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Report of the
UNITED STATES DELEGATION
at the Eighth

United Nations Regional Cartographic Conference for Africa

Addis Ababa, Ethiopia
22-27 February 1993

The Status of Cartographic Activities in The United States of America

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EIGHTH UNITED NATIONS REGIONAL CARTOGRAPHIC

CONFERENCE FOR AFRICA

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EIGHTH UNITED NATIONS REGIONAL CARTOGRAPHIC CONFERENCE FOR AFRICA
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THE STATUS OF CARTOGRAPHIC ACTIVITIES IN THE UNITED STATES OF AMERICA

INTRODUCTION

Since the Seventh United Nations Regional Cartographic Conference for Africa, U.S. cartographic activities have expanded to include advances in computer technology, remote sensing, geographic information systems, and inertial and satellite positioning systems.

All mapping and charting activities in the United States have been influenced by the development of automated cartographic techniques and equipment. Computers are applied to a broad spectrum of cartographic activities, including compilation, revision, maintenance, and production of topographic, orthophotographic, and image maps and aeronautical and nautical charts.

Advances in computer technology over the last decade have prompted Federal mapping and charting agencies to build digital data bases that are useful to the study of geology, soils, hydrology, land use, and land cover. A major achievement since 1984 has been the development of standards for digital cartographic data throughout the cartographic community.

The Defense Mapping Agency (DMA) of the U.S. Department of Defense (DOD) is responsible for the preparation of maps, charts and geodetic products on a worldwide (international) basis to meet national defense requirements and for the preparation of nautical and aeronautical products to support the safety of navigation. The U.S. Geological Survey (USGS) of the U.S. Department of the Interior (DOI) has the national responsibility for preparing and making available multi-purpose maps and base cartographic data in a variety of forms. In recent years, the USGS has concentrated on digitizing base categories of data on topographic maps, such as hypsography, hydrography, and transportation systems, to create a National Digital Cartographic Data Base (NDCDB). Other Federal agencies are responsible for collecting additional map data of public value. The National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) is responsible for geodetic surveys and for the preparation of aeronautical and nautical charts.

These activities are discussed under the following headings:

- Geodesy
- Image Mapping
- Topographic Mapping
- Hydrography and Oceanography
- Aeronautical Charting
- Geographic Names
- Digital Cartography
- Global Change

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

GEODESY

The National Geodetic Survey's (NGS) primary mission is to establish and maintain the geodetic horizontal, vertical, and gravity networks that make up the National Geodetic Reference System (NGRS). Progress in improving the NGRS during 1992 is described below.

Horizontal Geodetic Network

Processing of horizontal data into the North American Datum of 1983 (NAD 83) continued with new GPS projects and classically observed projects. In the past year, 200 projects containing 13,905 stations were completed. Results of the computations are added to the NGS Integrated Data Base. The priority on processing is NGS Global Positioning System (GPS) projects, other agencies GPS projects, and then classically observed projects.

Transfer of technology to State, county, and private surveyors and engineers is an important activity within the NGS. The NGS presented 11 horizontal workshops to over 1,000 State, local, and private users of the NGRS. Workshop topics included State plane coordinates, datum transformations, geographic information systems, and network planning and adjustments.

Vertical Geodetic Network

Implementation of the North American Vertical Datum of 1988 (NAVD 88) was begun during 1992. The project is part of an international effort, requiring close cooperation with counterpart agencies in Canada and Mexico.

During 1992, international cooperation was enhanced by technical exchange meetings, exchange of leveling data, and continued joint investigation of several technical and research efforts involving the NAVD 88. Completion of the general adjustment of the NAVD 88 was accomplished in June 1991, with publication of resulting heights in 1991-92. For 1992, NGS leveling units completed 3,250 kilometers of first-order geodetic leveling in the conterminous United States. Surveys involving 6,600 kilometers of new leveling lines were processed to include in the NAVD 88.

Heights from the NAVD 88 general adjustment were added to the NGS data base in June 1991. The NGS has now begun the next phase of the NAVD 88 project, which is to incorporate the remaining 30 percent of the network to include "posted" and crustal motion points. To date, slightly more than one-half of the posted blocks have been processed. Completion is scheduled for September 1993.

The Federal Geodetic Control Subcommittee (FGCS) Vertical Work Group and the American Congress on Surveying and Mapping Ad Hoc Committee on NAVD 88 continued to document the impact of the NAVD 88 on users. It was recommended that NGS perform a minimum constraint, least squares adjustment of appropriate leveling data for the NAVD 88 and that the datum be shifted vertically to minimize recompilation of national mapping products.

As recommended by both groups, a minimum constraint adjustment of Canadian-Mexican-U.S. leveling observations was performed by holding fixed the height of the primary tidal bench mark, referred to as the new International Great Lakes Datum of 1985 (IGLD 85) local mean sea level height value, at Father Point/Rimouski, Quebec, Canada. The IGLD 85 and the NAVD 88 are now the same. Father Point/Rimouski is located at the mouth of the St. Lawrence River and is the reference station used for the IGLD 85.

The national vertical control network was also strengthened by cooperative leveling projects and leveling by State, county, and private organizations.

The NGS, in cooperation with Federal Geodetic Control Committee, tested and evaluated the results of the WILD NA2000 and NA3000 digital leveling systems. The systems measure, calculate, and record leveling data electronically using barcode leveling rods. Test results are being tabulated. Work continues on the Rapid Precision Leveling System (RPLS) Development Project at the Coast & Geodetic Survey (C&GS). Various technical aspects of the RPLS, which promises to minimize or eliminate atmospheric refraction errors in leveling, were discussed with NGS and C&GS personnel.

Global Positioning Systems (GPS) Surveys and Applications

The NGS observed GPS satellite surveys at numerous sites in the country.

The NGS completed GPS surveys with 10 Trimble Navigation model 4000SST and 11 Trimble Navigation model 4000ST satellite survey systems. The Trimble 4000ST field party was discontinued during the year.

The projects supported the following activities: extension and densification of the NGRS; monitoring of vertical and horizontal displacements associated with tectonic movements; connection of FAA airports to the NGRS; and upgrade of the geodetic network and control survey. The NGS observed the following between July 1991 and June 1992 using GPS surveying techniques:

Number of projects.....18
Number of receivers per project.....5
Total stations occupied.....1005

Support was given on the transfer of GPS satellite surveying technology to Federal, State, and local governments and educational institutions. The NGS supported GPS technology transfer in panel discussions, technical papers, speeches, and training activities, both national and international.

Development of in-house GPS orbit computation software continues. Tracking data for 17 GPS satellites are routinely received from 29 Cooperative International GPS Network (CIGNET) tracking stations throughout the world. The CIGNET data are prepared for archiving, storage, and distribution and are used with the orbit software package PAGE2 to compute precise orbits. Forty-five precise GPS orbit sets were computed and distributed to the public beginning in September 1991.

At the USGS GPS surveying techniques are routinely used to perform traditional ground control surveys for mapping and play a major role in determining positions for geophysical surveys. The GPS is an accurate and cost-effective tool for georeferencing spatial data collected for geographic information systems. The USGS is continuing to research new applications for GPS technology.

Static and kinematic methods of relative positioning with GPS are used extensively in support of a variety of mapping projects. The projects include geodetic control for mapping, airborne GPS controlled photography, and positioning photoidentifiable points for testing the accuracy of mapping and digital orthophoto products. In 1993, the first operational airborne GPS project in support of the National Aerial Photography Program (NAPP) is planned. The USGS is investigating aerial triangulation software with enhanced capabilities to incorporate airborne GPS determined camera exposure station coordinates in the adjustments. Additionally, positioning requirements in Antarctica to support a wide variety of scientific projects are performed exclusively using the GPS. A permanent GPS receiver is operating continuously at the Amundsen-Scott South Pole station. The South Pole data contributes to the international cooperative projects of the Scientific Committee on Antarctic Research.

In its geologic activities, the USGS is employing the GPS as the principal method for measuring crustal motion in tectonically active areas and ground deformation in areas of volcanic activity. Two permanent GPS receivers were deployed in 1991 to make continuous measurements between stations that bridge known faults. Additional dual-frequency geodetic receivers are used for the collection of data periodically at new and existing stations of crustal motion monitoring networks. Immediately following a major earthquake, receivers are deployed on stations near the epicenter and in the effected region to measure post-earthquake rebound. Using advanced GPS data processing software and he precise orbital coordinate data, baseline vectors are determined to a few millimeters in each component.

The use of the GPS in the USGS's water resources activities continues to expand to meet a wide range of applications and accuracy requirements. Geodetic dual-frequency receivers are used to monitor subsidence networks. Continuous kinematic and stop-and-go GPS positioning techniques were used in 1991 and 1992 to determine height measurements to model the flood plain. Handheld single frequency GPS receivers collect data simultaneously relative to reference stations equipped with permanent trackers to determine meter-level positions by differential pseudorange GPS (DGPS) methods. DGPS methods are used in hydrologic studies to position ground-water test wells and to georeference data collected by boats on lakes and rivers.

