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COUNTRY REPORTS ON THE CURRENT STATUS AND ISSUES OF SURVEYING, CHARTING AND MAPPING AT THE NATIONAL LEVEL: NEEDS AND REQUIREMENTS VERSUS REALITY IN THE REGIONS

The status of cartographic activities in the United States of America

Submitted by the United States of America**

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** Prepared by the Defense Mapping Agency, National Ocean Service, and U.S. Geological Survey.

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THE STATUS OF CARTOGRAPHIC ACTIVITIES IN THE UNITED STATES OF AMERICA

INTRODUCTION

Since the Twelfth United Nations Regional Cartographic Conference for Asia and the Pacific, U.S. cartographic activities have expanded to include advances in computer technology, remote sensing, geospatial 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.

Recent activities are discussed under the following headings:

- Geodesy and Geophysics
- Topographic Mapping
- Hydrography and Oceanography
- Aeronautical Charting
- Geographic Names
- Digital Cartography
- Remote Sensing/Imagery Processing
- Global Change
- Other Projects

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

Federal Coordination

The Federal Geographic Data Committee (FGDC), which was established by the revised Office of Management and Budget Circular A-16, 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 Secretary of the Interior personally chairs the committee. The circular also assigns government-wide coordination leadership responsibilities to Federal departments for the data categories 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
Water	U.S. Geological Survey, Department of the Interior
Wetlands	U.S. Fish and Wildlife Service, Department of the Interior

Recent activities of the FGDC include developing a strategic plan for building the National Spatial Data Infrastructure (NSDI); completing and endorsing the use of a final version of a content standard for spatial metadata; initiating a working group composed of Federal, State and local government representatives to define a national framework of basic data to support the needs of most spatial data users (including such data types as digital orthographic imagery, elevations, spatial representations of transportation, hydrography, administrative and political boundaries, and cadastral reference systems), and a plan to achieve the framework by the year 2000; pilot testing of an Internet-based electronic clearinghouse to provide public access to spatial

data holdings produced by government agencies, academia and the private sector; and initiating a program of competitive cooperative agreements with States, local governments and other sectors to bolster projects that strengthen the NSDI.

Other Mapping Organization Data

The USGS adds base cartographic 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, policy guidance has been developed for acceptance of base cartographic data into the NDCDB. In addition, the Innovative Partnership Program has been established to provide a cooperative mechanism to fund other organizations who are collecting or have existing data that can contribute to the NDCDB.

GEODESY AND GEOPHYSICS

The mission of the National Geodetic Survey (NGS) is to apply state-of-the-art methods of precise positioning and advanced geodetic techniques to establish and maintain a consistent national coordinate system and to support mapping, charting, navigation, boundary determination, property delineation, infrastructure development, resource evaluation surveys, and scientific applications. Activities in 1993 are discussed below.

Total Quality Management (TQM) and the Mission, Vision, and Goals of NGS

Nearly 60 NGS employees participated in TQM activities to develop the mission, vision, and strategic goals of NGS. The Mission Statement, Vision Statement, and 13 Strategic Goals were approved by unanimous vote of the NGS Executive Steering Committee on August 4, 1993. The mission statement appears above. The vision statement, as adopted, follows:

"The vision of the National Geodetic Survey is to lead the rapidly expanding community of users of geodetic data into the 21st century. NGS sees this community as including professionals working in the areas of geodesy, surveying, mapping, navigation, geographic and land information systems, earth orientation, and earth and ocean dynamics. This leadership will require NGS to develop and produce new geodetic products such as: global terrestrial and celestial reference frames; Earth orientation time series; absolute gravity station values; marine gravity and bathymetric maps; altimeter geophysical data records; crustal motion models; global sea level variability analysis; a high-accuracy, multi-dimensional network of monumented control points; precise satellite ephemerides; improved data processing systems; specifications for advanced surveying technologies and techniques; and high-accuracy geodetic models. NGS will pursue the newest developments in data base systems and telecommunications, as well as programs for the transfer of technology, to enable its customers to accomplish their missions in a more efficient and cost-effective manner. In pursuit of this vision, NGS will continue to use the highest standards of quality, service, and integrity."

The strategic goals are designed for the evolution from the existing National Geodetic Reference System (NGRS) to a future National Spatial Reference System (NSRS) which includes a horizontal datum, a vertical datum, a high resolution geoid model, and weekly post-fit precise satellite orbits. The NSRS will be accessible through a hierarchy of monumented points which will be established by working closely in cooperation with state governments and the user community, and through a network of Continuously Operated GPS Reference Stations.

Horizontal Geodetic Network

Processing of horizontal data into North American Datum (NAD 83) was completed for 234 projects containing 9,802 stations. Horizontal control was provided at FAA airports in Arkansas, California, Idaho, Maryland, New Jersey, Nevada, Texas, Utah, Virginia, and Wyoming. NGS presented five workshops on State Plane Coordinates and Datum Transformations, Project Planning and Network Adjustments, and Building an Accurate GIS/LIS.

Post-NAD 83 Regional Adjustments

State high accuracy reference network (HARN) surveys were adjusted for Alaska, Alabama, Arizona, Louisiana, Maine, New Hampshire, Vermont, Rhode Island, Connecticut, Massachusetts, New York, New Jersey, and Pennsylvania, bringing the total to 25 states. The integration of classical horizontal survey data with the GPS observations was completed and loaded into the NGS Integrated Data Base for Alabama, Colorado, Idaho, Louisiana, and Montana. Integration of these data is now in progress for the states of Arizona, California, New Mexico, Maine, New Hampshire, Vermont, Rhode Island, Connecticut, Massachusetts, New York, New Jersey, and Pennsylvania.

Vertical Geodetic Network

Implementation of the North American Vertical Datum of 1988 (NAVD 88) continued in cooperation with international, Federal, state, local, and private organizations. About 20 percent of the U.S. bench marks (those deleted from the general adjustment) are undergoing additional analysis prior to publication. This "posted" effort for stable areas not involving subsidence or other crustal motion has been completed.

The June 24, 1993, Federal Register, page 34245, states in part: "This Notice announces a decision by the Federal Geodetic Control Subcommittee (FGCS) to affirm the North American Vertical Datum of 1988 (NAVD 88) as the official civilian vertical datum for surveying and mapping activities in the United States performed or financed by the Federal Government, and to the extent practicable, legally allowable, and feasible, require that all Federal agencies using or producing vertical height information undertake an orderly transition to NAVD 88.

NAVD 88 supersedes the National Geodetic Vertical Datum of 1929 (NGVD 29) which was the former official height reference (vertical datum) for the United States. NAVD 88 provides a modern, improved vertical datum for the United States, Canada, and Mexico. The NAVD 88 heights are the result of a mathematical least squares general adjustment of the vertical control portion of the National Geodetic Reference System and include 80,000 km of new U.S. leveling observations undertaken specifically for this project. NAVD 88 height information in hard copy or digital form is available from the National Geodetic Information Branch, NGS."

In February 1993, NGS began distribution of VERTCON, a new vertical datum transformation software program. VERTCON computes the modeled difference in orthometric height between NAVD 88 and NGVD 29 for a given location specified by latitude and longitude. This conversion is sufficient for many mapping purposes.

The root-mean-square error of the actual NGVD 29/NAVD 88 height differences at bench marks of the National Geodetic Reference System compared with the computed height differences from the model is +/-1 cm; the estimated maximum error is +/-2.5 cm. Depending on network design and terrain relief, larger differences may occur the further a control point is located from the survey control that was used to establish the model's coefficients. VERTCON is available from the National Geodetic Information Branch, NGS.

The vertical control portion of the National Geodetic Reference System (NGRS) was strengthened by field survey projects in support of the NAVD 88 readjustment program, cooperative leveling projects, and leveling by Federal, state, county, and private organizations. These surveys were accomplished

primarily by NGS field units, U.S. Geological Survey (USGS), Florida Department of Natural Resources, Maryland State Highway Administration, Metropolitan Water District of Southern California, Minnesota Department of Transportation, and South Carolina Geodetic Survey.

Cooperative surveys involving NGS field and office personnel (cooperating organizations in parentheses) included:

- resurveys to monitor vertical crustal motion in the vicinity of the Yucca Mountain Test site, Nevada; Loma Prieta Earthquake Area, California; and El Paso, Texas: (USGS),

- establishment of vertical control in Idaho: (Idaho National Engineering Laboratories),

- assessment of damage caused by Hurricane Andrew in Florida and Louisiana: (Federal Emergency Management Agency),

- establishment of heights in support of GPS surveys in Mississippi: (Stennis Space Center), and

- establishment of vertical control in Ohio: (Ohio Department of Transportation).

The Harris-Galveston Coastal Subsidence District (HGCSD) and NGS have signed a cooperative agreement to jointly pursue improved methods of monitoring land subsidence in the Houston Metropolitan area. Current activities are focusing on using several continuously operating GPS reference stations to measure changes in height. HGCSD is a local government agency created in 1975 by the 64th Texas legislature to regulate the withdrawal of groundwater within Harris and Galveston Counties and, in the words of the legislation, "... for the purpose of ending subsidence which contributes to or precipitates flooding, inundation, or overflow of any area within the district, including, without limitation, rising waters resulting from storms or hurricanes."

GPS Surveys and Ephemerides

NGS continued densification and accuracy upgrades for the National Geodetic Reference System (NGRS) with 16 GPS survey projects that included 906 stations. In addition to the NGS-observed surveys, 119 GPS survey projects were received from other agencies and adjusted into the NGRS. Enhancement of in-house GPS ephemeris computation software continued while tracking data for 23 GPS satellites are routinely being received from 32 Cooperative International GPS Network (CIGNET) tracking stations throughout the world. The tracking data are used to compute precise GPS ephemerides on a daily basis which are distributed through the NGS Information Center and via the U.S. Coast Guard's GPS Information Center Bulletin Board.

GPS-Derived Orthometric Heights/Gravity Observations

California Department of Transportation (CALTRANS) and NGS undertook a cooperative project to estimate GPS-derived orthometric heights in San Diego County, California, to +/-5 cm. The project included NGS' analysis of existing GPS, gravity, and leveling data, determination of requirements for additional observational data of the three types listed above, training of CALTRANS personnel to observe the required data, and computation of an improved regional geoid model of the county using the proper combination

of existing and new data. These activities will result in recommended procedures to improve CALTRANS' ability to determine more accurate GPS-derived orthometric heights to meet many of their vertical requirements for transportation improvement projects.

NGS is actively investigating GPS to supplement conventional geodetic leveling by cooperatively conducting new gravity field surveys, as well as soliciting new gravity data from other organizations, to support improved geoid models for GPS-derived orthometric heights. A two-part program is underway. First, existing gravity data are being quality checked. Second, areas deficient in gravity are being identified and additional, cooperative observations are being made. The goal of these densification projects is to provide a gravity observation every 3 kilometers.

