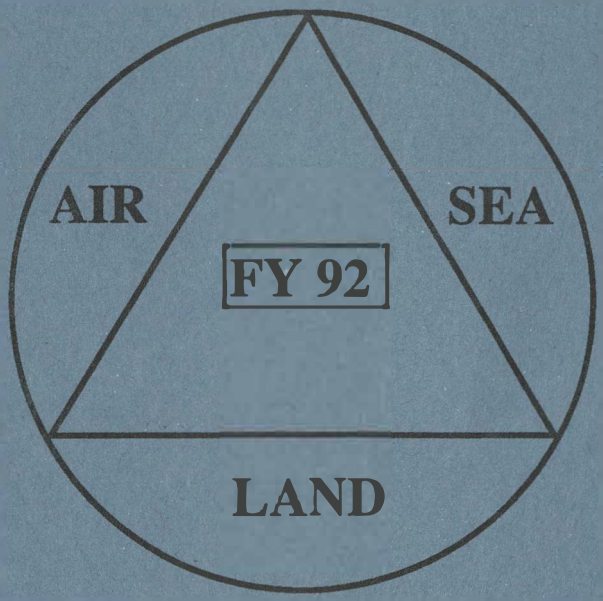
ANNUAL REPORT

COAST AND GEODETIC SURVEY



National Oceanic and Atmospheric Administration
National Ocean Service
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ANNUAL REPORT

COAST AND GEODETIC SURVEY

FISCAL YEAR 1992

U.S. Department of Commerce
Barbara H. Franklin, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

National Ocean Service
W. Stanley Wilson, Assistant Administrator

Coast and Geodetic Survey
Rear Admiral J. Austin Yeager, NOAA, Director

MESSAGE FROM THE DIRECTOR

This annual report summarizes the major accomplishments of Coast and Geodetic Survey (C&GS) during FY 92. C&GS is a line office within the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Organizationally, C&GS is composed of three Divisions with expertise in specific program areas: (1) geodesy, (2) nautical charting, and coastal and bathymetric mapping, and (3) aeronautical charting. This report emphasizes recent technological advances that have made C&GS more productive and efficient, resulting in more precise measurements, improved products, and better services to users.

J. Austin Yeager
Rear Admiral, NOAA
Director
Coast and Geodetic Survey

GLOSSARY OF FREQUENTLY USED ACRONYMS IN THIS REPORT

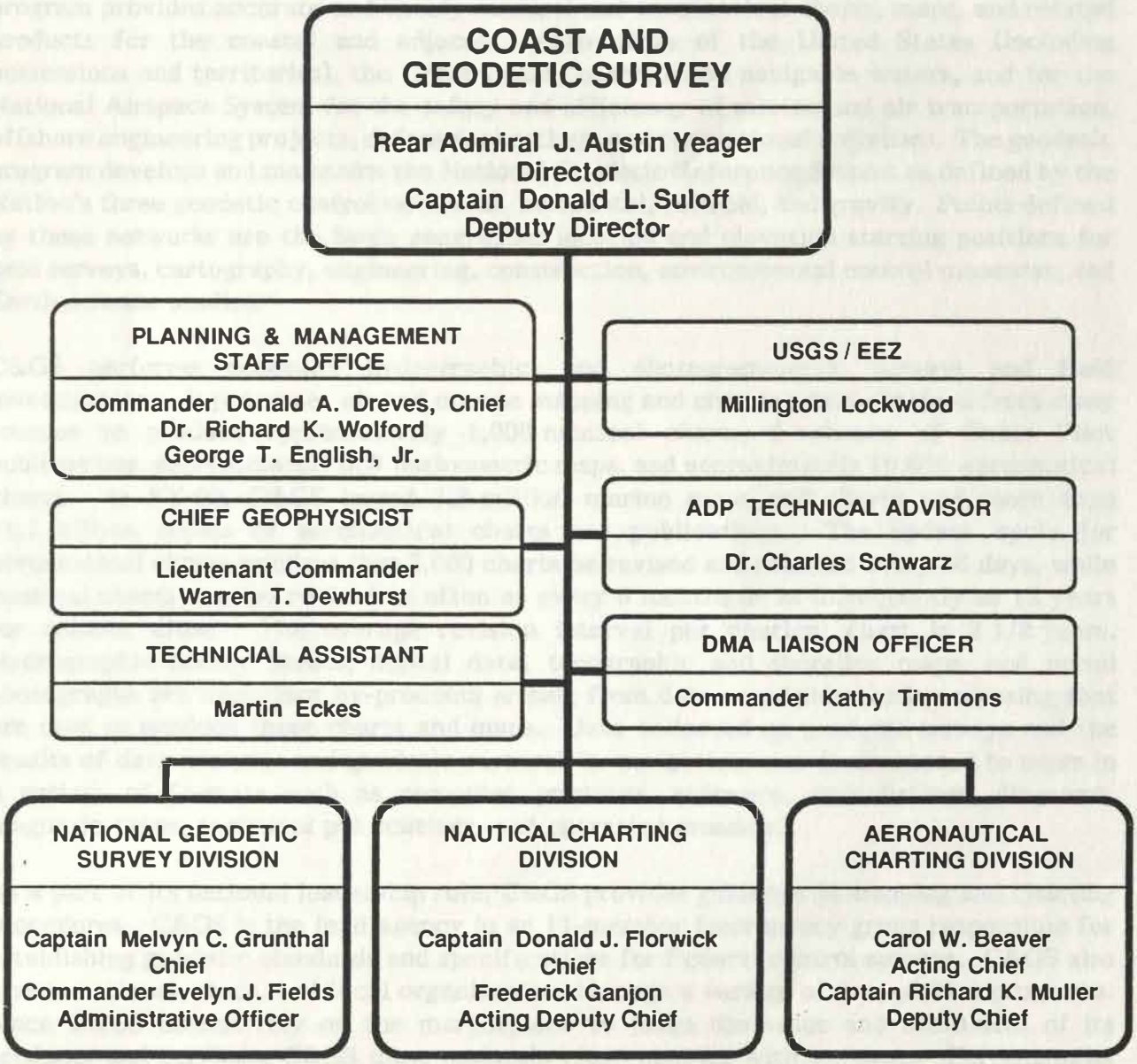
AAS	Advanced Automation System
ACAS	Aeronautical Chart Automation Section
ACB	Aeronautical Chart Branch
ACD	Aeronautical Charting Division
ACSM	American Congress on Surveying and Mapping
ACT	Advanced Correlation Technology
ADS	Automated Distribution System
ANCS II	Automated Nautical Charting System II
APTS	Airport Planning Tracking System
ARS	Automated Reproduction System
ARTCC	Air Route Traffic Control Center Chart
ATCSCC	Air Traffic Control System Command Center
CC	Controller Chart
CD-ROM	Compact Disk-Read Only Memory
CGDB	Chart Graphics Data Base
C&GS	Coast and Geodetic Survey
CIGNET	Cooperative International GPS Network
CMPSDB	Coastal Mapping Project Status Data Base
DACS	Digital Aeronautical Chart Supplement
DAS	Data Acquisition System
DBMS	Data Base Management System
DBRITE	Digital Bright Radar Indicator Tower Equipment
DGPS	Differential Global Positioning System
DMA	Defense Mapping Agency
DNC	Digital Nautical Chart
DOC	Department of Commerce
DPS	Data Processing System
EDM	Electronic Distance Measurement
ECDIS	Electronic Chart Display and Information Systems
EEZ	Exclusive Economic Zone
ESDIM	Earth System Data and Information Management System
FAA	Federal Aviation Administration
FGCS	Federal Geodetic Control Subcommittee
GIS	Geographic Information System
GPS	Global Positioning System
GRS 80	Geodetic Reference System of 1980

HARN	High Accuracy Reference Network
HSB	Hydrographic Surveys Branch
HDAPS	Hydrographic Data Acquisition and Processing System
HSHRSSS	High Speed, High Resolution Side Scan Sonar
HYDEX	Hydrographic Surveys Information Extract
HYDICE	Hyperspectral Digital Imagery Collection Experiment
ICAO	International Civil Aviation Organization
IDPF	Integrated Digital Photogrammetric Facility
IFR	Instrument Flight Rules
IGLD	International Great Lakes Datum
IHO	International Hydrographic Organization
LAN	Local Area Network
MCB	Mapping and Charting Branch
MGIS	Microcomputer Geographic Information System
MIS	Management Information System
MSS	Multispectral scanner
NOS	National Ocean Service
NOAA	National Oceanic and Atmospheric Administration
NAD 27	North American Datum of 1927
NAD 83	North American Datum of 1983
NAS	National Airspace System
NAVD 88	North American Vertical Datum of 1988
NCD	Nautical Charting Division
NCRDL	Nautical Charting Research and Development Laboratory
NGDC	National Geophysical Data Center
NGIB	National Geodetic Information Branch
NGRS	National Geodetic Reference System
NGS	National Geodetic Survey
NGSIDB	National Geodetic Survey Integrated Data Base
NIDB	Navigation Information Data Base
OC	Obstruction Charting
OCDB	Obstruction Charting Data Base
PB	Photogrammetry Branch
PCDB	Production Control Data Base
PDB	Photograph Data Base
PROM	Programmable Read Only Memory

RDBMS	Relational Data Base Management System
RPLS	Rapid Precision Leveling System
RVM	Radar Video Map
SAV	Submerged Aquatic Vegetation
SBIR	Small Business Innovation Research
SREG	Source Registry Program
SDTS	Spatial Data Transfer Standard
SSIDB	Shoreline Survey Index Data Base
SURDEX	Survey Boundary Index System
TDP	Time-Dependent Positioning
TDWR	Terminal Doppler Weather Radar
USCG	U.S. Coast Guard
USCOE	U.S. (Army) Corps of Engineers
USGS	U.S. Geological Survey
VFR	Visual Flight Rules
WORM	Write Once, Read Many (Disks)

CONTENTS

ORGANIZATION CHART



INTRODUCTION

The Coast and Geodetic Survey (C&GS) is responsible for the National Oceanic and Atmospheric Administration's (NOAA) mapping, charting, and geodesy programs, rendering national leadership in these scientific and technical areas. The mapping and charting program provides accurate and timely nautical and aeronautical charts, maps, and related products for the coastal and adjacent ocean areas of the United States (including possessions and territories), the Great Lakes, other inland navigable waters, and for the National Airspace System for the safety and efficiency of marine and air transportation, offshore engineering projects, defense operations, and recreational activities. The geodetic program develops and maintains the National Geodetic Reference System as defined by the Nation's three geodetic control networks: horizontal, vertical, and gravity. Points defined by these networks are the basic geographic location and elevation starting positions for land surveys, cartography, engineering, construction, environmental control measures, and Earth science studies.

C&GS performs geodetic, hydrographic, and photogrammetric surveys and field investigations. It processes air and marine mapping and charting data obtained from many sources to produce approximately 1,000 nautical charts, 9 volumes of Coast Pilot publications, approximately 600 bathymetric maps, and approximately 10,000 aeronautical charts. In FY 92, C&GS issued 1.8 million marine maps and charts and more than 11.1 million copies of aeronautical charts and publications. The update cycle for aeronautical charts requires that 9,000 charts be revised and reissued every 56 days, while nautical charts may be revised as often as every 6 months or as infrequently as 12 years for remote areas. The average revision interval per nautical chart is 2 1/2 years. Hydrographic survey sheets, digital data, topographic and shoreline maps, and aerial photographs are important by-products arising from data acquisition and processing that are used to produce these charts and maps. Data collected on geodetic surveys and the results of data analyses and geodetic research investigations are disseminated to users in a variety of formats such as computer printouts, software, data listings, diagrams, magnetic tapes, technical publications, and operation manuals.

As a part of its national leadership role, C&GS provides guidance in mapping and charting procedures. C&GS is the lead agency in an 11-member interagency group responsible for establishing geodetic standards and specifications for Federal control surveys. C&GS also assists national, state, and local organizations through a variety of cooperative programs. Since C&GS cannot rely on the marketplace to judge the value and usefulness of its products and services, C&GS must maintain close contact with its users. For example, geodetic advisors are assigned to those states participating in the State Geodetic Advisor Program. Personal contacts are made between C&GS personnel and local users during field surveys. The Cooperative Charting Program involving the U.S. Power Squadrons and the U.S. Coast Guard Auxiliary provides valuable feedback information on nautical charts. Additional contacts are made through professional organizations, technical conventions, boat and air shows, and similar activities. Marketing studies are conducted to determine

user reactions to existing products and to formulate plans for new products, formats, and coverage.

The major mapping, charting, and geodesy activities of C&GS include: (1) data base management, (2) establishment and maintenance of national standards and specifications, (3) information and technology transfer to Government and the private sector, and (4) research and development to increase productivity and to improve measurements, survey techniques, and the quality of data and products. FY 92 accomplishments are cited in separate chapters, each devoted to one of the three C&GS Divisions--Nautical Charting, Aeronautical Charting, and the National Geodetic Survey.

ACCOMPLISHMENTS OF THE NAUTICAL CHARTING DIVISION

SURVEYS AND CHARTING PRODUCTS

The primary mission of the Nautical Charting Division (NCD) is to provide accurate and timely maps, charts, and related products to improve the efficiency and safety of marine transportation, offshore engineering, coastal zone management, defense operations, and recreational activities. During the past year, bathymetric surveys were conducted in the Gulf of Mexico for the Exclusive Economic Zone (EEZ) program and hydrographic surveys were conducted in Alaska, California, Michigan, and along the Atlantic and Gulf of Mexico coasts. C&GS continued the installation of new hydrographic data acquisition and processing systems (HDAPS) aboard NOAA ships and C&GS field parties. All hydrographic field units using HDAPS were equipped with the Differential Global Positioning System (DGPS). Automated indexing and archiving systems for hydrographic surveys continued to be developed. Photogrammetric missions were carried out throughout the United States to support nautical charting and airport obstruction programs. Modernization of photogrammetric operations continued. New nautical charts were issued, the completely revised Nautical Chart Manual was published, and support for the national Electronic Chart Display and Information Systems (ECDIS) Project was continued.

REDUCTION IN BATHYMETRIC MAPPING

On July 31, 1992, C&GS was forced to abolish the Ocean Mapping Section of the Mapping and Charting Branch (MCB) due to financial constraints. This ended an effort that began in 1965, in cooperation with other federal agencies, to produce a suite of bathymetric mapping products. During its existence, over 800 map products, including the recently published Monterey Bay Marine Sanctuary map were produced. The primary responsibilities of the disbanded units have been delegated to MCB and the Hydrographic Surveys Branch (HSB). Distribution of multibeam black and white maps has been transferred to NOAA's National Geophysical Data Center (NGDC) in Boulder, Colorado. C&GS will continue to meet requests for printed products until supplies are depleted. Then NGDC will assume responsibility for equivalent black and white products derived from color maps.

The C&GS program for mapping the Exclusive Economic Zone (EEZ) has been severely affected by these financial constraints. NCD had been surveying the EEZ to International Hydrographic Organization standards using multibeam technology. The EEZ encompasses 3.4 million square nautical miles within 200 miles of the U.S. coastline, including the possessions and trust territories. In cooperation with the U.S. Geological Survey (USGS), NCD has been conducting a major program to determine the characteristics and resources within the EEZ by using modern survey techniques. That program had been concentrating on the outer continental shelves and continental slopes, but due to recent new requirements the process of shifting focus to shallower waters closer to shore was under consideration.

The objective of the NCD effort has been to produce high-resolution bathymetric data for the upgrade of bathymetric maps and nautical charts. Another objective was to produce a digital data base that would support other NOS mapping products tailored to satisfy various users. Thirty-three new 1:100,000-scale bathymetric maps with 20-meter contour intervals and covering portions of the EEZ off the west coast, Alaska, Hawaii, Virginia, and in the Gulf of Mexico have been printed since the fall of 1989. Additional bathymetric maps based upon multibeam surveys are available in black and white form. Before the recent curtailments, emphasis on the production of digital products rather than printed maps was under consideration.

NCD has printed 3-dimensional physiographic images of the central California coast and the continental slope off Louisiana. These new products consist of a 1:250,000-scale bathymetric map above the corresponding 3-dimensional image with a vertical exaggeration of 6:1. They each cover approximately 9,000 square nautical miles of the continental margin and are derived from the data from six of the 1:100,000-scale bathymetric maps.

During the past year, the NOAA Ships MT. MITCHELL and WHITING have continued multibeam surveys in the Gulf of Mexico, although the MT. MITCHELL was unavailable for much of the past field season due to deployment to the Middle East. The Gulf of Mexico surveys on the continental slope off Louisiana and Texas have provided the first detailed delineation of the extensive salt-related features, such as domes and basins. The maps and data from those surveys are expected to assist in the environmentally safe development of extensive oil and gas resources.

The contouring program used to produce the 1:100,000 bathymetric maps, mostly on the continental slope in water depths of over 150 meters, has been used with a fixed 250-meter grid. As emphasis shifts to mapping shallower waters, and with incorporation of more historical single-beam data into bathymetric maps, consideration will be given to the use of other gridding and contouring techniques. These include the use of nested grids (where the grid interval varies with the data density), as well as computer contouring using triangulated irregular networks.

Two hundred and fifty-eight (of 300) multibeam surveys have been archived to permanent optical storage media. The remaining surveys will be reprocessed into a more modern format and stored on archive media by the end of 1992. NOS is presently transferring multibeam data to NGDC for release to the public. These data include both full-resolution, digital, multibeam survey data and gridded data sets used to produce the bathymetric maps. To date over half of all multibeam survey data has been transferred to NGDC with the remainder to be sent in early 1993.

HYDROGRAPHIC SURVEYS

The Hydrographic Surveys Branch (HSB) planned and conducted hydrographic surveys during the year using four NOAA ships and two mobile field parties in the following areas: Cross Sound, Alaska; Cook Inlet, Alaska; Prince William Sound, Alaska; Sacramento River, California; southern New England Coast; approaches to Delaware Bay; Cape Henry, Virginia; Florida Keys National Marine Sanctuary; Choctawhatchee Bay, Florida; approaches to Mobile, Alabama; offshore Timbalier Island, Louisiana; Matagorda Bay, Texas; approaches to Corpus Christi, Texas; approaches to Port Isabel, Texas; and southern Lake Michigan. A charter vessel was utilized to acquire shallow-water multibeam data in support of a survey of the Florida Keys National Marine Sanctuary.