The DMA operates a worldwide GPS satellite tracking network with stations located in Argentina, Ecuador, Australia, Bahrain, and England. Data from the DMA network and the five U.S. Air Force GPS monitor stations are used by the DMA to compute precise orbits for all the GPS satellites. Precise ephemerides are produced and distributed weekly. The DMA is now upgrading its monitor stations with new receivers capable of handling antispoofing and selective availability. In addition to its TI 4100 receivers, the DMA has acquired over

50 Ashtech receivers for geodetic positioning work. Absolute (point) World Geodetic System (WGS) 84 positions can be computed from data from a single receiver to an accuracy of 1 meter in each component using software developed by the DMA. Cooperative GPS survey projects have been undertaken in Paraguay, Venezuela, Czechoslovakia, and Hungary, and GPS training was provided to Bolivia. The DMA is now using the GPS exclusively for satellite surveys in the United States and worldwide.

High-Resolution Geoid Heights and Deflections of the Vertical

Geoidal height variation across the United States is being systematically modeled. Models are tested against Very Long Baseline Interferometry (VLBI) and GPS-determined ellipsoidal heights where orthometric heights in the NAVD 88 datum have also been determined. Tests have identified a trend of 0.5 parts per million in a north-south orientation. This trend is currently being investigated as a function of either the fundamental model or the leveling data. Geoid studies indicate that recomputation of the gravity terrain correction will determine if higher accuracy is needed. In addition, the indirect effect correction and the second-order terms of the normal gravity gradient must now be incorporated into the model.

Time-Dependent Positioning (TDP) Models

In many locations, geodetic coordinates change significantly with time. Users of the published geodetic information need the coordinates to be correct at the time they are performing such work as mapping flood plains or building large-scale irrigation systems. Also, they need information about changes in coordinate relationships to develop regional building codes, to develop geophysical models to explain crustal deformation, or to predict hazards such as earthquakes, volcanic eruptions, or tsunamis. A TDP model can correct old geodetic measurements in a region, so that revised estimates of coordinates can be computed.

The NGS has implemented a first-generation system for rapid development and use of TDP models. The first-generation TDP models were applied to homogenize, in time, the measurements that were used to estimate positional coordinates for the 250,000 sites in the NAD 83 Geodetic Reference System. More recently, TDP models for horizontal motion have been improved by adding new data, as well as by applying new computer software. TDP models of vertical motion have also been developed for 5 of 22 areas identified as having significant vertical crustal motion. The NGS is assembling a vertical crustal motion data base for all of these locations and will eventually develop models for them.

TDP models are derived from histories of various types of geodetic measurements, including GPS, VLBI, leveling, gravity, triangulation, EDM, and astronomic observations. Nongeodetic data are also used to constrain models. Information on height change can come from measurements of uplifted barnacles or tide gauges. Parameters for earthquake models can be initially defined with seismograph data. Global models of plate motions provide boundary constraints for regional models of crustal motions.

Vertical crustal motions have a variety of causes, including post-glacial rebound, magma intrusion, withdrawal of ground fluids, sedimentary loading, hydrothermal activity, as well as the broad tectonic and seismic causes of horizontal motion. For this reason, a variety of functions have been designed to empirically describe vertical motions. Various height functions are incorporated into the NGS software. For example, simple linear motion is commonly used to portray almost any kind of motion over short time intervals or uniform motion for long periods. Current post-glacial uplift is adequately described by a linear model. If an acceleration term is added, the new function becomes quadratic and can be useful for regions where velocities slow or speed up. A sequence of linear models can also be used to describe non-linear motion. Postseismic motion may be nonlinear and can often be described by an exponential decay function. Following an earthquake, there is normally a period of rapid vertical readjustment, which slows with time.

Technology Transfer

Work on the development of "Multipurpose Land Information Systems: The Guidebook" continued. The third release (chapters 8, 9, 10, and 16) was published in 1992. The next release (chapters 12, 14, 15, 20, and 21) will be published in early 1993.

World Geodetic System 84 (WGS 84)

The DMA produces mapping, charting, geodetic, gravimetric, and digital products in support of the DOD. These products are referred to a single geocentric coordinate system because of accuracy and user interface considerations. Such a system also is needed to support the widest possible range of applications (local, worldwide); to relate information from one product to data obtained from another source; and to ensure a smooth transition in product use from one part of the world to another. Such a geocentric system, called the world geodetic system, provides the basic reference frame and geometric figure for the earth, models the earth gravimetrically, and provides the means for relating positions on various local geodetic systems to an earth-centered, earth-fixed coordinate system. This world geodetic system serves as the framework for DMA products and worldwide DOD operations.

The second edition of DMA Technical Report 8350.2 - DOD WGS 84 was published in September 1992 (DMA Stock No. DMATR83502WGS84). The second edition includes new transformation constants for geodetic datums and reference systems, deletion of multiple regression equations for small and isolated areas, and changes in symbols for the ellipsoidal and mean sea level heights. THe WGS 84 Earth Gravitational Model, complete through degree and order 180, has been declassified. In addition, the DMA is distributing a Mapping Datum Transformation software package for datum transformation and coordinate conversions (DMA Stock No. MADTRANIBMPC, Edition No. 2). The program allows input from geodetic, Universal Transverse Mercator (UTM), or the Military Grid Reference System (MGRS) coordinates. Over 100 datums are available for transformation to or from the WGS 84. Output is automatically presented as geodetic, UTM, and MGRS coordinates.

National Geodetic Information

The NGS distributes geodetic information products to satisfy user requirements. These products include the results of geodetic surveys; software programs to compute, verify, or adjust original survey observations; and publications describing how to obtain geodetic data and products. The NGS also conducts a marketing program to increase user awareness and understanding of these products and to improve NGS's responsiveness to its users.

One of the major accomplishments during 1992 was to provide numerous publications, historical records, and the results of research investigations to fulfill requests from universities, individuals, government agencies, and businesses throughout the United States and from other countries.

IMAGE MAPPING

Remotely sensed images are valuable mapping tools. Today, image maps are used as interim substitutes for line maps and as final products that show details not easily conveyed by line map symbols. Remotely sensed images include high-altitude photographs, orthophotographs, satellite images, and side-looking airborne radar data.

The National Aerial Photography Program (NAPP)

The NAPP is directed by a multiagency steering committee who contributes primary funding for the program. The program is administered by the USGS on behalf of other Federal contributors and State cooperators who also provide funding. The photographs acquired under this program are a primary source material supporting various programs in each of the contributing Federal and State agencies. These photographs will be the primary source material for the National Digital Orthophoto Program.

The goal of the NAPP is to acquire complete aerial photographic coverage of the United States (except Alaska) every 5 years. The NAPP acquires photographs from a flying height of 20,000 feet (6.1 kilometers) above mean terrain, with a single 6-inch (15.2 centimeters) focal length camera exposing color-infrared or black-and-white film at a scale of 1:40,000. The resulting photographs are centered on quarter sections of standard USGS 1:24,000-scale, 7.5-minute quadrangles. The resolution of the photographs is 1 to 1.5 meters, depending on the contrast of the terrain.

Inspected and accepted photography is available for an estimated 75 percent of the total area of the United States. Copies of accepted photographs are available from the U.S. Department of Agriculture, Aerial Photography Field Office, Salt Lake City, Utah, and the U.S. Department of the Interior, U.S. Geological Survey, Sioux Falls, South Dakota.

Orthophotographs

Analog orthophotoquads portray land features on photographic images that have been processed to show surface detail in true position. Orthophotoquads do not include topographic contours and are printed in shades of gray without image enhancements or cartographic symbols. The demand continues for orthophotoquads to support resource-management activities as companion maps to published topographic maps.

Like analog orthophotoquads, digital orthophotoquad images are produced from standard aerial photographs; the scanned image files are digitally rectified to show surface detail in true position. Because of their high positional accuracy and level of visible detail, digital orthophotoquads can be used in geographic information systems and other digital applications requiring spatial data. Usually, digital orthophotoquad image files were prepared in 3.75-minute quarter-quadrangle sections of standard 7.5-minute quadrangle areas. The ground resolution of each pixel of a monochrome image file is 1 m. To date, some 650 quarter-quadrangle digital orthophotos have been prepared.

Successful preliminary trials have placed uncompressed and highly compressed digital orthophotoquad files on CD-ROM (compact disc read only memory) as a test of medium, format, and compression.

Satellite Image Mapping

Since the last report, the USGS printed the 1:5,000,000-scale map of Antarctica using advanced very high resolution radiometer (AVHRR) data from NOAA satellites. The project was done as a cooperative effort among NOAA, the USGS, and the United Kingdom Royal Aircraft Establishment National Remote Sensing Council. The primary image combined bands 1 and 2 (visible and near-infrared) in a 1:5,000,000-scale image of the Antarctic Continent. An insert showed the data from the thermal band. A second edition is planned using the images as a base for topographic contours and geographic names. In addition the USGS has printed six image maps at 1:250,000 scale around Ross Island using Landsat multispectral scanner (MSS) data. Work is also in progress on ten image maps at 1:250,000 scale using Landsat thematic mapper (TM) data covering Ice Streams on the Siple Coast. Mosaicking is complete for the first five maps and digital processing is continuing on the next five maps. Image maps of 17 MSS scenes are being prepared to support USGS mapping requirements for nine 1:250,000-scale quadrangles on the Antarctic Peninsula.