During the past year, county-size gravity densification projects have been completed in California, Minnesota, and Ohio. Currently, densification projects are underway in Wisconsin, California, Vermont, Louisiana, and Ohio.

HARN Expansion

The horizontal network component of the NGRS, historically accurate to about 1:250,000 relative accuracy, is systematically being improved or upgraded. NGS plans to establish a High Accuracy Reference Network (HARN) of approximately 1,300 stations at 75-125 km spacing to a relative accuracy of 1:10,000,000 and, in cooperation with state, county, and municipal governments, and other Federal agencies, to establish approximately 16,000 stations at 25-30 km spacing to a relative accuracy of 1:1,000,000. All stations will be easily accessible for horizontal, vertical, and/or GPS occupation to extend local control. These stations have North American Datum of 1983 (NAD 83) horizontal positions, with differential positions that are accurate locally at the 1-3 cm level and absolute positions relative to the NAD 83 coordinate system accurate to the 5-10 cm level. Since GPS has 3-dimensional capability, HARN stations also have a vertical coordinate (ellipsoid height) associated with them. Ellipsoid heights can be converted to orthometric heights, the quantity obtained from leveling surveys, using geoid information. NGS currently publishes such geoid information from the high-resolution geoid height model known as GEOID93. This geoid can provide 10 cm accuracy (one sigma) between points spaced 100 km apart.

The HARN is independent of the existing horizontal reference network, but upgrades it. The existing reference network in a state is linked to stations of the HARN at intervals of 100 km or less. Using these connections, a complete readjustment of the existing statewide reference network is performed, holding the HARN positions fixed. The result is an upgraded, completely compatible higher accuracy statewide reference network that includes all of the existing network stations. Currently, HARN observations have been completed in 27 states. In 15 of these states, densification to the 25-50 km level has been completed. HARN observations are scheduled for at least 10 additional states during FY 1994.

Crustal Motion

NGS cooperated with federal, state, local, and academic institutions in conducting geodetic surveys for documenting displacements associated with the two magnitude 7+ earthquakes that occurred in California during 1992. A new model for the 1964 Prince William Sound, Alaska, earthquake was developed. Software was generated enabling the geodetic community to apply NGS's crustal motion model for updating geodetic coordinates and observations in California.

GEOID93

A high resolution geoid model (GEOID93) is now available for the contiguous United States, Hawaii, and Puerto Rico/Virgin Islands. A comparison of GEOID93 with GPS on benchmarks shows considerable improvement in areas of rough terrain. Deflections of the vertical consistent with GEOID93 were also computed. Further improvements in the model depend on the availability of new gravity measurements, especially in regions of rough terrain such as southern British Columbia. A comparison with GPS measurements after removal of long-wavelength trends in residual geoid heights yields a 8.2 cm RMS scatter nationally, equating to a 1-2 PPM relative accuracy.

Geodetic Research

NOAA has made important progress on the problem of determining GPS integer ambiguities (i.e., lanes) "On-The-Fly" (i.e., without a static initialization step). This method permits centimeter-level positioning for land, sea, and air applications. Although this technology will improve land survey efficiencies, it will primarily benefit those applications where stopping is prohibitive (e.g., hydrographic surveying, certification of aircraft or marine instruments, aerial photogrammetry). This methodology will be essential to real-time navigational (i.e., steering) robotics. First real-time demonstrations have been successful.

Federal GPS Base Station Activities

The Federal Geodetic Control Subcommittee (FGCS) of the Federal Geographic Data Committee (FGDC) convened a workshop on Federal GPS reference (base) station activities, May 18-20, 1993, in Rockville, Maryland. The Fixed Reference Station Work Group of FGCS explored issues to determine how best to integrate GPS reference station activities of Federal agencies to avoid duplication, improve efficiencies, and reduce costs. The workshop, attended by 25 participants representing nine Federal agencies (Bureau of Land Management, Environmental Protection Agency, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Park Service, U.S. Army Corps of Engineers, U.S. Coast Guard, U.S. Forest Service, U.S. Geological Survey), concentrated on four areas: user data requirements, reference station design, status of reference station implementation, and identification of barriers to reference station data exchange.

Four ways in which reference station requirements varied from user to user were identified:

- pseudo range (meter-level accuracy) vs. carrier phase (centimeter-level accuracy) observables;
- real time vs. after-the-fact data access;
- fixed station vs. moving platform applications; and
- level of reliability required.

Workshop participants agreed that specifications were needed for several classes of reference stations at varying levels of complexity. Factors that increase complexity are (1) data links for real-time data transmission, (2) dual receiver back-up for very high reliability, and (3) high data recording rates (0.5 to 1 second sampling vs. 5 to 30 sec sampling) for moving platform positioning.

Although agencies presently attempt to share reference station data at local, state, and regional levels, there are several technical and procedural barriers to data sharing. A significant technical barrier is the incompatibility of data from different types of GPS receivers, even when using the RINEX (Receiver INdependent EXchange) data format. This incompatibility can cause the determination of coordinates to be very difficult when using different types of GPS receivers during a survey. Procedural barriers include the closed nature of some agency data bases and agency policies on data cost recovery. The agency representatives agreed to work through the Fixed Reference Station Working Group to resolve the technical problems and through FGCS and FGDC to develop interagency agreements to eliminate procedural barriers.

Workshop participants concluded that the problem of integrating GPS reference station activities is not related to "turf battles." Indeed, many agencies indicated they would be happy to use reliable GPS reference station data from another agency. The problem lies in the lack of assigned responsibility, exacerbated by inadequate funding, to put in place a multi-use GPS reference station network to meet multiple agency needs. The FGCS and FGDC will continue their work to develop agreements and solutions to these problems.

Technology Transfer

Development of the publication Multipurpose Land Information Systems: The Guidebook continued with distribution of Chapters 12, 14, 15, and 21 during FY 93. Chapters 13 and 19 will be published during 1994.

The C&GS State Geodetic Advisor Program continued in 26 states, with inquiries about the program being received from the States of New York and Connecticut. The accompanying map summarizes the status of the current state participation.

NGS personnel are members of many surveying professional organizations on the national, state, and local levels, including the American Congress on Surveying and Mapping, The Institute of Navigation, the American Geophysical Union, the Urban and Regional Informational Systems Association, and the Society of American Military Engineers. NGS personnel, traditionally and currently, serve on various committees and hold appointive and elective offices among the various organizations.

On a continuing basis, NGS has been conducting workshops and seminars for state and local surveyors in concert with professional associations. Subject matter includes high accuracy network densification and its applications, vertical network densification and observational techniques, and applications of GPS to surveying.

National Geodetic Information Branch

The National Geodetic Information Branch (NGIB) of NGS distributes geodetic information products to satisfy current and anticipated 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 and use geodetic data and application products. The branch also conducts a marketing program to increase user awareness and understanding of these products, and to improve NGS's responsiveness to its users.

During FY 93, NGIB accomplished the following:

- Provided users with a new vertical datum transformation software program VERTCON. VERTCON computes the modeled difference in orthometric height between the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29) for a given location specified by latitude and longitude.

- Distributed a high-resolution geoid height model for the conterminous United States, called GEOID93. These geoid heights are referred to the Geodetic Reference System of 1980 (GRS 80) and are appropriate for use with the Global Positioning System (GPS).

- Distributed data for 31 new Calibration Base Lines in support of cooperative interagency agreements.

- Distributed a high-resolution deflection of the vertical model for the conterminous United States, called DEFLEC93. These deflections of the vertical are referred to the Geodetic Reference System of 1980 (GRS 80) and are appropriate for use in Laplace corrections and deflection corrections.

- Conducted workshops on how to obtain, understand, and use NGS information products.

- Marketed a new software program called CALIBRAT. This program is used to determine the scale and constant corrections for electronic distance measuring instruments by making measurements over previously determined base lines.

- Published the third set of chapters of a comprehensive guidebook for developing multipurpose land information systems, focusing on local government's role in developing the multipurpose cadastre.

- Completed the text edit processing of an additional 28,000 horizontal station descriptions. This brings the total reviewed and updated to 230,000, which is approximately 88 percent of the data set.

- Provided information on local geodetic control for environmental impact statements for 44 proposed construction projects throughout the United States.

- Displayed and described NGS products, services, and program activities at more than 20 symposia and professional society meetings throughout the United States.

- Conducted cost studies to ensure that the prices for all NGS information products are consistent with agency pricing guidelines.

- Provided numerous publications, historical records, and the results of research investigations in order to fulfill diverse requests from universities, individuals, Government agencies, and businesses throughout the United States and from other countries.

TRANSIT Doppler Satellite System

On 30 September 1993, DMA closed its worldwide Transit Doppler satellite tracking network after over 20 years of operation. As a result, DMA stopped producing precise ephemerides for the Transit satellites and now relies solely on GPS for geodetic surveying.

Astronomic Azimuth and Positioning

Continuing requirements for astronomic azimuth and positioning led DMA to develop a new astrolabe, the A35M. This state-of-the-art instrument will replace the CCD-equipped Wild T-4 theodolite and VUGTK astrolabe for all future work requiring astronomical observations.

Global Positioning System (GPS) Satellite Orbits, Surveys and Applications

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 DMA to compute precise orbits and satellite clock offset estimates for all the GPS satellites. DMA's precise ephemerides and tracking data provide quality assurance for the Air Force's GPS operations and support DMA's geodetic positioning work.

The precise ephemerides and satellite clock values are produced on a weekly basis. In December 1993, DMA replaced the TI 4100 GPS receivers at its permanent tracking stations with 12-channel Ashtech receivers. Initially, these receivers will operate in a "codeless" mode when anti-spoofing is in effect. During the summer 1994, the receivers will be upgraded to full Precise Positioning Service capability (direct Y-code tracking). At the end of 1994, the DMA stations will be converted to automated operation and then will be remotely controlled from the DMA Aerospace Center in St. Louis, Missouri. At the same time, a sixth DMA monitor station will be added at the U.S. Naval Observatory in Washington, D.C., which will provide a highly accurate time standard for DMA's orbit computations.

DMA has over 60 Ashtech GPS receivers in its inventory for geodetic positioning work. Absolute (point) positions can be computed from a single receiver's data to 1-1.5 m accuracy in each component in the World Geodetic System (WGS) 1984 using software developed at DMA. During the last two years, cooperative GPS survey projects have been carried out using absolute and relative positioning techniques in Venezuela, Paraguay, the Czech and Slovak Republics, Latvia, Poland, Albania, the Maldives and the islands of the Pacific Rim (with NGS). DMA also participated in the International GPS Service for Geodynamics campaign in 1992 sponsored by the International Association of Geodesy.