The NOS shore-based processing facilities utilize MicroVAX II and III computer systems for processing, verification, and map production. Similar MicroVAX systems are being used on the NOAA Ships MT. MITCHELL and WHITING. A workstation is being added in the Rockville processing facility to assist in the processing of multibeam data.

HYDROGRAPHIC SURVEY BOUNDARY INDEX AND HYDROGRAPHIC SURVEY DATA INFORMATION EXTRACT

The Hydrographic Survey Boundary Index (SURDEX) is an automated index system for delineating the limits of individual hydrographic surveys. It includes the boundaries of all inshore hydrographic surveys comprising approximately 95 percent of the C&GS hydrographic survey inventory. The Hydrographic Survey Data Information Extract (HYDEX) is an automated data base for the archiving of information about hydrographic surveys. Development began during 1990, and augmentation and improvements were continued during 1992. HYDEX incorporates information about each registered hydrographic survey commencing with registry number H-00001 (circa 1841).

HYDROGRAPHIC DIGITAL ARCHIVE

HSB continued working with NCD's Nautical Charting Research and Development Laboratory (NCRDL) during FY 92 to transfer over 3,000 digitized hydrographic survey data files to optical disk media. These surveys, covering the period from 1929 through 1965, were acquired by traditional (nonautomated) methods and digitized during the early 1970's. The automated acquisition of hydrographic survey information since the late 1960's has produced a growing inventory of digital hydrographic survey data. Some of these data have been transferred to optical disk media. Continued transfer of digital data is in abeyance pending software development. The Microcomputer-base Geographic Information System (MGIS) will allow simultaneous retrieval and display of HYDEX, SURDEX, and digital data.

HYDROGRAPHIC DATA RECOVERY

HSB received funding from NOAA's Earth System Data and Information Management System (ESDIM) for FY 92. ESDIM's goal is to improve the management of all NOAA environmental data, including the recovery of historical data that are now on deteriorating storage media, and make it available to all users. The money was used to digitize 18 hydrographic surveys in the Chesapeake Bay, procure an Intergraph workstation to validate 60 surveys not previously sent to NGDC, and contract for software support. The contract support provided the capability to display on a computer screen and plot all existing digital hydrographic surveys using the MGIS.

HYDROGRAPHIC DATA ACQUISITION AND PROCESSING SYSTEM

All NOAA field units conducting hydrographic surveys in support of nautical charting had Hydrographic Data Acquisition and Processing System (HDAPS) capability during FY 92. Systems are deployed aboard the NOAA Ships RAINIER, WHITING, RUDE, and HECK, as well as the Atlantic and Pacific Hydrographic Parties. The total number installed includes 15 Data Acquisition Systems (DAS) and 13 Data Processing Systems (DPS).

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

During FY 92, all field units using HDAPS were equipped with DGPS receivers for use as the primary positioning system. DGPS configurations allowed for input of differential correctors from USCG beacons (used by east coast ships) or correctors provided by locally established "fly-away" systems (used by west coast ships and the field parties). The DPS units were enhanced during FY 92 to improve data processing speed, increase the "ease of use," and maintain the "user-friendliness" of the system. Use of the mouse and "point-and-pick" menus have been integrated into most programs.

Extensive training was conducted for shipboard, field party, and marine center personnel during the year. The HDAPS Users Manual was also revised.

PHOTOGRAMMETRIC SURVEYS

The photogrammetric mapping mission of NOAA is carried out by NCD's Photogrammetry Branch (PB) to provide contemporary data and information required for the production of modern nautical and aeronautical products. Program activities include aerial photographic surveys, coastal mapping which encompasses the shoreline and the coastal zone, location

of fixed aids to navigation, nautical chart revisions, airport obstruction surveys and mapping, aeronautical navigational aid surveys, LORAN C navigation system surveys, airport datum tie upgrade surveys, submerged aquatic vegetation mapping, and marine sanctuary boundary demarcation.

During the year, two aerial photographic missions supplied 89 rolls (16,000 frames) of vertical, metric quality mapping photographs. While obstruction charting photographic missions secured photographs of airports throughout the conterminous United States, aerial photographs required for coastal mapping projects were secured for portions of the Florida, North Carolina, Virginia, Maryland, Texas, California, Washington, and Alaska coastlines. In addition, 22 harbors in Puerto Rico and the U. S. Virgin Islands were photographed for chart revision and controlled photogrammetric surveys.

Total surveying and mapping accomplishments include completing 130 airport surveys, 36 airport navigational aid surveys, 110 LORAN C surveys; publishing 130 Airport Obstruction Charts (OC), 83 LORAN C surveys, 50 special Navigational Aid surveys, and 140 Airport Obstruction Data Sheets; and completing 11 coastal mapping projects consisting of 61 map files in graphic and digital form. The coastal mapping projects provide coastal zone map file data in Alaska (27), Illinois (4), Michigan (5), Wisconsin (14), Maine (7), and Georgia-South Carolina (4).

INTEGRATION OF NEW TECHNOLOGY

In August 1992, PB finalized the transfer of a Daedalus Multi-spectral Scanner (MSS) from the NOAA Office of Ocean and Coastal Resource Management. PB is currently investigating the refurbishment of the MSS, training in MSS technology, making aerial platform alterations, and developing a plan for MSS data application for PB and NOAA programs. If the fiscal resources allow, PB plans to have the MSS in operation during FY 93.

In FY 90, Global Positioning System (GPS) technology was implemented in the field survey activities of PB's Coastal Mapping Program. During the past 30 months, the application of GPS technology has been expanded beyond positioning horizontal control for coastal and hydrographic surveys to include airport datum tie upgrades, use in the flight management system for a jet-powered aircraft, and the positioning of the camera exposure stations. Two examples of the benefits of applying GPS technology are the improved efficiency in establishing horizontal control and the accurate execution of the photo mission. In May 1992, the C&GS Pacific Photo Party set a record for establishing horizontal control through the aggressive utilization of GPS and the processing speed of 486 lap-top computer technology. During the 14 days of field operations in Alaska, the party established 51 GPS positions for photogrammetric and hydrographic surveying operations. Geodetic control was also established in order to strengthen the national network in response to requests by

C&GS' National Geodetic Survey (NGS) and Department of Interior's Mineral Management Service. During operations, 6 Alaska High Precision Network stations were tied, 236 GPS base lines were measured, 19 existing stations were repositioned, 13 new stations were established, and 19 temporary points were positioned. This phenomenal rate of success could not have been achieved without the availability of GPS and the greater processing capacity of portable computers. Similar survey results using traditional geodetic surveying techniques would have taken approximately 8 to 9 months. With this level of performance, it is easy to understand how over 500 geographic positions were determined with GPS during field survey operations this year.

During the Florida Keys National Marine Sanctuary mapping project, many of the flight lines could not have been flown without the utilization of GPS for flight management. Many of the flight lines for this mapping project were of offshore areas and could not be navigated through traditional visual navigation. But by using GPS positioning and a flight management that allows the navigator to make adjustments to the aircraft's attitude, flight line orientation was maintained to planned specifications. This resulted in less flight time, no re-flights because of poor navigation, and completion of the photo mission phase of the project well ahead of the predicted schedule. During the flights, GPS was also utilized to position the exposure station which provided additional horizontal control for the aerotriangulation phase.

INFORMATION MANAGEMENT SYSTEMS

During the year, information management systems containing data on coastal mapping and airport obstruction charting (OC) projects, aerial photographs, and flight management have been refined and integrated into program operations.

Within the airport obstruction program, the Airport Planning Tracking System (APTS) is a project planning information management system which assists the planner in completion of OC program projects. The information maintained in APTS is restricted to the planning phase, but may be expanded to include other phases of program operations in the future. The major information management system within the OC Program is the Obstruction Charting Data Base (OCDB). After 2 years of development and testing, the OCDB is utilized in all phases of an OC project life cycle which include planning, field surveying and verification, chart compilation, and the generation of associated products.

The Coastal Mapping Program also has two information management systems which pertain to project tracking and project data management. The Coastal Mapping Project Status Data Base (CMPSDB) was initiated this year and is updated on a monthly basis. Plans for the CMPSDB include updates at the time of status change rather than a monthly update, and access to the CMPSDB via the local area network for the convenience of project personnel as well as outside users. Within the Integrated Digital Photogrammetric Facility

(IDPF), coastal mapping project data files are maintained until project completion at which time data dissemination and project archival procedures are executed. During the year, PB investigated the possible methods of project data archive and initiated procedures to store coastal mapping digital map data on optical disk. This is only the first step in meeting the needs of its customers as PB continues to examine ways to meet the ever increasing demand for coastal information in digital form.

The Photograph Data Base (PDB) contains information on 138,000 airport and 244,000 coastal zone photographs. The PDB will now be continually expanded as project photographs are reviewed and indexed. Currently photo-center and related information is digitized and entered into the PDB. As the photo mission flight management systems (which are integrated with GPS) are refined, the pertinent information on project photographs will be handled in a totally digital mode for increased data quality and overall efficiency.

The Shoreline Survey Index Data Base (SSIDB) now includes information on 3,550 coastal mapping program maps. It contains pertinent information about each survey and depicts the area covered by each map. This information is superimposed on a base map file and viewed interactively and subsequently printed in color for customer use.

SPECIAL PHOTOGRAMMETRIC PRODUCTS

During the year, PB in cooperation with NOAA's National Marine Fishery Service Beaufort Laboratory printed a Submerged Aquatic Vegetation (SAV) chart depicting the change in SAV of the Drum Inlet to Ocracoke Inlet area of North Carolina. The chart depicts the change in SAV over the years by comparing the delineation of SAV from 1985 photographs to the delineation based on 1988 photographs. This chart is one of a series which will provide accurate spatial/temporal information for coastal zone scientists and managers. It is a regional product of NOAA's Coastal Ocean Program which is preparing to inventory coastal wetlands, including SAV habitats.

PB provided graphic products and boundary coordinate data for environmental impact statements of the Norfolk Canyon, Stellwagen Banks, and Monterey Bay National Marine Sanctuary proposals. The graphic products depicted appropriate information and boundary alternatives that were determined through project meetings with personnel of the NOS Office of Ocean and Coastal Resource Management. PB has assisted this office in developing information for sanctuary proposals over the past 15 years by providing cartographic products and related data and photogrammetric surveys, as in the case of the Looe Key National Marine Sanctuary. For the Looe Key sanctuary, PB provided products depicting the bathymetry and benthic characteristics of the sanctuary.

The States of Georgia and South Carolina requested a photogrammetric survey be completed of the Savannah to Atlantic coastline segment of the Savannah River. The contemporary survey data were to be merged with coordinate information of a proposed delineation of the boundary between the states. PB digitized the boundary data from an exhibit of the court decision and adjusted the coordinates to NAD 83. The proposed boundary line was then superimposed on the composite map generated from the four digital map files covering the area of dispute. A presentation of the findings was made to the representatives of Georgia and South Carolina in early October 1992, and the requested products will be forwarded to each state for the resolution of the boundary dispute.

NEW CHARTING PRODUCTS

Four new charts were issued during FY 92. These charts include two Canadian Hydrographic Service/NOS cooperative charts of the Maine/New Brunswick border area. Chart 13392 was constructed at 1:50,000 scale for coverage of the Grand Manan Channel-Southern Portion, and Chart 13398 was constructed at 1:50,000 scale for coverage of Passamaquoddy Bay and St. Croix River. Additionally, two new training charts were compiled during FY 92. These two training charts (Chart 12354 Long Island Sound - Eastern Part and Chart 13205 Block Island Sound and Approaches) were produced by NCD to satisfy Defense Mapping Agency's (DMA) requirement for training charts for use in the U.S. Coast Guard's (USCG) Merchant Marine Licensing Examinations.

NCD now maintains a suite of 996 nautical charts. New editions were prepared for 342 of these during FY 92. A total of 169 charts depict the territorial sea limit and the contiguous zone (12-mile limit), 56 show the Exclusive Economic Zone (EEZ) (200-mile limit), 29 show the Natural Resources Boundary (3-league limit), 283 depict LORAN-C, and 25 contain the OMEGA electronic positioning system.

Implementation of the North American Datum of 1983 (NAD 83) in the nautical charting program continues. This involves shifting the existing charted projection and/or adding datum reference and transformation notes to NOAA's suite of nautical charts. A total of 891 (approximately 90 percent of the total) charts have been converted to NAD 83.

NAUTICAL CHART MANUAL

The completely revised "Nautical Chart Manual, Seventh Edition" was issued during FY 92. The manual contains eight chapters and four appendices in two volumes defining C&GS policies, procedures, and other information required for nautical chart production. Also covered are the historical background of C&GS, its area of nautical charting responsibility, the legal requirements for the mariner to use appropriate scale, up-to-date charts in U.S. ports, the relationship between C&GS and international charting authorities, and C&GS coordination with international standards.

The reference section of the manual contains an extensive glossary of terms used in the compilation of nautical charts that has been compiled for over 40 authoritative national and international reference works, a list of abbreviations used in the manual, a summary of C&GS-approved standards and specifications for symbols used in charting, an extensive appendix, and an index.

CHART AUTOMATION AND DIGITAL DATA

The following sections describe current production activities during transitional mode between manual and the introduction of modern automated cartographic environments. In addition, progress in the development of electronic charting and response to demands for digital data are discussed.

PRODUCT AUTOMATION

In addition to the other activities, C&GS has acquired the necessary technology to become the official supplier of raster nautical charts. Computer graphics can take two forms: vector and raster. Vector graphics store data as points, lines, and arcs. Raster graphics store them as bit-mapped images. NOAA has users who are requesting both types of data. The raster chart would be a new addition to the products already offered by C&GS and could also serve as interim digital chart production solutions until the Automated Nautical Charting System II (ANCS II) comes on-line.

C&GS has submitted a proposal under the NOAA-wide ESDIM program to acquire funding to develop this technology and start production. The objective of this proposal is to create a full suite of digital nautical charts in a raster format. The data would then be available for marine navigation and also for scientists, researchers, and resource managers for use in geographic information systems, thematic mapping systems, desktop publishing systems for atlas preparation, and other uses. C&GS would issue new raster nautical charts and new paper charts concurrently.

MICROCOMPUTER APPLICATIONS

The use of the NCD's Local Area Network (LAN) continued to grow in FY 92, with additional users and nodes added in NCD staff offices, HSB, PB, and the Mapping and Charting Branch (MCB). The NCD LAN now serves approximately 250 users.

Micro-computer based software was developed in-house to provide drafting and graphic capabilities for rescheming C&GS nautical charts and printing page-sized chart representations. This development has eliminated the need for 9-track magnetic tape and flatbed plotting requirements. A technical paper describing this micro-computer

advancement and the NCD rescheming plan was presented at the Fifth Biennial NOS International Hydrographic Conference, in Baltimore, Maryland, February 25-28, 1992.

DIGITAL PRODUCTS

NCD continues to provide a variety of digital products for sale to government agencies, commercial interests, and the general public. They consist of digital shoreline data, digital navigational data, and LORAN-C overlays. Digital data products respond to the needs of electronic chart users, manufacturers, academic users, and individuals that require digital charting data. Due to limited resources, NCD has been unable to maintain the shoreline and aids to navigation digital data files to reflect the most current published nautical charts. As these data age, NCD will have to determine whether it is worth the cost to update these data files or to discontinue sales until new, up-to-date data are available from ANCS II. There have been only minimal efforts to market these data, which is reflected in the sale of only nine tapes this year.

Since 1984, C&GS has provided LORAN-C overlays for bathymetric maps. These overlays are used by commercial and sport fishermen to locate particular bottom features that may harbor fish. In addition, an increasing number of users are from academic and state institutions who use these overlays for various scientific studies. The sales of these products in FY 92 totalled 47 overlays.

CRITICAL CORRECTION SOFTWARE

CRITICAL, a personal computer (PC) software system for processing Notice to Mariners corrections was developed for use by the chart production teams. With this system, chart correction items are keyed into a data base from which laser printer plots are generated. The use of CRITICAL facilitates positional accuracy of chart features and allows compilers to quickly identify all charts affected by each Notice, reducing the time required to apply these corrections.

SOURCE REGISTRY PROGRAM (SREG)

SREG, a document information and tracking system, has been developed for MCB chart compilation units. SREG provides information concerning date received, type, authority, geographic area, charts affected, and status of processing for each source document received since January 1, 1985. It also can be used to produce listings of source documents affecting specific charts or products or for research purposes. It can be accessed from any of the more than 130 PC's now established on the LAN network in MCB.

ELECTRONIC CHART DIGITAL INFORMATION SYSTEM (ECDIS) DEVELOPMENTS

During the current fiscal year, C&GS, USCG, and other federal agencies have worked together to establish standards for electronic nautical charts. This includes defining a standard international format for digital chart data and information exchange.

The ECDIS Testbed Project, a cooperative effort between government agencies, academic institutions, and private corporations is being directed by the Woods Hole Oceanographic Institute. Intergraph Corporation is developing the basic system using a standard high performance graphics workstation and relying on off-the-shelf software.

The ECDIS development group has completed and delivered 10 cells of digital data covering the Buzzard's Bay area. Another 40 digital chart data cells covering several geographic areas including New York and Norfolk Harbors are being processed. ECDIS workstations will be tested on board a USCG vessel, the Merchant Marine Academy Training vessel, and privately owned tankers, ferries, and container ships beginning in November 1992 and continuing for about 1 year.

C&GS hosted the first annual ECDIS Conference held in Baltimore, Maryland, on February 28-29, 1992. Members of NCD's Nautical Charting Research and Development Laboratory (NCRDL) and the ECDIS development team presented technical papers at this international forum which was attended by representatives of USCG, Maritime Administration, cooperating hydrographic offices throughout the world, and national and international manufacturers and suppliers of related navigational hardware and software products.

TOTAL QUALITY MANAGEMENT (TQM) ACTIVITY

MCB entered the competition for the U.S. Department of Commerce (DOC) Quality Award. A site visit was made by U.S. Department of Commerce officials to evaluate the MCB award proposal. Although no quality award was made by DOC in 1992, MCB was congratulated on its achievements in quality management. The DOC Board of Judges was impressed by the progress made by MCB. MCB also submitted a proposal for the Federal Quality Institute Quality Improvement Prototype Award. In addition, the Chief of MCB is sponsoring the First Annual MCB Quality Award to recognize and reward significant quality circle and action team achievements.