The USGS, in cooperation with the Canada Centre for Remote Sensing, processed AVHRR data acquired from August 11 to 20, 1990, to produce a vegetation index map of North America. The vegetation information extends from northern Canada to the southern tip of Panama. The colors on the map represent the vegetation vigor and density for those 10 days. The map was printed in time to be distributed at the Global Forum of the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, in June 1992. A second map under preparation shows the vegetation vigor for the conterminous United States. Both of these maps were prepared from digital data on tape that was plotted on halftone film. Any necessary editing was done on an edit station attached to the plotting system.

The USGS continues to produce calibrated, georegistered biweekly vegetation greenness condition data sets from AVHRR satellite data. These data sets are useful for monitoring the vegetation condition in a number of ecosystems including forests, agriculture crops, and grasslands. Digital files of the final image data and statistics are distributed on CD-ROM's.

Numerous statewide spatial data bases were developed in support of ecoregion delineation and characterization. Published maps on data elements, such as soils, permafrost, physiographic provinces, stream basins, various climatic variables, hydrography, coastline, and geology were automated and integrated with digital elevation model (DEM) and normalized difference vegetation index information derived from biweekly composites of AVHRR data. These data bases serve a global change community interested in characterizing conditions in the arctic and boreal regions of Alaska and will directly support boreal forest monitoring programs.

A project done in cooperation with the DMA's Inter-American Geodetic Survey and the Instituto Geográfico Militar of Bolivia under the auspices of the Pan

American Institute of Geography and History (PAIGH) demonstrated the use of satellite images for map revision at 1:50,000 scale. The primary image merged SPOT MSS and XS data; insets show topographic maps from 1967, the SPOT XS image, and a merged image of SPOT XS and Landsat TM data for an area around the city of Santa Cruz, Bolivia. The project demonstrated the feasibility of map revision using satellite images combined with other source data and field verification as necessary.

A 73-scene MSS image mosaic of Pakistan was completed. Other products include a full country mosaic (150-meter pixels) reproduced at 1:2,000,000 scale, two maps (100-meter pixels) reproduced at 1:1,000,000 scale, and seven maps (50-meter pixels) reproduced at 1:500,000 scale.

Twenty-six 1:200,000-scale image quadrangles were produced from an 18-scene MSS mosaic of Burkina. Information from these images will be digitized and individual and full country crop use intensity (CUI) plots will be produced.

CUI coverages were completed for Zimbabwe, Zambia, Malawi, and Mozambique. Information from a total of 91 MSS scenes was digitized and 109 CUI plots were produced. All products were supplied to these countries.

Side-Looking Airborne Radar (SLAR) Data

The USGS originated the SLAR program in 1980 for topographic and geologic mapping, and geologic research surveys in promising areas. More than 140 research studies have been initiated to evaluate the use of SLAR for a variety of applications, including energy and mineral exploration, natural hazards mitigation, global change detection, glacial stability investigation, and image mapping.

TOPOGRAPHIC MAPPING

Topographic mapping in the United States (50 States, U.S. Territories, and outlying areas) is a primary responsibility of the USGS.

The principal cartographic products of the USGS are conventional maps--1:20,000-scale (Puerto Rico), 1:24,000-scale, 1:25,000-scale, and 1:63,360-scale (Alaska) topographic maps, 1:24,000-scale and 1:63,360-scale (Alaska) orthophotoquads, and 1:100,000- and 1:250,000-scale topographic maps. Other products include land use and land cover maps at 1:100,000 scale, State and national small-scale base maps, and a variety of special maps, including image maps prepared from high-altitude aircraft and satellite data.

The primary-scale maps have the following categories of base map data: reference systems, hypsography, hydrography, vegetative cover, cultural features, boundaries, transportation systems, geodetic control, survey monumentation, and geographic names.

Because of newly defined mapping requirements and the development of new mapping, remote sensing, and photographic techniques, the USGS has reorganized its cartographic and geographic activities and expanded its product lines. The following is a synopsis of progress by major categories.

Primary-Scale Map Revision

At the end of 1992, topographic map coverage at 1:24,000 scale (1:63,360 in Alaska) was complete for all States, with the exception of small areas in Alaska.

These maps are periodically reviewed for revision, with emphasis on changes in urban areas, coastal zones, airports, and other high national interest areas. Since September 1989, 3,340 primary-scale quadrangle maps have been revised and published.

Intermediate-Scale Mapping

Intermediate-scale mapping at scales ranging from 1:50,000 to 1:100,000 continues to be a growing part of the USGS's National Mapping Program (NMP). With the expanding interest in energy and mineral development and Federal land management, the demand for quadrangle maps at 1:100,000 scale has increased. Presently, intermediate-scale maps in quadrangle format are available or under production for the entire conterminous United States. Current program plans call for the completion of 1:100,000-scale topographic maps for the conterminous United States by September 30, 1994.

Small-Scale Mapping

Topographic map coverage of the United States is complete at 1:250,000 scale, totaling 635 sheets. The series is currently maintained by the USGS. In 1987, the USGS implemented a new revision policy to replace the existing series with an updated series in side panel and metric format, prepared from

paneled reductions of 1:100,000-scale topographic quadrangles. Digital terrain data for the 1:250,000-scale map series are available.

Other small-scale maps at 1:500,000 and 1:1,000,000 scale include the State base map series.

Special-Purpose and Thematic Mapping

Special-purpose maps are prepared from existing map bases and information collected from various sources to meet the needs of Federal, State, and regional agencies. Maps of national parks, monuments, and historic sites, produced by the USGS at various scales for the National Park Service, are examples of special maps. Additionally, various thematic maps emphasizing a single topic or theme, such as geology or hydrology, are also prepared and published by the USGS for the U.S. Government and scientific community.

The USGS continues to support the U.S. Antarctic Program by conducting geodetic ground surveys and by compiling topographic maps of the continent. To date, 92 maps of Antarctica at 1:250,000 scale have been published, as well as topographic maps at 1:50,000 scale, 1:1,000,000 scale and smaller, and Landsat image maps at several scales.

Land Use and Land Cover Mapping

The USGS continues its involvement in preparing land use and land cover products for the United States. The program provides the only systematic inventory of land use and land cover data that is nationwide and features a uniform classification system at standardized scales. The maps and digital data are used by the Federal, State, and private sectors to support resource management, planning, development, environmental monitoring, and geographic information systems activities.

Completion of land use and land cover and associated maps, primarily at 1:250,000 scale, for the conterminous United States and Hawaii was accomplished in 1987. The associated maps include political units, hydrologic units, and census county subdivisions; Federal and State ownership overlays were prepared under State cooperative programs. Digitizing of the graphic products was completed in 1992. The data are distributed by the USGS in both vector and composite-theme grid cell format. Statistical summaries by quadrangle are also available.

HYDROGRAPHY AND OCEANOGRAPHY

The NOS nautical charting program is responsible for providing accurate and timely maps, charts, and related products to improve the efficiency and safety of marine transportation, offshore engineering, coastal zone management, naval operations, and recreational activities. During the past year, bathymetric surveys were conducted in the Gulf of Mexico for the Exclusive Economic Zone program; hydrographic surveys were conducted in Alaska, east coast, Gulf, Great Lakes, and California waters. Photogrammetric missions not only supported the charting programs, but were also applied to many other diverse problems, and new nautical charts were issued.

The DMA provides nautical and marine navigational data for areas outside U.S. waters for national defense and to worldwide merchant marine and private vessel operators.

Hydrographic Surveys

In conjunction with the Naval Oceanographic Office (NAVOCEANO), the DMA has continued in its pursuit of improving nautical chart coverage of African waters in the interest of safety of navigation. Coop-erative surveying and charting programs (HYCOOP) with Tunisia and Morocco provided excellent hydrographic data and are contributing to the production of new charts.

Side Scan SONAR for Mapping Obstructions

The high-speed high-resolution side scan sonar (HSHRSSS) has been developed for C&GS. The HSHRSSS was tested extensively in a hull-mounted configuration on a 9-meter Jensen launch in an operational setting in the Chesapeake Bay, Virginia. High-quality images were obtained at a speed of 6 knots in water depths of 2.5 to 35 meters. A known target, deployed in 12-meter water depth, was acquired 30 times. This test was a success and demonstrates the feasibility and practicability of conducting shallow-water obstruction surveys from a launch.

Hydrographic Data Acquisition and Processing System

All NOAA field units conducting hydrographic surveys had Hydrographic Data Acquisition and Processing System (HDAPS) capabilities during 1992. Systems are deployed on board the NOAA ships *Rainier, Whiting, Rude,* and *Heck,* as well as the Atlantic and Pacific hydrographic parties. The total number of systems installed is 15 Data Acquisition Systems (DAS) and 13 Data Processing Systems (DPS).