Gravity Surveys and Data

DMA continues to collect and evaluate gravity data from around the world. DMA conducted a large gravity survey in Alaska and supported surface and airborne gravity surveys in Greenland (U.S. Naval Research Laboratory, Denmark's Kort-og Matrikelstyrelsen) and Brazil (University of Leeds). Absolute gravity measurements were made in the Czech and Slovak Republics, Morocco, Hungary, England and Diego Garcia. DMA has one absolute gravity meter and is acquiring one more in 1994. Existing gravity data are also

being obtained for large areas in Southeast Asia, the former Soviet Republics and Eastern Europe. The GRAVREP software was acquired for estimating gravity data from geological, terrain and altimetry data in areas where point gravity data are not available. A new data management system is being developed to store and retrieve all of DMA's point gravity anomaly data, gravity products and documentation.

World Geodetic System 1984 (WGS 84)

The DMA produces mapping, charting, geodetic, gravimetric, and digital products in support of the U.S. Department of Defense (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, Department of Defense World Geodetic System 1984, was published in September 1991 (DMA Stock No. DMATR83502WGS84) and a number of datum transformations were added in an insert to the report in August 1993. 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 Gravity Model, complete through degree and order 180, has been declassified. In addition, DMA is distributing a Mapping Datum Transformation software package for datum transformation and coordinate conversions (DMA Stock No. MADTRANIBMPC, Edition No. 3). 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 WGS 84. Output is automatically presented as geodetic, UTM and MGRS coordinates. DMA will continue to develop and improve transformations between local datums and WGS 84.

DMA is currently working on improvements to WGS 84 that will allow the realization of a worldwide ± 1 meter three dimensional reference system. To do this, DMA is working with the National Aeronautics and Space Administration to develop an improved Earth Gravity Model (EGM) using all of the new data that have become available since the original development of WGS 84 in the early 1980s. The new EGM will be used to generate an improved geoid with an accuracy goal of ± 0.5 to 1.0 meter over the entire earth. The enhanced WGS 84 geoid will be used to determine all mean sea level heights for DMA products and as a means of unifying the myriad vertical datums used around the world. DMA is also working on a project with the International Association of Geodesy, the Pan American Institute for Geography and History and the countries of South America to redefine the South American Datum. The project's goal is to establish a high precision continental network of geodetic control stations and then extend this control within each of the countries.

World Geodetic System 1984: A Three-Dimensional Reference Frame for Global Mapping, Charting and Geodetic Applications

The Defense Mapping Agency's latest version of the World Geodetic System (WGS 84) is the most accurate reference frame defined globally through the availability of recent extensive geodetic data sets. The WGS 84 provides an accurate reference frame, earth gravitational model, normal gravity formula, geoid and transformation constants with 115 local and regional datums covering all seven continents and many islands over major ocean areas. WGS 84 represents DMA's state-of-the-art modeling of the earth from a geometric, geodetic, and gravitational standpoint using contemporary data techniques and technology. DMA's efforts have resulted in significant simplification of the Mapping, Charting and Geodetic (MC&G) complexity and have improved the quality and accuracy of DMA products worldwide.

Global Geospatial Information and Services Initiative

The Defense Mapping Agency's Global Geospatial Information System (GGIS) initiative represents DMA's response to recent changes in the global political and technological climate of the world. It represents a visionary interoperability approach to address the new challenges for the Mapping, Charting and Geodesy (MC&G) community and the commitment to worldwide information management. GGIS will be compatible with the most sophisticated geographic information system technologies. It employs user-accessible databases in a "data warehousing" or federated architecture. GGIS will contain a wide variety of information and datasets will be compliant with international, government and industry standards. Layers of the database will include orthorectified and geocoded imagery precise geodetic positions centerline features with the necessary attributes, terrain and seafloor elevations, gravity and safety to navigation data. Information describing the data will accompany the datasets to support the exploitation software packages used by the customer. GGIS will employ fiber optics, asynchronous transmission and communication satellites to establish high speed reliable highways of information between the producer and customer. Customers will have powerful compact computers which have the capability of receiving heavily attributed datasets and allow tailored applications in offices, on ships, in space, or wherever high quality geospatial information is required.

Precise Satellite Survey Results in Revised Position for Northern Marianas Island

During 1993 the National Oceanic and Atmospheric Administration (NOAA) Coast and Geodetic Survey (C&GS) completed a large-scale Global Position survey of approximately 20 islands in the central and western Pacific Ocean. This project was jointly sponsored by the C&GS and U.S. Department of State, the Defense Mapping Agency, and the Federal Aviation Administration and involved the cooperation of 10 government and academic organizations. The subject survey established an accurate geodetic network throughout the Hawaiian Islands, American Samoa, the Republic of Marshall Islands, the Federated States of Micronesia, Northern Marianas and the Republic of Palu. The updated network accuracy will improve GPS aided air and ship navigation in the Pacific Basin, provide modern shoreline information for nautical charts, refine maritime boundaries and more specifically position 25 island airports.

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, 4,070 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. The 1:2,000,000-scale sectional map series provides coverage of the United States on 21 sheets.

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 Federally managed recreation lands, are also prepared and published by the USGS for the U.S. Government, the scientific community, and the general public.

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, 94 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 National Ocean Service (NOS), Coast and Geodetic Survey (C&GS), 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, hydrographic surveys were conducted in Alaska, U.S. east coast, Gulf of Mexico, Great Lakes, and California waters. Photogrammetric missions not only supported the charting programs, but were applied to many other diverse problems. A large number of new edition nautical charts were issued.

Shallow Water Multibeam (Seabat)

NOS has acquired a Seabat 9001 with the intent to employ it in the determination of least depth on wrecks and obstructions which have been previously detected via side scan sonar. NOS is developing operational techniques and processing protocol for this new system. It has been tested against least depths determined by diver-deployed pneumo techniques. Agreement on the order of 10 centimeters has been achieved between the two measurement techniques. Additional accuracy tests are planned. Full certification of the Seabat 9001 is expected by January 1, 1994.

HYGRO '93 Seabat 9001 Tests

In September 1993, the Nautical Charting Division (NCD) participated in the Hydrographic Ground Truthing Experiment (HYGRO) at St. John, New Brunswick, Canada. The Canadian Hydrographic Service and the University of New Brunswick, Ocean Mapping Group, provided considerable material and personnel to assist NCD in this international cooperative project.

The primary NCD objective was to obtain hydrographic survey data with the Reson Seabat 9001 Swath Bathymetric Sonar to support the determination of its performance relative to standards of the International Hydrographic Organization. Secondary objectives were: (1) intercomparison between a Reson Seabat 9001 and a Simrad EM-1000; (2) test the concept of using multiple site simultaneous phase tracking Global Positioning System (GPS) measurements to determine correctors for vessel squat, vessel settlement, and tide; and (3) obtain high resolution side scan imagery along the survey track lines.

NCD installed and operated survey equipment on the CHS FREDERICK G. CREED and the University of New Brunswick Vessel MARY-O. During the course of this field work, valid depth measurements were made with the Seabat 9001 which ranged from 30 centimeters to 60 meters below the face of the transducer. Results of this effort will be reported in April 1994 at the HYDRO '94 Conference in Norfolk, Virginia, U.S.A.

Differential Global Positioning System and Hydrographic Surveying

In 1993, the Differential Global Positioning System (DGPS) became the primary positioning system for all NOAA hydrographic surveys. DGPS configurations allow input of differential correctors from United States Coast Guard (USCG) differential beacons or correctors provided by field-unit-established portable systems.

Presently, there are seven USCG differential beacons that are available to control NOAA hydrographic surveys. Present broadcasts cover the western Gulf of Mexico and the northeast coast of the United States. Survey platforms

utilize Magnavox 50R beacon receivers linked to Ashtech 12-channel OEM Sensor GPS receivers. USCG beacons allow field units to operate over 100 nautical miles from the beacon, without the need for shore support.

Field units operating in areas out of range of USCG differential beacons use a portable system with either a VHF or HF data link. An Ashtech M-XII geodetic receiver is used as the reference station, set up over a geodetic survey point, and linked to a VHF or HF radio. Ranges for the VHF radio are limited to line of sight; maximum range attained was 22 nautical miles. The HF data link achieves ranges in excess of 250 nautical miles.

NOAA has improved productivity by switching to DGPS. DGPS control has been equally successful on both 22-foot launches and 230-foot ships.

Side Scan Sonar Verification Target

A low-cost side scan sonar verification target was developed by the Nautical Charting Research and Development Laboratory (NCRDL) for deployment in featureless survey areas. The absolute target strength and angular response pattern were designed to ensure detection at 150 meters by the EG&G Model 260 under the conditions of self-noise, limited-bottom reverberation and on a coarse sand bottom. Field tests conducted on board the NOAA Ship HECK indicate that a "ball and chain" configuration (see diagram below) is the best target, and these are expected to be introduced into field operations soon.

1 centimeter link chain (5 centimeter hollow balls)

----------(o-o-o-o-o)----(o-o-o-o-o)----(o-o-o-o-o)--------

----------10 meters----------

Implementation of verification targets will achieve greater efficiency and increase effectiveness of NOAA side scan surveys by reducing the number of gaps in verified surveys. The verification targets will also establish a basis on which to conclude the absence of sonar contact detection that will mean there are no contacts.

Least Depth Diver Gauge

A hand-held diver least depth gauge has been developed and will soon undergo both in-house and field testing. A PTC D-2000 digital pressure gauge has been calibrated and will be housed inside a 6-inch cylindrical tube 12 inches long. Also housed inside the tube is the computer which will record depths as the diver depresses an external switch. Expanded memory and battery power will allow for dives up to 90 minutes before downloading and recharging. Ships will have the capability to recharge the batteries and download the data via an RS-232 cable. This diver-deployed gauge will potentially replace the lead line and the pneumatic depth gauge which are now used to obtain the least depth readings.

Scanning Hydrographic Operational Airborne Laser Survey (SHOALS)

The U.S. Army Corps of Engineers (USACE) has contracted to provide an air-borne laser hydrography system. This SHOALS system, to be deployed in a Bell 212 helicopter, will be delivered and tested in the winter of 1994. DGPS 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 air-

craft. 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.

New Charting Products

C&GS maintains 1,002 nautical charts; 301 were published as new editions during 1993. 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), 280 depict LORAN-C, and 25 contain the OMEGA electronic positioning system.

Implementation of the new adjustment of the North American Datum of 1983 (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 1993, 917 charts had been adjusted to NAD 83.

