding line maps. A fitted grid was similarly made for the 1:250,000-scale radar mosaic of Butte, Montana, furnished by GEMS. Control points were chosen to lie at approximately the same elevation. The fitted grids for both radar mosaics produced planimetric RMSE's of approximately 250 m. However, radar layover produced discrepancies up to a kilometer in mountainous terrain. A 1:250,000-scale radar mosaic of Hoquiam, Washington (which includes Mount St. Helens), supplied by MARS, was printed in a black-green ink as a comparison to the black-brown ink used for the Seattle quadrangle.

Analysis of SLAR Imagery for Identification of Base Map Categories

Four types of radar imagery were evaluated in three separate studies for the detection of base map category data: (1) ERIM L- and X-band synthetic-aperture radar; (2) Seasat L-band synthetic-aperture radar; (3) GEMS X-band synthetic-aperture radar; and (4) MARS X-band real-aperture radar. The five base categories studied were hydrography, landforms, transportation networks, boundaries, and culture. The results of each study were essentially the same for all base map categories regardless of the type of radar imagery evaluated. Hydrography and landforms were easiest to detect and closely followed the configuration found on corresponding line maps. Cultural features tend to lose form on radar imagery and appear only as bright areas. Transportation networks are intermittent and difficult to follow unless orthogonal to the radar beam. Overall results indicate that SLAR imagery is not useful for the detection of base map category data and therefore has little application for topographic mapping except as a substitute data source in persistently cloud-covered areas where high-quality aerial photographs and satellite images are difficult to obtain.

Seasat Altimeter

Recent studies indicate that Seasat altimeter measurements over land are a useful data base for mapping smooth terrain. The Seasat altimeter was "on" nealy continuously from June 1978 until the spacecraft's electrical failure in October 1978, providing about 400 hours of overland altimeter measurements. Although the altimeter was designed for relatively small dynamic height changes over the ocean surface, profiles derived from some Seasat altimeter overland data agree with the true terrain profiles within a few meters. Adjusting the sampled waveforms from the satellite's onboard tracking device, or retracking the waveforms, may result in terrain profiles within 10 cm of the true profiles over nonmountainous areas (figure 21).

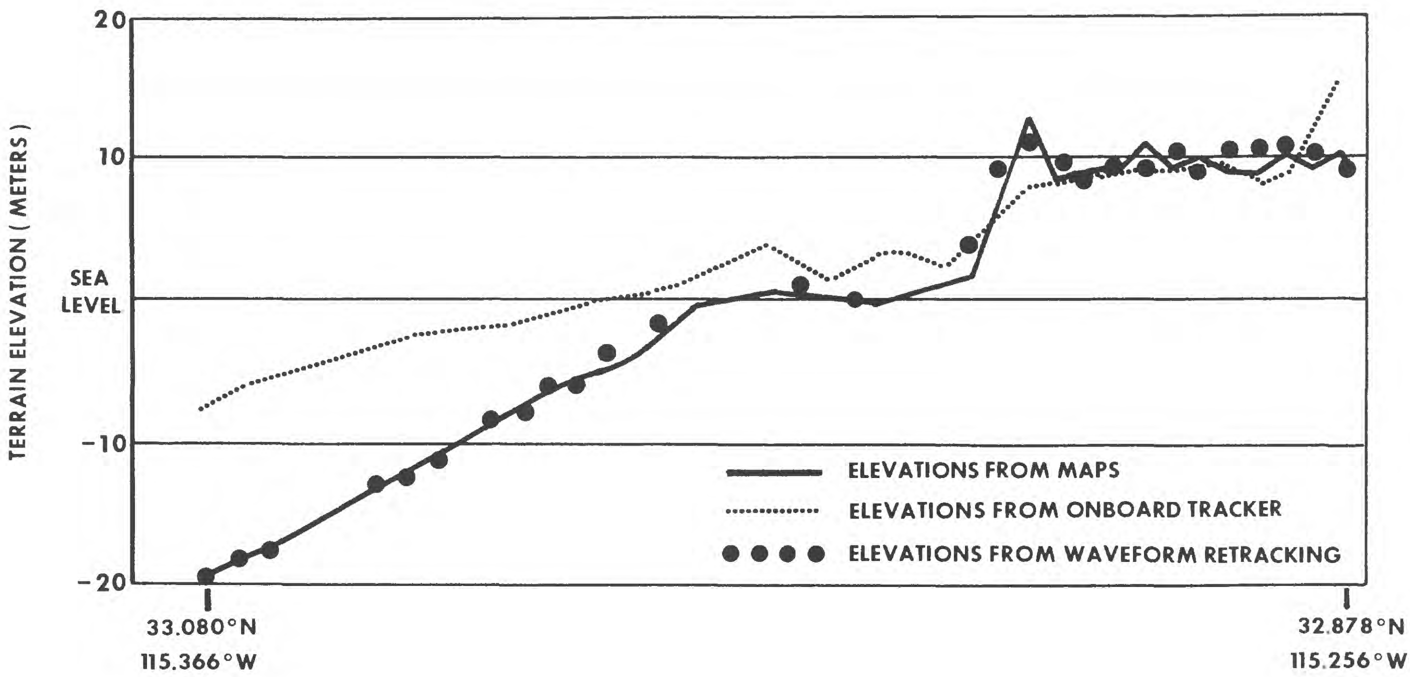

Figure 21. Correlation of Seasat altimeter-derived surface elevations with 1:24,000-scale map elevations for a 25.5 km groundtrack across East Mesa and Imperial Valley, California.