I-TEAMS

An NCD management conference led to the creation of 5- and 10-year plans. Several study groups were formed as a result of this strategic planning session. MCB created four process action teams (I-Teams) involving most of MCB's employees. The goal is to plan for a smooth transition as ANCS II is phased into MCB operations and becomes integrated in

the daily work environment. Each team was assigned different tasks and required to submit a comprehensive report. The results of these studies have been processed and many recommendations have already been implemented.

RESEARCH AND DEVELOPMENT

These activities are conducted by NCD's Nautical Charting Research and Development Laboratory (NCRDL). NCRDL has been modernizing all facets of map and chart production. Progress in automated cartography, including application of expert systems, and the newest hydrographic and photogrammetric technology developments are described below.

CARTOGRAPHIC TECHNOLOGY DEVELOPMENTS

The following narratives describe progress in the development and introduction of the next generation automated nautical charting into NCD's cartographic operations and the application of expert systems into the cartographic decision process.

Automated Nautical Charting System II

In 1988, C&GS contracted with Intergraph, Inc., for the development of the second generation automated nautical charting system (ANCS II). This major modernization effort will lead to the automated production and maintenance of NOAA's entire suite of nautical charting products. ANCS II will include three primary data bases: the Navigation Information Data Base (NIDB), the Chart Graphics Data Base (CGDB), and the Production Control Data Base (PCDB). The NIDB and the CGDB reflect a dual data base design strategy that separates real-world geographic data extracted from source documents from the highly symbolized cartographic products data. While both data bases are physically integrated, they are logically separated based on the different functional capabilities required for document/data management and chart maintenance and production tasks. When completed, the ANCS II will employ RISC-based color graphic workstations which will be physically distributed through NCD's Ethernet. A systems acceptance test is planned in late 1993. The ANCS II workflow diagram is shown on the accompanying figure.

Major software milestones were accomplished during FY 92. Phases two and three of ANCS II functional software were delivered as scheduled. Software is being developed and delivered in five incremental phases. The software delivered in phases two and three represents about half the total cartographic functionality for ANCS II. Another significant software milestone was the development of a bit mapping strategy for generating feature symbology in ANCS II. Feature symbology is generated based solely on its features attributes. The attributes are stored in one of several relational Oracle feature and attribute tables. Custom software has also been developed to perform all the low-level

AUTOMATED NAUTICAL CHARTING SYSTEM II - WORKFLOW

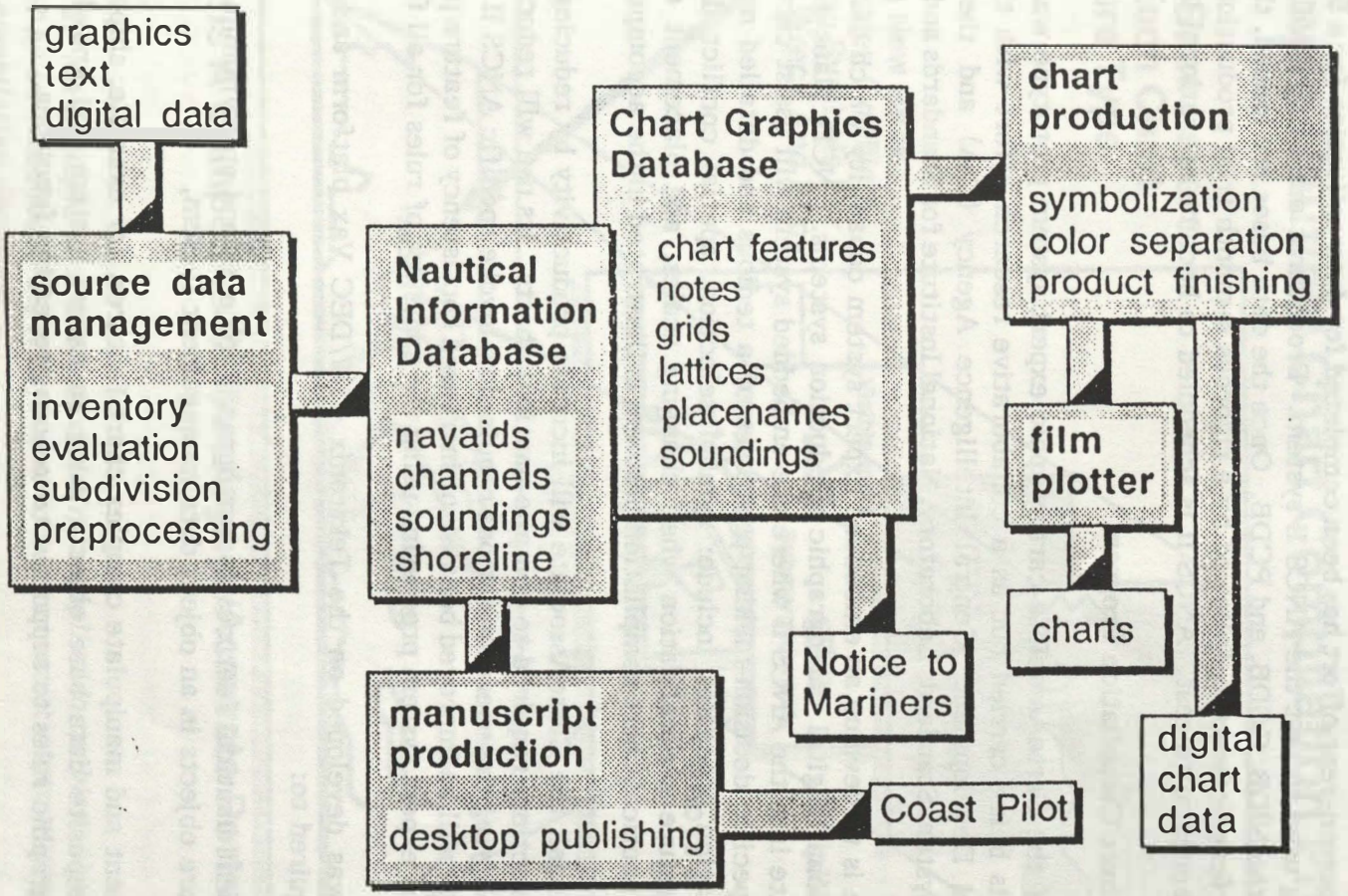


FIGURE 1. Diagram of the next generation Automated Nautical Charting System (ANCS II) and the data pathway through the various subsystems.

validation checks required to ensure feature symbology attributes exist. A symbol cell library has been developed for both the NIDB and CGDB.

Finally, a 15-person-year effort has been completed for data collection for a 50-chart area which is being used to test the ANCS II system. Procedures are being developed to load and populate the NIDB, CGDB, and PCDB. Once the data bases are loaded, they will then be used for a functional test, followed by a rigorous 6-month trial production test, and a final system acceptance test. ANCS II is scheduled to become operational in FY 94.

Automated Chart Compilation Program

Version 1.0 of the CartoAssociate cartographic expert system prototype was completed. This project is being carried out as a collaborative research effort with the Office of Research and Development, Central Intelligence Agency (CIA) and the Geographic Information System Standards Laboratory, National Institute for Standards and Technology.

The objective is to develop an embedded expert system capability which can be installed into conventional digital cartographic production systems. NCD plans to install the CartoAssociate into the ANCS II where the embedded system will assist cartographers in performing specific decision-making processes of a tedious and detailed nature. These chart compilation processes include: symbol selection, spatial conflict detection and resolution, feature generalization when changing scales, and placement of text. An example of a nautical chart compilation problem is illustrated in the accompanying figure.

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

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

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

- represent and manipulate complex chart features, for example, shipping channels, as composite data base objects using an expert system and knowledge base of cartographic rules to support autonomous processing functions,

- autonomously compile the most important nautical chart features (channels, buoys, hazards, soundings, and others) by detecting and resolving spatial conflicts between

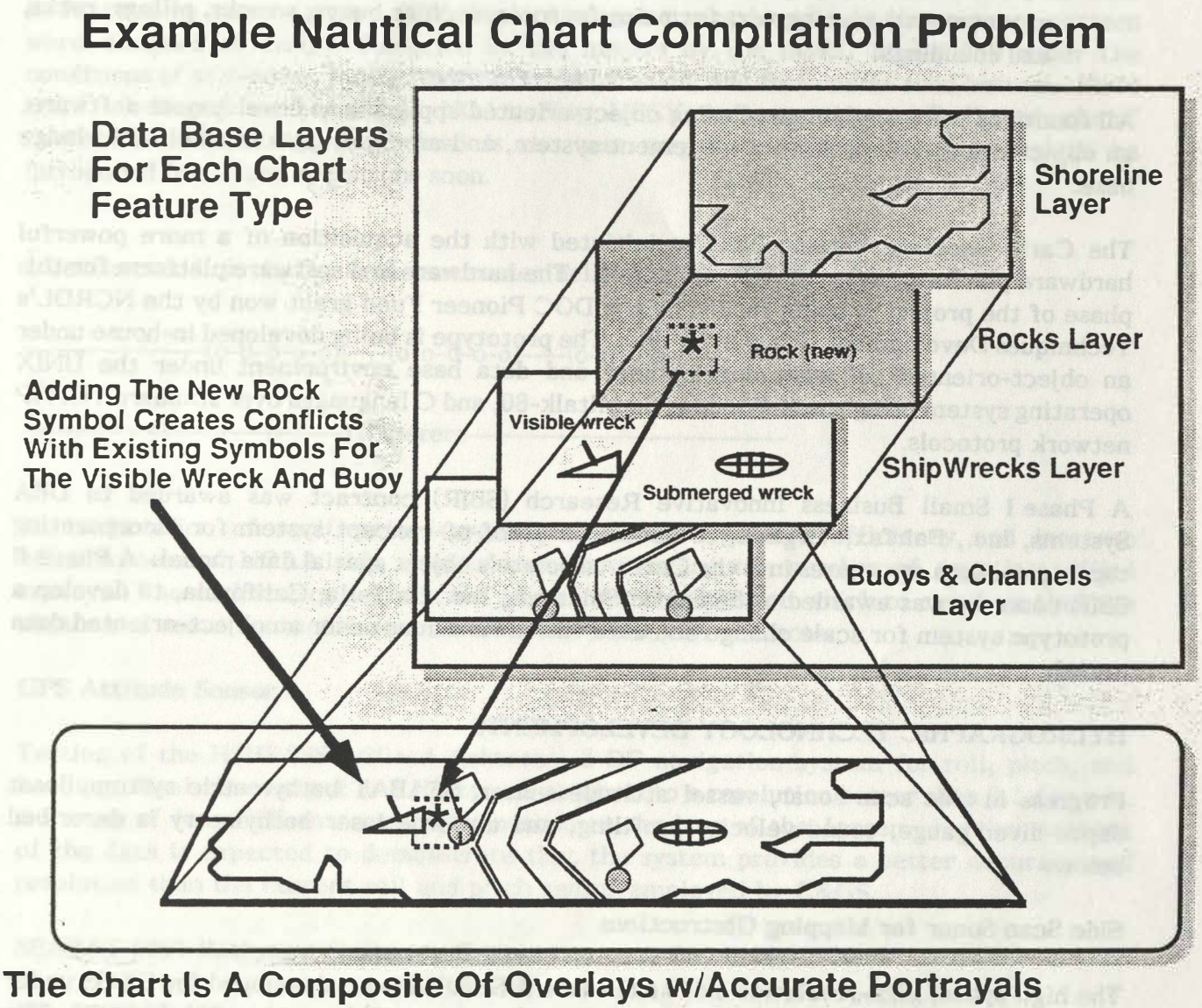


FIGURE 2. An example of a nautical charting compilation problem that can be addressed by an embedded "expert system." This can assist cartographers in making specific compilation decisions.

nearby features or text, determining symbols for individual features, and deducing symbolic portrayals for groups of features, and

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

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

The CartoAssociate Version 2.0 was initiated with the acquisition of a more powerful hardware platform, a Sun SPARC station II. The hardware and software platform for this phase of the project is being funded by the DOC Pioneer Fund grant won by the NCRDL's Techniques Development Group in FY 91. The prototype is being developed in-house under an object-oriented software development and data base environment under the UNIX operating system using the X-Window, Smalltalk-80, and C languages over standard TCP/IP network protocols.

A Phase I Small Business Innovative Research (SBIR) contract was awarded to DBA Systems, Inc., Fairfax, Virginia, to develop a proof-of-concept system for incorporating topological data structures into the CartoAssociate's object spatial data model. A Phase II SBIR contract was awarded to Semantic Solutions, Inc., La Jolla, California, to develop a prototype system for scale change and data fusion functions under an object-oriented data model.

HYDROGRAPHIC TECHNOLOGY DEVELOPMENTS

Progress in side scan sonar, vessel attitude sensor, SEABAT bathymetric system, least depth diver gauge, sound velocity profiling, and airborne laser bathymetry is described below.

Side Scan Sonar for Mapping Obstructions

The high-speed, high-resolution side scan sonar (HSHRSSS) was developed for C&GS under a prior year SBIR contract with Klein Associates, Inc., Salem, New Hampshire. The HSHRSSS was tested extensively in a hull-mounted configuration on a 29-foot Jensen launch in an operational setting in Chesapeake Bay, Virginia. High-quality images were obtained at 6 knots in water depths of 2.5 to 35 meters. A known target, deployed in 12 meter water depth, was reacquired 30 times. This test was an unqualified success and clearly demonstrates the feasibility and practicability of conducting shallow-water obstruction surveys from a launch.

Side Scan Sonar Verification Target

A low-cost side scan sonar verification target was developed by 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 that the absence of sonar contact detection means there are no contacts.

GPS Attitude Sensor

Testing of the HSHRSSS utilized Ashtech's 3-DF navigation system for roll, pitch, and heading. Real-time output at 2 Hertz was attained to a resolution better than 0.1 degrees. An array of four GPS antennas was mounted on the bow of the Jensen. Further analysis of the data is expected to demonstrate that the system provides a better accuracy and resolution than the current roll and pitch sensor employed by C&GS.

SEABAT 9001 Bathymetric Survey System

The SEABAT 9001 sonar system was temporarily mounted to the NOAA Ship RUDE for a survey in the area of the Queen Elizabeth II grounding near Vineyard Sound, Maine. One hundred percent bottom coverage at twice water depth was attained at speeds up to 6 knots. Results of the data have shown both vertical and horizontal accuracies consistent with International Hydrographic Organization standards. A real-time video display at 30 Hertz is provided on board, and swath survey data are stored in digital form at a 2 Hertz rate. Agreement to better than 15 centimeters in water depths of 12 meters was achieved when comparing SEABAT results with diver-determined least depths. The SEABAT could

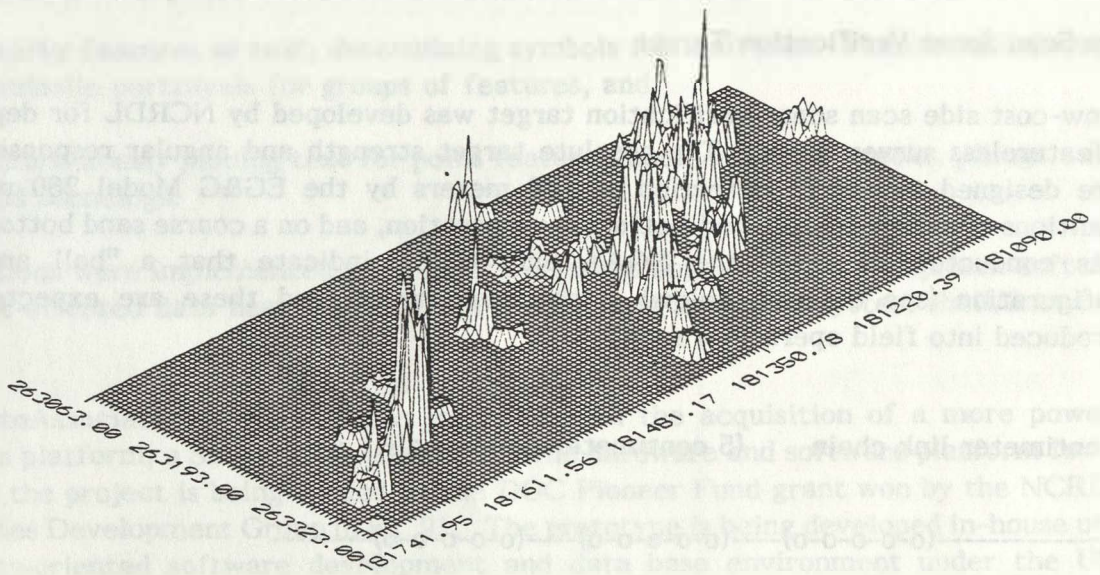


FIGURE 3. Display of SEABAT 9001 soundings less than 11.6 meters, corrected to predicted tides. Survey line spacing, 10 meters; grid spacing, 4 meters. Vertical exaggeration, 50:1.

eliminate dive operations over pinnacles, saving time and eliminating safety risks during such survey operations.

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 leadline and the pneumatic depth gauge which are now used to obtain the least depth readings.

Remote Acoustic Sensing of Sound Velocity Profiles

Sound speed profiles are needed to correct raw data from echo sounders and multibeam sonars. Use of remotely sensed data for this purpose would improve efficiency of surveys by wholly or partially eliminating the need for vessels to stop in order to perform Conductivity Temperature Depth (CTD) casts. Software that is designed for realistic simulation of sonar data will be acquired from the University of Washington for NCRDL to use in the development of this technology.

Airborne Laser Bathymetric Measurements

NCRDL has been at the forefront of laser hydrography for the past decade and continues to maintain international recognition for its analyses of system performance prediction based on environmental conditions and waveforms detections techniques. But faced with present-day funding limits, it is unlikely that the $10 million capital investment needed to develop and purchase a system can be obtained. However, work by NCRDL continues to contribute to several federally funded laser hydrography development projects. NOAA will benefit when these systems become readily available for lease operations, thereby avoiding the large one-time capital expenditure.