Metrication Effort and New Nautical Charts

C&GS continued with the systematic conversion of its existing nautical chart suite from English to metric units. During 1993, five additional charts were converted. C&GS has produced and maintains a total of 37 charts in metric units.

Eight new nautical charts were constructed during 1993. These charts were compiled to meet user needs for new coverage where no coverage previously existed or existing coverage did not meet current requirements.

NOAA Raster Nautical Chart Image

During 1993, C&GS created a prototype raster nautical chart image and launched beta mailings to introduce the image and assess the marketability of the product data. The prototype raster nautical chart image, NOAA nautical chart 12214 - Cape May to Fenwick Island, was distributed to over 1,000 hydrographic offices, private sector companies, and other Federal agencies for evaluation.

The product data were obtained by scanning at high resolution the color-separate films used for the NOAA paper chart. The resoluting raster files were electronically coregistered. Colors were assigned to all pixels in the file, and a single, full color chart image was produced.

C&GS intends to make the full suite of charts available as a raster image within 3 years. New editions of the raster images would be issued concurrently with new editions of the corresponding paper charts.

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 (GPS) in Photogrammetry

Development of an operational system for GPS-controlled photogrammetry was initiated in 1987, when experimental results demonstrated the feasibility of this technology. Aerotriangulation with little or no ground control, using differential phase observations from an on board GPS receiver to provide an accurate position of the aerial camera, is expected to reduce significantly the cost of shoreline mapping.

A system calibration method has been developed and tested with data acquired in October 1988 at the Transportation Research Center of Ohio, where an elaborate array of targets for aerial photography has been accurately positioned by ground survey using GPS. The calibration consists of precise determination of: (1) the components of the vector from the camera to the aircraft antenna, (2) the accuracy with which the exposure time is recorded, (3) the conventional elements of a lens calibration, which are not usually determinable from photos taken with the camera in its operating orientation, and (4) the effect of the camera port window.

NOS has continued to cooperate with the Texas Department of Highways and Public Transportation (DHPT), a participant in the original feasibility tests. Software developed by NOS for the GPS data reduction and aerotriangulation has been made available to DHPT who has provided NOS with copies of data they acquired during operational tests. NOS has also entered into a cooperative agreement of the same type with the North Carolina Department of Transportation and is also assisting USACE to develop a similar capability.

NOS has now acquired a precise navigation capability that uses GPS to assist the pilot in maintaining the correct amount of overlap between photo strips, thus eliminating all need for costly reflights. NOS is now using GPS-controlled photography for all shoreline mapping projects.

Integrated Digital Photogrammetric Facility

The Integrated Digital Photogrammetric Facility (IDPF) is being developed to meet C&GS' present and future needs for accurate, feature coded digital photogrammetric source data.

Specifically, IDPF supports the Automated Nautical Charting System II, the Hydrographic Data Acquisition and Processing System, and the Aeronautical Obstruction Charting (OC) Program. IDPF also facilitates digital exchange between C&GS and other Federal agencies that employ similar systems. IDPF couples advanced photogrammetric technology with computer graphics and a Relational Data Base Management (RDBM) system. Begun in 1984, IDPF development led to an operational system in 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 many additional application programs.

The IDPF configuration consists of five stereoviewers and their peripherals, forming photogrammetric workstations, linked as networked nodes sharing a common data base. The relationships are diagrammed in the accompanying two figures. The three data bases are: (1) the project data base, (2) camera calibration data base, and (3) the OC data base.

In support of Federal Aviation Administration tasks on the IDPF, the airport OC data base has now been 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 3-dimensional approach surfaces over any airport. This software will be integrated into IDPF and the OC data base for on-line obstruction penetration analysis.

The longevity of IDPF is assured by its independence from specific stereoviewer hardware, easily modified application software, and its integration with standard C&GS map projection, aerotriangulation, and camera calibration software packages. Hardware independence, which extends beyond the stereoviewer to various peripherals, allows the system to survive the rapidly changing hardware market and benefit from the incorporation of improved technology.

This open architecture and upgradability of the IDPF has been amply demonstrated by the fact that high-performance controllers have now been installed, replacing the obsolete controllers used initially, and any processor with Small Computer System Interface bus can now be used in the IDPF.

The key to IDPF's production utility is its integration with other NCRDL-developed mapping software, its diverse and extendible application modules, and its unique computer operational environment. Integrated mapping software includes the General Integrated Analytical Triangulation (GIANT) Program, the General Cartographic Transformation Package (GCTP), the NOS Camera Calibration System, and a Standardized Digital Data Exchange utility. GCTP converts coordinate data between geographic and any of 20 common map projections. IDPF accepts any photographic format, and performs diverse jobs such as airport mapping, photobathymetry (underwater mapping in clear water), and close-range (non-topographic) photogrammetry. Operationally, IDPF functions are menu driven and controlled by formatted screens. Errors are minimized by on-line error checking and system-supplied data.

The new IDPF Version 2.0 has been completed and is operational. Operation of the IDPF is fundamentally the same as before. For reasons of expediency and efficiency, the following improvements throughout IDPF have been made:

- An entirely new data base format for projects and cameras has been incorporated.

- The screen data editor has been vastly improved and modified.

- New editors for the project and camera data bases have been incorporated.

- Improvements in labeling and plotting digital maps have been made.

- The GIANT program has been modified to include adjustments for GPS data, self-camera calibration, and elimination of unknown systematic errors during photography.

Advanced Correlation Technology

The implementation of 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 C&GS. It was selected because of its extremely precise measuring capability of less than 1 micron and its large stage size of 9 by 18 inches. The combination of ACT on the LMASC has created the ACT workstation capable of performing many photogrammetric applications utilizing correlation techniques. The implementation of ACT has required considerable software developments in addition to the correlation software. The integration of the correlation software into a photogrammetric applications package was directed by C&GS personnel.

An ACT workstation was put into preliminary operation in the summer of 1990. A series of panchromatic photographs has been measured on the ACT workstation and the resultant triangulation computations compared with manual measuring. The results of these tests indicate that the correlation engine has a slight accuracy edge over manual measuring. In addition, while the manual techniques require careful concentration of the operator, the correlation engine performs independent of the operator's measuring skill or stamina.

Currently, the correlation system has several measuring functions that have been integrated into easy-to-use applications. 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 have been integrated using application software for aerotriangulation and various types of calibration plate measuring. A triangulation package has been developed that is compatible with IDPF. Other enhancements to the correlation engine are ongoing. These enhancements improve the speed and operators ease of use.

Shoreline Delineation from Multispectral Imagery

A primary function of NOS is the accurate delineation of shoreline for 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. An alternative process of shoreline delineation is being developed through the Small Business Innovative Research (SBIR) program. The SBIR vehicle has made possible the development of a semi-automated process for delineating shoreline. The process has two important features. First, it can be applied to virtually any digital data set; therefore, satellite or airborne remote sensing data and even digital data sets from scanned aerial photography. Second, it provides for human assistance when needed. Currently, aerial photography is of interest because of its availability and superior accuracy. The process can be readily applied to satellite and airborne multispectral sensors as their availability and accuracy match the demands of shoreline delineation.

The Phase II current development status is near completion of the SBIR program. The software development is targeted for existing microcomputer platforms. The completed system will support input from various multispectral data sets and produce vectorized shoreline 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 portion provides for constructive human intervention which significantly enhances the efficiency of the process.

The Coast and Geodetic Survey's Nautical Chart Rescheming Plan

The Coast and Geodetic Survey's (C&GS) first natural chart dates back to 1839 and depicted Newark Bay. Since that time, numerous additional charts have been produced, mainly on an individual basis, and resulting in more than two dozen scales, four different projections, and a variety of sizes. The C&GS is currently considering standardizing the scales of charts and chart paper sizes in conformance with international specifications.

Hydrography/Bathymetry

The development of the (DMA) Digital Production System (DPS), begun in 1982, was driven by a change in source materials from hardcopy to digital format. Products for our Navy customers benefit from use of more accurate source and the automation of formerly tedious manual processes. Current and emerging requirements for new bathymetric processes are found in five major areas, as follows: improved data collection capabilities, better source planning and management, robust data evaluation and analysis, integration of multiple sources, and new products generation.

This major program is currently being implemented as the Defense Hydrographic Initiative (DHI), which will deliver the modernization processes described above integrated into the Digital Production System. The DHI is being executed with the cooperation and support of the U.S. Navy and the National Oceanic and Atmospheric Administration.

The culmination of these efforts will be the Master Seafloor Digital Data Base (MSDDB), a distributed data base that combines multiple types of MC&G and oceanographic data to support Navy mission needs. It will provide authoritative bathymetric data for the ocean floor, supporting production needs of DMA and the U.S. Naval Oceanographic Office as well as serving as the data base to support new Navy digital products and data requirements. MSDDB will be accessible to users through various traditional and new electronic gateways.

Digital Nautical Chart Data

Navigational Sensor System Interface is being built by the U.S. Navy to satisfy the functional and performance specifications proposed by the International Hydrographic Organization (IHO) and the International Maritime Organization (IMO). With the Global Positioning System (GPS) providing accurate positioning data, advanced computing systems supplying the horsepower to handle large databases of charting data and the development of DoD standards for the exchange of digital data, it is now feasible to develop and deploy electronic chart navigation systems. This type of system is known in the international marine navigation community as an Electronic Chart Display

and Information System (ECDIS). To insure interoperability, Digital Nautical Charts will be distributed using U.S. Department of Defense standards for vector data as surface ship navigation moves into the digital environment.

A New Concept for Defining and Surveying Time-Invariant Bathymetry

DMA has developed a new concept for defining and surveying a time-invariant bathymetry and suggests the use of a high accuracy geoid as the new zero reference surface. Currently, there are hundreds of vertical datums for both land and ocean areas in use all over the world. For nautical chart datums, the problem is further complicated by lack of agreement on definitions by different countries. The result has been an adverse effect on international navigation safety. The DMA concept defines a nautical chart vertical datum which is non-dependent on time and involves the capability to compute geoid of very high accuracy over ocean areas tidal surfaces. The concurrent availability of the Global Positioning System makes it easy to establish this vertical chart datum and depict them on charts. Then, reversing the survey mode allows these charted depths to be realized in real-time during navigation to check depth clearances and avoid ship grounding.

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 additional tasks were performed under the visual flight program during FY93:

• The first phase of the FAA Airspace Reclassification Project was effective on October 15, 1992. This phase of the project required over 3000 new and revised federal rules to be applied to all Visual Flight Rule (VFR) charts, within a one year period of time. In addition to the federal rule changes, the following charting changes were made to improve the readability and quality of the charts:

-- The symbology for special use airspace, airport radar service areas (ARSAs) and depiction of controlled and uncontrolled airspace, was changed to meet a former recommendation from the National Airspace Review (NAR) held in the early 1980s.