A study of retracking of Seasat radar altimeter waveforms has been initiated under contract. The objectives of this study are to: (1) use the Seasat altimeter data collected over the Meade River, Alaska, 1:250,000-scale quadrangle to determine spot elevations and, from these, derive a topographic overlay of the quadrangle with a 2-meter contour interval; (2) make the computer software for altimeter retracking operational on the USGS Amdahl computer and train USGS personnel in the use of the software; and (3) perform a study of considerations required for the design of a satellite altimeter capable of determining elevations over mountainous terrain to within 1 meter. The Seasat altimeter was designed for use only over the relatively flat ocean surface and, hence, its overland use is limited to terrain with very little slope change.

The Seasat altimeter overland data base contains potential overland profiling lengths of approximately 1×10^7 kilometers. Even if only 10 percent of the data can be made geodetically useful, this represents a significant data base for providing terrain profiles over nonmountainous areas at relatively low cost.

Satellite Surveying System

In order to take advantage of rapid development in Earth satellite technology, the USGS teamed with the Defense Mapping Agency and the National Geodetic Survey in 1980 for development of geodetic application of the NAVSTAR Global Positioning System (GPS). GPS is a worldwide satellite navigation and positioning system under development by the Department of Defense. The GPS is scheduled to replace the TRANSIT satellite navigation system, now maintained by the U.S. Navy, in the 1986-1988 time frame. Use of the GPS promises to provide the capability of attaining geodetic positional data with much less effort and in less time than is required for current field data-collection techniques.

The results of this team effort have led to a contract awarded to the University of Texas, Applied Research Laboratory (ARL), to develop an Advanced Geodetic Receiver (AGR) to exploit the GPS signals. The AGR is a single-channel multiplex receiver which will track four satellites simultaneously and will be capable of achieving accuracies in the sub-meter range. ARL has subcontracted AGR hardware development to Texas Instruments. The Naval Surface Weapons Center is developing hardware and software for the navigation processor which will be used with the AGR. The first delivery of AGR's is planned for late 1982.

SYSTEMS AND TECHNIQUES RESEARCH AND DEVELOPMENT

Automated Cartographic Lettering

Since 1975 the NMD has used a second-generation Mergenthaler VIP phototypesetter located in the printing plant in Reston, Virginia, for preparing film copy of nearly all map product lettering. Map lettering is a major labor intensive activity in map production. The activity involves: (1) Design--selection, size, style, and placement; (2) Ordering--listing, keyboarding, and proofing; (3) Production--typesetting, proofing, photolab processing, film positive copies, and waxing; (4) Stick-up--locating lettering on order, cutting, and applying to film overlay; and (5) Editing--additions, corrections, and changes. Several research projects are in progress to modernize the map lettering process, which has remained essentially unchanged for the past 40 years.

A research project was conducted to determine the cost-effectiveness of developing quality type fonts in digital form for the DDES using interactive graphic editing terminals to enter and manipulate data and a Gerber 4477 plotter to produce photographic film images for map lettering plates. Initial research was directed toward determining the usefulness, for map lettering, of those fonts currently existing; then a search began for other sources of digital fonts. Other agencies, both Federal and State, were contacted to learn what advances they have made in automated type placement. A limited number of digital fonts were located, but few were suitable for mapping purposes.

Most of the research effort has been devoted to user command development on the DDES, with limited time spent on actual digitization of type. Refinement of user commands is continuing and cost analyses cannot be finalized until all tasks are completed. However, preliminary results indicate that interactive type placement is a cost-effective approach, particularly in light of the new Provisional Edition topographic maps. The primary advantages of this approach are speed, accuracy of text placement, and reduction in visual checking, which lead to a significant reduction in the cycle time for the editing phases of map production.

A separate project was conducted by NMD staff in Reston to decentralize typesetting and increase efficiency through automated type placement of map lettering on a film overlay. Simultaneously, the Geologic Division (GD) was investigating methods to reduce their type cost for book publications and had obtained approval for purchase of typesetters in Menlo Park, Calif., and Denver, Colo. A cooperative agreement was made between GD and NMD to procure the fourth-generation Mergenthaler Omnitech 2100--a digital font, laser printer which met GD's requirements for a word-processing interface and NMD's for automating horizontal letter placement on maps. Omnitech 2100 typesetters are now operational in all four Mapping Centers.

The Omnitech 2100 has 30 graphic-arts quality digital fonts online, a point size selection ranging from 4.5 to 127.5, a 12-inch wide film cassette, full editing capability, and imaging capability at a speed of 68 square inches per minute at a resolution of 362 scanlines per inch. Software features permit modifying those fonts online to double resolution, and modify fonts to expanded, condensed, or slanted versions which effectively increases the resolution and available selection of online fonts. Horizontal type can be placed to an accuracy of 0.014 inch in any position 11-inches wide by the length of the map with a "go-to" keystroke command. Two or more overlay strips from the Omnitech 2100 will cover a map product. Non-horizontal and curved lettering continue to require hand placement.

Savings with the new Omnitech 2100 will be in discontinued use of the teletype punch paper tape transmission, near elimination of correction cut-in due to editing capabilities, and rapid type delivery by on-site equipment. The printing of film negatives or positives direct from the typesetter will save photolaboratory labor and materials. The major savings, however, is in automated type placement of horizontal lettering. With the computer interface, future applications may include direct name input from the Geographic Names Information System.