Microcomputer Geographic Information System

The Microcomputer Geographic Information System (MGIS) has been built for managing and indexing NCD marine data available. A graphic interface provides access to hydrographic data, horizontal and vertical control points, marine sediment information, and tidal data. Software packages have been integrated to provide interaction with 32 data bases. MGIS runs on IBM-compatible microcomputers. Approximately 20 systems are in daily use.

Marine Data Computer Bulletin Board

A computer bulletin board, which runs on an IBM-compatible microcomputer, has been developed to provide public access to existing nautical charting digital data. Users will be able to log on using a PC, modem, and ordinary telephone lines. The bulletin board is menu driven and easy to use. Callers may search the available data bases and download results as compressed text files. Initially, 20 data bases will be on-line including: Wrecks and Obstructions, Nautical Chart Locator, Airport Mapping Photos, Sediment Data, and Tide Stations. Additional data bases will be added as they become available. The bulletin board will provide a means for assessing the demand for and uses of nautical charting digital data.

PHOTOGRAMMETRIC TECHNOLOGY DEVELOPMENTS

Progress is described below for GPS-controlled photogrammetric surveys, photogrammetric digital data, advanced correlation technology, and multispectral imagery.

Kinematic Global Positioning System in Photogrammetry

NCRDL is continuing development of GPS-controlled photogrammetry to improve and expand this highly productive and efficient technology. NCRDL scientists continue to work closely with NCD's Photogrammetry Branch (PB). This technology has now been developed to the point where PB is applying GPS-controlled photography on all shoreline mapping

projects and is routinely using real-time positioning with GPS to acquire strips of photography precisely where they were planned. This new application is expected to completely eliminate the need to rely on about 20 percent of the photo strips because they have inadequate coverage due to navigation errors.

NCD continues to transfer this technology to other agencies for their use. The U.S. Army Corps of Engineers (USCOE) is developing its GPS capability using private sector contractors and C&GS personnel consulting services. The U.S. Forest Service, assisted by personnel from Trimble Navigation, Inc., and a private aerial survey firm, completed testing GPS-controlled photogrammetry using software developed by NCRDL. In addition, NCRDL personnel have also completed a preliminary computer simulation for the Minerals Management Service of the Department of Interior. They are interested in using GPS-controlled photogrammetry to measure surface current velocities in the open ocean by photographing floating targets. NCRDL plans to assist them in conducting a feasibility demonstration sometime this winter.

This technology is also being transferred by NCRDL through its active participation in committees and working groups of both the American Society for Photogrammetry and Remote Sensing and the International Society for Photogrammetry and Remote Sensing. NCRDL is improving the software that it has developed to process GPS-controlled photogrammetry data. These programs are being distributed to Federal and state government agencies and to the private sector.

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 ANCS II, HDAPS, and the Aeronautical Obstruction Charting (OC) Program. IDPF also facilitates digital exchange between C&GS and other Federal agencies that employ similar systems. This modern system couples advanced photogrammetric technology with computer graphics and a relational data base management system (RDBMS). 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 new IDPF Version 2.0 became operational in October 1992. The various IDPF data bases will run under the digital RDBMS 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 figure. The three data bases are: (1) the project data base, (2) camera calibration data base, and (3) the OC data base.

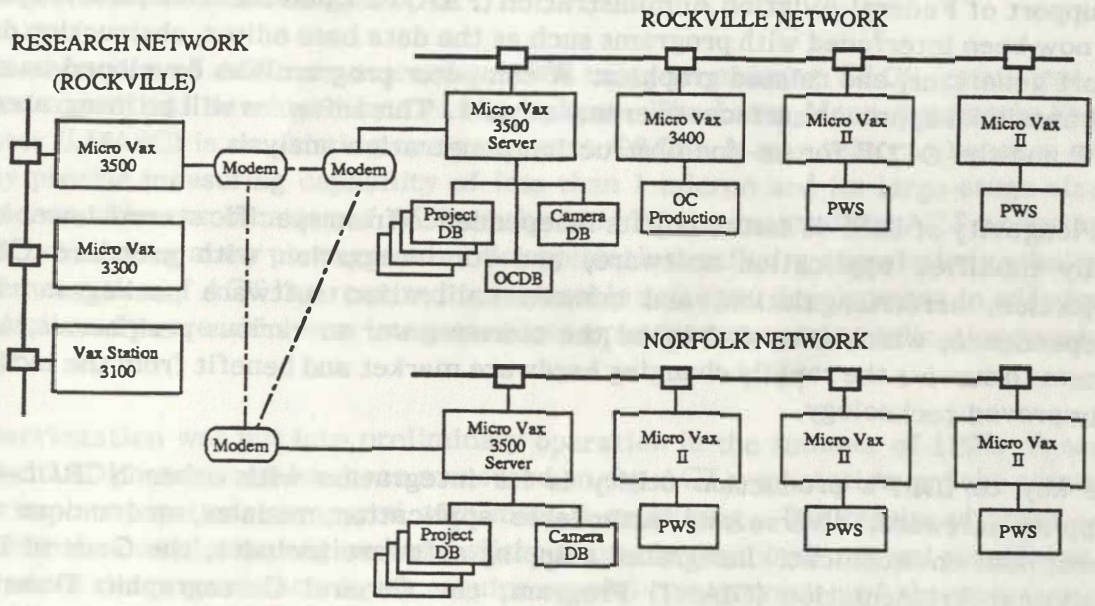


FIGURE 4. Diagram of a photogrammetric workstation in one node of the IDPF network.

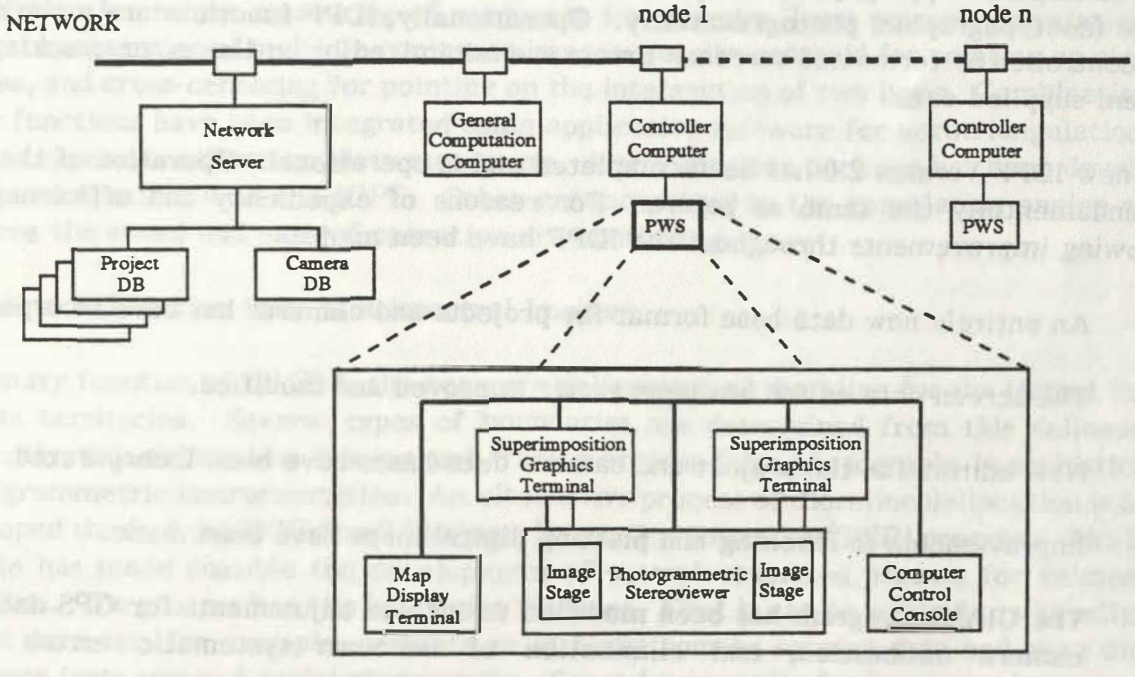


FIGURE 5. Diagram of the complete IDPF showing the relationships between the Norfolk, Virginia, and Rockville, Maryland, production units and the Rockville Research Network.

In support of Federal Aviation Administration (FAA) tasks on the IDPF, the Airport OCDB 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 the IDPF and the OCDB 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.

The key to IDPF's production utility is its integration with other NCRDL-developed mapping software, diverse and extendable application modules, and 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 (nontopographic) 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 the 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 labelling 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 (ACT)

The implementation of 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 development in addition to the correlation software which was integrated into a photogrammetric applications package by NCRDL.

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 independently 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 the IDPF. Other enhancements to the correlation engine which improve the speed and ease of operation are continuing.

Shoreline Delineation from Multispectral Imagery

A primary function of C&GS 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 DOC Small Business Innovation Research (SBIR) program. The SBIR vehicle has made possible the development of a semiautomated process for delineating shoreline. The process has two important features. First it can be applied to virtually any digital data set, for example, 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 current development status is midway through Phase II 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.

C&GS Participation in HYDICE

C&GS has, along with a number of other civilian agencies, signed a Memorandum of Understanding with the CIA to participate in the Hyperspectral Digital Imagery Collection Experiment (HYDICE).

Hyperspectral digital imagery can be defined in terms of multispectral imagery, such as that obtained from Landsat, which has proven to be very effective in automating the classification of feature types from their reflected spectra. Multispectral imagery provides a few wide spectral bands, while its hyperspectral counterpart is obtained by increasing the number of bands and decreasing their width until a continuous spectrum is approximated. The result should be much increased capacity for differentiating between similar object types.

The Naval Research Laboratory (NRL), acting as agent for the CIA, will contract for development and integration of the airborne HYDICE sensor system and will handle the acceptance testing. C&GS will participate in the activities of the HYDICE Collection Working Group (CWG) and the HYDICE Exploitation Working Group (EWG). The CWG will develop a data acquisition plan so that a limited number of collection missions will provide ample data for evaluating the benefit of this hyperspectral sensor for the various remote sensing requirements of all participants. The EWG will investigate, test, and implement hardware, software, and methods for evaluating and exploiting the collected data after completion of each mission. This cooperative effort will provide each participating civilian agency with access to data from a sensor system they could not, individually, afford to develop. Likewise, NRL will have assistance in evaluating their system from experts in all specialties of remote sensing.

SCIENTIFIC PAPERS AND TECHNICAL REPORTS

Hogan, Richard L., "Development of a Second Generation Automated Nautical Charting System at the National Ocean Service," Presented at the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland.

Huff, Lloyd C. and Weintroub, Jonathan (Klein Associates, Inc.), "Field Measurements of a Multibeam Focused Side Scan Sonar's Along Track Resolution," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 97-102.

Malhotra, Roop C., "Coastal Mapping with the Integrated Digital Photogrammetric Facility," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 41-46.

Malhotra, Roop C., "Simulated Study for Integrating GPS Control and Infrared Photography in Aerotriangulation for Shoreline Mapping," International Society of Photogrammetry and Remote Sensing XVII Congress, Washington, D.C., (in print).

Matula, Steven P., "Bridging the Gap: Creating Near-Shore Bathymetric Maps from Multibeam Swath Sonar Systems and Conventional Data Sources," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 81-89.

Miller, John A.; Danley, Howard P.; Gean, Kirby A.; West, Lynn; and Page, Eugene M., "The Coast and Geodetic Survey's Nautical Chart Rescheming Plan," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, Baltimore, Maryland, February 25-28, 1992.

Minkel, David H. and Whitney, Gene (NOAA Corps Operations), "Implementation of Differential GPS at the Coast and Geodetic Survey," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 31-36.

Pendleton, Dave and Alper, Stanley, "DX-90: A Digital Data Transfer Standard for the Hydrographic Community," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 111-118.

Perry, Leslie H., "Semiautomated Shoreline Extraction from Digital Imagery," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 37-40.

Seidel, Dean R.; Ross, V. Dale; Timmons, Duane; and Link, Brian, "A Survey for the USGS/NOAA Joint Office for Mapping and Research in the Vicinity of St. Joseph, Michigan," Proceedings of the Fifth Biennial National Ocean Service International Hydrograhic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 47-51.

Yeager, J. Austin, "Modernizing Photogrammetric Mapping Operations," The Military Engineer, January-February, 1992, 3 pp.

ACCOMPLISHMENTS OF THE AERONAUTICAL CHARTING DIVISION

NEW PROGRAMS AND PRODUCTS

The Aeronautical Charting Division (ACD) plans and directs the construction, maintenance, reproduction, and distribution of aeronautical charts, products, and digital data files of the United States and its territories and possessions to meet the requirements of civilian and military aviation. Approximately 10,000 aeronautical charts are produced annually for use by air flights in the National Airspace System (NAS). The continuous maintenance of charts and files is required to support the regularly scheduled update cycle for the program. This Division also prints and distributes all nautical charts and maps compiled by the Nautical Charting Division. Beginning October 1, 1992, ACD became the distributor of Defense Mapping Agency (DMA) public sale aeronautical and nautical charts and related products.

The Aeronautical Chart Branch is responsible for the cartographic functions of the Division. The activities of the Branch involve the following four categories:

- visual products
- instrument products
- special products
- data management for the above products.

The first three categories are discussed first. They define the general scope of ACD's products which are produced and distributed in printed formats. A select number of products are also available in digital formats.

VISUAL PROGRAM

The visual program of ACD produces 182 different charts that provide information to pilots flying under Federal Aviation Administration (FAA) visual flight rules (VFR). These charts are revised every 6-12 months, with approximately 2,500,000 copies distributed each year. The following additional tasks were performed under the visual flight program during FY 92:

- All 12 VFR Flyway Planning Charts were converted to the new four-color specifications. The new specifications require the aeronautical features to be portrayed in the same color as used in the Terminal Area Chart series. Additionally, town outlines were depicted on all VFR Flyway Charts.
- Three new VFR Flyway Planning Charts were published. The Seattle, Salt Lake City, and Chicago VFR Flyway Planning Charts were designed to assist pilots in planning flights through and/or around areas of high density air traffic. The new charts have the same coverage as the corresponding Terminal Area Charts and are

printed back to back on these charts. Some of the features included on the new charts are: the depiction of town outlines, prominent base features and airports, VFR flyway routes, special use airspace, terminal control area, major instrument flight rules (IFR) arrival and departure routes, and pictorials of prominent features.

- The existing Houston VFR Flyway Planning Chart was extended to coincide with the chart limits of the Houston Terminal Area Chart. The extension was required for depiction of the revised Houston-Hobby Terminal Control Area.

- A new Houston Helicopter Route Chart was published. The chart was produced at a scale of 1:125,000 and covers most of metropolitan Houston, extending southeast to include a portion of the city of Galveston and Galveston Bay. This three-color chart depicts current aeronautical information useful to helicopter pilots navigating in areas with high concentration of helicopter activity. Information depicted includes associated frequencies and lighting capabilities, Navigational Aids (NAVAID), and obstructions. In addition, pictorial symbols, roads, and easily identified geographic features are portrayed.

- Three- (or four-) character alphanumeric identifiers were depicted on all public use airports shown on sectional charts, terminal area charts, VFR flyway planning charts, and helicopter route charts. The identifiers were added immediately after the airport names, in parentheses.

- A new edition of the Aeronautical Chart Catalog, dated 1992-1994, was published. The updated catalog lists several new products and include the return of some previously canceled products. Prices are listed on a one-page insert. In addition, one DMA aeronautical catalog and nine DMA nautical catalogs were developed for the sale of DMA public sale charts and products.

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

- A prototype of the Lake Huron Sectional was published. The prototype reflects the depiction of the reclassification of U.S. airspace (discussed later in this report) which will become effective on September 16, 1993. The prototype also depicts new symbology that was proposed by the National Airspace Review. The implementation of this new symbology was begun with the visual aeronautical charts that were published on October 15, 1992.

- Through a cooperative agreement with the Earth Observation Satellite (EOSAT) Company, ACD developed a prototype hardcopy print of a geocoded Landsat image

bounded by the coordinates of the new Houston Helicopter Route Chart. The print was used in the compilation process for developing the Houston Helicopter Route Chart and proved to be a valuable source for extracting the most up-to-date data for the chart. The print was also used to verify data extracted from traditional source material.

- A VFR aeronautical chart insert depicting the charting changes resulting from the U.S. airspace reclassification and the National Airspace Review was developed on behalf of the FAA. This insert graphic is being used as an educational tool, and was distributed beginning with the October 15, 1992 editions of the visual aeronautical charts. This graphic presents the current symbology depiction and terminology usage, the changes that will occur with the October 15, 1992 editions, and the final depictions that will occur with the implementation of U.S. airspace reclassification on September 16, 1993.

Visual aeronautical charts are flight checked once every three years by a rotating crew of three NOAA commissioned officer pilots flying a government-owned twin engine "Shrike" Commander aircraft. During FY 92, the flight check program reviewed selected Sectional Aeronautical Charts and their associated Terminal Area Charts, as well as penetrated 167 Minimum Safe Altitude Warning sites in the conterminous United States.

These flight checks contributed 1,964 potential base feature changes for chart compilation. Three hundred and eighty-four photographic sites were compiled and 947 obstacles were measured. Of these obstacles, 324 were found to be new obstructions not previously contained in the obstacle data files. Sixty were found to have been dismantled and therefore relabeled in the current files; 563 obstacles were reverified for horizontal position and vertical accuracy. This combined photography and stereoplot operation yielded an outstanding 92.4 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 program of ACD provides more than 8,900 charts and publications, which are used by pilots flying under FAA instrument flight rules (IFR). Nearly 80 percent of these publications must be revised every 56 days. Approximately 7,800,000 copies of instrument charts and publications are distributed annually. The following are the accomplishments in the instrument program:

- The conversion of the IFR Enroute Chart series from two to four colors is in the third and final phase. 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, is underway. Data files were constructed, and compilation and drafting were fully automated. The 30-chart series is scheduled for printing in September 1993.

- The Air Traffic Control System Command Center Charts (ATCSCC), that were discontinued due to budget cutbacks in FY 91, have been reinstated by the FAA. The charts were reformatted and recompiled. These charts are used by the FAA's central flow control and central altitude reservation personnel to coordinate, plan, and approve the flow of VIP travel. The last chart of the 9-chart series is scheduled for printing October 1992.

- Two new Controller Charts (CC) for Montana were compiled and printed during FY 92. With the printing of these charts, FAA's Air Traffic Controllers, for the first time, will have complete coverage of the United States at a scale of 1:500,000.