DAS units are deployed on three types of vessels: 30- to 70-meter ships, 9-meter Jensen launches, and 7-meter MonArks. The ship and Jensen DAS units and all of the DPS units are based on the Hewlett-Packard (HP) Series 9000 Model 340 computer systems. The MonArk DAS is based on Intel 80286, MS-DOS compatible computers.

The HP data acquisition software has color graphic features to assist the hydrographer. Data can be recorded continuously at 1-second intervals. Data are logged in RAM and then downloaded to a high-density floppy disk where, at a later time, it is uploaded to the DPS.

During 1992, all field units using HDAPS were equipped with Differential Global Positioning System (DGPS) receivers for use as the primary positioning system. The DGPS configuration allowed for input of differential correctors from USCG beacons (used by east coast ships) or correctors provided by locally established "fly-away" systems (used by west coast ships and the field parties).

The DPS were enhanced during 1992 to improve data processing speed, increase the "ease of use," and maintain the "user-friendliness" of the system. A mouse and "point-and-pick" menus were integrated into most of the programs.

The DAS employed by the field parties on small boats is based on a PC-type computer. The computer, Hyflex, and sensors are all powered by either 24 or 12 volts. The system can accommodate the Falcon 484, the Krupp-Atlas Polarfix, the DE-719B echo sounder with Odom Digitrace, the Innerspace 448 echo sounder, and the EG&C 260 side scan sonar. Data are logged onto a hard disk and then downloaded to a floppy. During this process the data are converted from a PC format into an HP format.

The processing system is an HP-340C and can process data acquired from an HP-DAS or a PC-DAS. Data are uploaded via floppy disk onto a 300 mb hard drive. Graphic editing, listing, and plotting of data can then be performed. Upon completion of processing, the data are transmitted to the marine centers for verification via 32-track tape.

Scanning Hydrographic Operational Airborne Laser Survey (SHOALS)

The U.S. Army Corps of Engineers has contracted to provide an airborne laser hydrography system. This SHOALS system, to be deployed in a Bell 212 helicopter, will be delivered and tested in the spring and summer of 1993. Differential GPS will be used for positioning. The laser fires 200 pulses per second into a scanner that provides a broad, uniformly sampled swath of soundings under the aircraft. The design was completed in 1989, and construction was completed in 1992. The system will be operated by a private contractor. The Field Working Group, an ad hoc committee composed of representatives with operational hydrographic experience, participated in the design process. NOAA has provided support in hardware and software design, coding, and testing. NOAA will, additionally, provide support in field testing and data analysis.

Hydrographic Applications of Satellite Data and Images

In August 1992, the NOS completed the transfer of Daedalus data. NOS is currently investigating refurbishing the MSS, training in MSS technology, altering aerial platforms, and developing a plan for MSS data application for PB programs, as well as those of other NOAA components.

Mapping the Exclusive Economic Zone (EEZ)

On March 10, 1983, the President proclaimed the U.S. EEZ. This zone encompasses 3.4 million square nautical miles of the ocean and seafloor within 200 nautical miles of the U.S. coastline. It includes not only the United States, but also its territories. The NOS established a program to determine the characteristics and resources within the EEZ by using modern survey techniques to provide high-resolution bathymetric maps of areas rich in resource potential.

A joint office has been formed between the NOS and the USGS to coordinate the EEZ mapping and research activities of both agencies. The USGS provides image data that they have acquired to NOS for planning and evaluation. The NOS, in turn, provides the USGS with detailed bathymetry data to support geological interpretation of the seafloor.

Multibeam swath sonar systems are currently installed on four NOAA ships, with plans to equip one or more in FY 1993. The NOAA ship *Whiting* is equipped with the Hydrochart II Swath Survey System and surveys water depths between 150 and 1000 meters. The NOAA ships *Surveyor, Discoverer,* and *Mt. Mitchell* are equipped with the Sea Beam system and can survey areas where the depths range from 600 to 11,000 meters. All of the continental shelf, slope, and upper rise can be surveyed, as well as the deeper areas of the U.S. EEZ, such as the Aleutian and Puerto Rico trenches.

More than 106,000 square nautical miles of the EEZ off the Alaska, Washington, Oregon, California, Hawaii, Louisiana, Texas and Virginia coasts were surveyed. These multibeam systems provide 100 percent coverage of the seafloor and yield new details in the U.S. continental shelf and slope areas. Navigational use of the GPS to calibrate land-based navigation systems resulted in a significant increase in ship productivity. Starfix, another satellite-based navigation system, was used almost exclusively in the Gulf of Mexico with great success. Deployment of the full GPS satellite constellation by the DOD will be critical to complete the EEZ surveys and will be less expensive to operate than Starfix.

New Charting Products

The C&GS maintains 996 nautical charts; 342 were published as new editions during 1992. A total of 169 charts depict the territorial sea limit and the contiguous zone (6.5-km/12-mile limit), 56 show the EEZ (108-km/200-mile limit), 29 show the natural resources boundary (5.5-km league limit), 283 depict LORAN-C, and 25 contain the OMEGA electronic positioning system.

Implementation of the new adjustment of the NAD 83 in the nautical charting program began in May 1985. This adjustment involves shifting the existing charted projection and (or) adding datum reference and transformation notes to nautical charts. By the end of 1992, 889 charts had been adjusted to the NAD 83.

The DMA produced five new charts in Africa during fiscal year 1992. Four are Approach Charts, and one is a Harbor Chart covering Angola, Somalia, Nigeria, and Egypt.

The DMA's weekly publication "Notice to Mariners" advises mariners of matters affecting navigational safety, including new hydrographic discoveries, changes in channels, and modifications to navigational aids. It presents information affecting "Coast Pilots," "Sailing Directions," "Fleet Guides," catalogs and nautical charts, "Light Lists," "Radio Navigation Aids," and other publications that require updating. "Sailing Directions" are designed to assist navigators in planning voyages, even an ocean passage. This DMA series is compiled by ocean basin, such as the North Atlantic, South Pacific, Indian Ocean, etc. A planning guide for each area describes oceanography, meteorology, countries, and routes and is accompanied by two or more enroute publications describing approach and coastal information. The series consists of 46 publications and is designed for modern deep-draft ships provided with electronic navigational and communication equipment. Graphic directional displays supplement the text and provide mariners with recommendations for approaches to channels, harbors, and anchorages. Photographs, coastline displays, and navigational aid drawings are also used to identify landmarks.

Nautical Chart Manual

The completely revised "Nautical Chart Manual, Seventh Edition" was issued during 1992. The two-volume manual contains eight chapters and four appendices defining C&GS policies, procedures, and other information required for nautical chart production.

Also covered is the historical background of C&GS, its area of nautical charting responsibility, the legal requirements for the mariner to use appropriate-scale, up-to-date charts in U.S. ports; the relationship between C&GS and international charting authorities; and C&GS coordination with international standards.

The reference section of the manual contains an extensive glossary of terms that was compiled from more than 40 authoritative national and international reference works. It also includes a list of abbreviations used in the manual, a summary of C&GS-approved standards and specifications for symbols used in charting, an extensive appendix, and an index.

Photogrammetric Surveys

The photogrammetric surveying mission of NOAA, provides new coastal and special survey data in graphic and digital form and associated information for the production of nautical and aeronautical maps and charts. Photogrammetric survey data and aerial photographs are available to other Federal, State, and local agencies and the public. Program activities include aerial photogrammetric surveys, coastal mapping, shoreline surveys, aids to navigation placement, nautical chart revisions, airport obstruction surveys, obstruction chart production, submerged aquatic vegetation mapping, marine sanctuary boundary demarcation, glacier mapping, and Alaska boundary working group projects.

Kinematic Global Positioning System (GSP) in Photogrammetry

Development of an operational capability for GPS-controlled photogrammetry is still being pursued. Nautical Charting Research and Development Laboratory scientists continue to work closely with NOAA on all shoreline mapping projects. Real-time positioning with GPS also is used to acquire strips of photographs precisely where they were planned.

The C&GS is transferring this technology in order to assist others in developing a similar capability. The U.S. Army Corps of Engineers is developing their GPS capability using private sector contractors and C&GS personnel consulting services. The U.S. Forest Service, assisted by personnel from Trimble Navigation, Inc., and a private aerial survey firm, completed testing GPS-controlled photogrammetry using C&GS-developed software. The C&GS completed a preliminary computer simulation for the Minerals Management Service (MMS), who is interested in using GPS-controlled photogrammetry to measure surface current velocities in the open ocean by photographing floating targets. C&GS is planning to assist MMS in conducting a feasibility demonstration in early 1993.

This technology is shared through committees and working groups of the American Society for Photogrammetry and Remote Sensing and the International Society for Photogrammetry and Remote Sensing.