Screenless Lithography

For over 25 years, the NMD has explored a variety of lithographic printing techniques that do not use halftone screens for reproducing continuous tone images. In lithography, a halftone screen is used to break a continuous-tone or screenless image into dots of ink. The halftone dots tend to obscure fine detail such as houses, streets, and railroads at the scale of orthophotomapping used in NMD. In order to preserve the fine detail, "Image-Tone" and "Photolytic" systems of screenless printing were developed. Recently, new photopolymers and new processes of anodizing and graining of aluminum printing plates became available to produce similar fine-grain random dots with improved photographic and lithographic printing controls. In comparison, a random dot, lithographic screenless print is equal to 600 to 700 lines per inch while the finest halftone print possible is 300 lines per inch. Many experimental image maps have been printed by the USGS using the screenless plate process. However, additional developmental work in process control is needed to make screenless lithography a routine procedure for photo map production.

The screenless plate process requires exposure and chemical processing that is as critical as that of a photographic film system. To facilitate processing and meet the exacting chemical requirements, the National Mapping Division has designed and built a rocking development tray with temperature and time control to accommodate 60-inch plates. Previously, plates were limited to 40 inches and processed in a vertical dip tank. The new large tray processor will permit the production of maps as large as 42 by 60 inches by the screenless process.

Analysis of the Image Chain in the Orthophoto Production System

A study is in progress to determine the loss in resolution at each stage of the multiple processes that transform an aerial photoimage into a lithographed orthophotoquad or orthophotomap. Beginning with the original aerial image and progressing through to the final lithographic printing, the image is processed through six to nine steps, depending on the instrument used for simple or differential rectification. To aid the study, an image control target chart was designed and produced on film to evaluate resolution, tone reproduction, and flare characteristics (figure 22). This control target evaluated along with the image to determine the loss of resolution occurring with each step in the process. The study also includes an analysis of resolution loss by photolab processing, pressplate processing, and the printing system. Upon completion of the study, calibration of and modifications to equipment and changes in processing of materials will be recommended to minimize losses.

Aerial Profiling of Terrain System

The Aerial Profiling of Terrain System (APTS) has been under development since 1974. It will be a precision airborne surveying system capable of measuring elevation profiles across various types of terrain from a relatively light aircraft at flight heights up to 1,000 m above the ground (figure 23). A laser profiler measures the distance from the aircraft to

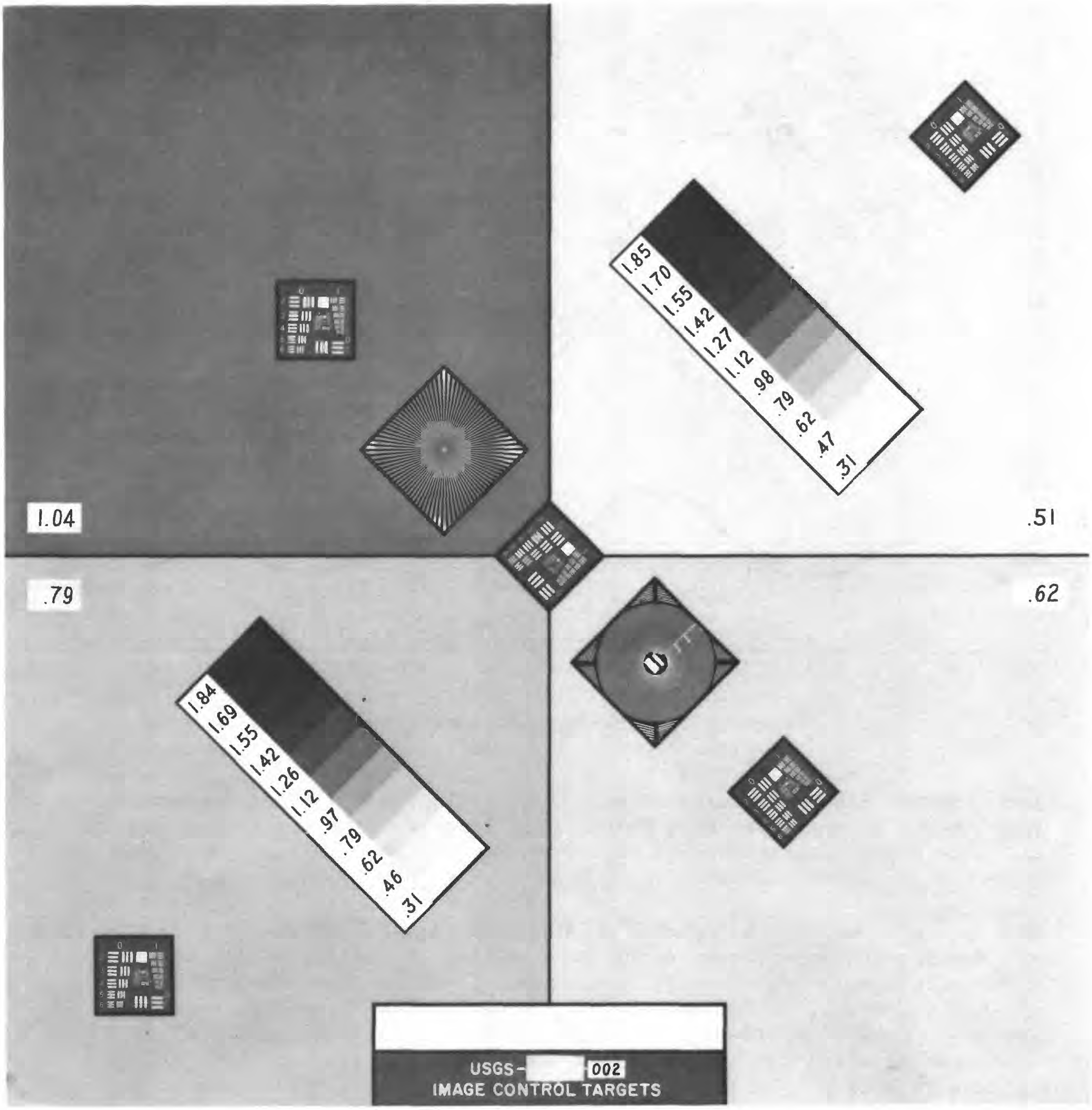

Figure 22. Image control target chart.