-- The aeronautical information portion of the Inter-Agency Air Cartographic Committee (IACC) specifications for the sectional/terminal area charts and the world aeronautical charts were rewritten. The entire IACC specification for the helicopter route charts and the VFR flyway charts were rewritten.

The project required changes to 54 sectionals, 21 world aeronautical charts, 30 terminal area charts, 12 flyway charts, and 7 helicopter charts.

-- 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.

-- The 40th edition of the Denver Terminal Area Chart was extended to the north and east to accommodate the opening of the new Denver International Airport. The effective cycles of the Denver Sectional, Denver Terminal Area Chart, Cheyenne Sectional and Wichita Sectional were adjusted so that the future effective cycles of all four charts coincide.

-- All Visual Flight Rule products were converted from the North American Datum of 1927 (NAD 27) to the new North American Datum 1983 (NAD 83).

The following Inter-Agency Air Cartographic Committee (IACC) requirements were implemented in FY93:

-- Charting of non-continuous navigational aids

-- Revisions to the charting of the availability of transcribed weather broadcast (TWEB), automated weather observation system (AWOS), and hazardous inflight weather advisory service (HIWAS).

-- In February 1993, a briefing was held at FAA with the Obstruction Chart-Engine Out working group. This working group is comprised of FAA representatives and engineers from the major airlines. The working group was provided with information on the application and maintenance of the base information and obstructions, shown on the Visual Flight Rule (VFR) charts. A request by the group for a prototype of Walker Field, Grand Junction, Colorado has been completed. Final charting guidelines, an appendix page, and markups for 10 future sites were also completed. FAA will be presenting the prototype and future plans at the Chart Forum scheduled for January 1994.

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 1993, 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 United States Aeronautical Information Publication (AIP) published by the FAA. The NOS produces duplicate negatives for approximately 65 percent of its instrument approach procedures production as a requirement for the U.S. military community. The charts are included in the DoD Flight Information Publication (FLIP) produced and published by the Defense Mapping Agency (DMA).

The Global Positioning System (GPS) is being implemented by the FAA. The NOS expects to increase the Instrument Approach Procedures chart production by 50 percent over the next five to six years.

During 1993 the following accomplishments were realized:

• All 42 IFR Enroute Charts were converted to the new four color specifications. The project was completed in three phases. The first phase, consisting of the Enroute High Altitude Charts, was carried out using standard cartographic practices (i.e., manual compilation and drafting). The second phase consisting of the Alaska Low Altitude Charts was accomplished using computer-assisted cartographic techniques to compile the charts. Drafting was manual. The third and final phase, consisting of the U.S. Enroute Low Altitude Charts, was fully automated. Data files were constructed, compiled and drafted using VAX workstations. The charts were printed in September 1993.

• The Denver, Colorado airspace is undergoing an extensive reconfiguration that will affect airways, routes, facilities, altitudes, fixes, and most air-space within 100 miles of the airport. In support of the new Denver International Airport, ACD provided the FAA with two enroute charts depicting the new airspace.

• On September 16, 1993 the final phase of the FAA's new airspace classification system was implemented. The changes were intended to: (1) simplify airspace designations; (2) achieve international commonality of airspace designations; (3) increase standardization of equipment requirements, and (4) describe visual flight rule requirements and services offered in each class of airspace. Prototype visual and instrument charts were provided for evaluation and training.

• Over 1,400 Radar Video Maps (RVM) were produced in FY93 for the 213 FAA facilities being served by this product. The video maps depicted on radar displays are entirely specified by the air traffic control facility. Each map represents an accurate stable representation of the airways, fixes, boundaries, and runway extension lines which meet the unique requirements of each facility. The RVM is constructed on a 2.3-inch negative plate which is inserted into a five-channel video mapper at the ARTCC site. The terminal maps have standard ranges of 10 to 60 nautical miles.

• The Digital Bright Radar Indicator Tower Equipment (DBRITE) program provides for video maps to be generated and displayed digitally in the air traffic control tower. During FY93, 267 facilities were serviced with 148 new maps constructed and 530 maps revised.

• ACD provides FAA terminal facilities with maps to support the Terminal Doppler Weather Radar (TDWR) System. TDWR is one part of a vast new weather watching system designed to streamline travel and has the capabilities of producing "nowcasts." Nowcasts are extremely accurate localized 1-hour forecasts of violent storms and other items of intense interest to pilots including icing conditions, heavy snow, wind shear, turbulence, winds aloft, and fog. The TDWR system is particularly valuable to air traffic controllers in detecting wind shear, which are sudden wind shifts that have been blamed for more than 650 deaths in the last 25 years. Plans have been made to deploy radar systems at major airports throughout the country. During FY93, 19 FAA facilities were serviced with 24 new maps and 92 revised maps.

• The ACD is in the process of preparing twelve (12) maps for the new Denver International Airport to be used as Final Monitor Aids. These maps are needed due to the precision required when running simultaneous double, triple and quadruple approaches into Denver's four (4) parallel north/south runways and two (2) east/west runways. The maps are produced at a scale of 1:24,000

to provide maximum accuracy. Information portrayed on the maps is levelized and eventually colorized at the monitor positions when in use. Map data is sent to Denver in digital format and processed into a graphic for use by the controllers.

• Effective April 28, 1994 all IAP volumes, except Alaska, will be printed loose leaf, shrink wrapped packaging with a 4-ring binder mechanism eliminating the bound volume fold over 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 7,500 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.

The Challenges of Air Traffic Control Graphics for the Advanced Automation System

The Advanced Automation System (AAS) is comprised of hardware and software for enroute, terminal and tower operations. It has been designed to improve air traffic control and safety and will upgrade the Federal Aviation Administration's current system to handle increased traffic loads well into the 21st century. Currently, the National Ocean Service (NOS) is delivering prototype digital data to support the Initial Sector Suite System (ISS)for the AAS project. The ISSS is comprised of approximately 7500 computer consoles which will be installed at enroute and terminal facilities. They will provide displays of charts and other data on high resolution, multi-color, graphics monitors. NOS will be supplying thousands of digital aeronautical charts to support this system. The creation and delivery of such vast numbers of high quality digital charts is an unprecedented task for NOS.

Mapping Applications of the Airborne Global Positioning System

The U.S. Geological Survey (USGS) is investigating the use of the Global Positioning System (GPS) to determine the positions of camera exposure stations associated with 1:40,000 scale images. This ability would reduce the cost of establishing the geodetic control on the ground that is needed to revise 1:24,000 scale maps and produce 1:1,200 scale digital orthophotos. The results of USGS projects showed that positions established in block adjustments of 1:40,000 scale images controlled with GPS-derived positions of camera exposure stations and a reduced amount of ground control were within 1-2 meters of positions established using GPS ground surveys. These data will be used to develop aerotriangulation production procedures incorporating GPS-derived positions of camera exposure stations.

GEOGRAPHIC NAMES

1. PUBLICATIONS.

During 1992-94, DMA has published gazetteers of the following countries:

Afghanistan	Albania
Argentina	Bolivia
Guyana	Haiti
Hungary	Mexico
South Africa	Sri Lanka
Uruguay	Venezuela
West Bank and Gaza Strip	

These gazetteers contain standard placename spellings approved for U.S. Government use by the U.S. Board on Geographic Names (USBGN). Over the next several years, DMA will update its names files for approximately twenty additional countries, and is actively seeking the assistance and cooperation of the countries involved in ensuring that up-to-date names information is available.

DMA continues to publish the *Foreign Names Information Bulletin*, which contains up-to-date name change information. The sixth issue of this publication is in preparation.

DMA is issuing a completely revised *Romanization Systems and Roman Script Spelling Conventions*. This publication contains all of the Romanization systems currently approved by the USBGN and the Permanent Committee on Geographical Names for British Official Use (PCGN). It should be available by April, 1994.

USBGN issued its *USBGN Publications Catalog* in 1993. Copies are available from DMA and the U.S. Geological Survey (USGS).

2. AUTOMATION.

An digital database of foreign names information has been established at DMA. Called the Geographic Names Processing System (GNPS), this system supports the names standardization work of USBGN, gazetteer production, and DMA's mapping and charting programs. The GNPS database currently holds placename information for over three and a half million features, totalling over four and a half million names. DMA is currently investigating the establishment of remote on-line access to this names information for the geographic names user community.

DMA continues work on a Digital Gazetteer of foreign placename information. A product specification for the Digital Gazetteer is in final review stages. The second Digital Gazetteer prototype is due to be issued on CD-ROM by April of 1994.

3. CONFERENCES.

A DMA representative, Dr. Gerd Quinting, attended the International Conference on the Reproduction of Ukrainian Names in Foreign Languages, held in Kiev in December, 1993. Dr. Quinting presented a paper describing the USBGN/PCGN Romanization system for Ukrainian.

DMA is currently preparing for the 17th Meeting of the UN Group of Experts on Geographical Names (UNGEGN), to be held in New York in June, 1994. DMA representatives will prepare papers covering progress made since the last UNGEGN Meeting in Romanization and automation. The U.S. delegation to the 17th Meeting will also include representatives from USGS and the Department of State.

DMA is also preparing for the 17th Conference of the USBGN and PCGN, to be held in London in November, 1994. This important biannual conference affords an excellent opportunity for information exchange between two long-time partners in geographic names work.

4. TRAINING

DMA, in collaboration with USGS and the Pan American Institute of Geography and History (PAIGH), supported the Sixth PAIGH Course on Geographic Names, in Tegucigalpa, Honduras, from October 25 to November 6, 1993. Twenty two students from eight Latin American countries attended the two-week course which included lectures on geographic names standardization, a field exercise in names collection, an automated names database workshop, and several guest lectures by experts from the host country.

DIGITAL CARTOGRAPHY

Product Exchange Format for the Defense Mapping Agency's Vector Products

Vector Product Format (VPF) has recently been developed by the Defense Mapping Agency in cooperation with the military mapping agencies of Australia, Canada and the United Kingdom. This standard for distributing digital geographic information in vector format, provides digital products to users. It has been designed to support a wide range of products and allow direct access to the data from storage media without conversion to a working format. Released simultaneously with the standard, Digital Chart of the World (DCW) is the first in a family of Defense Mapping Agency vector products to use VPF. The DCW carries planimetric and topographic information equivalent to the resolution of a 1:1 million scale chart and provides global coverage. It is a public sales item obtainable through the U.S. Geological Survey.