- At the direction of the FAA, a CC prototype containing military training routes for CC-31 was compiled. The chart was used to determine if the CC is a suitable vehicle for providing this type of information to air traffic controllers.

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

- The Terminal Procedure Publication, produced in 17 volumes every 56 days, depicting approximately 7,500 instrument charts for arrival, landing, and take-off at over 2,500 airports in the United States, had a major production enhancement this year. Through the use of PC's in the Instrument Approach Procedure Section, off-the-shelf software, and a local area network, all of the tabulated data for the charts are produced inhouse, in camera-ready form.

  Previously, the indices were prepared through a computer program that created a composition tape that was sent to the Government Printing Office for creation of negative images. The alternate, take-off, and radar minimums were sent to ACD's Reproduction Branch for creation of negatives.

  The advantages afforded by the use of PC's in the production of these items has enabled the Instrument Approach Procedure Section of ACD to gain 3 days in the

production process, thereby reducing costs, and exercising total control over the data. Without these advances, several requests by the FAA for last minute changes could not have been made.

- ACD is preparing to change the format of the Instrument Approach Procedure Charts (IAPCs). Instead of bound volumes, each volume of charts will be hole-punched and shrink wrapped for distribution. The change in format will be effective in FY 93.

SPECIAL PRODUCTS AND SERVICES

The special products and services program provides Controller Charts, Obstruction Charts, Radar Video Maps, digital data, and information on possible airport obstructions. To provide this information, C&GS maintains a series of automated data bases containing information on approximately:

61,000	Obstacles
18,600	Airports
5,400	NAVAIDS
32,000	Reporting Points
475	Restricted Areas
34	Alert Areas
371	Military Operations Areas
9	Prohibited Areas
117	Warning Areas
120	Airport Radar Service Areas
842	Control Zones
30	Terminal Control Areas

Data Base development for Transition Areas, Special Air Traffic, and all remaining Airspace Files are progressing.

Nearly 2,500 different charts are produced annually, with revision cycles varying from 28 days to 2 years. Approximately 170,000 copies were produced last year. The following are some of the major accomplishments during FY 92:

- Compilation of 219 FAA-sponsored Minimum Safe Altitude Warning system sites has been completed. The project is now directed toward the continuous maintenance of the obstruction data at 6-month intervals and recompilation of various sites for relocations and magnetic variation changes.

- The Digital Obstacle File has grown to over 60,000 structures affecting air navigation. This file is used to support the needs of the FAA, Department of Defense, and NOS charting requirements. The complete file is available to the public digitally and in hard copy.

- Subscriptions for the NOS digital NAVAID's file has reached almost 30 subscribers in the past year. The NAVAID files contains the NAVAID identifier, type, status, latitude, longitude, name, Air Route Traffic Control Center (ARTCC), altitude usage, frequency, channel, elevation, magnetic variation, and the state or country. These data support both civil and military navigation systems.

- The Digital Aeronautical Chart Supplement (DACS) is currently available in both hardcopy and magnetic tape. However, effective December 10, 1992, DACS were available only on 3.5 inch or 5.25 inch floppy diskettes. The diskettes will contain all nine sections of the DACS. The DACS is a composite of information used in conjunction with aeronautical charts. Its main function is to provide ground coordinates needed by air traffic controllers, aviation system developers, and the general aviation community for flight planning.

  Eight of the nine DACS sections are produced every 56 days. Section nine is produced annually. In addition, section three includes a change notice issued at the 28-day mid-point containing changes that occur during the 56-day publication cycle.

- Over 1,400 Radar Video Maps (RVM) were produced in FY 92 for the 212 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.

- A new Digital Bright RVM system has been developed by the U.S. Air Force. The system provides for video maps to be generated and displayed digitally. Instead of a 2.3-inch plate, the data are stored on a Programmable Read Only Memory (PROM) chip. ACD has converted 1,452 analog RVM's to digital files for loading on the PROM's. The first Digital Bright Radar Indicator Tower Equipment (DBRITE) was delivered in FY 91; to date, 952 maps have been delivered to 252 sites. Approximately 100 additional sites are scheduled for installation of DBRITE.

- RVM digital data have been provided to 16 FAA facilities for testing. These data, extracted from RVM design files, are evaluated to determine if the data meet

requirements to support the new FAA Terminal Doppler Weather Radar (TDWR) System. TDWR is one part of a vast new weather watching system designed to streamline travel and will have 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 will be 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 doppler radar systems at major airports throughout the country.

- During FY 92, ACD has completed its Digital Special Use Airspace Files data base. This data base provides 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 the designations included in this airspace.

OTHER MAJOR ACCOMPLISHMENTS

In addition to the accomplishments described above, ACD has been working feverishly on two major projects. These include the conversion to the North American Datum of 1983 (NAD 83), and the restructuring of all charts to conform to the FAA's reclassification of the Nation's airspace.

NAD 83 CONVERSION

The conversion from the North American Datum of 1927 (NAD 27) to NAD 83 was in place on aeronautical charts and related publications with an effective date of October 15, 1992. The conversion process was guided by the Aeronautical Charting Data Conversion Committee composed of members from NOS, the National Geodetic Survey Division of C&GS (NGS), and the FAA. The Committee developed plans for implementing the conversion, identified potential problems, and developed solutions to meet the congressionally mandated implementation date. An educational program for FAA field activities was developed, and a notice was sent to aeronautical chart users to inform them in advance of the datum change and how the change would affect the National Airspace. A copy of the notification which was released to the public is shown on the accompanying page. The conversion to NAD 83 was closely coordinated with elements of the DMA and the Canadian Charting Agency to ensure a smooth transition to the new datum.

AIRSPACE RECLASSIFICATION

In 1982, the National Airspace Review recommended that U.S. airspace be simplified, thus making it common with other members of the International Civil Aviation Organization

Important Information on

☞ LATITUDE AND LONGITUDE ADJUSTMENT ☜

To All Chart Users and Chart-Product Users

Beginning October 15, 1992, the horizontal geodetic referencing system used in all charts and chart products published by the National Oceanic and Atmospheric Administration (NOAA) / National Ocean Service (NOS) will change from the North American Datum of 1927 (NAD27) to the North American Datum of 1983 (NAD83). **You should become familiar with this Congressionally mandated change in advance because it will affect the latitude and longitude coordinates of almost all points identified in the National Airspace System.** You can expect coordinates to change by zero to 16 seconds.

In the United States, our latitude and longitude are based on a network of geodetic control points established and maintained by the National Geodetic Survey (Department of Commerce). Control point coordinates are determined mathematically based on a reference point. The NAD27 used a reference point in Kansas for the lower 48 states (conterminous U.S.), Canada, and Alaska. Technological advances called Global Positioning Systems (GPS) now allow satellites to pinpoint much more accurately geographic locations by referencing the center of the earth. NAD83 is based on the center of the earth and geodetically ties Puerto Rico and Hawaii to North America.

The greatest coordinate shifts will be in Alaska and Hawaii where latitude will be moved by as much as 1200 feet and longitude by up to 950 feet. In the conterminous U.S., the maximum changes will be approximately 165 feet in latitude and 345 feet in longitude. Magnetic variation will be altered so minutely the aviation community need not be concerned.

The shift will not be significant enough to change the latitude and longitude grid on Sectional charts or WACs, but it could change the grid on the TACs, Helicopter Charts, and Sectional Insets, and most certainly will affect Airport Diagram Charts. All coordinates in the Digital Aeronautical Chart Supplement, Airport/Facility Directory, Pacific and Alaska Chart Supplements, on Enroute navigation charts and all digital products sold by NOS or FAA will be affected.

If you use digital data from NOS or the FAA, you **must** purge your entire data base when NAD83 replaces NAD27 so that there is no confusion over which referencing system your data is based on. If you use ellipsoidal parameters in your software, they will need to be revised as follows:

a (semi-major axis) = 6,378,137.000 meters
b (semi-minor axis) = 6,356,752.314 meters
1/f = 298.2572221

User questions relating to NOS charts and chart products should be directed to 1-800-626-3677. Technical questions on the datum conversion should be referred to Mr. Doyle (National Geodetic Survey) at 1-301-443-8684.

AGENTS
Please Post

FIGURE 6. Copy of notification released to the public describing the impact on aeronautical products due to the conversion from the North American Datum of 1927 (NAD 27) to NAD 83.

(ICAO). On March 12, 1992, the ICAO adopted a reorganized airspace reclassification concept.

Both IFR and VFR charts are impacted by the airspace reclassification effort. New symbology for both the IFR and VFR charts were developed and will be shown on charts scheduled for printing with an airspace effective date of September 18, 1993.

The following actions are being performed by the ACD chart compilation units in support of the reclassification:

- Statute miles are being converted to nautical miles for approximately 3,000 airspace configurations.
- Approximately 3,100 reclassified airspace descriptions are being validated for configuration and class.
- A digital data base is being developed to be used by the charting sections to portray separate portions of airspace graphically.

ACD has completed verifying and creating its digital data base of all reclassified airspace. Thus far, the charting units have incorporated the changes to charts with October 1992 effective dates. ACD will continue to make these changes to other charts with later effective dates until all charts have been completed.

CHART AUTOMATION

The goal of the Aeronautical Chart Automation Section (ACAS) is to produce and implement an overall system containing a central host computer interfaced with graphic workstations and special digitizing subsystems. Past experience has shown that specially configured and modified computers, and their unique operating systems that frequently incorporate turnkey digitizing systems, can be impossible to expand or upgrade at a later date. The current ACAS plan envisions the modular implementation of a comprehensive system in support of all major aeronautical charting products.

The ACAS Aeronautical Information Data Base is capable of supporting graphic overlay compilation, overlay production, and generalized support for all products. The system is installed at the Rockville, Maryland, site of ACD.

In FY 92, ACAS continued to develop new automated mapping procedures required to support the aeronautical chart compilation production processes and expanded its responsibilities to provide data in support of next generation aviation systems. ACAS is actively involved in providing automated support to new digital products that include

Doppler Radar Systems, Fully Digital Automated Radar Terminal System Display, DBRITE, and FAA's Advanced Automation System.

ACD is now operating an automated mapping system to produce digital Radar Video Maps (RVM). This system supports the FAA's DBRITE program. DBRITE allows air traffic controllers to view high quality RVM's on radar displays in the control tower. In FY 92, approximately 200 new DBRITE maps and 1,000 revised DBRITE maps were produced. The maps are delivered on PROM chips that are plugged into FAA display hardware. ACD is responsible for maintaining all DBRITE maps in the future.

The ACAS system configuration (see accompanying diagram) is a Local Area Network (LAN) connecting four computer servers (VAX 751, VAX 785, VAX 4300, and Unix 5200) serving over 100 alphanumeric terminals, graphic workstations, and microcomputers in all production and development areas of ACD. Peripheral devices on the LAN include color electrostatic and vector plotters, burners, Compact Disk-Read Only Memory (CD-ROM) drives, high speed line and laser graphic printers, and assorted floppy disk drives and tape drives.

Development continues on upgrading and expanding ACAS' aeronautical data base management system. The DEVCONDOR Relational Data Base System relies on dictionaries which uniquely describe the data tables in the data base and all the ACD products. A single update procedure creates the program code to update the data tables and ACD products. Because specific update code is created at runtime, only the dictionaries are modified to keep up with changing product requirements.

ADVANCED AUTOMATION SYSTEM (AAS)

AAS is a major project of ACD. It is the FAA's 3.5 billion dollar massive effort to overhaul the nation's air traffic control system. The overall objective is to modernize and improve the systems to accommodate the spiraling demands for aviation services into the 21st century. AAS will allow the area and tower air traffic control facilities to track 7 times more aircraft than the current systems. Aircraft will operate with less constraints, over more routes, and with greater fuel efficiency. Significant savings in manpower, rents, utilities, and energy costs will be realized.

ACD has an important role to play as the sole supplier of the navigational information that will be incorporated into what will be the largest and most complex real-time data system of its kind in the world. State-of-the-art computer hardware and integrated software are being designed by International Business Machine (IBM) for the AAS, in part, around the data bases and digitized charts provided by ACD. In addition, ACD is acting as the expert advisor on technical points concerning the use of ACD supplied data. The ACD effort is being financed by reimbursable funding from the FAA.

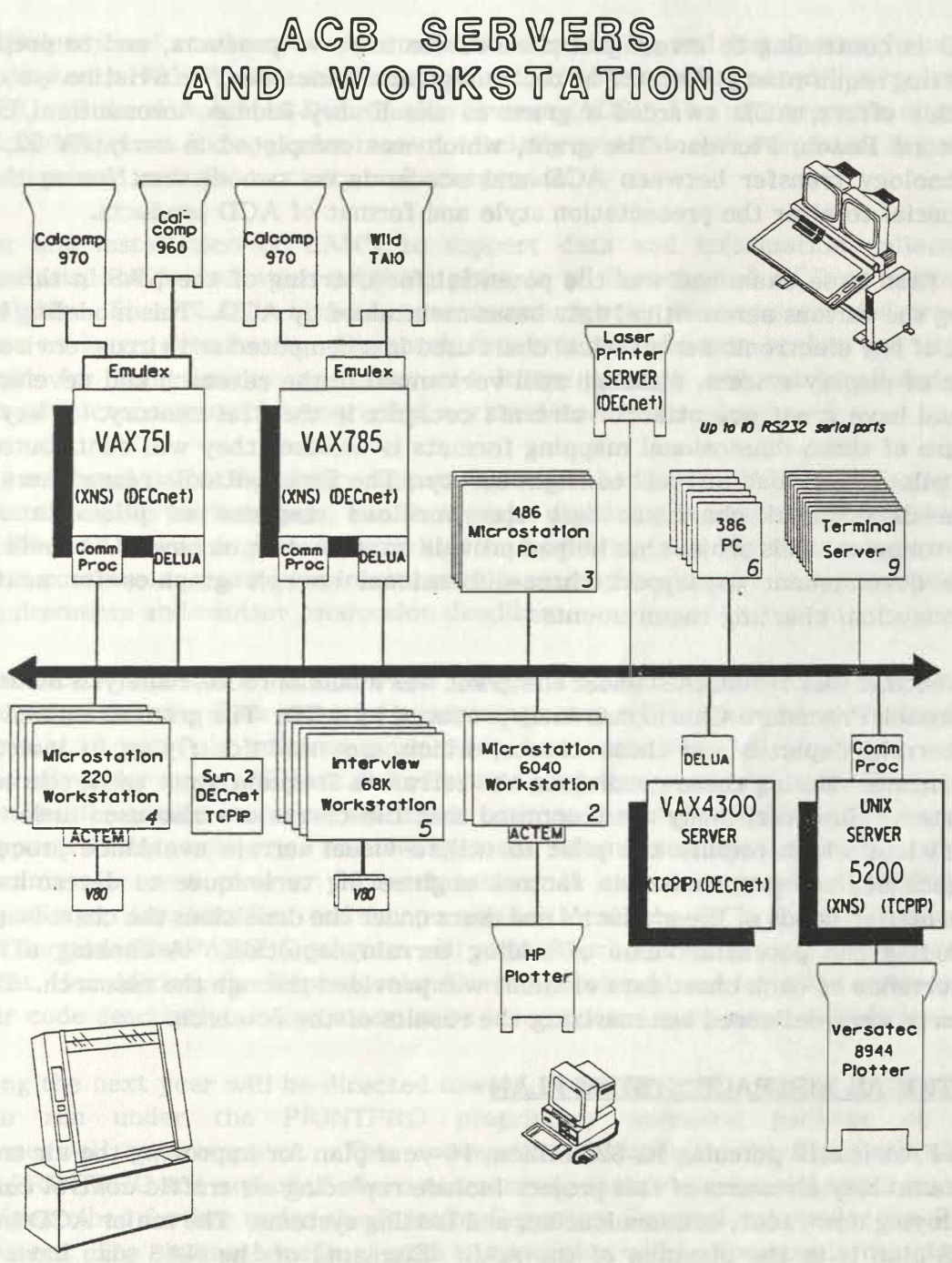


FIGURE 7. Diagram of the Aeronautical Chart Automation Section's local area network configuration connecting computer servers, alphanumeric terminals, graphic workstations, and micro computers in production and development areas of the Aeronautical Charting Division.

HUMAN FACTORS ENGINEERING FOR C&GS CARTOGRAPHY PROGRAM

ACD is continuing to investigate methods to improve products, and to prepare for new charting requirements dictated by technological advancements in aviation systems. As part of this effort, ACD awarded a grant to the Embry-Riddle Aeronautical University of Daytona Beach, Florida. The grant, which was completed in early FY 92, allowed for technology transfer between ACD and academia on two distinct issues that have the potential to alter the presentation style and format of ACD products.

The first issue examined was the potential for charting of the NAS in three dimensions using the various aeronautical data bases maintained by ACD. This modeling is an integral part of any electronic aeronautical chart used in a computerized virtual environment. This type of display system, although still very much in the research and development stage, should have great potential for aircraft cockpits in the 21st century. A key issue in the future of three-dimensional mapping formats is whether they will contribute to lowering the pilot's workload and add to flight safety. The Embry-Riddle researchers used pseudo three-dimensional charts to test the workload response of pilots in a simulation environment. This project has helped provide an indication on how ACD could plan its data base development to support three-dimensional cockpit graphics for next generation aeronautical charting requirements.

The second task researched under the grant was a human factors analysis of the Instrument Approach Procedure Charts currently produced by ACD. The grant examined the question of terrain depiction on these charts, which are used for flying in instrument flight conditions. During these conditions, the terrain is frequently not seen, therefore it is not charted. However, many users contend that the charts are also used under visual flight conditions which require the pilot to utilize visual terrain avoidance procedures. This project utilizes proven human factors engineering techniques to determine the actual information needs of the product's end users under the conditions the chart is actually used, including the potential value of adding terrain depiction. A ranking of the relative importance of each chart data element was provided through the research. Two intensive reports were delivered summarizing the results of the research.

NATIONAL AIRSPACE SYSTEM PLAN

The FAA is still pursuing its $20 billion, 10-year plan for improving the air traffic control system. Key elements of this project include replacing air traffic control computers, and deploying new radar, communication, and landing systems. The major ACD interest in the NAS plan is in the planning of the AAS. Elements of the NAS plan have had a major impact on ACD by requiring new aeronautical charting projects, creating a demand for additional service and emphasizing the need for C&GS to move forward quickly with its modernization efforts.