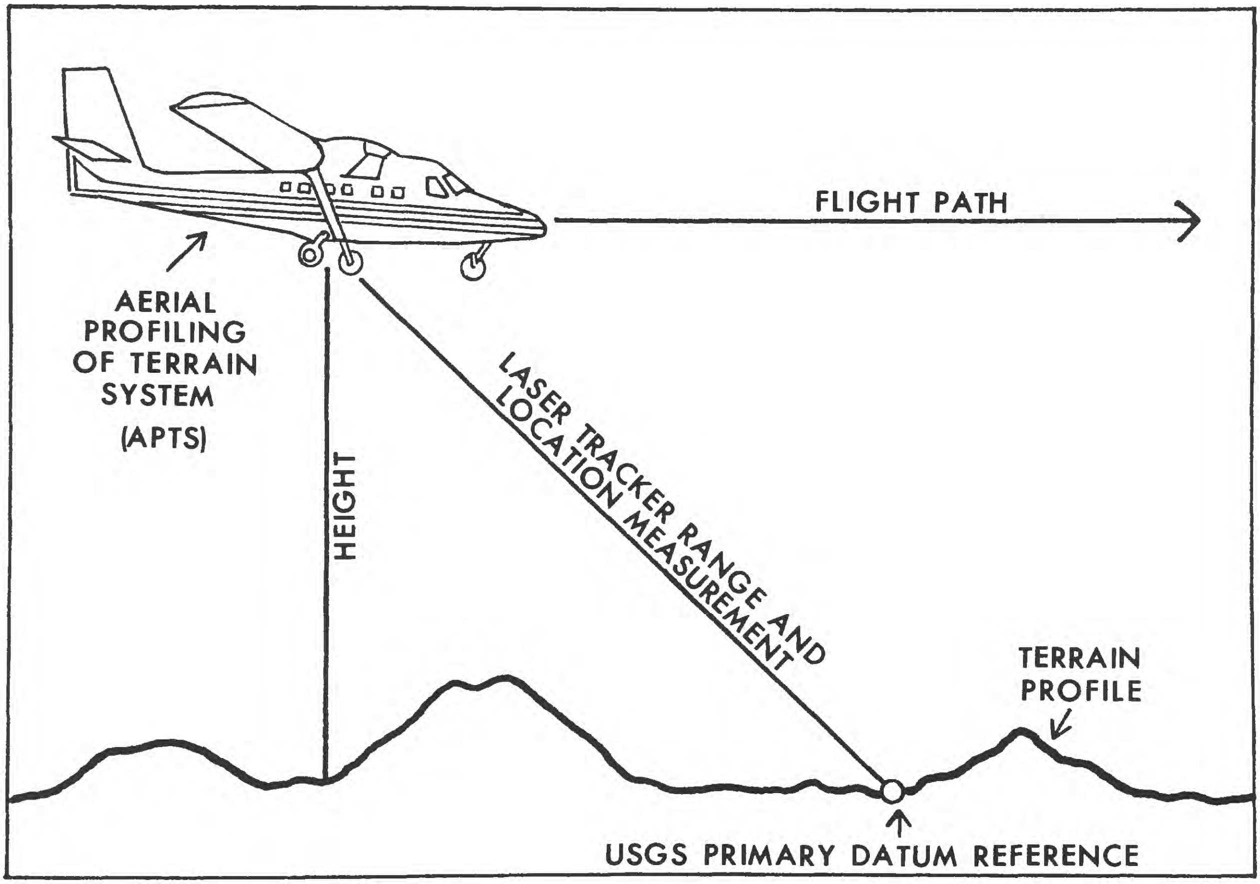

Figure 23. Terrain profiling with APTS.

the terrain, and an inertial measuring unit (IMU) and a laser tracker provide the aircraft position datum. The tracker measures the distance to previously placed retroreflectors to provide a high-precision positional update to the IMU.

This research work is being done at the Charles Stark Draper Laboratory, and the fabrication of components (navigation, tracker, profiler, and video subsystems) was recently completed. Integration of the components has begun and will be followed by extensive laboratory testing. In a parallel effort, a Twin-Otter aircraft is being modified for the APTS installation which will begin in mid-summer of 1982 (figure 24). Flight testing is to begin in January 1983 and the calibration flights will be completed in June 1983. The APTS is expected to meet system accuracy goals of $\pm$ 0.5 feet vertically and $\pm$ 2.0 feet horizontally.

A 2-year series of application tests are planned to follow the calibration flights. The tests will include three general types of applications: (1) topographic profiling, such as establishing vertical control for producing topographic maps; (2) sensor control, providing positional information for other sensors, such as aerial cameras, infrared scanners, magnetometers, and side-looking airborne radar; and (3) new geodetic control surveying and gravity modeling.