Vector Products

DMA has undertaken a major development program to implement a family of vector products. These products will be produced in the Vector Product Format (VPF), which employs a topologically structured georelational data model that fully implements the vector relational format of the Digital Geographic Exchange Standards (DIGEST) Annex C. Data elements are described using the Feature and Attribute Coding Catalog (FACC). Vector products will generally be distributed on CD-ROM. Data for the family of vector products will be maintained, and in some cases produced, on the Vector Product Production System (VPPS), which is currently in development. For many vector products, initial production will involve digitization of existing hardcopy maps and charts; in the future, a Digital Production System (DPS) database import capability will be implemented in order to allow the generation of such products from centerline data.

Digital Chart of the World (DCW)

DCW is a low-resolution digital product consisting of base map features found on the hardcopy ONC and TPC products. It has been in distribution since August 1992. This 1:1,000,000-scale product is packaged on four CD-ROMs and is provided with access, view, and rudimentary exploitation software for MS-DOS based operating systems. DCW will be replaced by VMap Level 0, a development outlined below.

Vector Map (VMAP)

This product line, formerly titled GEOMAP, was developed in response to the increasing use of Geographic Information Systems (GIS) in electronic battlefield and intelligence architectures. In addition to supporting requirements for detailed geographic analysis, VMap products are designed to meet background display dataset requirements. They facilitate the fusion of mapping, charting and geodetic (MC&G) data with a variety of databases and can serve as spatial data indices for situation graphics. The VMap family consists of:

a. VMap Level 0: a low-resolution digital product with feature density and attribution equivalent to the base map content of the hardcopy ONC and JNC products. VMap Level 0 is currently scheduled for early 1995 production. This product is a redesign of the current Digital Chart of the World (DCW)

product. It will include the following enhancements: global vegetation, low-resolution bathymetric contours, offshore boundaries, International Hydrographic Organization (IHO) defined limits of oceans and seas, thematic structure consistent with other VMap databases, and use of FACC. VMap Level 0 will incorporate up-to-date boundaries and country designators.

b. VMap Level 1: a medium-resolution digital product with feature density and attribution equivalent to that found on the hardcopy 1:250,000 JOG and equivalent medium resolution products. Prototype III is currently scheduled for release shortly. Initial production is scheduled for Autumn 1994.

c. VMap Level 2: a high-resolution digital product with feature density and attribution equivalent to that found on the hardcopy 1:50,000 and 1:100,000 Topographic Line Map (TLM) products. Prototype III is currently scheduled for release shortly. Development of an early hardcopy conversion production capability is scheduled. Full production capability from digital sources will follow.

d. VMap Level 3, currently being coordinated as Urban Vector Map (UVMap): a very-high-resolution digital product with feature density and attribution equivalent to that found on hardcopy City Graphics, Military City Maps, or City Route Graphics. The first prototype is scheduled for release in December 1994, with production start scheduled for Summer 1995.

Interim Terrain Data (ITD) in VPF

ITD is a high-resolution digital terrain analysis product with features grouped into six coverages, as follows: slope/surface configuration, soil/surface material, vegetation, surface drainage, transportation, and obstacles. This product is intended to satisfy requirements for terrain analysis data until TTD becomes available, and is a refinement of ITD in Standard Linear Format (SLF). ITD is currently scheduled for production in late 1996.

Tactical Terrain Data (TTD)

TTD is a required high-resolution general-purpose land combat data set. TTD incorporates topographic and coastal hydrographic data. First prototyping of TTD in 1988 attempted to use a fully topologically-integrated data structure known as MINITOPO; MINITOPO was too complex and rigid for most users, and demands for more open topology, coupled with advances in VPF, led to a TTD prototype targeted for release in May 1994. Full production is scheduled to begin in Summer 1996.

Digital Nautical Chart (DNC)

DNC is a multi-resolution digital product consisting of features found on hardcopy General Navigation Charts, Coastal Charts, and Harbor and Approach Charts. The DNC design specifies five libraries, as follows: Harbor, Approach, Coastal, and General (which contain twelve thematic layers each), and Browse (which contains two thematic layers). This product supports Navy and Coast Guard electronic chart display systems. The Navy Navigation Sensor System Interface (NAVSSI) will undergo tests in the Spring of 1994 to evaluate the operational effectiveness of electronic bridge display functions. Forty-five ships are expected to be equipped with NAVSSI in 1994, and over two hundred by the end of 1999. NAVSSI and DNC have been developed to meet the functional, performance, and content requirements being established by the International Hydrographic Organization and the International Maritime

Organization. DNC production has begun with the completion of DNC001 covering Norfolk (Virginia) and the Virginia Capes. Under contract to DMA, National Ocean Service also will produce DNCs to satisfy Navy requirements over their area of responsibility. Production is currently underway and initial products will be available in September 1994.

DNC Update

DNC Update is a digital product that will support the DNC with up-to-date hydrographic/navigational change information. It will be the DNC equivalent of the hardcopy Notice to Mariners product and will therefore be produced on the same cycle. Concept development is currently underway, with parallel prototyping currently scheduled for 1994. The strategies developed for this product may set the policies for update of all VPF datasets.

Aeronautical Information Data (AID)

AID is a digital product consisting of the features present on the aeronautical overprint found on hardcopy ONC, TPC, and JOG-A products. The AID is intended to be used in conjunction with VMap Level 0 and Level 1. AID will be updated through the digital equivalent of today's hardcopy Chart Update Manual (CHUM). Production is currently scheduled for early 1995.

Digital Flight Information Publications (DFLIP)

DFLIP is a digital product with information content equivalent to that of the hardcopy FLIP product. Final requirements definition and preliminary designs will begin in early 1994. Both the Vector Product Format and a new Text Product Format will be used. Production is currently scheduled for early 1996.

Raster Products

DMA and the U.S. Military Services have recognized that raster-based scans of maps and charts will continue to be needed until vector maps can be read from media and displayed at least as quickly as scanned maps can be used today. ARC-Digitized Raster Graphics (ADRG), DMA's current standard product, is unsuitable for use in most field-deployed systems and must be compressed. Separate Service-unique compressions were developed in response to this requirement, and must be carried as legacy compressions until migration can occur to a single compression for U.S. forces. Raster map initiatives include:

Scanned Map (SMap)

Scanned Map (SMap), currently being coordinated as Compressed ADRG (CADRG): a general purpose data set of computer-readable digital images supporting various weapons, theater battle management, mission planning, and digital moving map systems. The prototype is derived directly from ADRG through downsampling, filtering, compression including vector quantization, and reformatting to the proposed Raster Product Format (RPF) standard. The final product has a nominal 55:1 compression from the ADRG source files and is decompressible to 4-bit or 8-bit color graphics files for use. Prototype coordination is underway, and production scheduled for January 1994.

Legacy Compressions

Some systems have been designed to depend on Service-unique compressions of ADRG, forcing continued production support until migration can occur to the SMap or the systems complete their useful lives. Legacy compressions include Compressed Aeronautical Chart (CAC) for the Navy and Marine Corps, first-generation Common Mapping Standard (CMS) for the Air Force, and Compressed Raster Graphics (CRG) for the Army. CAC is produced within the Navy with DMA support; first-generation CMS will continue as an Air Force-supported program until 1995, when migration will have occurred for all Air Force systems; and CRG will be produced, as required, by DMA for the Army. Migration or sunset plans are to be developed for all systems using legacy compressions.

Digital Standards

DMA has recently made a very strong commitment to enhancing interoperability of data and increasing the efficiency of MC&G support through standardization.

DMA's early standardization initiatives had been focused on controlling proliferation of product types to keep production workload within bounds and to provide documentation that developers could use to ensure conformance to DMA products. U.S. military forces reverted to primarily expeditionary roles (with associated reliance on small, tailored, joint and/or coalition task forces) at the same time that regional instability increased around the world. These conditions placed a new premium on exchange of information and other vital services throughout small joint forces. U.S. forces quickly found that the heritage of many types of MC&G products, optimized for system or service-specific applications, was creating barriers to interoperability.

In response, DMA has recognized the primacy of standards that apply across a range of MC&G products and is rapidly defining a robust suite of required standards. Some of these standards were already in development, and are now being brought quickly to closure. DMA has also recognized that it cannot achieve MC&G interoperability by simply standardizing the data it produces, and is expanding the scope of its standardization efforts to take in applications (this would be done primarily through certification of modules nominated by the Services or industry) and technical infrastructure.

The expected long-range effects of DMA's standardization and interoperability program include the following: significant reduction in the number of standard digital datasets ("products") populated and maintained, while increasing the availability of information to users; certification of numerous "best of breed" non-proprietary applications as reusable software modules; significant increases in the number of digital MC&G standards, with adoption from the international, national, and federal sectors where suitable standards exist; and simplification of product specifications through citing of standards.

Joint management of the MC&G standardization and interoperability program is occurring through the MC&G Joint Interoperability Board (MJIB) and its supporting Geospatial Standards Management Committee (GMSC).

Digital Production System (DPS)

The DPS achieved Full Operational Capability (FOC) in November 1992. The system exercise and rehearsal phase was completed in September 1993, and DPS has now been turned over for production with the exception of the Aeronautical Data Management (ADM) System, which is currently scheduled for turnover in April 1994.

Global Spatial Information and Services (GGIS)

DMA's future lies in its ability to populate a massive data base or data bases that will provide to the user, the customer, the most current information at the right time, and with the needed accuracy. The Global Geospatial Information and Services (GGIS) initiative encompasses a commitment to information production, information management, information dissemination, and information servicing. The Global Geospatial Information (GGI) requirement is for worldwide, accurate, current, spatially co-referenced information about the earth, arranged in a coherent structure to support measurement, mapping, monitoring, modeling, terrain evaluation, and spatial reasoning applications. Data type layers include elevation, features, imagery, and gravity. Feature information may be thematically layered. Data from GGIS will be compatible with geographic information system technologies for ease of export, manipulation, update, and value adding. DMA is currently laying the foundation for this initiative.

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 became effective February 15, 1993; use of the standard is mandatory for all Federal agencies 1 year from 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 are being sought from the American National Standards Institute to broaden access to the FIPS 173 among the commercial communities with the United States. Also, the USGS is participating in International Standards Organization efforts to address data transfer standards for international applications.

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 was submitted to the National Institute for Standards and Technology (NIST) for approval as an amendment to FIPS 173 late in 1993. USGS DLG data will be available from the NDCDB in the TVP beginning February 15, 1994. The USGS coordinated the development of a raster profile by following 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 is limited to georeferenced data, sampled uniformly and in a geodetic or cartographic coordinate system, and optionally allows compressed data. The raster profile needs further enhancement and will be submitted to NIST for approval as Part 5 of SDTS in mid-1994. Additional profiles, such as those needed to support non-topological vector data (e.g. CAD) and point-only vector data (e.g. for mining and geochemical data), are currently in development throughout the spatial community.