Integrated Digital Photogrammetric Facility (IDPF)

The IDPF is being developed to meet C&GS's needs for accurate, feature coded, digital photogrammetric source data. Specifically, the IDPF supports ANCS II, HDAPS, and the Aeronautical Obstruction Charting (OC) Program. The IDPF also facilitates digital exchange between the C&GS and other Federal agencies that employ similar systems. The IDPF couples advanced photogrammetric technology with computer graphics and a relational data base management (RDBM) system. Begun in 1984, the IDPF was operational 1987. The system's capabilities, then limited to aerotriangulation, were expanded to a complete compilation package in 1989. The final developmental phase was completed in September 1992. The various IDPF data bases will run under the digital RDBM system with additional application programs.

The IDPF configuration consists of five stereoviewers and their peripherals, which creates photogrammetric workstations, linked as a network sharing a common data base. The three data bases are: (1) the project data base, (2) camera calibration data base, and (3) the OC data base.

In support of the FAA, the Airport Obstruction Chart Database (OCDB) was interfaced with programs such as the data base editor, obstruction data sheet report generator, and related graphics. A computer program was developed to model the three-dimensional approach surfaces over any airport. This software will be integrated into the IDPF and the OCDB for online obstruction penetration analysis.

Advanced Correlation Technology

Advanced Correlation Technology (ACT) was started in 1988 using an existing C&GS instrument and correlation algorithms developed by Dr. Uki Helava. The Laser Mann Automatic Stellar Comparator (LMASC) is an existing comparator at the C&GS. Currently, the correlation system has several measuring functions. These functions include hierarchical relaxation correlation for robust measuring of conjugate image pairs, least squares correlation for accurate measuring of multiple conjugate images, density centroid for pointing on circular images, and cross-centering for pointing on the intersection of two lines. Combinations of these functions were integrated using application software for aerotriangulation and various types of calibration plate measuring. A triangulation package was developed that is compatible with the IDPF. Other enhancements to the correlation engine will improve its speed and ease of use.

Shoreline Delineation from Multispectral Images

A primary function of NOS is the accurate delineation of the shoreline of the United States and its territories. Several types of boundaries are determined from this delineation. Currently, this delineation is a manual tracing process from photographs in sophisticated photogrammetric instrumentation. The process has two important features. First, it can be applied to virtually any digital data set. These data sets include digital data from scanned aerial photographs and satellite or airborne remote sensing images. Second, it provides for human assistance when needed. Currently aerial photographs are used because of their availability and superior accuracy, but various multispectral sensors, both satellite and airborne, can be used when their availability and accuracy match the demands of shoreline delineation.

Development is in Phase II. The software development is targeted for existing microcomputer platforms. The completed system will support input from various multispectral data sets and produce vectorized shoreline data in formats compatible with NCD operations. The system combines classification, vectorization, geocoding, and editing processes to produce a polygonal extraction of an edge shared by two continuous surfaces, land and water. The classification provides constructive human intervention which significantly enhances the efficiency of the process.

AERONAUTICAL CHARTING

The NOS's aeronautical charting program consists of the compilation, printing, and distribution of charts and digital files of the United States and its territories to meet the requirements of civilian and military aviation. Approximately 15,000 aeronautical charts are produced annually for use by air flights in the National Airspace System. Chart and digital data file maintenance is required to support the update cycle for the program.

The aeronautical charting program is divided into visual, instrument, and special products activities.

Visual Program

The visual program produces 182 different charts that provide information to pilots flying under FAA visual flight rules. These charts are revised every 6 to 12 months, with approximately 2,500,000 copies distributed each year. The following tasks were performed during 1992:

- All VFR flyway planning charts were converted to the new four-color specifications. The new specifications require the aeronautical features to be portrayed in the same color as used in the terminal area chart (TAC) series. Additionally, town outlines were depicted on all VFR flyway charts.

- Three (or four) character alphanumeric identifiers were depicted on all public use airports shown on the sectional charts, TAC's, VFR flyway planning charts, and helicopter route charts. The identifiers were added immediately after the airport name, in parenthesis.

- A new edition of the "Aeronautical Chart Catalog," dated 1992-94, was published. The catalog lists several new products and some previously canceled products. Prices are listed on a one-page insert.

- A new edition of the "Visual and Instrument Aeronautical Chart Subscription Order Brochure" was published. The brochure includes all aeronautical charts and related products, prices, and general information for ordering.

- A prototype of the Lake Huron sectional chart was published. The prototype depicts the reclassification of U.S. airspace, which will become effective on September 16, 1993, and new symbols proposed by the National Airspace Review. This new symbology will be used beginning with the visual aeronautical charts published in 1992.

Visual aeronautical charts are flight checked every 3 years by a rotating crew of NOAA commissioned officer pilots flying a U.S. Government-owned aircraft. During 1992, the flight check program reviewed 17 aeronautical sectional charts and their associated TAC's, as well as 123 minimum safe altitude warning areas in the conterminous United States. These flight checks contributed more than 2,000 potential base feature changes and in excess of 1,200 aeronautical changes for chart compilation. More than 478 photographic sites

were compiled, and 1,165 obstacles were measured (273 were new obstructions not contained in the data files, 82 obstructions had been dismantled and were relabeled in the files, and 810 obstacles were reverified for horizontal position and vertical accuracy). This combined photographic and stereoplot operation yielded 93 percent usable data return. The flight check program permits the resolution of source data inconsistencies and provides pilot input to the compilation and design of visual aeronautical chart products.

Instrument Program

The instrument approach procedures chart program provides approximately 7,500 charts and products that are used by civilian and military pilots in 17 volumes distributed across the country. Almost 20 percent of the charts are subject to revision every 56 days. A Banyan Vines local area network and RBASE data base management software is used to cross reference charted items including airports, fixes, radio facilities, and special use airspace. In 1992, a desktop publishing system produced camera-ready copy for all alternate minimum, take-off minimums and departure procedures, radar minimums, and indexing tabulated data found in the 17 volumes.

The NOS supports the FAA by quality controlling all procedural information before publication. Also, the NOS produces 85 airport diagrams for inclusion in the FAA airman information publication (AIP). The NOS produces duplicate negatives for approximately 65 percent of the charts specified for inclusion in the DMA military FLIP publications for the United States.

During 1992 the following accomplishments were realized:

- The conversion of the IFR enroute chart series from two to four colors is in the final phase. The first phase, the enroute high altitude charts, was accomplished using standard cartographic practices -- manual compilation and drafting. The second phase, the Alaska low altitude charts, was accomplished using computer-assisted cartographic techniques. Drafting was manual. The third and final phase, U.S. enroute low altitude charts, is under preparation. Data files were built, and compilation and drafting were fully automated. The chart series, consisting of 28 charts, is scheduled for printing September 1993.

- The air traffic control system command center charts, discontinued in 1991, were reinstated by the FAA. The charts were reformatted and recompiled. These charts are used by the FAA's central flow control and central altitude reservation personnel to coordinate, plan, and approve the flow of VIP travel. The last chart, of the nine-chart series, was printed in 1992.

- Two new controller charts were compiled and printed in 1992. These charts give FAA air traffic controllers complete coverage of the U.S. at a scale of 1:500,000.

- At the direction of the FAA, a controller chart (CC) prototype containing military training routes was compiled. The chart was used to determine if the CC is a suitable vehicle for providing this type of information to air traffic controllers.

- The Dallas-Ft. Worth airspace is undergoing an extensive reconfiguration that will affect airways, routes, facilities, altitudes, and fixes - indeed most airspace within 100 miles of the airport. In support of this effort, the FAA was provided with a Dallas-Ft. Worth area planning chart. As new airspace is developed it will be depicted on the planning chart.

- Effective October 1992, the horizontal geodetic referencing system used in all charts was changed from the NAD 27 to the NAD 83. All data base coordinates and all charted coordinates were converted to NAD 83.

- The FAA implemented a less complex airspace system. Formerly used acronyms will be replaced by the six internationally recommended alphabetic classifications (A, B, C, D, E, and G). The first phase was to revise control zones and transition areas; charts will show both old and new classifications during the transition. On September 16, 1993 the airspace will be fully reclassified. Prototype charts were provided for evaluation and training.

- Over 1,400 radar video maps (RVM's) were produced for the 211 FAA airport surveillance radars serving 300 facilities. The video maps depicted on radar displays are specified by the air traffic control facility. Each map represents an accurate stable representation of the airways, fixes, boundaries, and runway extension lines that meet the unique requirements of each facility. All radar maps were converted to digital files. This process improved the accuracy of these maps and also made them available for use in other products.

- A new Digital Bright Radar Indicator Tower Equipment (DBRITE) system was developed by the NOS. The system, completed in January 1991, provides digitally displayed RVM's. Instead of a 2.3-inch RVM plate, the data are stored on a erasable programmable read only memory chip. Hardware is being installed at 350 FAA facilities, and maps have been provided to approximately 250 of these facilities. As equipment is installed at the remaining sites requests for the maps will be completed. All 1,400 RVM's are converted to digital files for use in DBRITE.

- A new printing and distribution contract planned for 1993 will produce all volumes in shrink wrap packaging with a 4-ring binder to eliminate the bound volume foldover problems in the cockpit.