MANAGEMENT IMPROVEMENTS AND AUTOMATION

Improved efficiency and accuracy of the compilation, printing, and distribution functions were accomplished in FY 92 with enhancements to ACAS, the Automated Reproduction System (ARS), and the Automated Distribution System (ADS). The procurement of more powerful microcomputers and upgrades to commercially available software in all Branches of ACD has improved user productivity and acceptance.

Procurement and installation of LAN's to support data and information collection, retrieval, analysis, and presentation is taking place in all Branches of ACD as resources become available. These LAN's also increase communication among users and provide better access to large data bases. Research into the use of laser analog and digital compact disks for high density narrative and image storage and retrieval and the development of microcomputer cartographic workstations are continuing.

ACAS has completed a cartographic support system that uses VAX minicomputers, Intergraph cartographic workstations, and Intergraph digitizing subsystems. This system is more reliable and allows improved flexibility in specifying data formats. Automated enhancements continue to provide uninterrupted cartographic support to meet changing charting requirements and routine production deadlines.

ACD has enhanced the ARS with a LAN of powerful microcomputers and the Novell Netware operating system. This powerful processing setup will take some of the load off of the existing 10-year old minicomputer that has been reliable but slow. This improvement allows for more efficient and effective preparation of jobs in the Production Management Section where resource needs are estimated and schedules are developed. ARS now supports 50 data collection and management information terminals. Plans are to increase user involvement to over 60 workstations in the next year. PARSEC, an estimating package, was installed and is operational in all the PC's in the Production Management Section. The PARSEC program will assist Reproduction Branch personnel with cost estimates. In addition, the Reproduction Branch purchased and installed software to allow for bar code descriptive information to be incorporated onto maps and charts.

Efforts during the next year will be directed toward converting the existing applications software to run under the PRINTPRO proprietary software package on the Ultimate/Honeywell minicomputer. This conversion will require the functions to be described to PRINTPRO and expanded where necessary to satisfy any special requirements. PRINTPRO (described further under the Printing Functions Section) runs under the PICK operating system. The obvious benefit of such a conversion will be the standardization of programming skills and data management techniques with those of the ADS. As a result, the technical skills needed by the programmers and analysts in the Systems Development

Group will also be standardized. This will be of great benefit when the Reproduction and Distribution Branches collocate.

ADS is now operating with improved capability as a result of the enhancements to memory and disk storage, in part, to accommodate the acquisition of the distribution of DMA public sale products. The computer system now responds in a very effective and efficient way to the large amount of processing necessary to support the normal functional activity of the Reproduction Branch, the financial reporting and statistical analysis requirements of upper management, and normal systems support requirements such as data base management, data backup, and error recovery. The enhancement of the computer system has reduced the processing time required by over 66 percent. A major result of this improvement is a drastic reduction in the overtime necessary to complete all processing. Work on weekends and daily second shifts now occurs less frequently.

MANAGEMENT INFORMATION SYSTEM

ACD is implementing a Management Information System (MIS) which will be designed to supply staff members with real-time data to support planning and budgeting as well as management of personnel, material, and financial resources. This system will improve the timeliness and accuracy of managing the vast amount of data received from and transmitted to ACD headquarters staff and organizational Branches.

The present automated MIS consists of microcomputers, printers, modems, and appropriate job-specific, off-the-shelf software. These components assist staff and management in the areas of cost accounting, production control, data analysis, and presentation. These functions identify product costs, develop pricing recommendations, determine the net income or loss from chart operations, project sales data to determine marketing strategies, develop and control production schedules, tabulate employee's time on specific projects and tasks, and consolidate information for appropriate technological solutions to the problems associated with the presentation of charting data.

While the use of stand-alone computers has provided the staff with greatly improved productivity, both management and production effectiveness and efficiency could increase dramatically if these computers were capable of communicating with each other. Thus, the planned procurement and installation of a Local Area Network (LAN) in FY 93 will allow for data to be easily accessible by all managers, staff personnel, and other users in Silver Spring and Riverdale, Maryland, and the Hoover Building in the District of Columbia. The MIS can then bring together and correlate the cost, revenue, and production data currently residing on diverse computer systems. It can also eliminate redundant data entry, decrease the possibility for erroneous data, and allow for a more timely dissemination of summarized information. The new LAN will link the microcomputers in the ACD staff to those in the three subordinate Branches.

The major functional areas that will be supported by the MIS include time scheduling, word processing, document publishing, presentation graphics, tabular analysis of financial and statistical data, project management, electronic mail, data base and program development, and management decision support.

PRINTING FUNCTIONS

The Reproduction Branch plans and directs integrated printing production facilities for the prepress services, printing, and finishing of charts and maps. The Branch engages in and uses all of the prepress processes for producing printed charts and maps from manuscripts, operates a 60" five-color press, develops production techniques and controls, and provides for maintenance of equipment. Through the increased use of automated techniques and systems, the Branch has improved its administrative efficiency and production control capabilities. The mission of the Reproduction Branch is to revise, construct, and reconstruct nautical and aeronautical charts in accordance with prescribed specifications, print and finish these charts for dissemination in accordance with established production quality standards and product specifications, and provide support services to internal and external organizations engaged in mapping and charting activities.

The Branch consists of various production-oriented elements, each performing an integral segment of the total operation. These sections include production management, negative engraving, quality assurance, photography, lithography, typesetting, and pressroom and finishing operations.

During FY 92, the Reproduction Branch incorporated two new equipment systems into the Photo Unit and the Type Unit that have greatly expanded production capabilities. The Photo Unit is now using a Carlson color proofing system with a Kreonite processor that allows for closer approximation of the colors achieved on the presses. The system utilizes three color filters that work separately and in combination to produce most of the full color spectrum. Proofs are now being made on a mylar base that allows for the proof to be used as a chart overlay for applying compilation corrections.

Production in the Type Unit has been greatly expanded with the installation of a new typesetting system. This system combines the flexibility of the Apple MacIntosh page make-up workstations for composition with the quality output of the Linotronic 300 image setter. This state-of-the-art system offers many advantages over the MultiSet III system previously used in the unit. Page make-up is now performed directly on the system, integrating textual and graphic data on-line. The output from the Linotronic 300 can be either film (positive or negative) or paper, which results in cost savings for the Branch's Photo Unit on both film and paper supplies.

The aeronautical charts (except IFR Enroute Charts and book-bound products) are all printed by the Branch during a 2-week period every 28 days to meet strict publication dates. Between these periods, all nautical charts/maps and supplemental work are printed. The printing schedules are exceedingly tight so that the printed products are as current as possible. All equipment has back-up arrangements to handle emergencies and ensure against missed publication dates. Enroute Charts and book-bound products are printed under contract which makes up approximately 45 percent of the aeronautical chart and related chart product printing.

To support their mission, more than 90 employees of the Reproduction Branch and other units of ACD interface with ARS through the automated production control, work-in-progress, time accounting, cost accounting, and job status reporting systems. ARS provides the collection, editing, and correction of cost accounting, employee time, material usage, and job control information; supports the initiation and scheduling of jobs through the Branch; and performs all processing functions necessary to generate management reports from the data base.

The hardware presently supporting the ARS has been in service for 10 years, and reached the end of its expected life cycle 3 years ago. It is being replaced by an Ultimate/Honeywell minicomputer in order to continue to supply adequate support to production managers and cost-control analysts in a timely and reliable manner. Planned actions to reduce costs and improve services include the conversion of the existing applications software to PRINTPRO software.

This proprietary program is used in many printing plants in the private sector. It is expected that such a standard software package will allow the Government to operate at a greater level of efficiency than with the present internally developed system. PrintPro was developed in BASIC under the PICK operating system. Implementation of PrintPro on the Ultimate/Honeywell computer will then produce a system that is consistent with that supporting ADS. The software conversion process is expected to be completed in FY 93. After 1 or 2 years of operation to ensure user and management satisfaction, the computer hardware will be upgraded with new state-of-the-art equipment. This equipment is expected to be very powerful, and relatively inexpensive, microprocessors.

The new system will provide on-line support in the areas of cost and time data collection, job scheduling, and resource estimating. The system will be capable of providing support 24 hours a day, if needed, and will be able to enter a "fail-soft" operating condition in case of a power failure. As user requirements change, the system will be flexible enough to respond in an efficient and effective manner. System capability will allow for local data storage at the user terminals, and on-line data validation and correction by the users.

DISTRIBUTION FUNCTIONS

The ACD Distribution Branch plans and directs the distribution of NOS' aeronautical and nautical charts and related publications to Government agencies, the public, and approximately 4,000 authorized sales agents. In FY 93, the Branch will start to distribute those charts and products that are available to the public from DMA. Approximately 6,000 different DMA aeronautical and nautical charts and products will be available for public sale. The magnitude of this effort required new contractual arrangements for the distribution of these products, and sales are expected to be greater than when distributed by DMA. Sales and orders for NOS and DMA public sale products will be done both directly from NOS and through the established network of chart sales agents.

The Branch also selects and monitors sales agents, determines quantity requirements for charts and related publications, initiates print orders, and performs bookkeeping, accounting, and maintenance of mailing lists pertaining to the receipt and issuance of charts and publications. Critical missions of the Branch include the timely distribution of date-sensitive charts and publications and the maintenance and production of current information about inventory and revenue. The successful operation of these functions depends on contractual support that presently includes warehousing, order filling, and shipping.

Distribution of charts and related publications, as well as internal functions such as the determination of quantity requirements, initiation of printing orders, and maintenance of accounts and mailing lists, are being made more efficient by the use of automated techniques and improved operational procedures. These procedures include a realignment of internal Branch duties to provide the flexibility required to meet goals and objectives.

In its ongoing efforts to increase the efficiency of distribution methods, decrease costs, and to better serve the public, the Branch is invoking major changes in its procedures. During FY 92, the Branch began using commercial trucking, instead of the United Parcel Service, to fill orders to its large volume chart sales agents. This new method proved to be at least as efficient, and also showed a substantial cost savings (approximately 80 percent) over the former procedure for shipping orders to large volume chart sales agents.

The Branch has also developed a program with the U.S. Postal Service to increase the efficiency of distributing products. Effective the beginning of FY 93, a manifest system will be used to determine the cost of postage. The manifest will replace the previously used weighing/stamping method. ACD will be charged for the postage dictated by a manifest list. Through the manifest system, a formula using the predetermined weights of each product (including packaging) and the destination of the product determines the cost for shipping. This eliminates the need for weighing and stamping each filled order.

The Branch is continuing to increase its customer service operation by training its personnel to be more skilled at handling all types of situations and to have expertise in providing technical information on all NOAA products, as well as publications available from other Federal agencies. The Branch has also installed new telecommunication equipment to enable customers to telefax orders for faster turn-around time. The functions of the Distribution Branch are being supported by a commercially available on-line software package that was procured to provide a large degree of standardization to the operational environment. The ADS supports the processing of orders for charting products, customer credit verification, invoices and monthly statements, back orders and standing orders, accounts receivable, subscriptions, and inventory. The related computer programs are easily adaptable to changing functional requirements. The computer system was expanded in FY 92 with 32 million bytes of additional random access memory and two additional disk drives of 1,700 million bytes of storage each. These enhancements tripled both the memory size and the disk storage space. This new hardware has improved the system response time to the users and also has speeded up the processing and printing of voluminous output requirements such as labels, invoices, and account statements.

MARKETING EFFORTS

The long-term goals of the C&GS Marketing Program support the efforts of NOS to maintain or increase sales volume and revenue for charts and related products by improving NOS and NOAA product awareness, identifying user needs, locating new markets, and supporting the national network of chart agent retailers.

The following tasks were accomplished in FY 92 to support these goals:

- ACD continued its long-standing program of participation in aviation trade and air shows. Ten shows were attended in FY 92. The shows were staffed by ACD personnel knowledgeable, not only in aeronautical charting products and services, but in the broad spectrum of C&GS activities. The Division also provided funding and personnel staffing for several boat shows and nautical trade shows during the year.

- C&GS exhibited at seven technical shows in FY 92. Nautical, aeronautical and geodetic products were displayed at the exhibit booths. Knowledgeable personnel from the three C&GS Divisions distributed catalogs and answered questions from show attendees.

- The sixth Workshop for NOS Chart Agents was held at the Holiday Inn Bethesda, in Bethesda, Maryland, on March 24-25, 1992. In attendance were over 50 NOS and DMA chart agents from around the country and the world. The workshop served as an opportunity for agents to become more familiar with the activities and products

within C&GS, receive an update on current issues, and to be briefed on the future of the organization and how it may affect the agents. It also was an opportunity for ACD to personally meet its agents and discuss any concerns or problems they may be encountering as an NOS chart agent.

The 2-day sessions consisted of speakers from NOS and a variety of other Government and private industry organizations, closed door working sessions, and an exhibit area to allow attendees to view and discuss displays and products from 15 exhibiting organizations. Attendees were also offered tours of the aeronautical and nautical compilation areas, as well as the printing facilities. The next chart agent workshop is tentatively planned for FY 94.

- To improve product awareness in the aviation community, ACD has continued to develop promotional campaigns to reach customers. These include: (1) safety seminars conducted by Division personnel to encourage aviators to use current aeronautical charts and products, (2) programs designed for flight schools incorporating the Chart User's Guide to teach student pilots the proper use of charts, and (3) printed notices and advertisements to promote ACD charts and publications.

- During FY 92, ACD developed a program to visit and make presentations to certified flight instructors at airports throughout the country. The presentations are designed to educate flight instructors on the vast amount of changes which occur to charts during a chart cycle and to emphasize the importance of using current and up-to-date charts for safe navigation. The presentations also provide an overview of the chart-making process and give the instructors an appreciation for the painstaking efforts employed in producing aeronautical charts. The flight instructors are encouraged to educate their students on the importance of using current charts and to include discussions on this topic as part of the flight school's curriculum.

The program is targeting those areas of the country where users and potential users of NOS products do not have the opportunity to have discussions with NOS representatives at air and technical shows. The program is designed to educate the public, promote safe air navigation, and in the process, increase chart sales.

- ACD continues to provide promotional items for distribution at trade shows, workshops, and technical conferences. These include NOAA pens, cloth lapel appliques, plastic NOAA tote bags, NOAA promotional bumper stickers, and NOAA magnets.

- The C&GS publication entitled "C&GS Update" is now in its fifth year of production and is a useful source of information to its constituency. C&GS continues to receive requests from commercial companies wanting to be on the mailing list for this publication.

- ACD has developed and distributed catalogs for the marketing of DMA public sale products and publications. Additionally, the Division developed flyers and solicited public service announcements from a variety of pilot and mariner magazines and newsletters announcing its acquisition of the sales and distribution of DMA public sale charts and products.

- The Distribution Branch has continued to provide training in customer service and telephone techniques for its customer service representatives and other Branch and staff personnel. This training emphasizes total customer satisfaction in all dealings with the public.

- The Division produced several flyers and special announcements regarding new and revised products. These flyers and announcements are distributed to all chart agents and subscription customers. The new product announcements are also released to several aviation industry magazines for publication to better inform potential chart users.

- ACD is staying in touch with its users through its customer inquiry system. A selected number of aeronautical and nautical chart agents are called periodically to inquire about products, services, and problems. All problems in servicing and product delivery are routed to and resolved by the Distribution Branch to improve service to chart agents. In addition, the Chart Agent Visitation Program continues to provide valuable information on customer service. A selection of chart agents are visited each year by ACD personnel. Information gathered from these visits allow the Division to better serve the varied needs of its chart agents.

- ACD participates in many programs to enhance the safety and usability of aeronautical charts and publications and to assess future requirements of the aviation community. These programs include: (1) the FAA Industry Charting Forum, (2) the Society of Automotive Engineers G-10 Subcommittee for Aeronautical Charting, (3) the Interagency Air Cartographic Committee, (4) the annual Aeronautical Charting Division External Review, and (5) coordination and liaison with user groups such as the Aircraft Owners and Pilots Association and the Airline Pilots Association.

- As part of C&GS' marketing efforts during FY 92, ACD has designed and constructed new exhibits for use at all the technical shows attended by C&GS.

Working with representatives from the other two C&GS Divisions, new graphics have been designed and new frames have been acquired. The graphics for the exhibits will be completed in early FY 93.

SCIENTIFIC PAPERS AND TECHNICAL REPORTS

Bolton, Ronald M., "The Impact of the Implementation of the North American Datum of 1983 (NAD 83) on Aeronautical Navigation in the United States," North American Cartographic Information Society XII, October 14-17, 1992, St. Paul, Minnesota.

ACCOMPLISHMENTS OF THE NATIONAL GEODETIC SURVEY

NATIONAL GEODETIC REFERENCE SYSTEM

The primary mission of the National Geodetic Survey Division (NGS) is to establish and maintain the national geodetic horizontal, vertical, and gravity networks which make up the National Geodetic Reference System (NGRS). Progress in improving the NGRS during FY 92 is described below.

HORIZONTAL GEODETIC NETWORK

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

Cooperative efforts to provide horizontal control were conducted for the U.S. Army Corps of Engineers in the District of Columbia and Virginia, for the U.S. Coast Guard in New England, and for the Saint Lawrence Seaway Commission in New York.

NGS continued to provide the Federal Aviation Administration (FAA) with horizontal control at airport facilities. During the past year, final coordinates were computed for 205 airports. Since the beginning of the project, coordinates have been computed for 1,369 airports. New to the effort are airports under consideration for LORAN approach procedures. During the last year, final coordinates were computed for 32 LORAN airports.

POST-NAD 83 REGIONAL ADJUSTMENTS

High Accuracy Reference Network (HARN) surveys for California, Colorado, Delaware, Idaho, Maryland, Montana, New Mexico, and Wisconsin were completed in FY 92. The integration of classically surveyed data with the GPS observations has been completed and loaded into the NGSIDB for Maryland, Delaware, and Wisconsin. Integration of classical data for the states of California, Colorado, Idaho, Montana, and New Mexico are in progress. These successful state adjustments demonstrate NGS' ability to merge the new technology of GPS with the classical network. The accompanying map shows the status of the statewide HARN's.