In addition, the USGS has developed a suite of public domain software tools that supports 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 developing a spatial data transfer processor to support profile-based FIPS 173 exchanges. Also, USGS is developing conformance testing software to validate SDTS compliance of profile-based data transfers, encoders, and decoders.

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 has been drafted and is currently being reviewed and refined. The Federal Geographic Data Committee (FGDC) is actively involved in developing and maintaining this register. Because the register will allow users to update the glossary continuously, part 2 of FIPS 173 will evolve over time.

Geographic Data Clearinghouse

The U.S. Federal Government, as a first step toward a National Spatial Data Infrastructure (NSDI), is establishing a Geographic Data Clearinghouse under the auspices of the Federal Geographic Data Committee (FGDC). This clearinghouse will initially provide nationwide access through Internet to directories of information about geographic data sets held by Federal agencies, and eventually will provide on-line access to the data themselves and to data sets from the non-Federal sector. DMA has encouraged participation of other DoD activities in the first phases of the clearinghouse initiative, and is acquiring Internet connectivity which will allow its own participation. DMA envisions strong participation by Department of Defense activities in the NSDI, both as data users and as providers of data cleared for release outside the military.

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.

Traditional map production techniques cannot adequately provide products that meet user requirements for computer-assisted applications and are unable to use the variety of source materials now available from advanced remote sensing and satellite technologies. Outdated graphic mapping equipment is being replaced with more efficient automated hardware and software systems that are capable of producing cartographic data in both graphic and digital forms.

The National Mapping Division initiated the Advanced Cartographic System (ACS) activity which is a modernization program to implement advanced technologies and production procedures to satisfy spatial data requirements through the year 2000. The ACS activity includes the planning, acquisition, development, testing, and maintenance of state-of-the-art equipment,

facilities, and software and the retraining of personnel to use these systems for the purpose of modernizing the map and digital data production, management, and distribution operations of the National Mapping Program.

New capabilities for collection and management of digital cartographic data have made the development of an integrated digital cartographic production system economically feasible. The new system can be conceptually divided into four major functions as follows:

Graphic conversion includes the hardware and software to convert graphic map data into digital data for inclusion in the National Digital Cartographic Data Base. This system development will result in a mass processing capability which will substantially increase digital data production and map revision capabilities.

Sensor Exploitation consists of hardware and software to collect digital cartographic data directly from various types of remotely sensed data such as aerial photographs and satellite images.

Data base operations include the computers and the mass storage capabilities needed to manage large archive data bases, source materials, products, and production management information.

Product finishing includes the hardware and software to convert digital cartographic data from archive data bases to specific products, such as general-purpose maps, image maps, thematic maps, special maps, and digital data products.

When in place, the system will significantly increase the capability to produce and update digital cartographic data and graphic products at less cost. Through this system, the U.S. Geological Survey will continue to fulfill its lead civilian agency responsibility to provide the user community with the current cartographic and geographic information required to support their programs.

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; multi-scale, multi-source, 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 distribution of GIS technology throughout the USGS is continuing, through the procurement and networking of UNIX-based GIS processing systems. GIS is now being applied by scientists in the fields of cartography, hydrology, geology, and other earth science related disciplines.

The USGS is developing databases from remotely sensed data (satellite and aircraft) and the merger and analysis of these data with digital cartographic, geologic, hydrologic, and other earth science data sets. Data sets of importance to global change research and ecological analysis on regional and global scales are being made available to the earth science community. For

example, satellite data are being used to produce bi-weekly estimates of vegetation conditions across the North American continent. In turn, these data are being analyzed to produce maps of land cover characteristics. Research cooperatives with researchers from other Federal agencies and universities are assessing the utility of this information for a variety of modeling applications. The USGS continues to provide 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.

The USGS is providing GIS expertise to Federal agencies involved in ecosystem study and management. For example, the Columbia River ecosystem initiative represents a collaborative, multi-disciplinary effort to provide the unbiased data and information needed for the management of terrestrial and aquatic ecosystems and was developed jointly by the USGS and the National Biological Survey (NBS).

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 Digital Line Graph (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 are above or below 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 first version of the production system has been delivered and will focus on converting 1:100,000-scale DLG data to the DLG-E model. 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.

REMOTE SENSING/IMAGERY PROCESSING

General Exploitation

DMA continues to refine requirements for multispectral image (MSI)-based products. Such products have proved very effective for counterdrug applications and for rapid response during crises.

Current MSI-based products are available in both hardcopy and digital form, and include unrectified, rectified, and orthorectified scenes. Military specifications for MSI maps are in development. In response to user requests, investigations of spectral band combinations, sensor fusion, hardcopy product finishing, and digital transmission are ongoing.

Controlled Image Base (CIB)

The MC&G Joint Interoperability Board (MJIB), a flag-level advisory board to the DMA Director, recently recognized a multi-Service requirement for a broad-area Controlled Image Base (CIB). Major projected uses include rapid overview of areas of operations, use as a map substitute for emergencies and crises, use as a metric foundation for anchoring other data in command/control/communications/computers/intelligence (C4I) systems or image exploitation, use as positionally-correct images for draping in terrain visualization, and for use as image backgrounds for mission planning and rehearsal. This product would be unclassified (hence moderate resolution) black-and-white orthorectified digital imagery. Harmonization of formats with USGS's digital orthophotoquad program is desired, and the product will be compliant with both the Raster Product Format pending joint coordination and the U.S. National Imagery Transmission Format Standard (NITFS). DMA has begun prototyping of CIB as an extension of its current ARC Digital Raster Imagery (ADRI) program, with a formal target of mid-CY94; the first prototype may be available much earlier.

Controlled Multispectral Image Base (CMIB)

The MJIB also recognized a multi-Service requirement for a broad-area Controlled Multispectral Image Base (CMIB). This product would, like the companion black and white CIB, be unclassified, orthorectified, and digital. Primary uses, beyond those envisioned for the CIB, would be both analytical (computer-assisted feature classification, etc.) and visual (simulated full-color maps, terrain drapes, etc.). DMA will begin prototyping against a mid-CY94 target.

Remote Sensing

DMA is initiating a development program for incorporating panchromatic data from the LANDSAT 7 High Resolution Multi-Spectral Imager (HRMSI) into the Digital Production System (DPS). LANDSAT 7 data, assuming major program adjustments do not occur in the wake of the loss of LANDSAT 6, should become available in early 1998.

DMA is also investigating the benefits of utilizing MSI data and associated processing algorithms for enhancing the effectiveness of the DPS.

Implementation of the Spatial Data Transfer Standard

The Spatial Data Transfer Standard (SDTS) was approved by the Department of Commerce as the Federal Information Processing Standard in July 1992. The SDTS will serve as the spatial data transfer mechanism for all U.S. Federal agencies and is available for use by state and local governments, private sector and research organizations. The standard is valuable to users and producers of digital spatial data for reduced information loss in data exchange, for the elimination of the duplication of data acquisition and for increased quality and integrity of spatial data. The U.S. Geological Survey has been designated the SDTS maintenance authority and is engaged in developing software tools, conducting training and workshops and developing a spatial features register.

The U.S. National Spatial Data Infrastructure

Concerns about high costs and limited availability of accurate, current resolution and geospatial data have led to the conceptualization in the U.S. of a National Spatial Data Infrastructure (NSDI). The NSDI will be a set of policies, standards, materials, technologies, people, procedures as well as geospatial data that will provide a foundation for efficient collection, management and use of data. Strategies to build the NSDI include establishing forums for communications facilitating access to data-building a framework and thematic data sets, developing educational programs and fostering partnerships for data sharing.

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 annually. 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 continue to 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 second 5-year cycle of NAPP covers 1992 to 1996. 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.

In 1994 the NAPP is spending $3.9 million for flying photography for S. California, Florida, Oregon, Nevada, South Carolina, Louisiana, Arkansas, Virginia, Wyoming, Ohio, and New York. Four of the eleven States are to be flown with color infrared film, and seven with black and white. The years of 1995 and 1996 call for another ten States each. The third 5-year cycle for the NAPP is scheduled to begin in 1997.

Inspected and accepted photography since 1987 is available in the archives for an estimated 85 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 are 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, 1,740 quarter-quadrangle digital orthophotos have been prepared. The standard distribution policy will be to place compressed digital orthophotos, formatted by county, on CD-ROM.

Satellite Image Mapping

Work is in progress on the second edition of the 1:5,000,000-scale satellite image map of Antarctica using advanced very high resolution radar (AVHRR) data from NOAA satellites. Enhancements include replacing areas of cloud cover on the first edition with cloud-free data where available, adding spot elevations and contours, and adding a significant number of names for geographic features. The map will include larger scale (1:3,000,000 and 1:1,000,000 respectively) insets of the Antarctic Peninsula and the Dry Valley area.

Five maps using Landsat thematic mapper (TM) data of the Siple Coast and Ice Streams have been published. The geometrically and radiometrically corrected mosaic of the scenes covering the entire area is complete and the individual 1:250,000-scale quadrangles have been extracted. The remaining 10 image maps are in work for collar preparation and review. Plans include a CD-ROM of the geometrically corrected mosaic at 1:1,000,000 scale and either the individual Landsat TM scenes or the quadrangles along with public domain viewing software.

Seven topographic maps at 1:250,000 scale in the Antarctic Peninsula are in work. These maps use Landsat multispectral scanner (MSS) imagery as a substitute for airbrush shaded relief portrayal.

Work is in progress on a topographic map at 1:10,000 scale of Seymour Island in the Antarctic Peninsula. This map is a cooperative project involving the Argentine Antarctic Institute and a geologist at the Ohio State University, Byrd Polar Research Center and uses photography flown by the Argentine government and geologic field work. The map has a 5 meter contour interval and shows the extensive drainage network as well as outwash features and ice areas.

Side-Looking Airborne Radar (SLAR) Data

The USGS SLAR program was initiated during 1980 and has acquired and archived for public use, data of about 40 percent of the conterminous United States, Alaska, and Puerto Rico. The areas chosen by USGS scientists for acquisition usually have high potential for energy and mineral resources or are areas of earth-hazards investigations. SLAR data are available variously as photographic reproductions, generally at 1:250,000 scale, and as digital files on magnetic tape and CD-ROM.

GLOBAL CHANGE

The U.S. Global Change Research Program (USGCRP) is a coordinated effort involving 15 U.S. Government agencies and many universities. It sponsors studies of the atmosphere, oceans, and land surface; the physical, chemical, and biological processes that define these environments; and the linkages between them, to improve understanding of the Earth system in support of national and international policy making activities. There are four main program areas: (1) observations 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. The USGCRP emphasizes interdisciplinary studies and the development of an integrated understanding of large-scale environmental processes and causes of environmental change. The Program is addressing several critical issues: climate change and greenhouse warming; seasonal to interannual climate prediction; stratospheric ozone and ultraviolet-B (UV-B) radiation; ecological change and biodiversity; human dimensions (including economics); international cooperation, and education and public assistance.