Special Products and Services

The special products and services program provides obstruction charts, digital data, and information on obstructions to navigation. The NOS maintains an automated data base containing obstacle information and other data. Nearly

2,500 different charts are produced annually, with revision cycles varying from 28 days to 2 years.

Compilation of 233 FAA-sponsored minimum safe altitude warning system sites was completed. The project is now directed toward continuous maintenance at 6-month intervals and recompilation of 14 to 20 sites per year for relocations and magnetic variation changes.

The digital obstacle file has grown to over 63,000 structures affecting air navigation. Heights and locations of these obstructions are continually verified and maintained in a unique digital data base that is available to the public in a hardcopy format.

The NAVAIDS file maintained by NOS is now available to the public in digital format. The NAVAIDS file contains data fields including the NAVAID identifier and type, name, geographic positions, frequency, channel, elevation, magnetic variation, and the State or country. This data supports both civil and military navigation systems.

The digital aeronautical chart supplement (DACS) is available to the public in digital format. The DACS is a composite of information used in conjunction with aeronautical charts and provides ground coordinates needed by air traffic controllers, aviation system developers, and the general aviation community for flight planning. The DACS provides digital information in a usable, convenient, and timely format not otherwise readily available to members of the flying public, the FAA, and to air traffic control personnel. All nine sections of the supplement are available in either 3 1/2-inch or 5 1/4-inch diskettes.

The special use airspace files were automated to reflect the new airspace reclassification descriptions of all regulatory airspace. This data base gives ground coordinates necessary for graphic portrayal of regulatory and nonregulatory airspace. Alert areas, prohibited areas, restricted areas, airport radar service areas, transition areas, and control zones are among this airspace. Completion of this data base coincided with the publication of the final rule descriptions or reclassified special use airspace in the Federal Register dated August 27, 1992.

GEOGRAPHIC NAMES

Since 1989, the United States has continued to be active in a number of programs involving the study and treatment of geographic names. These programs are carried out principally under the authority of the U.S. Board on Geographic Names (BGN). The BGN is an interdepartmental organization legally responsible for standardizing geographic names for official U.S. purposes. Working in conjunction with the U.S. Secretary of the Interior, the BGN receives technical support from the USGS and the DMA. The 100th anniversary of the BGN was celebrated in 1990.

Gazetteers of 22 foreign areas have been published under the direction of the BGN since 1989. A current focus of the BGN is to record new names resulting from political events in Eastern Europe and the former Soviet Union.

A periodical entitled "Foreign Names Information Bulletin" was recently issued by the BGN. In addition, the BGN prepared guidelines on automated names processing, terminology, training, and other related topics.

BGN support continues for United Nations initiatives involving geographic names. In addition to several meetings of the United Nations Group of Experts on Geographical Names (UNGEGN), BGN representatives participated in the Sixth United Nations Conference on the Standardization of Geographical Names held in New York from August 25 through September 4, 1992. The conferees adopted new aims and functions proposed by the U.S. delegation calling for more training courses and other practical programs.

A paper prepared by the U.S. delegation to the Sixth Conference focusing on the important relation of names and cartography, generated a subsequent UNGEGN study. Several countries were surveyed on the topic and most respondents agreed on the following: (1) national cartographic agencies should support the creation and operation of names authorities, and (2) names issues should be added to the agendas of United Nations regional cartographic conferences. THe DMA will now offer to assist countries in the creation or improvement of national names programs as part of cooperative mapping programs.

Automated names processing techniques developed by the USGS and DMA have greatly benefited the work of the BGN. The automated Geographic Names Information System (GNIS), designed by the USGS in 1975, is capable of providing information on almost 2 million feature names used throughout the United States and its territories. The USGS recently embarked on a major program to modernize the GNIS. The new system should be operational in about 3 years. The primary purpose of the GNIS is to support the USGS and other civilian mapping agency activities; other users can apply the information in situations requiring the analysis of geographic names data. Standard and special reports from the data base are available on paper, microfiche, magnetic tape, and compact disk. The GNIS is the basis for the State volumes of the National Gazetteer series published under the direction of the BGN.

The DMA is developing the Geographic Names Processing System (GNPS) to support increasing BGN and DMA requirements for names. The GNPS will enable DMA to convert its manual files containing information on approximately 4.5 million geographic names of foreign areas into a format suitable for automatic data processing. The DMA is developing a prototype of a digitially produced gazetteer.

DIGITAL CARTOGRAPHY

The USGS has collected and archived digital cartographic data from standard USGS maps and from aerial photographs since 1979 as part of its National Mapping Program (NMP). The USGS digital cartography program has rapidly become the central focus of the NMP. Most mapping research within the USGS is now aimed at expanding automated cartographic data collection, processing, revision, and product generation capabilities; at enhancing digital line data by adding feature layers to existing topology; and at increasing data use through applications employing geographic information systems.

The digital cartography program produces and archives two basic types of data: digital line graphs (DLG's) and DEM's. Both types are essential elements in automated digital revision and product generation procedures being developed. They are also key data layers for numerous land and resource management and geographic information system applications by Federal, State, and local agencies and the private sector.

Digital Line Graphs (DLG)

The DLG is a digitized map data set representing points, lines, and areas in vector form. DLG's are topologically structured with identifiers that express the spatial relationships between map features appearing on a printed map. They are also encoded with attributes representing topographic map symbols. DLG data layers being produced include the Public Land Survey System (PLSS), boundaries, hydrography, transportation, hypsography (contours), manmade features, survey control, vegetative surface cover, and nonvegetative features.

The collection of boundary, hydrography, and transportation DLG data is complete for the 1:2,000,000-scale National Atlas sectional map series. These 1:2,000,000-scale DLG's will be updated over the next several years. Hydrography and transportation data were collected at 1:100,000 scale for the conterminous United States and Hawaii, with completion of PLSS, boundaries, and hypsography planned for the mid-1990's. To date, about 48,000 DLG's have been prepared and archived for the 1:24,000- and 1:63,360-scale map series.

Digital Elevation Models (DEM)

The DEM is a sampled array of elevation values portrayed at regularly spaced intervals along south to north profiles that are ordered from west to east. The DEM's are referenced horizontally either to a cartesian UTM or to a geographic coordinate system. The USGS distributes DEM's produced by the DMA covering 1° x 1° blocks from the 1:250,000-scale map series.

National Digital Cartographic Data Base (NDCDB)

Digital cartographic data sets reside in a centralized USGS archiving and distribution system, the NDCDB. The data are stored on magnetic tapes in separate DLG and DEM data bases for each major map series. The data are distributed through the USGS Earth Science Information Center and are

available on 9-track tapes at either 1,600 or 6,250 bpi density. DLG data are distributed in either a standard or optional format. The standard format, which limits topological linkages to line elements, is oriented toward generating map graphics. The optional format includes linkages for all lines, nodes, and areas, which allows the creation of a polygon data structure useful in geographic information systems applications. The development of products on CD-ROM is also underway.

Advanced Cartographic System Developments

The computer changed the practice of mapping in the United States. For more than 40 years the USGS has provided map users with primary quadrangle map coverage of the United States at 1:24,000 scale in the lower 49 States and at 1:63,360 scale in Alaska. Initial national coverage of the graphic products for the lower 49 States was completed in 1990. The Alaska coverage is completed on the mainland. In recent years, however, it has become apparent that digital versions of these maps must be produced to support a computer-oriented society.

In 1979, the USGS's Digital Cartography Program was formally initiated. This modernization program will implement advanced technologies and production procedures to satisfy NMP requirements through the year 2000. The most critical of these requirements is population of the NDCDB with digital data representing the content of primary map series and other smaller scale series. The NDCDB will serve two major functions: (1) as a central archive for the dissemination of digital data to the user community for information systems analysis, and (2) as a working data base for production and revision of digital and graphic map products.

To accomplish this development, the following tasks are being implemented: expanding and improving mass digitization capabilities; modifying data structures to support increased content and access requirements; developing digital revision capability; developing product generation capability for standard, derivative, and digital products; improving quality control; and supporting production and data management.

Specific requirements for the NDCDB contents and related production processes have been identified in order to satisfy the overall modernization objectives. These requirements cover sources of data, categories of data, levels of data integration, data revision, data quality, and both digital and graphic products to be produced from the NDCDB.

The Digital Cartography Program is divided into 11 project areas: production management, digital cartographic production segment, digital revision, data collection, orthophoto production, digital line graph-enhanced, modernization-product generation, spatial data transfer standard, data bases and inventories, sales and distribution, and telecommunications. The development emphasis within the modernization program is on proven off-the-shelf digital technology (considered a low development risk) that will provide a flexible production capability to support USGS requirements. In-house development activities required to maintain and enhance current production and the

integration of commercial procurements with existing operations are a large portion of the modernization program.

Geographic Information Systems (GIS)

The rapid development of GIS technology continues. Mathematical modeling, visualization, statistical analysis, object oriented systems, artificial intelligence, and neural networks are being merged with GIS's; multiscale, multisource, temporal, vector, and raster data are being integrated with GIS's. The scale of applications is expanding from regional to global. Some applications, such as forest fire control and airborne pollution can be operated in real time. Desktop publishing is available to move GIS analytical output and displays directly into publications. GIS technology is used in decision support systems and policy analysis and has become an integral part of map production and revision.