VERTICAL GEODETIC NETWORK

Implementation of the North American Vertical Datum of 1988 (NAVD 88) was begun during FY 92. The project is part of an international effort, requiring close cooperation with NGS' counterpart agencies in Canada and Mexico (the Geodetic Survey Division,

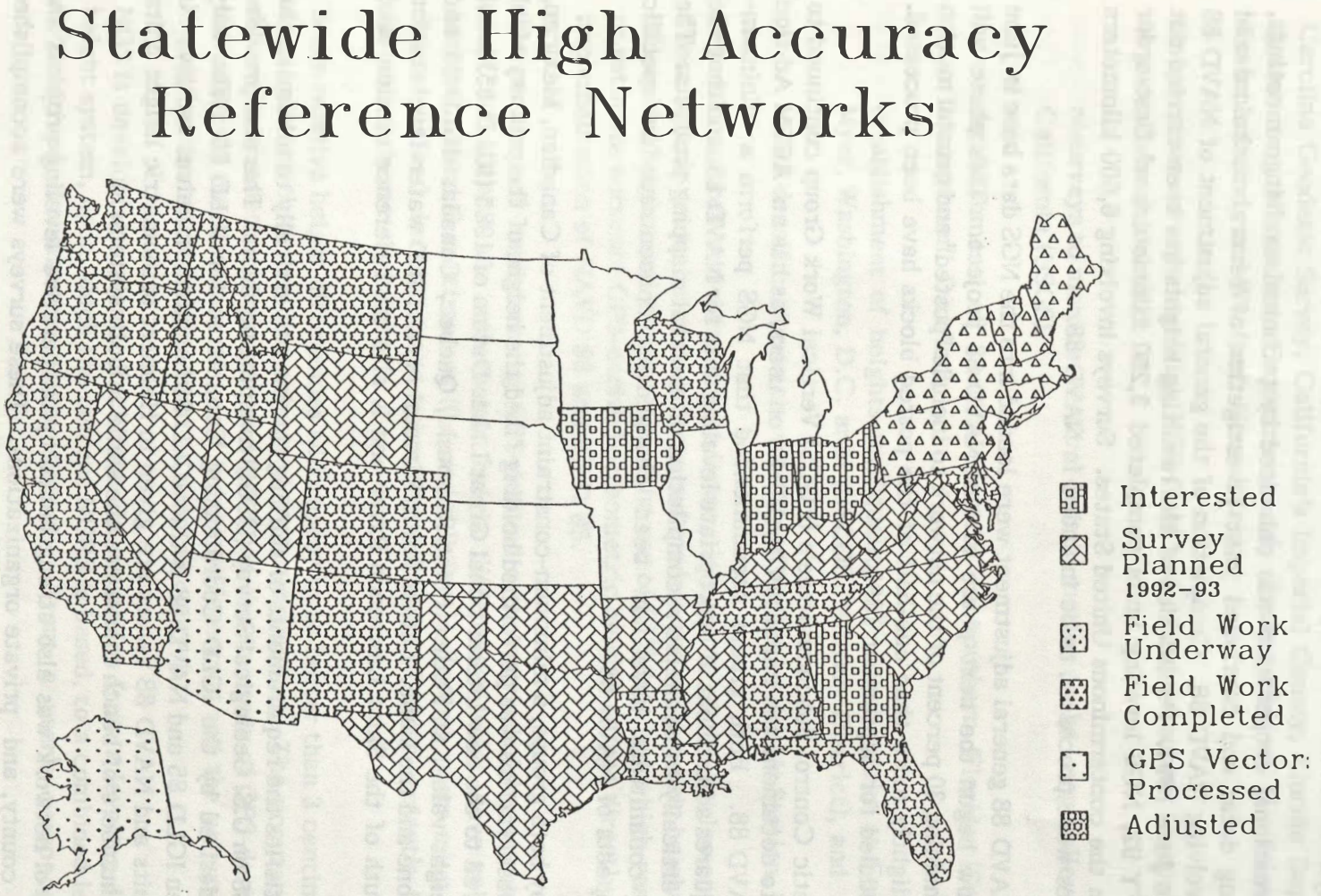


FIGURE 8. Map showing participation by states requesting NGS support in establishment of high accuracy reference networks based on GPS surveys.

Canada Centre for Surveying (GSD), and Instituto Nacional de Estadistica e Informatica (INEGI), respectively).

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

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

The Federal Geodetic Control Subcommittee's (FGCS) Vertical Work Group continued to meet periodically to document the impact of NAVD 88 on users, as has an ACSM Ad Hoc Committee on NAVD 88. Both groups recommended that NGS perform a minimum-constraint, least squares adjustment of appropriate leveling data for NAVD 88, and that the datum be shifted vertically to minimize recompilation of national mapping products. The missions of both committees have now been changed to concentrate on specific implementation aspects of NAVD 88.

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

This constraint satisfies the requirements of shifting the datum vertically to minimize the impact of NAVD 88 on U.S. Geological Survey (USGS) mapping products. This also provides the datum point desired by the IGLD Coordinating Committee for IGLD 85. The only difference between IGLD 85 and NAVD 88 is that IGLD 85 bench mark values are given in dynamic height units and NAVD 88 values are given in Helmert orthometric height units. The geopotential numbers of bench marks are the same in both systems.

The vertical control network was also strengthened by cooperative leveling projects and leveling by state, county, and private organizations. These surveys were accomplished

primarily by NGS field units, USGS, Alabama Highway Department, Maryland Department of Transportation, New Jersey Geodetic Survey, North Carolina Geodetic Survey, South Carolina Geodetic Survey, California's Imperial County, Florida Department of Natural Resources, Minnesota Department of Transportation, Louisiana Department of Transportation, and Woolpert Consultants.

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

- resurveys to monitor vertical crustal motion in the Long Valley and Coalinga areas, California (USGS),
- establishment of vertical control in southern Florida (South Florida Water Management District),
- establishment of heights for "quality A" bench marks at Fort McNair and Fort Myer, Washington, D.C. area (USCOE, Military District), and
- NGRS densification in the vicinity of Fallon Naval Air Station, Nevada (U.S. Navy).

Several research activities are underway in support of the implementation of NAVD 88. These include crustal motion effects and models and orthometric heights derived from GPS ellipsoidal heights and gravity data. The use of GPS data and a high-resolution geoid model to estimate accurate GPS-derived orthometric heights will be directly associated with the implementation of NAVD 88 and IGLD 85.

The problem of implementing GPS-derived orthometric heights is two-fold. First, users must accept and use orthometric height differences which have relative uncertainties between 3 and 6 centimeters (0.1 and 0.2 feet). Second, users must be able to reliably determine and document the accuracy estimates of their project's final adjusted GPS-derived orthometric heights.

Some relative height differences will appear to be better than 3 centimeters, while others may indicate that they are only good to 6 centimeters. The accuracy of adjusted GPS-derived orthometric height values depends on the accuracy of GPS-derived ellipsoid height differences, the accuracy of geoid height differences, and the accuracy of the leveling-derived orthometric heights used as vertical control.

NGS is developing a plan to facilitate the transition from a leveling-derived orthometric height system, upon which the current NGRS is based, to a combined leveling-derived and GPS-derived orthometric height system. From a user's perspective, an accurate,

consistent, constant set of orthometric heights is very important. This may be difficult to maintain during the transition period.

During the transition period, specifications and procedures will be modified to account for the use of more accurate geoid models, improvements in estimating GPS-derived ellipsoidal heights, and the establishment of additional precise leveling-derived orthometric heights. The plan must take into account issues such as consistency, distortions, and long-term Federal programs which are dependent upon accurate vertical control data.

The Vertical Network Branch, in cooperation with FGCS, also coordinated a test survey and evaluated the results of the WILD NA2000 and NA3000 digital leveling systems. The systems measure, calculate, and record leveling data electronically using bar-code leveling rods. Reports, documenting the results of the tests, are being prepared. Work continues under contract on the Rapid Precision Leveling System (RPLS) Development Project. Progress is monitored by the C&GS Nautical Charting Research and Development Laboratory. An important technical advantage of RPLS is the promise of minimizing or eliminating atmospheric refraction errors in leveling.

GPS SURVEYS AND APPLICATIONS

NGS observed GPS satellite surveys in the following areas:

- Kayak Island to Cape Fairweather and FAA Radar Sites, Alaska;
- 1990 Center of Population Survey, Missouri;
- Washington, D.C. area;
- Hebgen Lake/Yellowstone Area Survey, Montana;
- Alabama, Alaska, Arizona, California, Colorado, Idaho, Louisiana, and Montana statewide network upgrades;
- for the FAA Test Center at Atlantic City, New Jersey, and the FAA and the National Aeronautics and Space Agency at Los Angeles, California;
- in support of the Airport Datum Monumentation program in four states and the LORAN airport survey project of FAA in five states.

In addition to NGS-observed surveys, 74 GPS survey projects were received from other agencies including:

- Cross Sound Survey, Alaska;
- US 43 GPS Survey, US 82 GPS Survey, US 280 GPS Survey, US 72 GPS Survey, US 78 Project, and US 41 GPS Survey, Alabama;
- Norteado Survey Phase 2, Arizona;
- Moss Landing Harbor, Sacramento and San Joaquin Rivers Survey, Monument Peak Footprints Survey, and San Diego High Precision Geodetic Network, California;

- Telluride Airport Tie, Colorado;
- SR72 Milford Crossroads to Pleasant Hills, Delaware;
- Polk County Densification Network, Navigation Aids - Egmont Channel, Pasco County Network, Homosassa Reserve Control, Okaloosa County Survey, Florida Keys Mapping Project, Palm Beach County Survey, Blackwater River State Forest, and Orange County GIS Control Survey, Florida;
- Cobb County Survey, Powder Springs Road Survey, and Gwinnett County Survey, Georgia;
- Lexington Densification Survey, Kentucky;
- White Lake to West Cote Blanche Bay and St. Mary Parish Survey, Louisiana;
- Interstate 95 Maryland to Delaware line and Howard County Survey, Maryland;
- Lake Michigan (Great Lakes Mapping Project), I94 (Jackson County Survey), I96 (Livingston County Survey), I75 (Oakland County Survey), M-43 (Ingham County Survey), and Huron and Manistee National Forests Surveys, Michigan;
- City of Joplin Survey and City of Rolla Survey, Missouri;
- Gaston County Project, Western Shoreline (Pamlico Sound), Burke-Caldwell GPS Project, and Western North Carolina (Georgia to Tennessee) Survey, North Carolina;
- Mandan 1991 Survey, North Dakota;
- Wallkill River Basin Survey, Western Middlesex County Survey, East Brunswick Township, and Mercer County Survey, New Jersey;
- USCG RDC Montauk Bay Survey and Nassau County Project, New York;
- City of Cincinnati Horizontal Survey and Fairfield County Survey, Ohio;
- HARN Replacement Station Survey, Aids to Navigation Structures (Coos Bay), US Highway 26 (Austin Junction), Oregon;
- Charles County Survey, South Carolina;
- Black Hills National Forest, South Dakota;
- City of Knoxville, Tennessee;
- Galveston Jetty Lights Survey and Airport ties at Harlingen, Brownsville, and McCallen, Texas;
- City of Lynchburg Survey, Fairfax County, National Airport Survey, Richmond International Airport Survey, Patrick Henry Airport Survey, Norfolk International Airport Survey, Atlantic Marine Center GPS Tie, and Rappahannock and Potomac Rivers Survey, Virginia;
- South Puget Sound (Narrows to Olympia) and Yakima County Order B GPS Survey, Washington.

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

The projects completed were in support of varied requirements including extension and densification of NGRS; monitoring of vertical and horizontal displacements associated with

tectonic movements; connecting FAA airports to the NGRS; and geodetic network and control survey upgrades. GPS surveying statistics accomplished by NGS for the period July 1991 to June 1992 are as follows:

Number of projects.....18
Number of receivers per project.....5
Total stations occupied.....1,005

In support of the transfer of GPS satellite surveying technology to Federal, state, local government, and educational institutions, a seminar was presented to members of the Bureau of Land Management and U.S. Forest Service. GPS technology transfer was also supported by participation in panel discussions, technical papers, speeches, and the training of scientists and surveyors, both national and international, visiting NGS during FY 92.

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

Other GPS satellite survey developments are as follows:

- Operational kinematic GPS field units completed observations for FAA's LORAN C airport program and the FAA Airport Datum and Monumentation Program.
- The operational use of the GPS vector reduction package OMNI continued in the office and on two of the NGS GPS field units. Extensive experience has been gained computing vectors in orbit relaxation mode in support of statewide network upgrades.
- Both NGS GPS field units are now capable of doing least squares adjustments of field reduced vector data. The two units carry out this analysis on a routine basis.
- All orbit tracking data and computation results, office vector computations, field computations, and raw GPS observations are routinely archived on optical WORM (Write Once, Read Many) cartridges.

HIGH RESOLUTION GEOID HEIGHTS AND DEFLECTIONS OF THE VERTICAL

Precise geoid heights are becoming more important because they relate the ellipsoidal heights obtained from GPS satellite measurements to the orthometric heights obtained

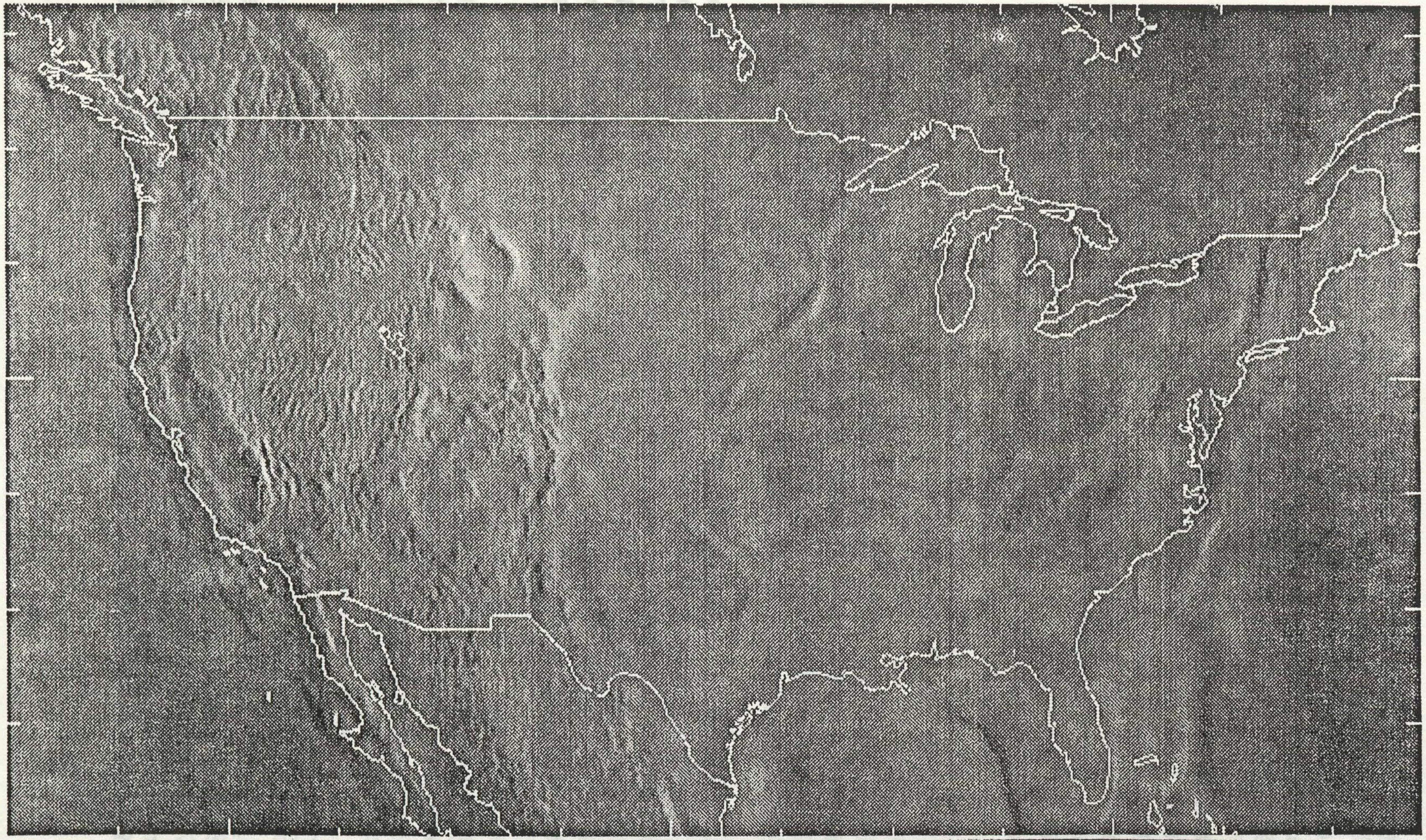


FIGURE 9. Map of the United States that depicts geoid heights determined by a model developed by NGS. Calculated geoid heights range from a low of -53 meters in the Atlantic Ocean to a high of -5 meters in the Rocky Mountains.

from geodetic leveling. By means of a precise geoid model, one may convert the heights from GPS systems into heights consistent with mapping and charting products. If this conversion can be done accurately enough, it will be possible to eliminate the need for supplemental observations taken by means of expensive geodetic leveling for many applications in areas where existing geodetic control can be utilized.

Geoidal height variation across the United States is being systematically modeled. Models are tested against ellipsoidal heights which have been determined by Very Long Baseline Interferometry (VLBI) and GPS. Orthometric heights in the NAVD 88 datum have also been determined. The accompanying map shows geoid height variations in the United States calculated from the model. Tests have identified a trend of 0.5 parts per million in a North-South orientation. This trend is currently being investigated as a function of either the fundamental model or the leveling data. Geoid studies indicate that recomputation of the gravity terrain correction will determine whether higher accuracy is to be achieved. In addition, the indirect effect correction and the second-order terms of the normal gravity gradient must now be incorporated into the model.

The NGS has computed a high-resolution deflection of the vertical model for the conterminous United States, known as DEFLEC90. These deflections of the vertical are referenced to the Geodetic Reference System of 1980 (GRS 80) and are appropriate for use in LaPlace corrections and deflection corrections.