The U.S. Geological Survey (USGS) is conducting global change research under three goals: improving understanding of land-atmosphere and land-ocean exchanges of water, energy, carbon, and nutrients; describing past and contemporary states and changes in the Earth's environment; and facilitating access to, and use of global change data and information for research, resource management, education, and policy decisions. One component of the USGS program is developing, managing, applying, and facilitating access to regional, continental, and global land data sets for use in understanding and modeling land processes and their interactions with the hydrosphere and atmosphere.

The availability of spatial data to the global change research community is often limited by the difficulty of access to information about data the many types of data that are needed for interdisciplinary research. USGS has developed the Global Land Information System (GLIS) to provide information about and access to global land data sets. Accessible via modem dialup and the Internet, GLIS offers users information about satellite data and derivative products such as Advanced Very High Resolution Radiometer (AVHRR), Landsat Multispectral Scanner (MSS), and Landsat Thematic Mapper (TM) data, and global cartographic, terrain, vegetation, and soils data.

The USGS is also working to preserve a unique and consistent set of Earth observations obtained over the last 21 years from the Landsat satellites. Landsat MSS and TM data in the EROS Data Center archive are being converted to longer life, computer-compatible media. Over 200,000 scenes of post-1978 MSS data and 15,000 scenes of Landsat TM data have been converted. Improved Landsat data processing capabilities are also being developed to meet the growing user demand for historical Landsat data products.

Long-term, consistent land data sets at regional to global scales are also being developed to meet the needs of global change modelers and researchers. Emphasis is given to data sets related to land cover characteristics, soils, terrain, and derived data such as vegetation indexes and land surface brightness. Example applications of these data include modeling land-atmosphere exchange processes and developing methods to monitor, analyze, and predict patterns of change in the landscape.

OTHER PROJECTS

DMA Technical Assistance to International Coproducers

The Defense Mapping Agency, in an expansion of its role in the international cooperation and coproduction of mapping, charting and geodetic (MC&G) materials, is providing technical assessment and assistance to the international community to achieve standardization and interoperability of MC&G products and materials. As the mapping world moves toward digital data, the exchange of data becomes more complex and the margin for deviation from data standards more critical. To overcome this problem, the Defense Mapping Agency offers technical assistance to its international coproducers in exchange for finished products. The requirements for technical assistance are increasing with the availability of commercial digital capabilities in many areas of Eastern Europe, Asia and Latin America. DMA's experience in digital mapping production is a valuable commodity being used to reduce the learning curve and contemporize foreign military mapping.

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 Digital Production System

APPENDIX II - The U.S. Geological Survey's Modernization Program and Cooperative Surveying and Mapping Protocol with the People's Republic of China

APPENDIX III - National Ocean Service Automated Chart Production

APPENDIX I

Defense Mapping Agency (DMA)
Digital Production System (DPS)

The Defense Mapping Agency (DMA) continues to enhance its present output as more of DMA's products are shifted to production on the Digital Production System (DPS).

The DPS, a program that permits exploitation of new source materials for Mapping, Charting and Geodesy (MC&G), has been implemented in two phases: Mark 85 and Mark 90.

Mark 85, a transitional step that provided an interim capability to use the new source material in hardcopy, also supported existing production processes. The Mark 85 phase was characterized by a significant push of manual terrain and feature extraction processes into semi-automatic capabilities on interactive computer workstations. In addition, Mark 85 provided automated inventory capabilities for all DMA source holdings and production plans.

Mark 90, an all-digital production system using the new source material in softcopy, retains part of the Mark 85 capability, but replaces the rest along with most of the existing production line. The Mark 90 phase, now known as DPS, provides a higher level of automation in data extraction plus uses that extracted data to populate a worldwide MC&G database from which any of the DPS products may be derived. In addition, Mark 90 capabilities include automatic generation of digital products and semi-automatic generation of graphic products from the same database, including digital generation of film separates for printing.

The initial delivery of Mark 90 in 1992 supported production of source geopositioning, and was soon followed by terrain and feature extraction for input to the production world database. The first DPS products to be created from this production database will be digital elevation products and topographic line maps in 1994. The DPS has also produced Airfields, Points, and Text Flight Information Publications to date.

Enhancements to the original DPS design now include crisis support capabilities that permit production of overprint update data for existing maps within a fraction of the normal production time for totally new products.

APPENDIX II

The U.S. Geological Survey's Modernization Program
and
Cooperative Surveying and Mapping Protocol
with the
People's Republic of China

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.

In April, 1985, the USGS and the National Bureau of Surveying and Mapping (NBSM) of the People's Republic of China (PRC) jointly signed a Protocol for Scientific and Technical Cooperation in Surveying and Mapping Studies covering a period of 5 years. This signing was in accordance with the general agreement between the U.S. Government and the Government of the PRC on Cooperation in Science and Technology (S&T) that was signed in Washington, D.C., in January, 1979, and extended by agreement in January, 1984. In April, 1990, the USGS and NBSM agreed to extend the Protocol for 1 year, and again in April, 1991, for another 5 years to April, 1996, to co-terminate with the umbrella S&T agreement between the USA and the PRC. The Protocol, which contains three work project annexes, is intended to promote scientific and technical cooperation in photogrammetry, remote sensing, cartography, geographic information systems (GIS), and production management applied to surveying and mapping.

During 1993, personnel exchanges between the USGS and NBSM in support of the project annex work plans resulted in the following activities and accomplishments: Both sides conducted joint research in GIS analyses and applications, digital revision, data base development, standards for spatial data transfer, new digital data and software, and the generation of standard digital cartographic products (Annex II-Developing Geographic Information Systems); the parties also conducted ongoing joint research on the development of software for change detection, continued investigations on temporal analysis of 1-km Advanced Very High Resolution Radiometer (AVHRR) data for land characterization, jointly prepared AVHRR mosaics of a selected region in central China, and began the conversion of software using digital elevation model data to define hydrologic drainage channels (Annex III-Application of Remote Sensing

Information to Cartography); and both sides sent management experts to the other's country to exchange and evaluate information on the problems related to the transition from traditional to modern map production methods, with emphasis on digital revision management and production (Annex IV-Developing Production Management Systems).

The U.S. Geological Survey considers the activities conducted under this Protocol to be beneficial to both the USA and the PRC and both sides are currently developing plans to carry project annex activity through 1994 and into 1995. Information, technology and data have been shared between both governments, and cartographic information and data have been provided to other U.S. Government agencies.

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 II (ANCS II) which will lead to the automated production and maintenance of NOAA's nautical charting products. ANCS II will include three primary data bases: (1) the Navigation Information Data Base (NIDB), (2) the Chart Graphics Data Base (CGDB), and (3) 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, ANCS II will employ RISC-based color graphic workstations which will be physically distributed throughout the NCD Ethernet.

Software has been developed in five incremental phases. The bulk of the code written supports the five major functional areas that comprise the ANCS II system. The five functional areas are: (1) Manage Source, (2) Produce Charts, (3) Produce Manuscripts, (4) Manage Archives, and (5) Manage System.

A Functional Test of the developed software for ANCS II is scheduled to begin during the first quarter of FY 94 and last about 2 months. A 6-month trial production test of the developed system is scheduled to begin during the second quarter of FY 94. Trial production will be staged in a simulated production environment. A 50-chart test area of the Chesapeake Bay area will be used to perform all cartographic production and maintenance tasks required to fully exercise the system. Performance tuning and final debugging of the system is also expected to be made at this time.

A final System Acceptance Test (SAT) is planned to occur 1 month after trial production concludes and will last about a month. At that time, ANCS II will have an initial operating capability. Implementation of ANCS II into a nautical charting production environment will follow SAT. Enhancements to the operational and system software environment are also expected to be made after the initial system is delivered and is operational.

Automated Chart Compilation Program

Version 2.0 of the CartoAssociate cartographic expert system prototype was completed. This project is being carried out as a collaborative research effort with other Federal agencies including the Geographic Information System Standards Laboratory within the National Institute of Standards and Technology (NIST).

The original objective was to develop an embedded expert system capability to be installed into conventional digital cartographic production systems, such as the ANCS II. This was expanded to include certain Geographic Information System (GIS) algorithms necessary to enable the expert system to accomplish its processing. The embedded system will alleviate cartographers from having to make tedious and detailed chart compilation decisions by issuing higher

level commands. These chart compilation processes include: symbol selection, spatial conflict detection and resolution, feature generalization when changing scales, and placement of text.

Because of the GIS enhancements, the CartoAssociate prototype has been renamed the Marine Coastal GIS and Compilation System and will increase productivity by reducing the level of operator interactions required to manipulate data and compile nautical charts. Its use will reduce operational costs by simplifying the operator actions required to invoke specific ANCS II actions, and the product quality will be improved because of increased consistency of feature portrayals due to autonomous expert system processing using the same set of rules for all feature types.

Version 2.0 was developed on a Sun SPARCstation II platform using an advanced object-oriented software design and performs functions required to:

- Represent nautical features as cartographic objects and store/ manipulate them as software objects in an object data management system;

- Represent and manipulate complex chart features, e.g., shipping channels as composite data base objects using an expert system and knowledge base of cartographic rules to support autonomous processing functions;

- Autonomously compile the most important nautical chart features (channels, buoys, hazards, soundings, etc.) by detecting and resolving spatial conflicts between nearby features or text, determining symbols for individual features, and by deducing symbolic portrayals for groups of features; and

- Autonomously placing text for point features such as buoys, wrecks, pilings, rocks, and soundings.

The prototype is being developed using a combination of in-house and contract resources under an object-oriented software development and database environment. The UNIX operating system, X-Window graphics tools, and the Smalltalk-80 and C languages are the development tools in use.

A Phase II Small Business Innovative Research (SBIR) contract was awarded to DBA Systems, Inc., of Fairfax, Virginia to develop a system for including GIS topological data structures into the CartoAssociate's object spatial data model. A Phase II SBIR contract to Semantic Solutions, Inc., of La Jolla, California continued in progress to develop algorithms for scale change and data fusion under an object-oriented data model. A Phase I SBIR contract was awarded to QUBA, Inc., of Arlington, Virginia to explore the feasibility of extending the expert system module with a neural net capability.

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 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. Fourteen data bases are on-line which include wrecks and obstructions, the 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 information.

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 up-grades 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-scribed plots were produced in 1992 to support chart production and 670 erasable Programmable Read Only Memory chips 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 80 gigabytes that connects over 100 graphic and alphanumeric workstations located in the chart compilation areas.