The USGS is moving its spatial data processing applications from a national network of minicomputers to a distributed network of file servers and workstations. Some 3,000 UNIX-based, high-performance workstations and 200 file servers are already in use for earth science studies. About 1,000 USGS scientists are using GIS technology. This number could triple over the next 4 years.

The USGS is developing cost effective techniques for using remotely sensed data (satellite and aircraft) and for merging and analyzing these data with digital cartographic, geologic, hydrologic, and other earth science data sets to build comprehensive GIS's to inventory, monitor, and manage natural resources. Recent research accomplishments include: (1) algorithms and data processing procedures for automated derivation of hydrologically related terrain characteristics from DEM's; (2) procedures to enhance and merge satellite image data with other earth science data sets; (3) techniques for using topographic, cartographic, and geochemical data sets for modeling the occurrence of toxic elements such as radon and selenium; (4) prototype software to exchange data between a number of different GIS's; and (5) assistance to other GIS users in linking disparate spatial data bases and in conducting GIS projects that apply to local, State, national, and international earth science projects.

The USGS participates in cooperative remote sensing and GIS demonstration projects and training activities. The purpose of cooperative projects and training courses is to transfer remote sensing and spatial data analysis techniques to environmental scientists of other organizations.

Digital Line Graph-Enhanced (DLG-E)

The USGS faces the task of providing users with up-to-date digital data and, at the same time, enhancing the structure of that data to meet changing needs. It is not sufficient to automate the mapmaking process for reproducing graphics; spatial data users require a data structure that can support complex queries and the analysis of thematic information to answer national (and global) problems.

To address this need, the USGS has created a modernized and enhanced version of its DLG vector data structure called DLG-E. This new structure is feature-based to resemble the way physical surroundings are perceived. The features shown on a map, such as roads, streams, or buildings, are represented by corresponding "features" encoded in the digital file. Over 200 features derived from USGS topographic maps have been defined. These features are further described by attributes that define such characteristics as name or function and by relationships that describe such interactions between features as flow through a network or features that bound one another.

Ultimately, all features in the DLG-E model are linked to the spatial components that comprise them: polygons, chains and nodes. The expression of topology occurs at the spatial level in the file, just as in existing DLG files. The current DLG files, however, also encode feature-level information at the spatial level through a series of attribute codes attached to each spatial element. This limitation serves to point out the most important advantage of DLG-E - the separation of spatial components from nonspatial components for more flexibility in manipulating the data base.

Implementation specifications are being generated to explain how spatial data is described and manipulated. These specifications are currently being developed for the 1:24,000- and 1:100,000-scale map series and include delineation specifications describing what a feature looks like on the ground; extraction specifications describing when a feature is collected from the source for inclusion in the data base; representation rules describing how a feature is represented in the data base; product specifications describing when a feature from the data base is included on the graphic; and product generation rules providing for symbolization, generalization, conflict detection and resolution, and names and label placement for graphic production. A standards data base is being developed that will integrate DLG-E rules and content specifications directly into data collection and production operations.

A DLG-E production system is under development that will collect, revise, and validate digital spatial data. A prototype system has been built and test data sets have been generated. The DLG-E data model provides the USGS with a flexible tool to support the Nation's fast-growing spatial data needs into the next century.

The Spatial Data Transfer Standard (FIPS 173)

A major milestone for the spatial data community occurred on July 29, 1992 - the approval of the Spatial Data Transfer Standard (SDTS) as Federal Information Processing Standard (FIPS) Publication 173. The SDTS facilitates the transfer of digital spatial data between dissimilar computer systems. FIPS 173 becomes effective February 15, 1993; use of the standard is mandatory for all Federal agencies 1 year from this date, by February 15, 1994.

The USGS, as the FIPS 173 maintenance authority, is committed to involving the spatial data community in various activities to promote acceptance of FIPS 173 and support FIPS 173 implementations. Additional approvals will be sought from the American National Standards Institute and the International Standards

Organization during 1993 to broaden access to the FIPS 173 among the commercial and international communities.

The USGS will coordinate the development of profiles within the user community to ensure maximum consistency among all FIPS 173 profiles. A profile is a clearly defined and limited subset of a standard that is designed for use with a specific type of data. The first of these profiles, the Topological Vector Profile (TVP), underwent a rigorous test and review period in 1992 and will soon be submitted to the National Institute for Standards and Technology (NIST) for approval as an amendment to FIPS 173. USGS DLG data will be available from the NDCDB in the TVP when it is approved as an amendment. The USGS started development of a raster profile that will follow a similar sequence of events as those for the TVP - developing a draft profile and test data sets, conducting a test and demonstration period to evaluate completeness, and completing the profile based on test results. The raster profile will probably be limited to georeferenced data, sampled uniformly and in a geodetic or cartographic coordinate system, rather than including raw sensor data. Additional profiles, such as those for State and local, utilities, and graphics profiles, will also be considered in the future.

In addition, the USGS is developing a suite of public domain software tools designed to support the encoding and decoding of logically compliant FIPS 173 data in and out of the required ISO 8211/FIPS 123 physical file implementation. The USGS is designing a spatial data transfer processor to support FIPS 173 transfers of its own digital spatial data. Requirements for conformance testing software are being determined by the spatial data community.

Part 2 of FIPS 173 presents a standard model for a spatial features data dictionary and a list of terms and definitions for entities and attributes. This model currently contains only a limited set of hydrographic and topographic features. For part 2 of FIPS 173 to be useful, additional terms and definitions must be included for other types of data. The USGS has been authorized by the NIST to establish a FIPS Spatial Features Register to accomplish this effort. A strategic plan to maintain part 2 using the FIPS Spatial Features Register is being developed and will be completed at a national forum to be held early in 1993. The Federal Geographic Data Committee (FGDC) is actively involved in developing the register and cosponsoring this forum. Because the register will allow users to update the glossary continuously, part 2 of FIPS 173 will evolve over time.

Federal Coordination

Established by the revised Office of Management and Budget Circular A-16, the FGDC coordinates surveying, mapping, and related spatial data activities among Federal agencies and between the Federal and non-Federal communities. Fourteen departments and independent agencies are members of the FGDC, including the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; and the Tennessee Valley Authority. The Department of the Interior chairs the committee. The circular also assigns

governmentwide coordination leadership responsibilities to Federal departments for data categories as listed in table 1.

Table 1. Geographic data coordination responsibilities assigned by the revised Office of Management and Budget Circular A-16.

Geographic data category	Lead agency
Base cartographic	U.S. Geological Survey, Department of the Interior
Bathymetric	Coast and Geodetic Survey, Department of Commerce
Cadastral	Bureau of Land Management, Department of the Interior
Cultural and demographic	Bureau of the Census, Department of Commerce
Geodetic	Coast and Geodetic Survey, Department of Commerce
Geologic	U.S. Geological Survey, Department of the Interior
Ground transportation	Federal Highway Administration, Department of Transportation
Portrayal of certain international boundaries	Office of The Geographer, Department of State
Soils	Soil Conservation Service, Department of Agriculture
Vegetation	Forest Service, Department of Agriculture
Wetlands	U.S. Fish and Wildlife Service, Department of the Interior

Recent activities of the FGDC include conducting a user needs assessment for land use and land cover data; gathering information from the user and producer communities; developing a multiagency proposal to meet high-priority requirements for base cartographic data (including digital topographic data, orthophotographs, and nautical charts) for the Nation; assisting in the completion of the SDTS to reduce technical barriers to data sharing; sponsoring a public review of a content standard for spatial metadata; developing a recommendation of means for long-term cooperation between the Federal and non-Federal communities; and publishing a "Manual of Federal Geographic Data Products," which describes publicly-available Federal geographic data sets.

Other Mapping Organization Data

The USGS adds data produced by other mapping organizations to the NDCDB and uses these data in the digital revision process. A USGS practice is to use other organizations' data to the fullest extent possible whenever it is practicable and economical.

To encourage cooperative efforts with other organizations to produce and share digital data, guidelines have been developed for acceptance of base category data into the NDCDB. At the present time, these guidelines address acceptance criteria only for base cartographic data collected from USGS source graphics.

GLOBAL CHANGE

The U.S. Global Change Research Program (USGCRP) is a coordinated effort involving seven departments and agencies of the U.S. Government and numerous academic research institutions. It sponsors studies of the atmosphere, oceans, and land surface; the physical, chemical, and biological processes that occur in these environments; and the linkages between them. The program focuses activities in four areas: (1) observation and data management; (2) process research to understand the physical, biogeochemical, and social processes that influence Earth system behavior; (3) development of integrated models for prediction; and (4) assessments of the state of scientific knowledge and the implications for policy making. Interdisciplinary studies are emphasized as well as the development of an integrated understanding of large-scale environmental processes and causes of environmental change. These areas are organized under four themes that integrate the scientific research: (1) greenhouse gases, aerosols, and ozone; (2) water, energy, and sea-level; (3) ecological systems and (4) economics and human interactions.