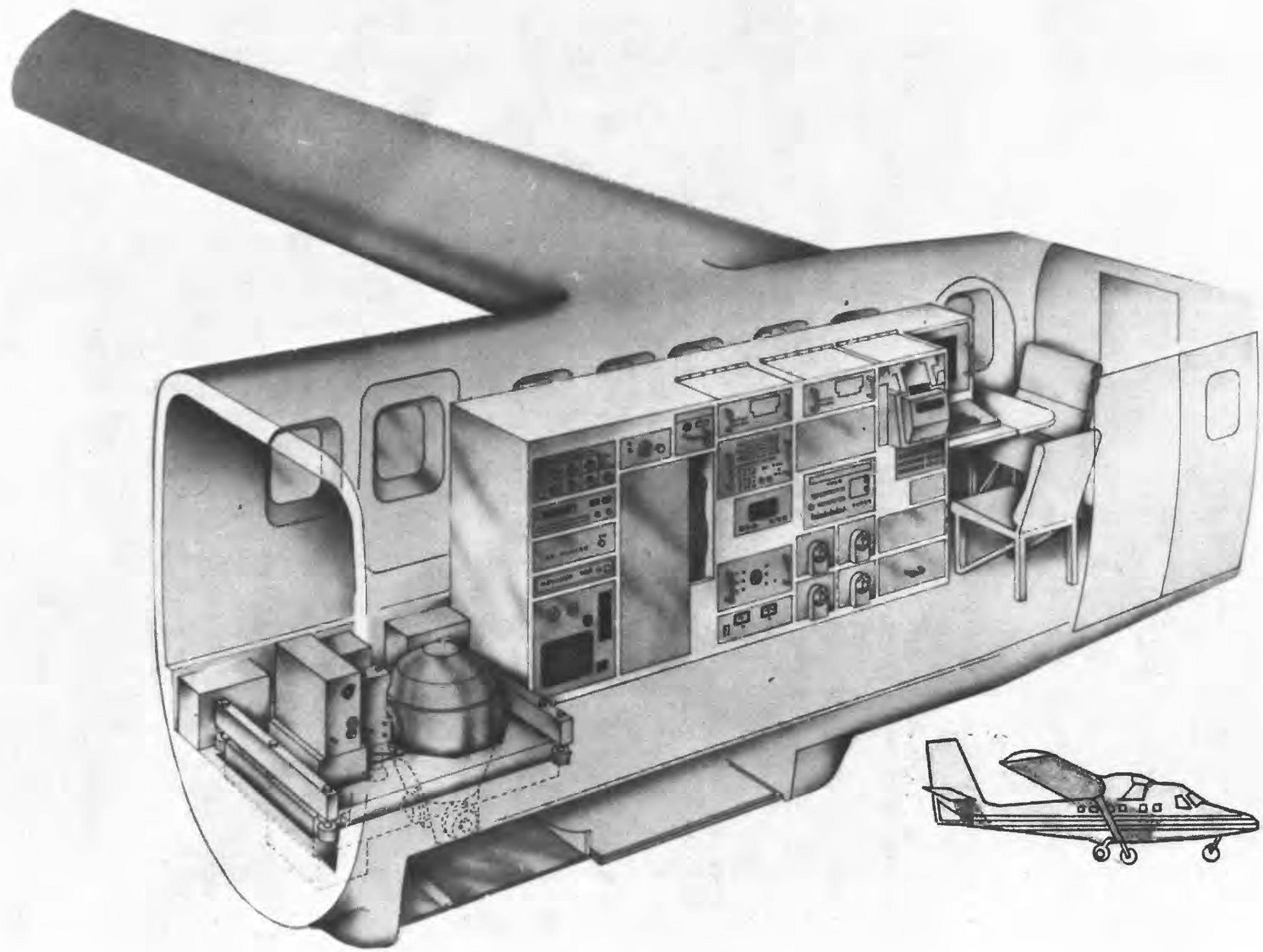

Figure 24. Cutaway view of APTS in aircraft.

Digital Data Editing System

All digital map data must be edited--either to remove or correct errors, or to revise established files as new data become available. The NMD uses the Digital Data Editing System (DDES), produced by the Intergraph Corporation, for editing digital map data. The NMD has five DDES installations, each having multiple editing stations--digitizing tables, editing tables, dual Tektronix 4014 video screens, and alphanumeric keyboards--all interactively interfaced with DEC PDP 11/70 control processing computers with disk and tape peripherals (figure 25). The systems have the capability to: (1) digitize map data; (2) add or delete points and lines; (3) reformat or change position of the data; (4) add or revise descriptive header data; (5) generate map collars and names; and (6) perform many other tasks required for digital data editing.

The first two systems, installed in Reston in 1977, were obtained to develop the application of digital technology and interactive graphic capability to NMD cartographic programs. Recognized immediately was a need to modify or develop software to allow better interaction with software supplied with the systems. Software was developed to support specific projects, and a variety of programs were developed to reformat data gathered at the DDES editing stations to interface with various plotting hardware and software processing systems.

One of the current DDES production efforts is centered on capturing and editing data for the 1:2,000,000-scale digital cartographic data base. Small-scale special-purpose base map graphics, prepared from World Data Bank I or II in response to specific requests, are occasionally entered into the system for data manipulation or type placement prior to outputting on the Gerber or Versatec plotter. The major development efforts on the DDES are being directed toward: (1) improving DLG data-capture techniques; (2) completing interim format software links to various hardware/software modules to standardize procedures for other map digitizing projects; (3) improving the interactive editing and processing of data acquired on the Scitex Map Scanning and Digitizing System; and (4) investigating several methods for editing DEM data generated on the GPM-2. DDES systems are now operational in each of the Mapping Centers.

Applications and Techniques Development for Raster-Formatted Data

The NMD is conducting applications research and software and techniques development with respect to raster-formatted data for digital cartographic applications. These efforts center on the capabilities of the NMD's Scitex RESPONSE 250 map scanning and digitizing system (figure 26). This system is composed of four major subcomponents: (1) two large-format (36- by 36-inch) color raster scanners capable of encoding up to 12 colors or gray levels; (2) two interactive digital graphic editing and design consoles; (3) a large-format (40- by 60-inch) laser printer capable of producing raster-format positive and negative film transparencies; and (4) a DEC PDP 11/60 minicomputer for raster-to-vector data conversion and batch-oriented processing.