DEFLEC90, derived from gravity and terrain data, consists of grids of deflection values with a 3-minute by 3-minute spacing in latitude and longitude. A computer program known as DEFLEC is provided with DEFLEC90 to facilitate the extraction and interpolation of values from the grids to discrete points. DEFLEC90 was developed from gravity data held by NGS and terrain data available from NOAA's NGDCenter in Boulder, Colorado. The global geopotential model known as OSU89B, available from the Ohio State University, was also used.

DEFLEC90 displays 1 arc-second RMS (root mean square) accuracy compared with astronomic and geodetic (NAD 83) latitudes and longitudes. Accuracy is correlated with elevation and terrain roughness. Significantly better accuracy is evident in the eastern United States.

TIME-DEPENDENT POSITIONING (TDP) MODELS

In many locations, geodetic coordinates change significantly with time. Users of the published geodetic information need the coordinates to be correct at the time they are performing such work as mapping flood planes or building large scale irrigation systems. Also, they need information about changes in coordinate relationships to support work involving development of regional building codes, development of geophysical models to

explain crustal deformation, or prediction of hazards such as earthquakes, volcanic eruptions, or tsunamis. A TDP model can be used to correct old geodetic measurements in a region so that revised estimates of coordinates can be computed.

NGS' Advanced Geodetic Science Branch has implemented a first generation system for rapid development and use of TDP models. The first generation TDP models were applied to homogenize, in time, the measurements that were used to estimate positional coordinates for the 250,000 sites in the NGRS. More recently, TDP models for horizontal motion have been significantly improved by the addition of new data, as well as by the application of a new generation of computing software (see the accompanying figure for an example). TDP models of vertical motion have also been developed for 5 of 22 areas identified as having significant vertical crustal motion. NGS is assembling a vertical crustal motion data base for all of these locations and will eventually develop models for them.

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

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

NGS collaborates with scientists at USGS and universities to develop accurate models and exchange support data. NGS convened and cosponsored the American Geophysical Union Conference, "Time-Dependent Positioning: Modeling Crustal Deformation," in Annapolis, Maryland, in September 1991. Moreover, NGS scientists are editing a collection of research papers on crustal deformation. The papers were contributed by scientists from several institutions, and they will be published in a special issue of the Journal of

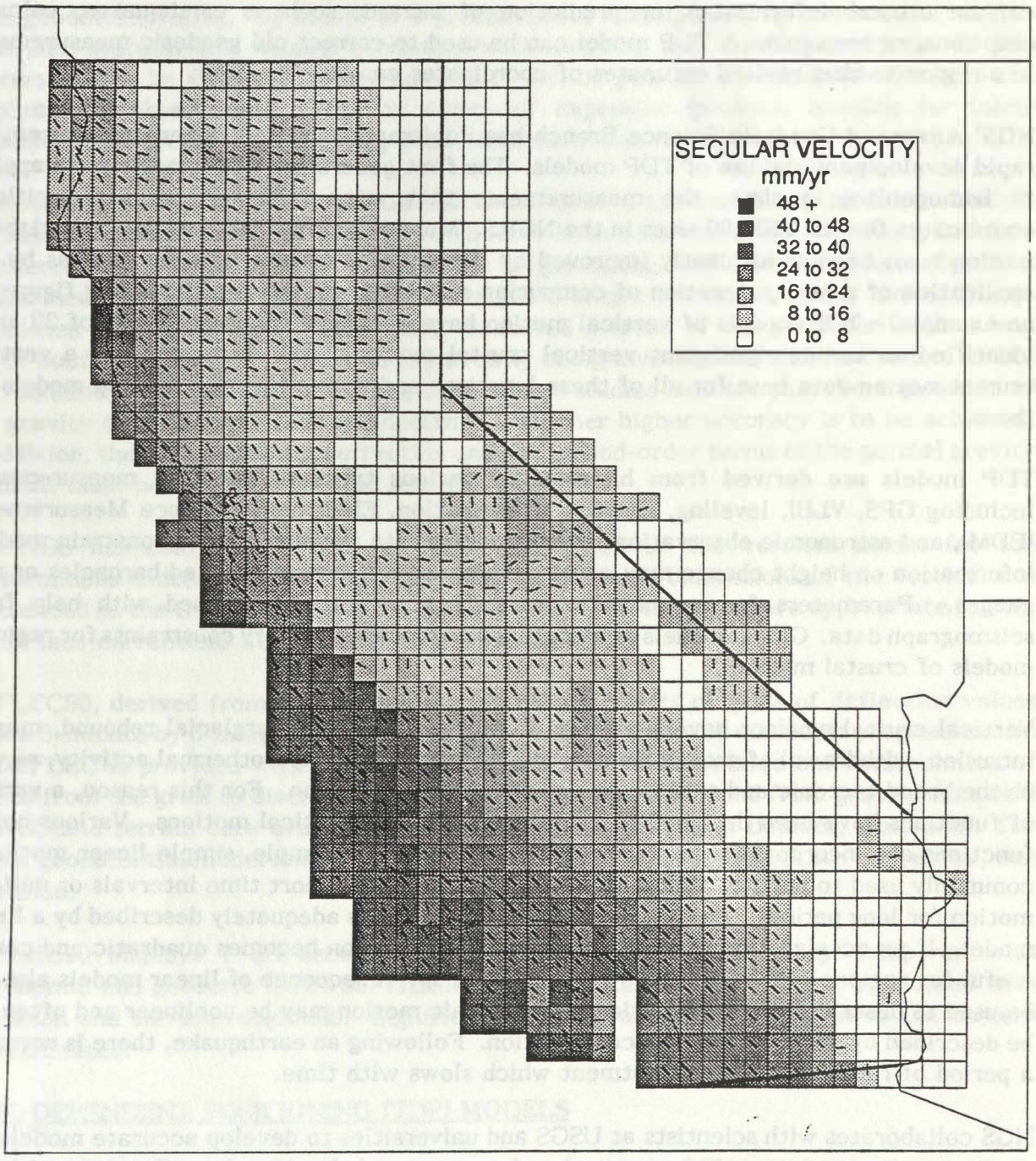


FIGURE 10. Horizontal crustal velocities in California relative to the stable part of North America as derived from geodetic data.

Geophysical Research. Also NGS, in collaboration with the USGS, New Mexico State University, and Stanford University, performed a geodetic survey to determine crustal deformation in the New Madrid seismic zone of southeastern Missouri.

TECHNOLOGY TRANSFER

Work on the development of Multipurpose Land Information Systems: The Guidebook continued. The third release (consisting of Chapters 8, 9, 10, and 16) was published in FY 92. The next release (Chapters 12, 14, 15, 20, and 21) will be published in early 1993.

The C&GS State Geodetic Advisor Program continued in 26 states, with the State of Colorado being added during FY 92. This program is a 50/50 cost-sharing cooperative effort between NGS and the states involved. NGS assists the states with their geodetic and surveying programs, suggests maintenance functions, ensures that surveys performed by the states meet Federal standards and specifications, and helps in the transfer of new surveying technologies. The accompanying map summaries the status of the current state participation.

Other examples of transfer of technology to state, county, and private surveyors and engineers, which continues to be an increasingly important activity within NGS are:

- NGS presented 11 horizontal workshops to over 1,000 state, local, and private users of the NGRS. The workshops on topics such as State Plane Coordinates, Datum Transformations, Geographic Information Systems, and Network Planning and Adjustments, were evaluated by the participants as being of great value. These workshops were presented in Puerto Rico, New Mexico, New, Jersey, Vermont, Virginia, Texas, New Hampshire, Maryland, and Wisconsin.

- During FY 92, four 1-day NAVD 88 and 2-day Vertical Control Workshops were sponsored by state surveying and mapping professional societies. Several other workshops, including those covering geographic information systems, coordinate computations, and coordinate transformations, were coordinated through NGS' Vertical Network Branch.

NATIONAL GEODETIC INFORMATION BRANCH

NGS' National Geodetic Information Branch (NGIB) 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. NGIB also conducts a marketing program to increase user awareness and understanding of these products and to improve NGS' responsiveness to its users.

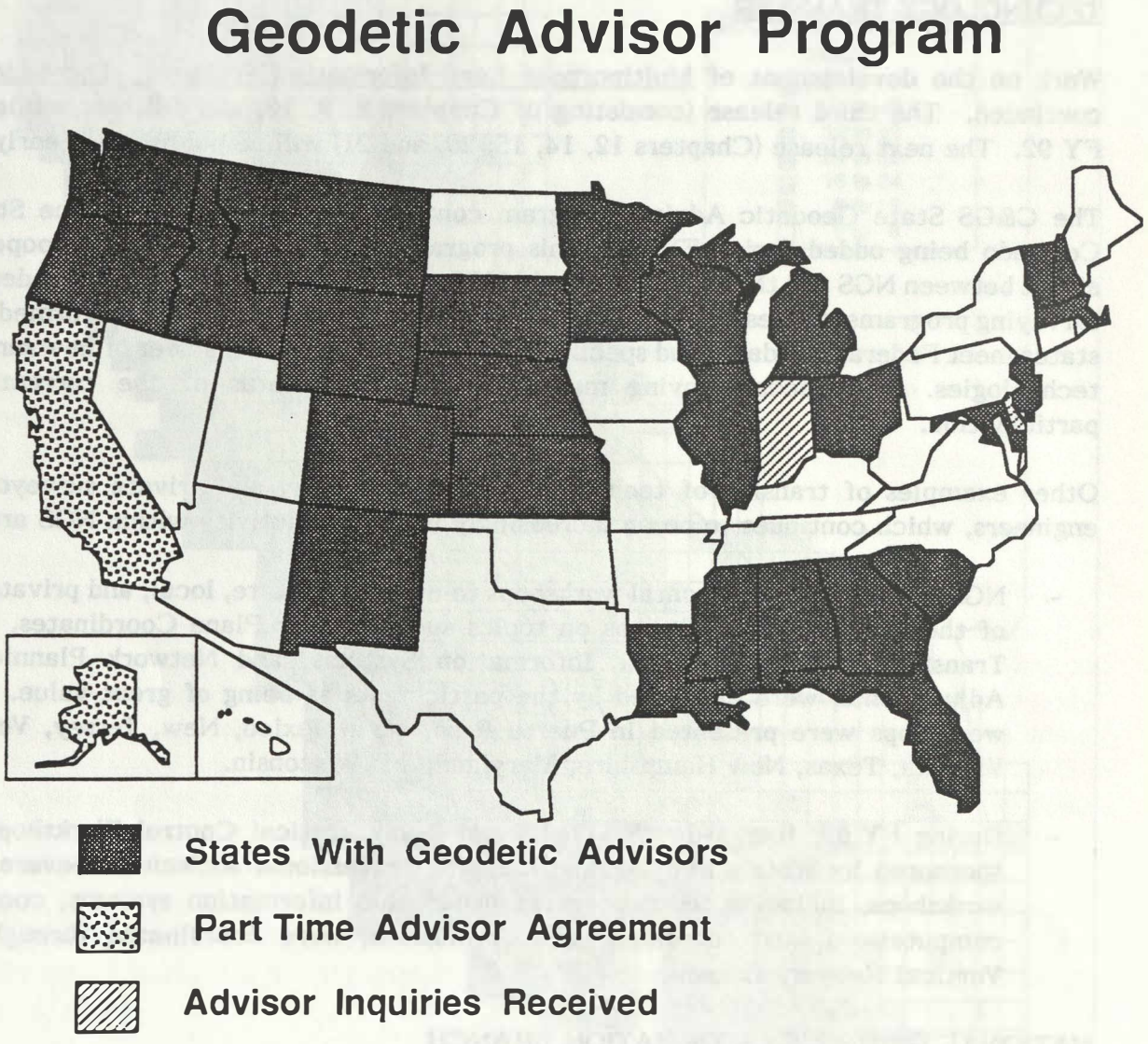


FIGURE 11. Map of the United States showing state participation in the NGS State Geodetic Advisor Program.

Major accomplishments during FY 92 are as follows:

- New heights resulting from the NAVD 88 project beginning in November 1991 were distributed.

- The new "integrated" NGS Data Sheet that combines horizontal, vertical, GPS, and descriptive information in a single format was completed for distribution. Standard products include 7 1/2-minute quads in booklets, and counties on high density diskette.

- New software and digital data products such as GEOID 90 (a high-resolution geoid height model), DEFLEC90 (high-resolution deflection of the vertical model), CORPSCON (converts between NAD 27 and NAD 83 with geographic positions or state plane coordinates), and a new version of NADCON (allows conversions between NAD 83 (1986) and HARN's for those states which have network upgrades) were distributed.

- NGS-computed precise orbital positions and velocities for GPS satellites were distributed. These data can also be retrieved through the Civil GPS Service Information Center bulletin board, operated as a free service by USCG in Alexandria, Virginia.

- The third release of the Multipurpose Land Information Systems Guidebook was distributed.

- Text edit processing of an additional 50,000 horizontal station descriptions was completed. This brings the total reviewed and updated to 202,000, which is approximately 80 percent of the data set.

- Data for 50 new Calibration Base Lines in support of cooperative interagency agreements were distributed.

- Cost studies to ensure that the prices for all NGS information products are consistent with agency pricing guidelines were conducted.

- Numerous publications, historical records, and the results of research investigations were provided to fulfill diverse requests from universities, individuals, Government agencies, and businesses throughout the United States and from other countries.

SCIENTIFIC PAPERS AND TECHNICAL REPORTS

Challstrom, Charles W., "Federal Geodetic Control Classification Standards Revision for Network Upgrades," Proceedings of ACSM/ASPRS Conference on GIS/LIS Systems, 1991, 7 pp.

Doyle, David R. and Frakes, Steven J., "GPS Surveys and the Horizontal Network," Proceedings of ACSM Conference on GIS/LIS Systems, Atlanta, Georgia, 1991, 10 pp.

Doyle, David R., "New Coordinate Adjustment for Maryland/Delaware," Maryland and Delaware Surveying Societies Newsletters, 1992, 2 pp.

Grunthal, Melvyn C., "High Accuracy Regional Upgrades to the National Geodetic Reference System," Proceedings of the 1992 ACSM/ASPRS Convention, 12 pp.

Grunthal, Melvyn C., "Development of a High Accuracy Horizontal Network in the United States," Proceedings of the 1992 Australian Surveyors' Congress, 15 pp.

Grunthal, Melvyn C., "National Geodetic Reference System," The Coastal Society, 1992, 11 pp.

Hilla, Stephen A., "GPS Static Data Processing at the National Geodetic Survey: Completed Projects, Current Software, and Future Trends," Proceedings of the Sixth International Geodetic Symposium on Satellite Positioning, 1992, 10 pp.

Hothem, Larry D. and Strange, William E., "Accurate Determination of Cartesian Coordinates at Geodetic Stations Using the Global Positioning System," Geophysical Research Letters, Vol. 19, No. 6, 1992, pp 533-536.

Hoyle, Dixon B., "NAD 27-NAD 83 datum Transformations, What's the Fuss?," Proceedings of the 1991 Minnesota GIS/LIS Consortium Conference, Bloomington, Minnesota, October 10-11, 1991, 9 pp.

Love, John D., and White, Madeline B., "Submitting GPS Projects to the National Geodetic Survey: How and What?," NOAA Technical Publication Series, 1991, 9 pp.

Milbert, Dennis G., "A High-Resolution Geoid Height Model for the Conterminous United States," Proceedings of the 62nd International Meeting of the Society of Exploration Geophysics, 1992.

Milbert, Dennis G., "Computer GPS-Derived Orthometric Heights with the GEOID90 Geoid Model," Proceedings of the ACSM/ASPRS Fall 1991 Conference, 13 pp.

Moyer, D. David, "Why, What, and How of GIS Standards: Issues for Discussion," Proceedings of Panel Discussion at GIS/LIS Conference, Atlanta, Georgia, 1991, 25 pp.

Moyer, D. David, "Geographic Information Systems: Designs on Our Natural Resources," The Journal of Agricultural Economics Research, Vol. 43, No. 4, 1992, 2 pp.

Remondi, Benjamin W., "Real-Time, Centimeter-Accuracy GPS for Marine Applications," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 19-23.

Remondi, Benjamin W., "GPS Positioning Techniques," Proceedings of On Common Ground Conference, Hyatt Regency Tech Center, Denver, Colorado, 1992, 4 pp.

Remondi, Benjamin W., "Real-Time, Centimeter-Accuracy GPS Without Static Initialization," Proceedings of the Sixth International Geodetic Symposium on Positioning, Columbus, Ohio, 1992, 6 pp.

Remondi, Benjamin W., "Artificial Constellations: The Global Positioning System," The Military Engineer, September-October, Vol. 84, No. 545, 1991, 6 pp.

Snay, Richard A., and Holdahl, Sanford R., "Time-Dependent Positioning," EOS, Transactions of the AGU, Vol. 73, No. 3, 1992, 2 pp.

Snay, Richard A., Neugebauer, Helen C., and Prescott, W. H., "Horizontal Deformation Associated with the Loma Prieta Earthquake," Bulletin of the Seismological Society of America, Vol. 81, No. 5, 1991 pp. 1647-1659.

Snay, Richard A.,"Geodetically Derived Strain Across the Northern New Madrid Seismic Zone," Department of Physics, New Mexico State University Technical Publication, Las Cruces, New Mexico, 1992, 18 pp.

Soler, Tomas, and Love, John D., "Establishment of a GPS Geodetic High Accuracy Reference Network in Mexico," Proceedings of the Sixth International Geodetic Symposium on Satellite Positioning, 1992, 4 pp.

Soler, Tomas, Hall, Lucy, W., and Foote, Richard, H., "GPS Results from Statewide High Precision Networks in the United States," Proceedings of the Sixth International Geodetic Symposium on Satellite Positioning, 1992, 10 pp.

Spofford, Paul R., "National Geodetic Survey Precise GPS Orbit Computations: Status, Availability, and Accuracy," Sixth International Symposium on Satellite Positioning, Civil GPS Service Information Committee Proceedings, 1992, 19 pp.

Zilkoski, David B., "North American Vertical Datum of 1988: Benefits of Improved Heights Outweigh Conversion Costs," Proceedings of the 1991 GIS/LIS Conference, 9 pp.

Zilkoski, David B., "North American Vertical Datum and International Great Lakes Datum: They Are Now One and the Same," Proceedings of the Fifth Biennial National Ocean Service International Hydrographic Conference, February 25-28, 1992, Baltimore, Maryland, pp. 68-74.