The USGS manages and facilitates access to global land data sets that support global change research and is developing land characterizations for use in modeling land processes and their interactions with the hydrosphere and atmosphere.

The availability of geographic data to the global change research community is often limited by the difficulty of access to metadata, that is, information about the data such as data holdings, data quality, and so on. Improved access to metadata is being addressed through the development of the Global Land Information System (GLIS), an online information system that provides users with information about geographic data holdings via network access from a personal computer. Queries by date, location, and data type and quality will be supported, and some classes of information will be portrayed graphically on the user's computer.

The USGS is also working to preserve a unique and consistent set of observations of land characteristics and conditions obtained over the last 20 years from the Landsat Program. The Landsat data maintenance and conversion project is an effort to convert the Landsat MSS and TM data archive from high-density tape to longer life, computer-compatible media.

APPENDIXES

The following appendixes contain information on selected digital cartographic capabilities and systems supplied by the principal Federal agencies that contributed to this report. The agencies can be contacted for additional information on their activities.

APPENDIX I

Defense Mapping Agency Automated Cartography

The Defense Mapping Agency (DMA) is improving present production processes with a new program called the Digital Production System, to be implemented in two phases, MARK 85 and MARK 90.

The first phase, MARK 85, modified and supplemented existing production equipment to provide an interim capability to exploit new source materials. The MARK 85 has six segments that support existing production procedures and operates primarily in a hard-copy environment.

The MARK 85 provides computer software to implement photogrammetric models to a variety of existing DMA hardware, as well as to modern interactive workstations capable of semiautomatic terrain and feature extraction. This system inventories all DMA source holdings and plans production for all DMA projects.

The second phase, MARK 90, delivered in 1992, provides the end-to-end digital production system that replaces most of the current production line and significantly enhances productivity. The MARK 90 is being developed in five segments. When linked together, the system has a fully integrated production capability. Three segments of the MARK 85 are included in the MARK 90 to support required production capabilities.

The MARK 90 builds upon the MARK 85 to enhance production and program management for the DMA. This system will accomplish automatic terrain extraction and semiautomated feature extraction. Feature delineation and attribution are facilitated using knowledge-based engineering. All extracted data will be stored in a data base where these data can be generalized and segregated to produce a defined set of DMA products.

APPENDIX II

The Modernization Program at the U.S. Geological Survey

The goal of the U.S. Geological Survey (USGS) modernization program is to implement advanced technologies and production procedures that will satisfy project requirements through the year 2000. This program will fulfill national requirements for up-to-date cartographic data and graphic products that are produced more quickly and efficiently.

To accomplish this goal, tasks are being implemented to (1) expand and improve mass digitization capabilities; (2) modify data structures to support increased content and access requirements; (3) develop a digital revision capability; (4) develop a product generation capability for standard, derivative, and digital products; (5) generate a digital orthophoto production capability; (6) improve quality control; and (7) develop production and data base management capabilities. The modernization program will lead to an advanced digital cartographic production capability by the mid-1990's.

The development and implementation of the modernization program will exploit state-of-the-art mapping technology and will result in a highly responsive digital cartographic production system. The timing of this developmental effort is necessary to meet Federal requirements for digital and graphic cartographic products, and state of available technology will support the effort.

APPENDIX III

National Ocean Service Automated Chart Production

Nautical Charts

The Coast and Geodetic Survey (C&GS) has entered into a long-term contract for the development of the second-generation automated nautical charting system (ANCS II), which will lead to the automated production and maintenance of NOAA's nautical charting products. The ANCS II will include three primary data bases: the Navigation Information Data Base (NIDB), the Chart Graphics Data Base (CGDB), and the Production Control Data Base (PCDB). The NIDB and the CGDB reflect a dual data base design strategy that separates real world geographic data extracted from source documents from the highly symbolized cartographic products data. Although both data bases are physically integrated, they are logically separated based on the different functional capabilities required for document and data management and chart maintenance and production tasks. When completed, the ANCS II will employ RISC-based color graphic workstations, which will be physically distributed through the NCD Ethernet. A systems acceptance test is planned in late 1993.

Two milestones were accomplished during 1992. Phases two and three of ANCS II functional software were delivered as scheduled. The software is being developed and delivered in five incremental phases. The software delivered in phase two and three represents about one-half of the total cartographic function for the ANCS II.

The second software milestone was a bit mapping strategy developed for generating feature symbology in the ANCS II. Feature symbology is generated based solely on its features attributes. The attributes are stored in one of several relational Oracle feature and attribute tables. Custom software was developed to perform all the low-level validation checks required to ensure feature symbology attributes exist. A symbol cell library was developed for both the NIDB and CGDB.

A 15 year effort was completed for data collection for a 50-chart test area. Procedures are being developed to load and populate the NIDB, CGDB, and PCDB. When these data bases are loaded, they will be used for a functional test, followed by a rigorous 6-month trial production test, and a final system acceptance test. The ANCS II is scheduled to become operational in 1994.

Automated Chart Compilation Program

Version 1.0 of the CartoAssociate cartographic expert system prototype was completed. The objective is to develop an embedded expert system capability that can be installed into conventional digital cartographic production systems. The C&GS plans to install the CartoAssociate into the ANCS II where the embedded system will assist cartographers in performing specific decision-making processes of a detailed nature. These chart compilation processes include symbol selection, spatial conflict detection and resolution, feature generalization when changing scales, and text placement.

When operational, the CartoAssociate will increase productivity by reducing the level of operator interactions required to compile nautical charts. Its use also will reduce operational costs by simplifying the operator actions required to invoke specific ANCS II actions. The product quality will be improved because of increased consistency of feature portrayals by using the same set of rules for all feature types.

Version 1.0 was developed on the Tektronix 4317/DEC Vax platform and performs all functions required to:

- represent nautical features as cartographic objects and store and manipulate them as software objects in an object data management system;
- represent and manipulate complex chart features, for example shipping channels, as composite data base objects using an expert system and knowledge base of cartographic rules to support autonomous processing functions;
- autonomously compile nautical chart features (channels, buoys, hazards, soundings, etc.) by detecting and resolving spatial conflicts between nearby features or text, by determining symbols for individual features, and by deducing symbolic portrayals for groups of features; and
- autonomously place text for point features, such as buoys, wrecks, pilings, rocks, and soundings.

All functions were implemented using object-oriented applications development software, an object-oriented data base management system, and an expert system shell and knowledge base.

The CartoAssociate version 2.0 was initiated with the acquisition of a more powerful hardware platform, a Sun SPARCstation II. The hardware and software platform for this phase of the project is being funded by the Department of Commerce Pioneer Fund grant won by the Techniques Development Group in 1991. The prototype is being designed under an object-oriented software development and in a data base environment using the UNIX operating system with the X-Window, Smalltalk-80, and C languages over standard TCP/IP network protocols.

Marine Data Computer Bulletin Board

A computer bulletin board, which runs on an IBM-compatible microcomputer, provides public access to existing nautical charting digital data. Users are able to log on using a PC, modem, and ordinary telephone lines. The bulletin board is menu driven and easy to use. Callers may search the available data bases and download results as compressed text files. Initially, 20 data bases will be online including wrecks and obstructions, nautical chart locator, airport mapping photos, sediment data, and tide stations. Additional data bases will be added as they become available. The bulletin board is a means for assessing the demand for and uses of nautical charting digital data.

Aeronautical Charts

Aeronautical charting requirements have grown steadily over the past decade - most products now must be revised every 56 days. To meet these demands, automated techniques must be applied to a number of cartographic functions. Although similarities exist between the automation efforts in both nautical and aeronautical charting, each has unique requirements that can best be met by somewhat different approaches. For the present, each system will evolve essentially independent of the other. Common use of compatible equipment will be used whenever possible.

An overall system containing a central host computer interfaced with graphic workstations and special digitizing subsystems is needed. A unique digitizing capability is necessary to the overall system concept because of later upgrades of the host computer. Past experience has shown that specially configured and modified computers, and their unique operating systems that frequently incorporated turnkey digitizing systems, can be impossible to expand or upgrade at a later date. The current plan envisions the modular implementation of a comprehensive system in support of all major aeronautical charting products. This includes the automated production of chart overlays suitable for direct use in the reproduction process.

Although the automation of the topographic base for large charts was never a goal, the Aeronautical Information Data Base will be capable of directly supporting graphic overlay compilation, overlay production, and generalized support for all products. Over 2,500 press ready photo scribe plots were produced in 1992 to support chart production and 670 erasable Programmable Read Only Memory's to support the Digital Bright Radar Indicator Tower Equipment.

The Federal Aviation Administration's (FAA) multibillion dollar upgrade to the National Airspace System is known as the Advanced Automation System (AAS). The overall objective of AAS is to accommodate the spiraling demand for aviation services into the 21st century. The system configuration is a local area network of four computer servers with a combined storage of 20 gigabytes that connects over 100 graphic and alphanumeric workstations located in the chart compilation areas.