Figure 25. Digital Data Editing System.

Figure 26. Scitex RESPONSE 250 map scanning and digitizing system.

NMD personnel are currently in the process of developing special applications software for this system; however several digital cartographic applications have already been investigated:

Map Replication. Reproduction of a 1931 edition of a USGS map demonstrated the application of the Scitex for map manuscript production. The only available copy of the map was a paper copy that showed its age through fold marks, age stains, and other signs of use. The original color separates were hand-engraved on copper plates that are no longer useable for reprint purposes. The paper copy was scanned and, using the editing functions of the Scitex electronic design console, the age stains, fold lines and other blemishes were erased from the digital copy. Lines and symbols were retouched and repaired, and the map was rescaled to more modern dimensions. The laser printer was then used to generate reproduction-quality color separates for printing.

Processed-Image Graphic Generation. Through contractual arrangements, digital images of Landsat MSS scenes are computer processed to obtain land use classifications and other thematic data sets. These data sets are input, via magnetic tape, to the Scitex interactive design console for multicolor display and to perform several editing functions, such as resolving indeterminate feature boundary situations and performing edge enhancements.

Shaded-Relief Map Separates. DEM data can be used to computer-generate topographic shading representations based on slope aspect, sun angle, and sun azimuth. These representations, coded with numeric color or gray levels, are input to the design console via magnetic tape for editing. Electronic artifacts are removed or corrected as needed, and line screens are added to the digital data to produce desired patterns and densities of shading. The laser printer is used to generate a film transparency that can be composited with other map separates to produce a shaded-relief representation.

Slope Map Thematic Graphics. The DEM's can also be used for generating digital and slope-zone thematic graphics. Each DEM grid cell or pixel is assigned a numeric color or density code as with the shaded relief separate; but in this case, based only on percent of slope. The data set, once generated, is formatted for the Scitex hardware and then input to the design console via magnetic tape and edited. The various slope zones are assigned colors or color intensities (line-screening densities) as needed to graphically portray the data for the intended application. The slope zone graphics produced by the laser printer can then be composited with such map separates as may be required to print a particular thematic graphic.

Open-Window Thematic Graphics. NMD land use and land cover map graphics often contain thousands of polygons, each carrying one of 37 different classification numbers. Manually etching and peeling an open-window color separate for just one classification is a labor-intensive and time-consuming task. A large quantity of polygon data exists in a digital data base in vector form. These data can be retrieved from the data base and converted to color-coded raster form that can be input to the Scitex via magnetic tape. The console controls are then used to perform color design operations to produce the desired pictorial rendition. Variable-density line screening or other symbolic pattern fill are added to selected polygons, or sets of polygons, for either feature enhancement or general readability. The open-window graphics output by the laser printer can be composited or overprinted in any combination to produce a particular thematic graphic.

Production of DLG Data. Another important application of raster scanning technology is the production of DLG data. Hypsographic (contour) color separates are raster scanned at a density of 40 cell points per millimeter. The data are then reduced (centerlined) so that the line data are represented in one-cell-wide centerline form. These data are then displayed and edited to erase name information, contour numbers, depression ticks, spot elevations, and other extraneous information. Line spurs, overruns, and other spurious artifacts of the scanning and data reduction processes are deleted. Unwanted line gaps are closed and congested areas are erased. The edited raster data are then converted to vector data, compacted (filtered) to remove any nonessential line vertices, and reformatted for input into the vector-oriented DDES equipment. Once in the DDES, residual line gaps are closed and any residual line continuity and direction problems are corrected. The feature code and name (height) of each contour line are appended to its x,y spatial data string, and the data are formatted into standard form for use by USGS and its customers. From this general form, the data can be further computer-processed into digital elevation matrices, perspective views, contour line graphs, contour plot tapes, or other forms required by the user.

The NMD digital raster hardware is still in the developmental stage, with most of the current efforts centered on the development of operating procedures for the above applications. Development of optimal raster-to-vector software for hypsography is well underway, and NMD will soon begin developing raster-to-vector conversion software and techniques for hydrography, transportation networks, and polygonal data.

Pass Point Marking System

The NMD has designed a computer-controlled pass point marking system which will be used to: (1) mark pass points on new copies of original photographs for customers outside the USGS; (2) perform point transfer; and (3) gather pass point data without marking the points for input to analytical plotters.

The hardware consists of a Kern CPM-1 monocomparator/stereoscopic point marker interfaced to an Altek AC-74 digitizer. The left stage of the CPM-1 is equipped with linear encoders and serves as a monocomparator. The digitizer is interfaced to a Hewlett-Packard desktop computer (HP-85) which is supported by a flexible disk drive.

The original pass point coordinates are obtained from a magnetic tape and transferred to a flexible disk. These pass points are transformed into the stage coordinate system of the CPM-1 using a six-parameter affine transformation and measurements of the fiducial marks. The operator manually moves the stages to the displayed coordinates and marks the left photographic plate by drilling holes in the emulsion.

Online Aerotriangulation Data Collection and Edit System

The NMD presently collects aerotriangulation data using manual comparators and plotters interfaced to Altek digitizers which then output to punch cards. There is presently no procedure to verify the data while they are being collected. The Online Aerotriangulation Data Collection and Edit System (OADCES) is being developed to automate the collection and editing of coordinate data while aerial photographic plate measurements are being made (figure 27). The system will detect mensuration blunders by performing interior orientation on a single photograph and relative orientation between successive photographs. Image coordinates will be corrected for lens distortion and film deformation. Microcomputers will be interfaced to manual comparators and stereoplotters and to peripherals such as flexible disk drives. Communication between each computer and its comparator/plotter will be through an Altek digitizer. The computer programs will be written in BASIC. Data from each individual system will be output to disk and then transferred to magnetic tape on the standalone system for input to an aerotriangulation program on a larger computer. Each Mapping Center will have one standalone system consisting of a microcomputer, flexible disk drive, magnetic tape drive, and printer.

The OADCES will increase the throughput of the aerotriangulation mensuration phase by: (1) relieving the comparator operator of some of the present bookkeeping tasks, (2) performing online data verification, (3) allowing online data editing/remensuration, and (4) making the aerotriangulation mensuration process operator-friendly.

Map Revision Module for Kern PG2-AT Stereoplotter

The NMD is engaged in the continuing task of updating topographic maps of the United States and its territories. The map revision phase now makes up about one-eighth of the NMD workload. To meet the increasing production requirements for map revision, the NMD has purchased a prototype map revision module for the Kern PG2-AT Stereoplotter (figure 28). The basic function of the revision module is the superimposition of the map manuscript image into the optical train of the stereoplotter, allowing the instrument operator to simultaneously view the stereomodel and the map manuscript being revised. An increase in productivity should result, since under the former mode of operation, the PG-2 operator was required to constantly shift attention between the stereo instrument and the map manuscript. This simultaneous viewing capability is accomplished by integrating a TV camera and a special high-contrast TV monitor, a beam splitter, and auxiliary optics into a unit capable of being retrofitted to

Figure 27. Online Aerotriangulation Data Collection and Edit System.

the PG2-AT stereoplotter. The prototype module has met the basic functional requirements. However, the NMD is currently modifying some of the components and the location of operator controls to further increase efficiency and ease of operation.

Figure 28. Revision module with Kern PG2-AT stereoplotter.

Automatic Map Symbol Placement System

The NMD is developing an Automatic Map Symbol Placement System based on the capabilities of the Kongsberg automatic plotter (figure 29). In this application the Kongsberg is used to position and imprint topographic and geologic symbols during the map plotting process. The map symbols are placed at precise x,y coordinates and rotated to specific angles using commands stored on digital tapes which direct the plotter movements.

Tests were made of geologic formation and letter symbols using digital data tapes collected on the Altek angle-measuring data acquisition system. The Altek is used to generate a drive plot tape that provides the proper symbol identification, location, and angle of orientation. Software was

Figure 29. Kongsberg automatic plotter.

also developed to produce plot tapes of design files stored on the DDES. These magnetic data tapes contain all of the commands and coordinate data needed to drive the photohead on the Kongsberg plotter.

This system can be used to produce high-quality ink, scribe, or photoplots. At this time, the primary advantage appears to be the quick, efficient generation of symbol overlays for geologic maps.

Voice Data Entry System

The NMD has purchased, tested, and accepted five new voice data entry systems for use in map digitizing work. The major advantage of these systems is the capability of their users to make voiced data entries with no interruption to their manual cartographic tasks. The operator of a digitizer, for example, is not required to enter attribute code changes by hand. The operator simply speaks the appropriate word, the voice-recognition module recognizes the speech by comparing it to a previously stored vocabulary reference pattern for that user, and the proper code is entered. To verify that the word was properly interpreted, the voice synthesizer is used to "speak" the word for the entered code.

Each standalone system is composed of a microcomputer with an interactive terminal having an alphanumeric display, line printer, voice recognition module, voice synthesizer module, and magnetic floppy-disk storage (figure 30). The floppy-disk storage is used to store users' vocabularies, applications, programs, and system control software.

A voice response capability has also been developed for the existing Threshold Technology Inc. T-600 voice recognition input terminals. The T-600s and digitizer/recorders are used to add spoken input feature codes to cartographic data being recorded from stereoplotters. The newly added voice output capability eliminates the need for an operator to look away from the stereoplotter in order to confirm voice data input; instead, a synthesized "voice" repeats each feature as it is entered and allows multi-word feature designations to be entered. Interactive editing is provided. A DEC LSI-11/03 microcomputer is used for control, input/output buffering, and vocabulary storage.

ASSOCIATED ACTIVITIES

Computer Software Distribution

The mission of the NMD is to provide topographic and geographic information in the form of maps and digital data. In the fulfillment of this mission a large number of computer programs are written. The NMD develops computer software for the solution of problems in the fields of surveying, geodesy, remote sensing, and photogrammetry. Although these programs are not intentionally created for distribution, it is the policy of the NMD to distribute them when appropriate. Program distribution packages normally consist of FORTRAN source code, job control language used to control the execution of the software, a sample data set, sample output from the

Figure 30. Voice Data Entry System.

execution of the sample, and documentation. It is important to note that many of these programs may not be fully documented, and that the NMD is not in a position to support their installation, modification, or update. Some of the computer software used by the NMD is proprietary to a private company, used under a non-disclosure license, and cannot be released.

Testing and Calibration of Aerial Cameras

During the past year the USGS NMD Optical Calibration Laboratory has continued work in aerial mapping camera calibrations, lens camera performance, and investigations in areas of calibration accuracy. A total of 96 cameras were calibrated during the year, submitted from private mapping contractors, State highway departments, the NASA Johnson Space Flight Center, and NOAA National Ocean Survey. Several special cameras used on contract work for the Nuclear Regulatory Commission in the investigation of nuclear generation station accidents and safety violations were also calibrated.

An investigation was completed into the spectral characteristics of calibration light sources to be used in the 53 collimators of the camera calibrator in order to change the output color temperature to that of average noon sunlight, which is considered to be from 5000° Kelvin to 5500° Kelvin. A new illumination system was developed which has full-spectrum light with a color composition of approximately 5200° Kelvin. Samples of these lamps were measured by the National Bureau of Standards along with calibration of NMD's color temperature measuring equipment. The new system will allow a closer approximation of optimum theoretical results between film and camera lens performance in the photographic testing process.

Resolution Targets

An array of resolution targets has been painted on the roof of the USGS National Center, Reston, Va. The target array consists of standard bar targets and a Siemens star target (figure 31). These permanent targets provide the USGS and other agencies with the capabilities of testing the resolution of camera systems, evaluating image motion compensation devices, and measuring the effects of other aircraft actions.

The bar targets, based on a design used by the National Bureau of Standards, consist of alternating black and gray bars arranged in two groups perpendicular to each other. Each group is 20 by 100 feet and contains six sets of bars. Each set contains six individual bars, three black and three gray of equal width. The individual bar widths of each set are, in descending order, 6.0 feet, 4.0 feet, 2.5 feet, 1.5 feet, 1.0 feet, and 0.75 feet.

The Siemens star consists of alternating black and gray wedges every 5 degrees of arc. The target diameter is 140 feet yielding a maximum wedge width of 6 feet. The measured contrast ratios are 2.3:1 for the star and 2.1:1 for the bar. This relatively low contrast was chosed to simulate conditions typically found in aerial photography.

Figure 31. Standard bar targets and Siemans star target on roof of USGS National Center.

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APPENDIX
CURRENT RESEARCH PROJECTS

Information on all research activities discussed in this report may be obtained by contacting the Assistant Division Chief for Research, National Mapping Division, USGS National Center, Mail Stop 519, Reston, Va. 22092 (703) 860-6291, FTS 928-6291). Information about the following topics may also be obtained by contacting the responsible Office or Mapping Center at the address given below.

Assistant Division Chief for Research
National Center, Mail Stop 519
Reston, VA 22092
(703) 860-6291
FTS 928-6291

- System Alpha Study

NMD Office of Cartographic Research
National Center, Mail Stop 522
Reston, VA 22092
(703) 860-6271
FTS 928-6271

- DEM Editing Using a Polygon Scan Conversion Process
- Automated Cartography
- Automated Cartographic Lettering
- Automated Names Handling Research
- Map Projections
- Application of Linear Algebra to Computation of Gridded Data
- Generalized Adjustment by Least Squares
- Radar Studies
- Seasat Altimeter
- Resolution Targets

NMD Office of Geographic Research
National Center, Mail Stop 521
Reston, VA 22092
(703) 860-6341
FTS 928-6341

- Geographic Information System Development
- Geographic Names Information System
- Algorithms for Generalization of Land Use and Land Cover Data
- Identifying Changes in Land Use and Land Cover
- Land Use and Land Cover Statistics
- An Assessment of the Accuracy of Land Use and Land Cover Maps
- Land Use and Land Cover Change Research - Allegheny County, Pa.
- Computer-plotted Map of Land Use and Land Cover, Three Mile Island and Vicinity
- Computer Graphics Experiments and Techniques
- Barrier Islands Coastal Studies
- Level III Land Use and Land Cover Classification of the North Carolina Barrier Islands

Level III Land Use and Land Cover Mapping in Connecticut
Mapping of Irrigated Cropland with Landsat Digital Data
Mapping of Vegetation and Land Cover in Alaska with Landsat Digital Data

Research Cartographer, EROS
NMD Office of Research
National Center, Mail Stop 519
Reston, VA 22092
(703) 860-6294
FTS 928-6294

Mapsat
Landsat Cartographic Research
Combination of Unlike Data Sets
Multispatial Data Acquisition and Processing

NMD Office of Systems and Techniques Development
National Center Mail Stop 526
Reston, VA 22092
(703) 860-6301
FTS 928-6301

Provisional Map Standards Development
Image Map Research
Satellite Surveying System
Screenless Lithography
Analysis of the Image Chain in the Orthophoto Production System
Aerial Profiling of Terrain System
Digital Data Editing System
Applications and Techniques Development for Raster-formatted Data
Pass Point Marking System
Online Aerotriangulation Data Collection and Edit System
Map Revision Module for Kern PG2-AT Stereoplotter
Automatic Map Symbol Placement System
Voice Data Entry System
Computer Software Distribution
Testing and Calibration of Aerial Cameras

USGS Eastern Mapping Center
National Center, Mail Stop 567
Reston, VA 22092
(703) 860-6352
FTS 928-6352

The 1:2,000,000-scale Data Base
Data Base Development

USGS Mid-Continent Mapping Center
1400 Independence Road
Rolla, MO 65401
(314) 341-0880
FTS 277-0880

Applications Software Development for Land Use and Land Cover Data
Land Use and Land Cover and Environmental Interpretation Keys: A Guide for Missouri

USGS Rocky Mountain Mapping Center
Denver Federal Center, Box 25046
Denver, CO 80225
(303) 234-2351
FTS 234-2351

- Experimental 1:63,360-scale Orthophotoquad of Kodiak A-6 Quadrangle, Alaska
- Land Use and Land Cover Mapping in South-central Alaska
- Mapping Perennial Snow and Ice in South-central Alaska

USGS Western Mapping Center
345 Middlefield Road
Menlo Park, CA 94025
(415) 323-2411
FTS 467-2411

- Mapping of Irrigated Cropland with Landsat Digital Data
- Mapping of Vegetation and Land Cover in Alaska with Landsat Digital Data
- Mount St. Helens Mapping

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